

Chapter 25C. Geohydrologic Summary of the South Helmand Travertine Area of Interest

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25C.1 Introduction

This chapter describes the geohydrology of the South Helmand travertine area of interest (AOI) in southern Afghanistan identified by Peters and others (2007). The AOI is located in the Dishu and Garmser Districts in southeast Helmand Province and the Reg District in southwest Kandahar Province. The AOI encompasses an area of 6,628 km² (square kilometers). The southern boundary of the AOI, known as the Chagai Hills, forms the border between Afghanistan and Pakistan (fig. 25C–1*a,b*). The Chagai Hills also form the southwestern extent of the Registan, a desert region whose name locally means “land of sand.” The Registan extends into the northern part of the AOI and is characterized by active dunes (Whitney, 2006). Lashkar Gah, the province center for Helmand Province and the closest major population center to the AOI in Afghanistan, is approximately 195 km (kilometers) north-northeast of the AOI.

Water is needed not only to process mineral resources in Afghanistan, but also to supply existing communities and the associated community growth that may accompany a developing mining economy. Information on the climate, vegetation, topography, and demographics of the AOI is summarized to provide information on the seasonal availability of, and seasonal demands for, water. The geohydrology of the AOI is described through the use of maps of streams and irrigated areas, generalized geohydrology and topography, and well locations. The results of lineament analyses are presented to identify areas where the rock may be more fractured than in other areas, which may be an indicator of high relative water yield and storage in bedrock aquifers.

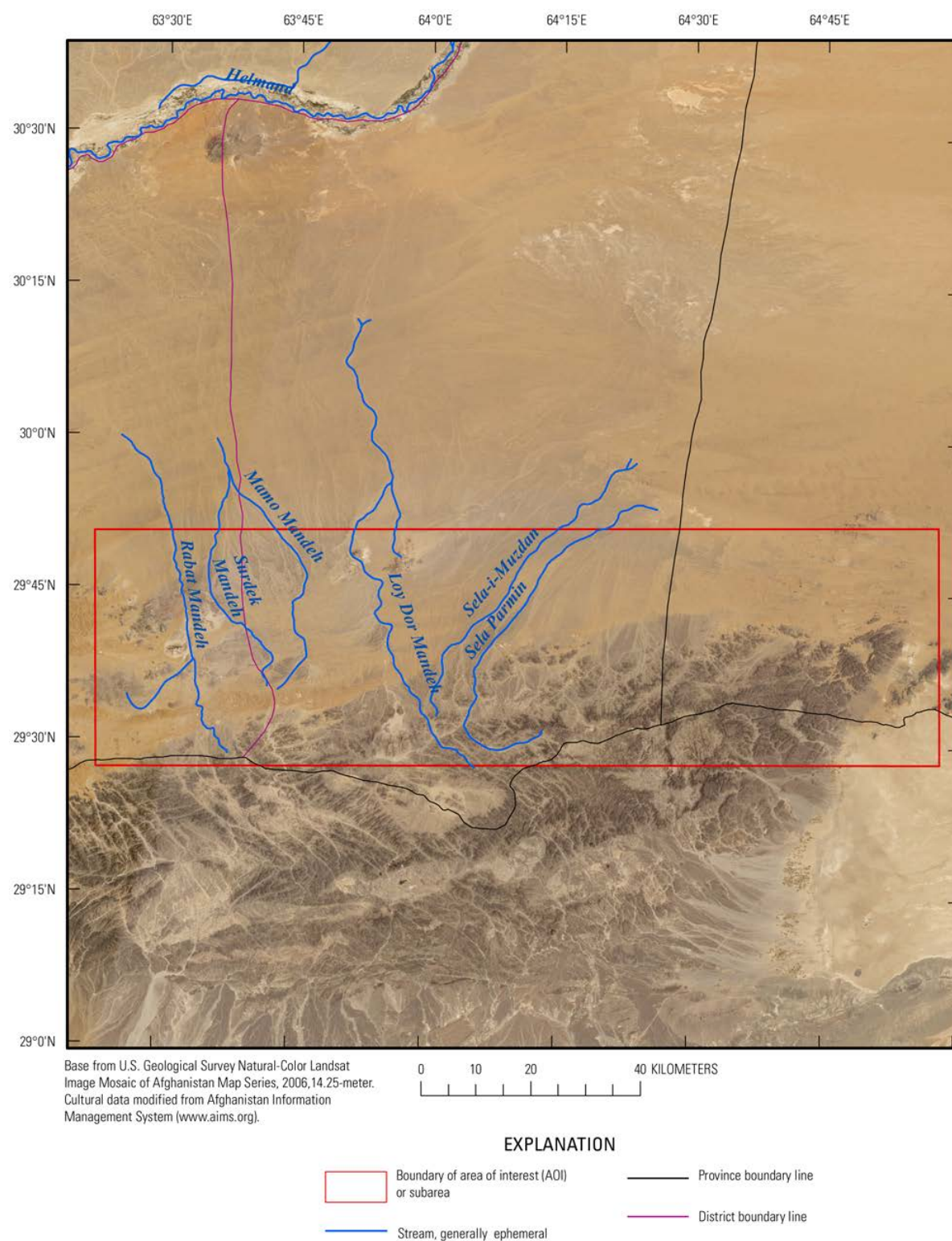
Afghanistan’s recent turbulent history has left many of the traditional archival institutions in ruins, and most water-resource and meteorological data-collection activities had stopped by 1980. Recently (2011), nongovernmental organizations (NGOs), foreign government agencies, and the Afghan government have begun water-resource investigations, and U.S. Geological Survey (USGS) minerals teams conducted field reconnaissance work in the AOI in September 2009; however, these activities and the amount of data collected are limited. This report summarizes the satellite imagery and climatic, topographic, geologic, surface-water, and groundwater data available. Geohydrologic inferences are made on the basis of an integrated analysis of these data and an understanding of conditions in other areas of Afghanistan.

25C.2 Climate and Vegetation

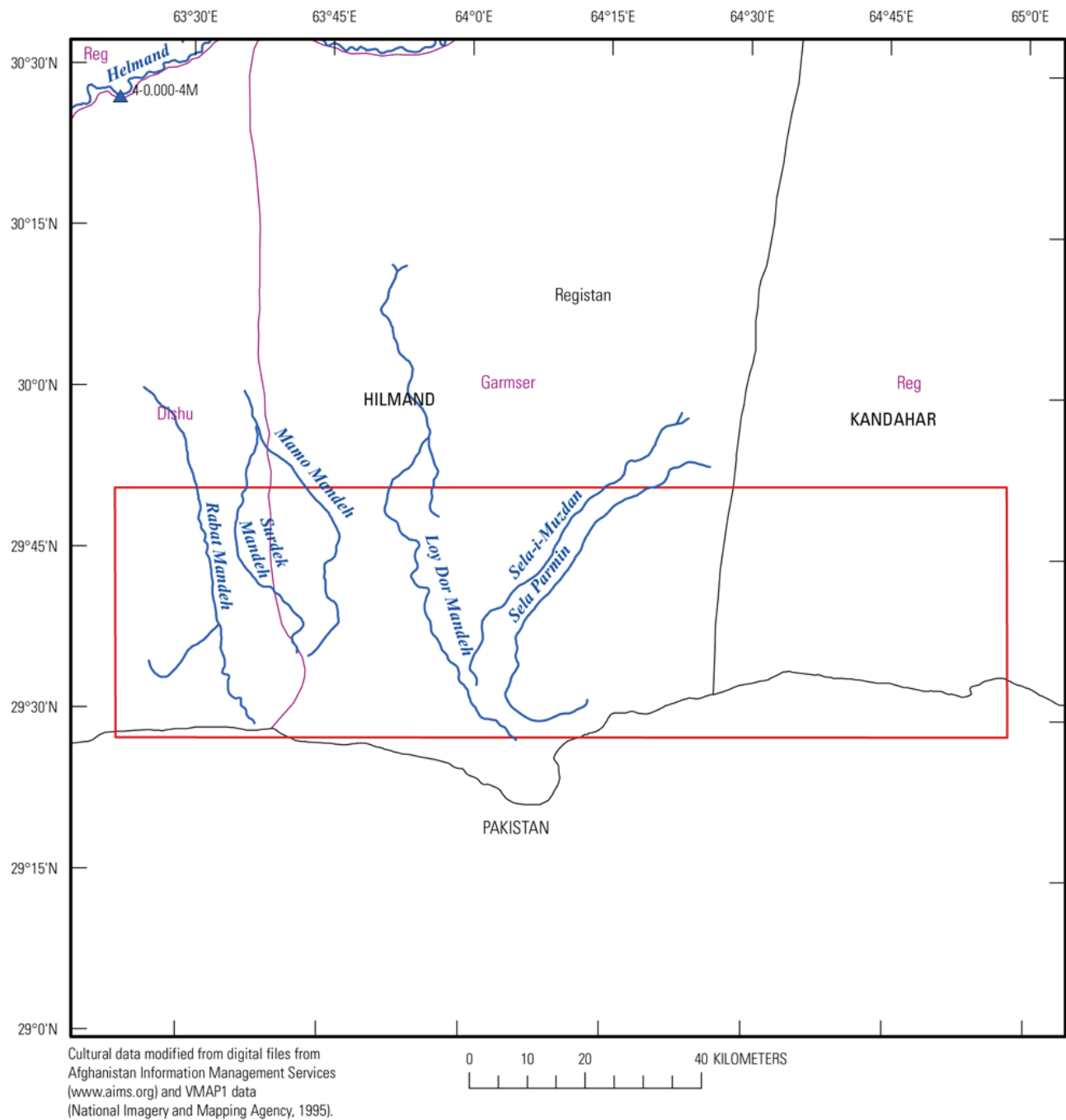
Climate information for the South Helmand travertine AOI is based on data generated for the Afghanistan agricultural-meteorological (Agromet) project. Agromet was initiated by the U.S. Agency for International Development and the United Nations Food and Agriculture Organization in 2003 to establish data-collection stations and develop country-wide agrometeorological services. Scientists with the Agromet project are assisting the Afghan Government to collect and analyze agricultural and meteorological data as they relate to crop production, irrigation, water supply, energy, and aviation. The U.S. Geological Survey (USGS) assumed responsibility for the operation of the project in 2005; by the end of August 2010, 87 Agromet stations were recording precipitation data and other parameters. Additionally, the Agromet project receives data from 18 Afghanistan Meteorological Authority (AMA) weather stations. The Agromet project has developed a database that includes data collected at the

Agromet stations over the past 6 years (2005–2011), data collected at the AMA weather stations, and historical data collected at weather stations from 1942 to 1993. Data collected as part of the Agromet project are compiled annually by water year (September through August) and are reported in the Afghanistan Agrometeorological Seasonal Bulletin (Seasonal Bulletin) published by the Ministry of Agriculture, Irrigation, and Livestock. Unless otherwise specified, the Agromet data cited in this report are from the agricultural season that extends from 1 September, 2009, to 31 August, 2010.

a



b



EXPLANATION

- Boundary of area of interest (AOI) or subarea
- Province boundary line
- District boundary line
- Stream, generally ephemeral
- Stream or spring** (all types may not be present)
 - ▲ Historical streamgage and Afghan identification number, approximately located
 - ▲ Ungaged streamflow estimation point and identifier; see appendix 2 for flow statistics.

Figure 25C–1. (a) Landsat image showing the location of, and (b) place names, stream names, and streamgage station numbers in, the South Helmand travertine area of interest in southern Afghanistan.

Weather conditions in the AOI are harsh (Whitney, 2006). The annual average rainfall for the 11 Agromet stations that make up the Agromet South Region is 177.8 mm (millimeters) (Ministry of Agriculture, Irrigation, and Livestock, 2010). The South Region includes the provinces of Helmand, Kandahar, Nimroz, Urozgan, and Zabol. Much of the area is desert. The average rainfall for the four Agromet stations located in Helmand Province is 172 mm. The four stations in Helmand Province are all located in agricultural areas near the Helmand River, near the eastern border of the province; their elevations range from 770 to 980 m (meters) above sea level (asl). The amount of precipitation received in the eastern Helmand Basin averages about two to three times the amount received in the desert plain (Whitney, 2006). The Agromet station at Zaranj, Nimroz Province, is approximately 210 km northwest of the AOI at about 490 m asl. Rainfall recorded at this station during the 2009–2010 water year was 41 mm with the following monthly totals: 29 mm in December 2009, 7 mm in January 2010, 3 mm in February 2010, and 2 mm in May 2010 (Ministry of Agriculture, Irrigation, and Livestock, 2010). The prevailing wind direction is northwest to southeast in this part of Afghanistan and west to east over the AOI, so the amount of rainfall at Zaranj is probably a good indicator of the amount of rainfall in the AOI (Whitney, 2006).

Temperatures in the AOI vary widely. The maximum temperature recorded at the Zaranj Agromet station during the 2009–2010 water year was 47.6°C (degrees Celsius) during July 2010; the average low temperature was 9.3°C during December 2009 (Ministry of Agriculture, Irrigation, and Livestock, 2010, p. 24). Long-term average (LTA) temperature data are available for the Agromet station at Kandahar, located 240 km northeast of the center of the AOI. The LTA high temperature was 31.8°C for July and the LTA low temperature was 4.8°C for January (Ministry of Agriculture, Irrigation, and Livestock, 2010). Annual, LTA, and LTA minimum and maximum precipitation and temperature data for the Kandahar Agromet station are presented in table 25C–1.

Table 25C–1. Annual, long-term annual average, and long-term average minimum and maximum precipitation and temperature at the Kandahar Agrometeorological (Agromet) station located 260 km northeast of the South Helmand travertine area of interest, Afghanistan.

[AOI, area of interest; km, kilometers; m, meters; mm, millimeters; °C, degrees Celsius]

Agromet Station	Distance from AOI center (km)	Elevation (m)	2009–2010 Annual (mm)	Precipitation			Temperature		
				Annual (mm)	Long-term average ¹		Minimum and month (°C)	Long-term average ¹	
					Monthly minimum and month (mm)	Monthly maximum and month (mm)		Monthly mean (°C)	Maximum and month (°C)
Kandahar	240	1,020	166	155.5	0 September June	49.1 January	4.8 January	15.9	31.8 July

¹ Long-term averages are based on data from 1942 to 1993 and 2005 to 2010 as reported in the Afghanistan Agrometeorological Seasonal Bulletin (Ministry of Agriculture, Irrigation, and Livestock, 2010).

Data on evaporation rates in 1964 are available for Kandahar (1.8 m/yr (meters per year) and Chakhansur (4.3 m/yr) (Whitney, 2006). Chakhansur is about 220 km northwest of the AOI. Although these pan evaporation sites are about 220 to 240 km from the AOI, evaporation rates at these sites are probably similar to those in the AOI. The station at Chakhansur is probably more representative of the AOI because the prevailing wind direction is similar. The high evaporation rates and low rainfall totals (especially during the summer to early winter) limit the amount of precipitation that is available to recharge the groundwater system in the AOI. Without some mechanism, such as focused flow in washes, to concentrate recharge at the surface, the occurrence of local groundwater recharge is unlikely.

The “Potential Natural Vegetation” described in Breckle (2007) is the vegetation cover that would be present in the various regions of Afghanistan if it had not been modified by human activity. Today, as a result of continued exploitation such as grazing, farming, and deforestation, much of the original natural vegetation is found only in a few remote areas of Afghanistan. The destruction of the natural vegetation has resulted in the degradation and erosion of the soil cover in some areas. Many areas exhibit signs of long-lasting desertification caused by human activity.

According to Breckle’s “Map of potential natural vegetation” (Breckle, 2007, fig. 2), there are three vegetation types in the AOI. The vegetation types indicated on this map represent the “Potential Natural Vegetation.” The Other Deserts type (rich in Chenopod) occupies the eolian sand areas of the Registan in the northern part of the AOI. The vegetation type adjacent to the Chagai Hills is dwarf *Amygdalus*-Semidesert. The Chagai Hills are mapped as *Pistacia atlantica*-Woodlands. Breckle (2007) states, “The deserts of the north, west and south in the Registan and Dashte Margo contain active sand dune areas and dunes fixed by a rather open vegetation. The flora here is scarcely modified by man.”

The USGS made a field visit to the AOI in September 2009. This visit took place during a month when rainfall typically is low and temperatures typically are high. During this visit, some general observations about the vegetation in the AOI were made. Widely spaced desert shrubs, bushes, and grasses were present in the AOI. No irrigated fields were mapped in the drainage channels in the AOI (fig. 25C–2) (Afghanistan Information Management Service, 1997), and the shrubs and bushes were low, generally about 30 cm in height. The plants that were growing in drainage channels showed some green foliage, indicating that the soil moisture in the root zone was sufficient to support growth. Plants not near drainages exhibited little, if any, green foliage. The vegetation in the Registan Desert between subareas consisted of sparse desert shrubs and bushes (fig. 25C–3). Vegetation was less abundant in an area in the northeastern part of the AOI than in other areas visited (fig. 25C–4). More plants were growing in the bottom of the ephemeral drainage channels than on the upland surfaces.

25C.3 Demographics

The population of the South Helmand travertine AOI is small and dispersed as mapped by LandScan (Oak Ridge National Laboratory, 2010) (fig. 25C–5). The linear nature of some of the pixels in the Registan Desert in which population density is estimated to be 1 to 5 inhabitants per square kilometer (fig. 25C–5) might be the result of vehicle traffic and not be indicative of permanent settlements. Another possibility is that these areas are temporary camps being used by nomadic Afghan families or groups. No settlements were observed in the Registan Desert along the flight lines traveled to and from the AOI for the field visit. The population per square kilometer in and adjacent to the Chagai Hills in figure 25C–5 is probably representative of the actual population density, especially in the areas in Pakistan where farming areas and a few large towns are concentrated south of the AOI. The largest settlement in Afghanistan near the AOI is in the Chagai Hills south of and just outside the AOI on the Afghanistan-Pakistan border (Bohannon, 2005b). Some small, irrigated farming areas and settlements are present within and adjacent to the Chagai Hills in the southern part of the AOI. The presence of these settlements and small irrigated areas indicates that some perennial groundwater resources are available in and around the Chagai Hills for domestic consumption. Any irrigation in this area probably relies on ephemeral streamflows and spring discharge. Aerial images (Google Earth) show that karezes (traditional hand-dug water-supply tunnels) and earthen dams have been constructed to provide water for irrigation. No roads are shown in the AOI on the Helmand Province district maps (Afghanistan Information Management Service, 2004). A few tracks are present east of the AOI from the Helmand River valley to Pakistan.

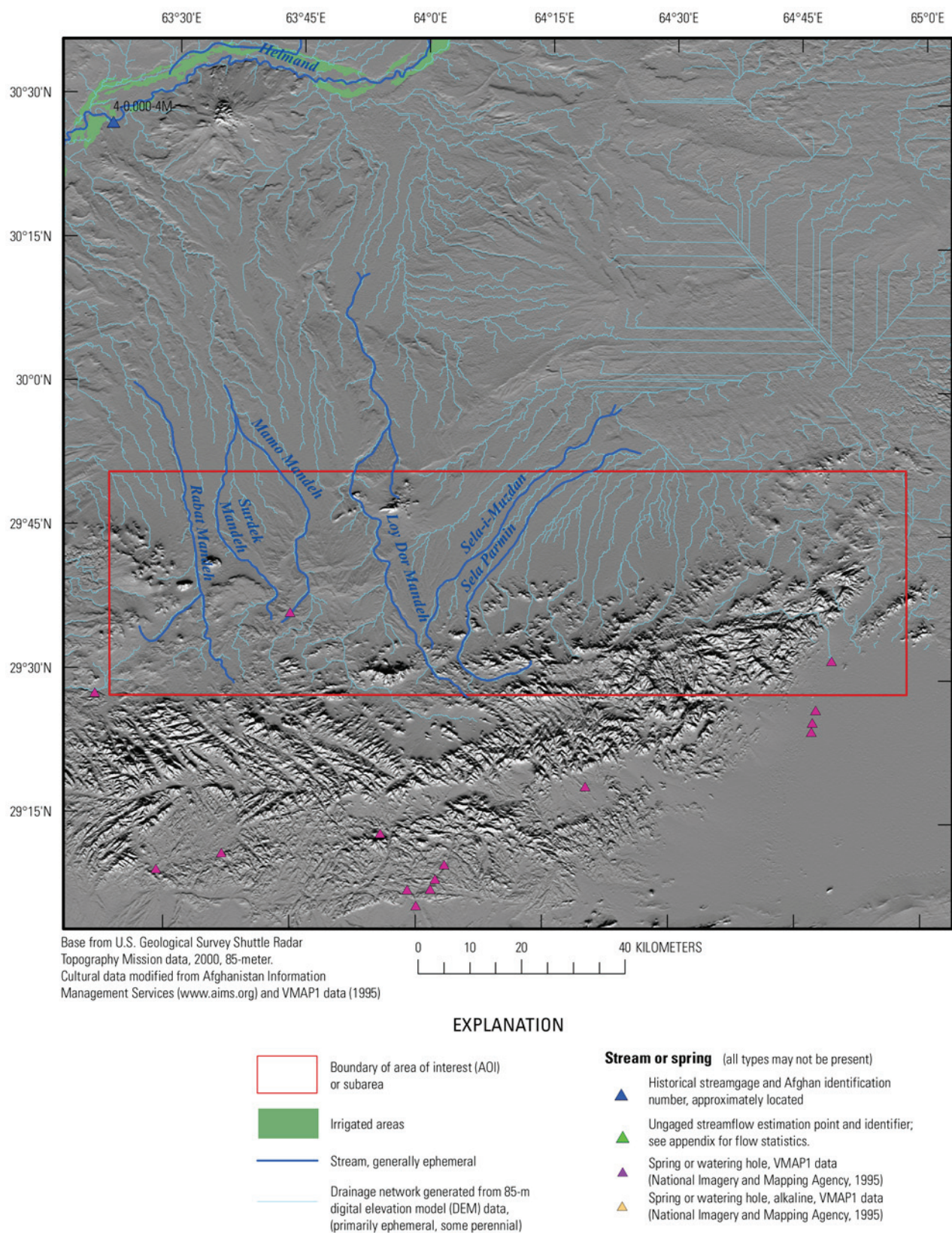


Figure 25C–2. Historical streamgauge locations, digitally generated drainage network, and irrigated areas in the South Helmand travertine area of interest in southern Afghanistan.

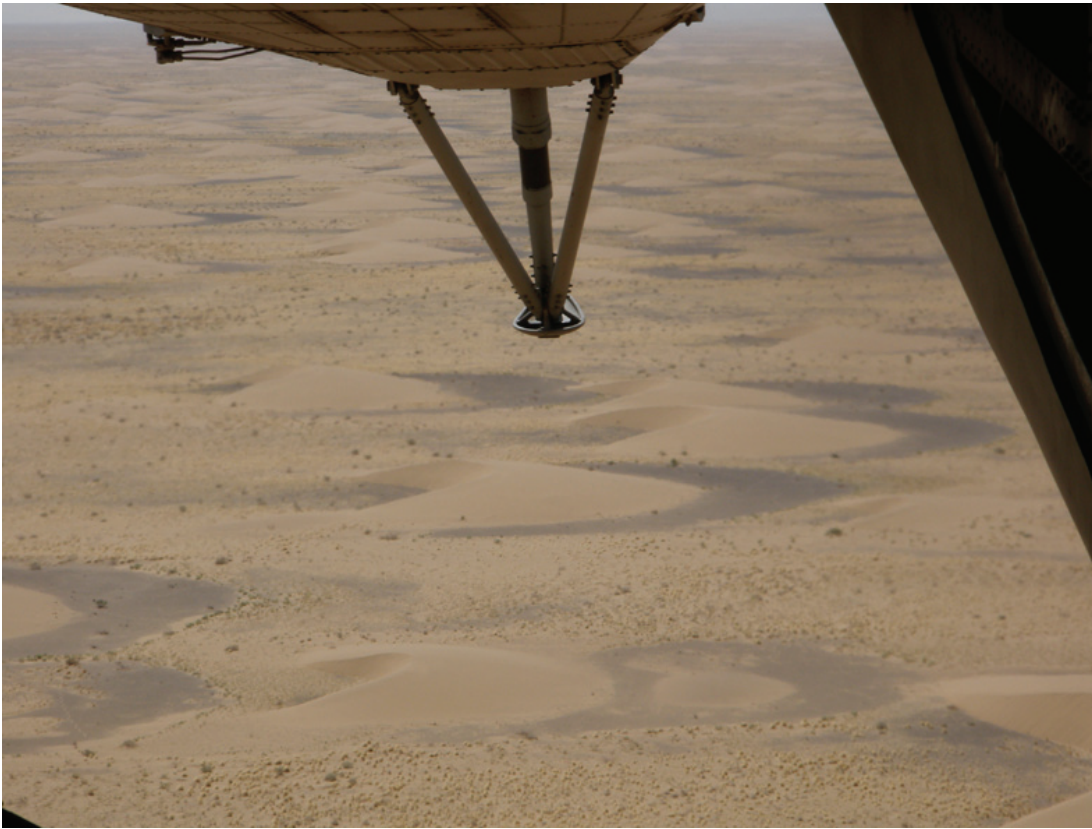


Figure 25C–3. Photograph of vegetation in the Registan Desert between landing areas in the South Helmand travertine area of interest in southern Afghanistan.



Figure 25C–4. Photograph of vegetation at a travertine quarry in the South Helmand travertine area of interest in southern Afghanistan.

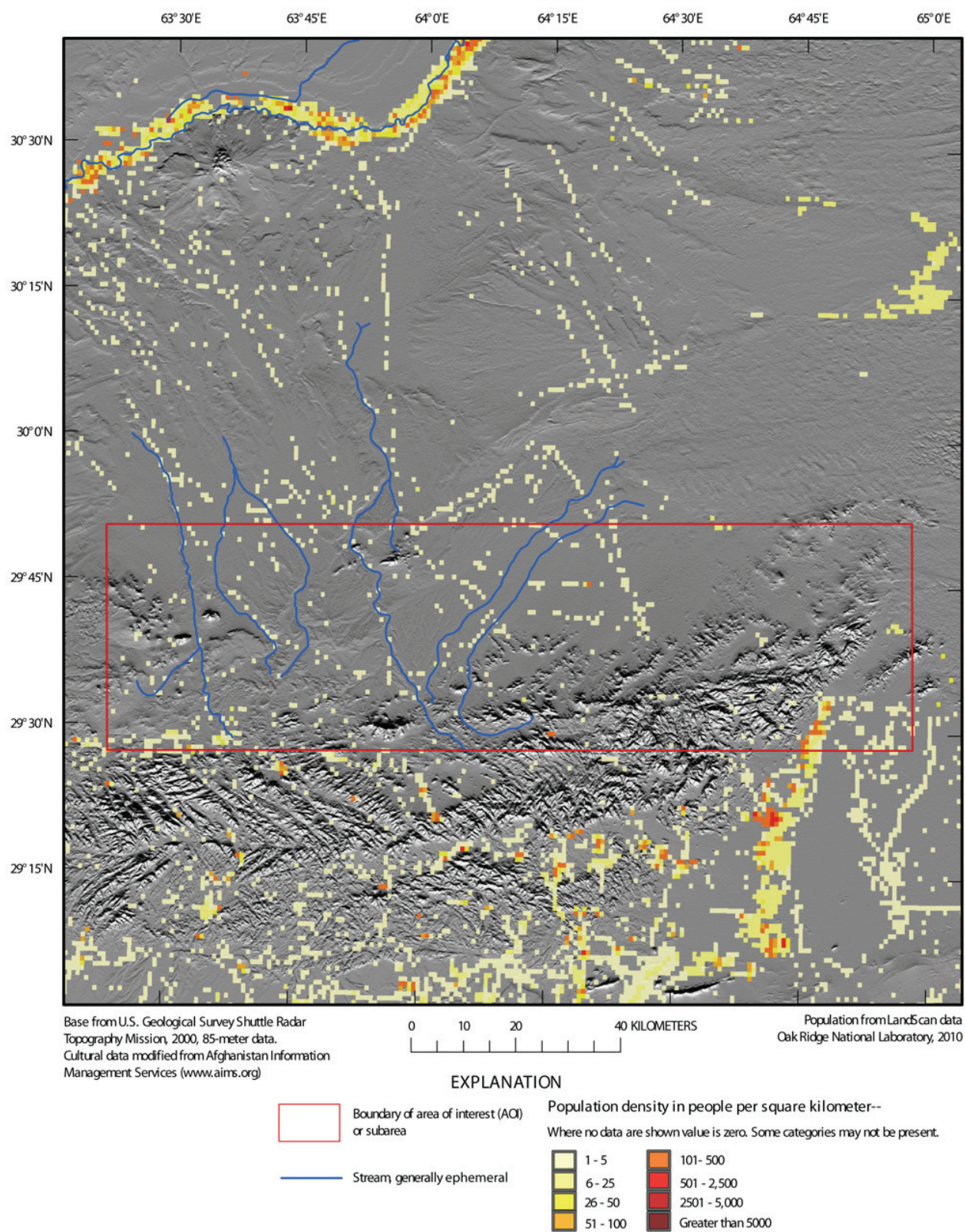


Figure 25C-5. Population density for the South Helmand travertine area of interest and surrounding areas in southern Afghanistan.

25C.4 Topography and Geomorphology

The topography of the South Helmand travertine AOI transitions from the highlands of the Chagai Hills in the south to the windswept desert plains of the Registan in the north (fig. 25C–6). The Chagai Hills form the southern boundary of the Registan in Helmand Province (Whitney, 2006); they reach an elevation of slightly more than 1,500 m asl along the border with Pakistan and are dissected by incised ephemeral streams (Bohannon, 2005a,b; Davis, 2006). The range-front transition from bedrock outcrop to sediments is abrupt and occurs at an elevation that ranges from about 1,470 m asl in the western area of the hills to 1,200 m asl in the eastern area. The surface of the Registan Desert slopes gently to the north toward the Helmand River, decreasing in elevation from about 1,400 to 650 m asl over a distance of 100 km. Several ephemeral streams that originate in the Chagai Hills terminate in a large east-west-trending ephemeral stream that is adjacent to the bedrock contact of the Chagai Hills (fig. 25C–2). Active dune fields currently occupy most of this region. The drainage patterns of the ephemeral streams in the Chagai Hills appear to be dendritic and are superimposed on an older, rectangular drainage pattern. The rock outcrops that make up the Chagai Hills are broken by a prominent set of northeast-southwest- and northwest-southeast-trending fractures that control the drainage pattern of the smaller ephemeral streams.

25C.5 Geohydrology

The geohydrology of Afghanistan has been described in general terms by Abdullah and Chmyriov (1977, book 2). As defined in their “Geology and mineral resources of Afghanistan,” the South Helmand travertine AOI is in the South Afghanistan Artesian Region. Abdullah and Chmyriov (1977) further describe the basin areas as having between 1,000 and 3,000 m of sediments. On the basis of an interpretation of recent and historical aeromagnetic data, Drenth (2009) estimated the unconsolidated sediments in the Registan to be thousands of meters thick over basement rocks.

The outcrops and near-surface rocks in the AOI can be grouped according to their physical and hydraulic properties. The generalized geohydrology of the AOI is shown in figure 25C–6 with the underlying topography to allow examination of the geohydrology in the context of relief. Figure 25C–7 shows the generalized geohydrology without topography for a clearer depiction of the geohydrologic units and mapped faults. Wells present in the map area (discussed in the Groundwater section) are shown in figure 25C–7. Generalized geohydrologic groups were created from a country-wide geologic coverage (Doebrich and Wahl, 2006) by combining sediments and rocks into major sediment- or rock-type groups of similar hydrologic characteristics. The geohydrologic groups in the AOI, ranked from high to low relative hydraulic conductivity (Freeze and Cherry, 1979, table 2.3), are “river channel; sands, undifferentiated; conglomerate sediments and rocks; and intrusive rocks and lavas” (figs. 25C–6, 25C–7). Doebrich and Wahl (2006) used geologic maps at a scale of 1:250,000, modified from Russian and Afghan Geological Survey (AGS) mapping, to generate the country-wide geologic coverage. The 1:250,000-scale geologic maps that cover this AOI are provided by O’Leary and Whitney (2005) and O’Leary and others (2005).

The surface of the Registan is mapped as the sands, undifferentiated, and conglomerate sediments and rocks geohydrologic groups; and the river channel geohydrologic group in some ephemeral stream beds. The bedrock outcrops of the Chagai Hills and the isolated bedrock outcrops north of the Chagai Hills are made up of the intrusive rocks and lavas geohydrologic group (figs. 25C–6, 25C–7).

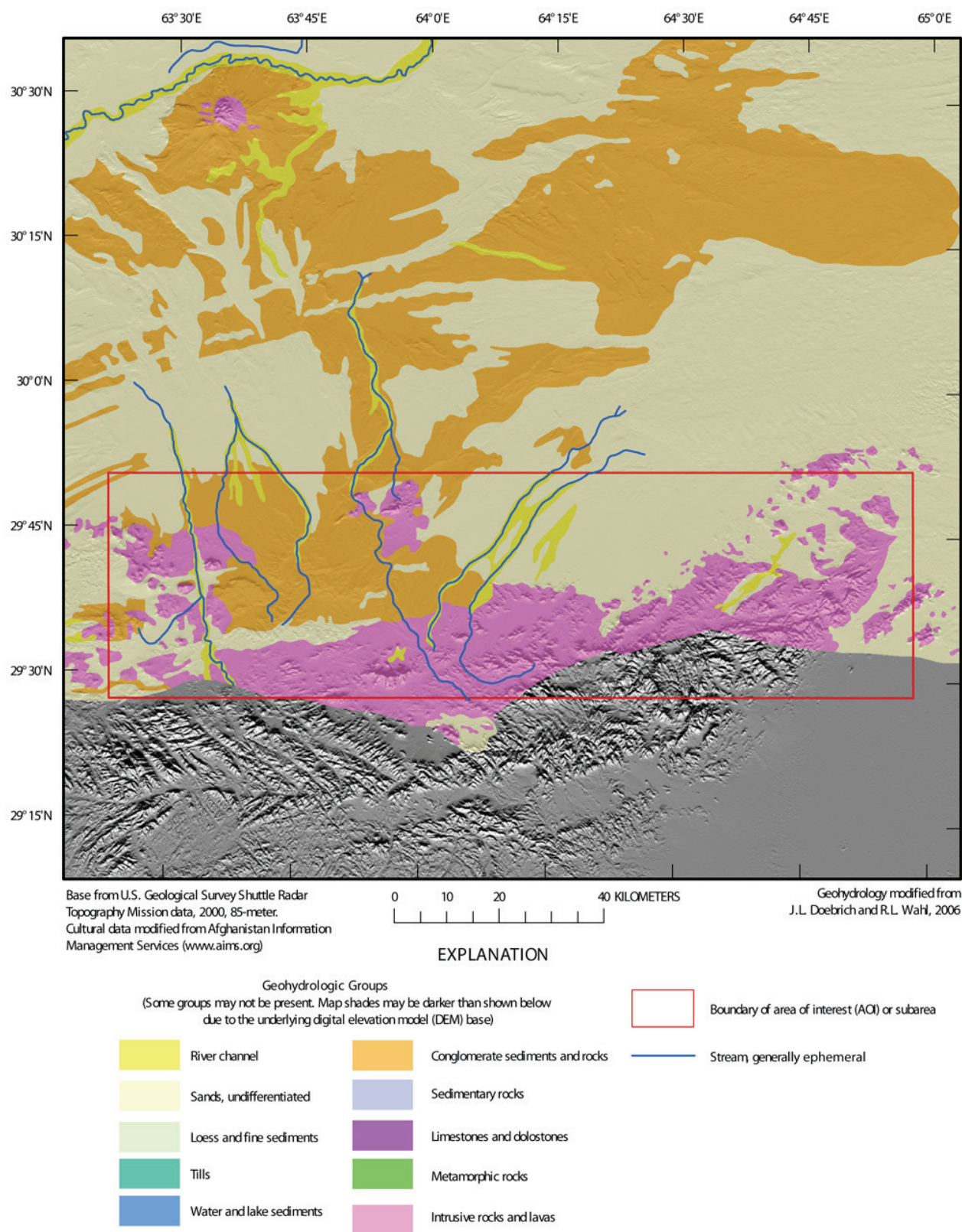


Figure 25C–6. Generalized geohydrology and topography in the South Helmand travertine area of interest in southern Afghanistan.

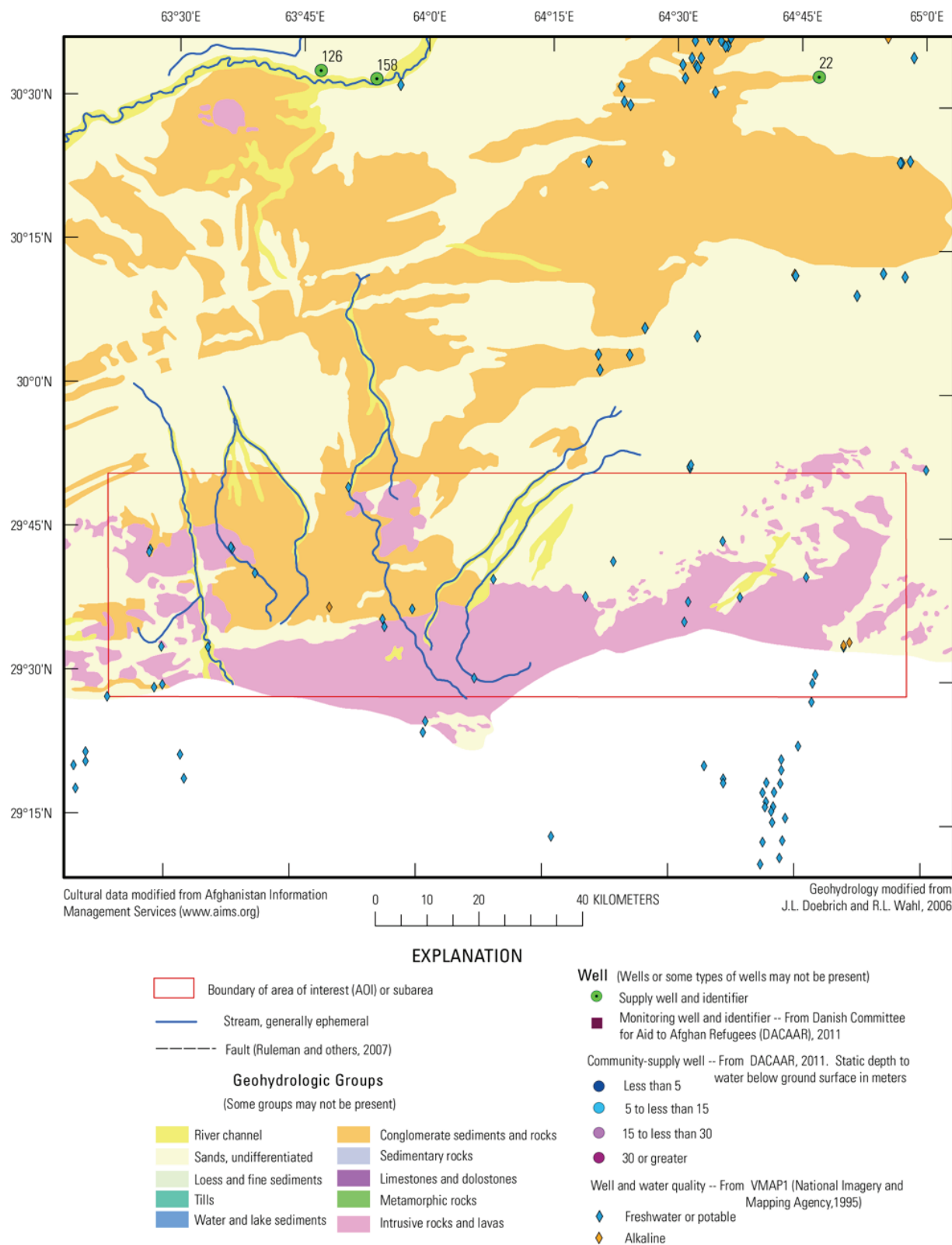


Figure 25C–7. Generalized geohydrology and wells in the South Helmand travertine area of interest in southern Afghanistan.

25C.6 Surface Water

The Helmand River, about 75 km north of the South Helmand travertine AOI, is the closest source of abundant and perennial surface water to the AOI in Afghanistan (fig. 25C-2). Six named streams shown in figure 25C-2 (see also 25C-1b) are mapped as “streams, generally ephemeral” as modified from AIMS (Afghanistan Information Management Services, 1997) and VMAP1 (National Imagery and Mapping Agency, 1995) databases. A network representing likely smaller ephemeral streams, generated with a digital elevation model (DEM), also is shown in figure 25C-2. Mapped springs, identified in the VMAP1 database (National Imagery and Mapping Agency, 1995), also are shown in and adjacent to the AOI. The six generally ephemeral streams begin in or near the Chagai Hills and flow north into the Registan (figs. 25C-1a,b and 25C-2). These streams terminate in the unconsolidated sediments of the Registan. The Loy Dor Mandeh stream is about 80 km long and can be traced about 40 km north of the AOI before it fans out into several braided channels (fig. 25C-2). The next longest stream in the AOI is the Rabat Mandeh, which is about 60 km long. Statistical summaries of streamflow data for all available historical gages in Afghanistan can be accessed at <http://afghanistan.cr.usgs.gov/water.php>.

Aerial images (Google Earth) of the AOI show several springs that may be discharging saline or calcitic water, as indicated by white deposits on the stream banks around the discharge areas, into some ephemeral stream channels. One of these spring discharge areas is located near the head of the Mamo Mandeh stream and is identified in the VMAP1 database (fig. 25C-2). Another spring discharge area is on the Loy Dor Mandeh stream about 7 km downstream from the location where it emerges from the Chagai Hills. The discharge from this spring area appears to support the flow of water in the Loy Dor Mandeh stream in the spring discharge area.

Earthen dams have been constructed in many of the ephemeral streams in the Chagai Hills. The size and number of these earthen dams indicate that seasonal runoff or runoff from large precipitation events is sufficient to capture and store surface water. Aerial images of this area show several karezes (hand-dug water-supply tunnels commonly used in Afghanistan that are constructed in unconsolidated and semi-consolidated sediments) are immediately downgradient from some of the earthen dams. Their presence could indicate that a component of shallow groundwater recharge is associated with the earthen dams. The presence of settlements indicates that the intrusive rocks may have fractured the surrounding rocks (O’Leary and others, 2005), resulting in enhanced erosion and the formation of valleys in the Chagai Hills. One such valley in the Chagai Hills contains an ephemeral stream that is a tributary to the Loy Dor Mandeh stream (fig. 25C-1a,b).

25C.7 Groundwater

Although few data are available to quantify this resource, groundwater is likely present in the South Helmand travertine AOI in thick, unconsolidated to semi-consolidated basin-fill sediments consisting of the sands, undifferentiated and the conglomerate sediments and rocks geohydrologic groups. The basin-fill material could be thousands of meters thick (Drenth, 2009). The depth to water in ephemeral stream channels may be near land surface near the Chagai Hills. Away from ephemeral stream channels and the Chagai Hills, the depth to water may be tens to hundreds of meters. Water wells in and adjacent to the AOI (fig. 25C-7) are identified in the VMAP1 database, but no information on well depth, depth to water, or lithostratigraphy is available (National Imagery and Mapping Agency, 1995). The “Watershed atlas of Afghanistan, Part IV, Description of watersheds” (Favre and Kamal, 2004) provides the following description: “Chagai watershed is a small watershed draining water on the southern slope of the Khanishin Gar volcano located near the town Khan Neshin and the northern slopes of the Chagai Mountains on the other side of the border in Pakistan. The water flows from a multitude of seasonal streams back into the Helmand River on each side of the Khanishin Gar volcano.” The reference to seasonal streams on Khanneshin volcano, about 75 km to the north, supports the concept

that the discharge of water from ephemeral streams in the Chagai Hills onto the Registan could result in zones of saturation in the discharge areas.

The wells in the VMAP1 database (National Imagery and Mapping Agency, 1995) identified in figure 25C–7 are likely shallow dug wells that were constructed before the 1998–2005 drought (Whitney, 2006). Some of the wells are likely to have become dry during this drought—especially those wells that are far from potential recharge areas, such as along ephemeral stream channels or in the Chagai Hills. Well-location and water-characteristic (alkaline or fresh/potable) information, but no water-chemistry information, is associated with the VMAP1 coverage. Well locations are correlated with population density (figs. 25C–5 and 25C–7) below the southeast corner of the AOI in Pakistan. Several springs or water holes also are present in this area of Pakistan (fig. 25C–2). In the AOI, the wells are located primarily in the unconsolidated sediment geohydrologic groups, but a few are located in material mapped as bedrock outcrop. The wells in areas mapped as the intrusive rocks and lavas geohydrologic group are most likely in unconsolidated sediments in ephemeral stream valleys where the extent, and possibly the thickness, of these deposits are too small to show on the geologic maps. In areas where the shallow aquifers currently supply water, it is unlikely that additional groundwater could be withdrawn without disrupting the availability of water for local uses such as domestic consumption and irrigation.

Considerable development is present on the southeast flanks of the Chagai Hills in Pakistan (fig. 25C–5). The bedrock-alluvium contact at the base of the Chagai Hills is lower here than on the Afghanistan side. The concentration of wells along this contact (fig. 25C–7) and the presence of mapped springs or water holes (fig. 25C–2) indicate that water is being accessed through wells or is being discharged at the land surface. The number of wells and the concentrated population indicate that the groundwater resource is sufficient to support permanent settlements. These water sources, as indicated by the population density, form a linear pattern that is roughly parallel to the bedrock-alluvium contact (figs. 25C–1a, 25C–5, 25C–7, and 25C–8). There are two possible sources of groundwater in this area. There is a large area of alluvial sediments located east of the Chagai Hills that drain to the west into an ephemeral lake at the base of the Chagai Hills. During periods of high precipitation, this lake probably contains water that could produce groundwater recharge. Lateral flow of water in the subsurface could recharge wells located to the west on the alluvial fans adjacent to the Chagai Hills. The highest shoreline of the ephemeral lake is about 840 m asl. The elevation of the wells and springs or watering holes on the Pakistan side of the Chagai Hills is between 844 and 850 m asl; therefore, the depth to groundwater recharged from the lake is likely to be within range of shallow wells. A second possible source of groundwater in the wells and springs is an aquifer that is developed in and adjacent to the Chagai Hills in Pakistan. If the aquifer is present on the Afghanistan side of the Chagai Hills, wells could be drilled in the AOI to access the groundwater in this aquifer. The difference in elevation between the irrigated areas in Pakistan and the surface of the Registan is about 400 m; therefore, wells drilled in the AOI would likely need to be about 400 m deep. On the basis of an interpretation of recent and historical aeromagnetic data, Drenth (2009) estimated the unconsolidated sediments to be thousands of meters thick over basement rocks in some basin settings in the AOI. Some supply wells about 100 km to the north in the Helmand River basin have been installed in sediments that are more than 450 m deep; however, yields from these wells may be limited and the water is likely to be thousands of years old. Groundwater studies would be needed to determine the hydraulic properties of the deep aquifers in the AOI and to characterize the chemical composition of the water they contain.

25C.8 Lineament Analyses

Lineaments are photolinear features that could be the result of underlying zones of high-angle bedrock fractures, fracture zones, faults, or bedding-plane weaknesses. Lineament analyses of the Southern Helmand travertine AOI (B.E. Hubbard, T.J. Mack, and A.L. Thompson, unpub. data, 2011) were conducted using DEM and natural-color satellite imagery (fig. 25C–8) and Advanced Spaceborne Thermal Emission and Reflection Radiometry (ASTER) satellite imagery (fig. 25C–9a,b). Lineament

identification and analysis have long been used as a reconnaissance tool for identifying areas in carbonate bedrock environments where groundwater resources are likely to be found (Lattman and Parizek, 1964; Siddiqui and Parizek, 1971). Lineament analysis is increasingly used to identify areas of high relative well yields in other bedrock settings, including crystalline bedrock (Mabee, 1999; Moore and others, 2002). The lineaments shown in figure 25C–8 were delineated visually, whereas those in figure 25C–9 were delineated using an automated process and on the basis of the multispectral characteristics of the land surface (B.E. Hubbard, T.J. Mack, and A.L. Thompson, unpub. data, 2011). Water wells in bedrock aquifers generally are most productive where boreholes are located in areas of highly fractured bedrock. Areas where lineament density is high (figs. 25C–8, 25C–9a, 25C–9b) potentially are areas where bedrock fractures are more prevalent than in other areas of the AOI. Lineaments provide an indication of areas that warrant further investigation for optimal bedrock water-well placement. Lineaments may also indicate areas of preferential flow and storage of groundwater, and areas with a high density of lineaments may indicate high secondary porosity. Areas of possible fracture-controlled stream drainages are discussed in the Surface Water section (above). Any lineament analyses, including those presented in this investigation, need to be corroborated by field investigations and additional data to confirm the nature of the lineaments and their relation to water-filled bedrock fracture zones.

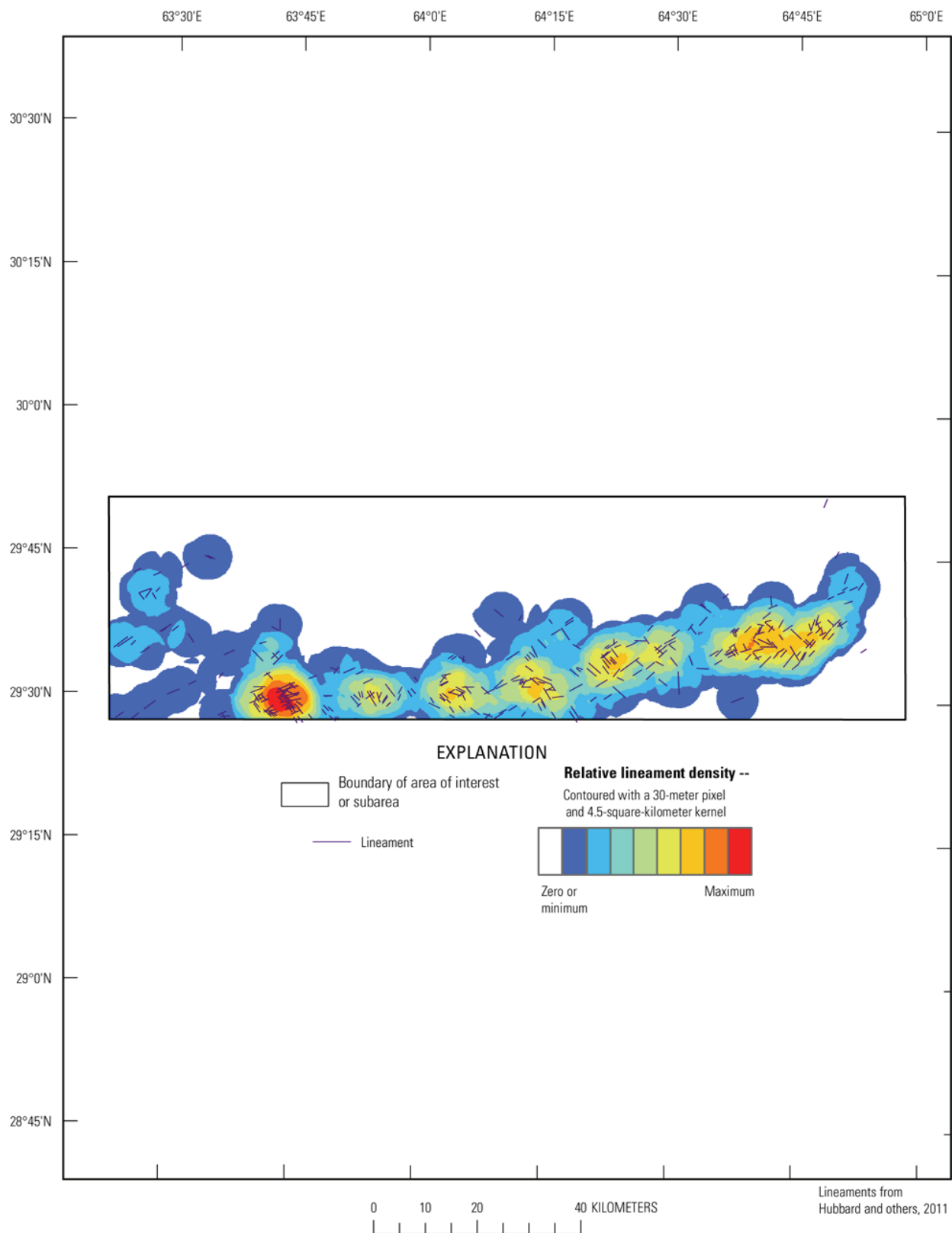
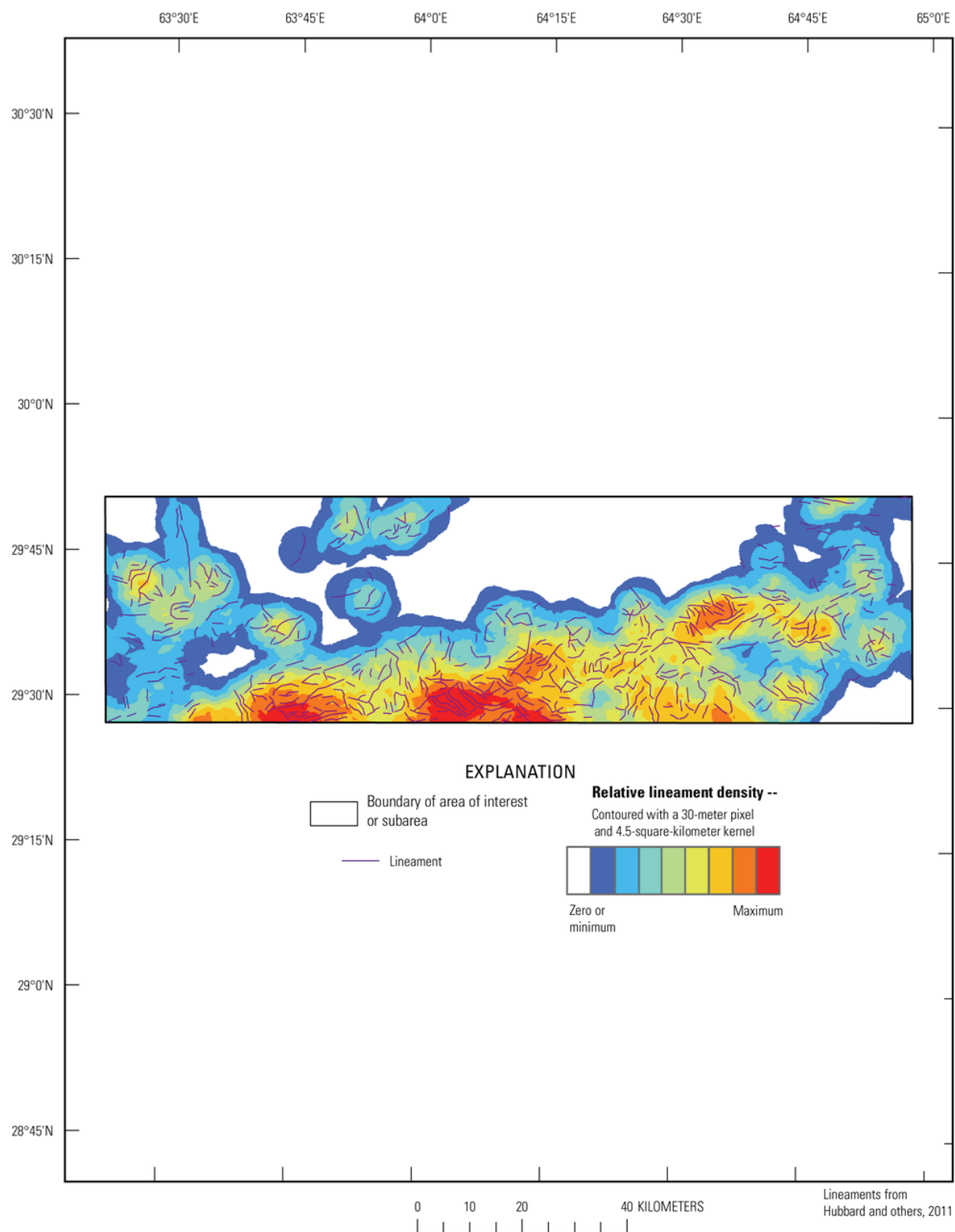


Figure 25C–8. Lineaments and lineament density based on 30-meter digital-elevation-model data and natural-color Landsat imagery in the South Helmand travertine area of interest in southern Afghanistan.

a



b

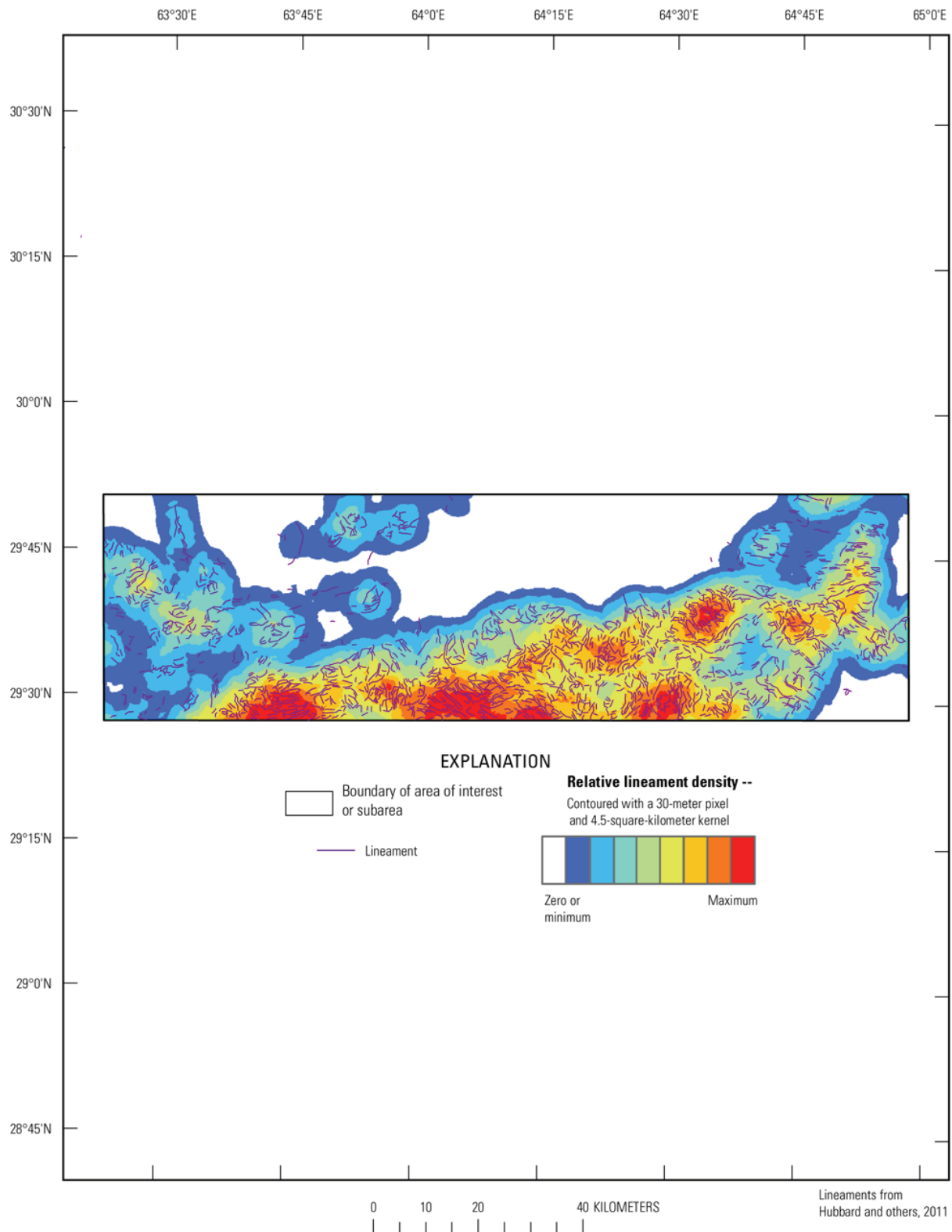


Figure 25C–9. (a) Lineaments and lineament density based on 30-meter multispectral Landsat imagery and (b) lineaments and lineament density based on 15-meter multispectral Landsat imagery in the South Helmand travertine area of interest in southern Afghanistan.

25C.9 Summary and Conclusions

Surface-water and groundwater resources are likely to be less available in the South Helmand travertine area of interest (AOI) than in other areas of Afghanistan as a result of low precipitation and the absence of perennial streams. The closest permanent source of surface water is the Helmand River, about 75 km to the north. The presence of earthen dams and karezes in the larger ephemeral streams indicates that the limited surface water in the AOI is probably being used for irrigation. Groundwater in the AOI is an unproven resource but likely is present in limited quantities in shallow aquifers and may also be available in deeper aquifers where basin sediments are thick. Generalized geohydrologic maps and results of lineament analyses indicate that some areas of the AOI are likely areas for further exploration for groundwater resources.

Seasonal recharge to the shallow aquifers probably occurs following runoff events in the Chagai Hills. It is unlikely that the shallow aquifers could supply additional water to support mining activities because recharge is low. The quantity and quality of water in deep aquifers in the AOI are unknown at this time. Limited recharge to deeper aquifers probably occurs locally, but such water is likely to be thousands of years old. The production of water from deeper aquifers may be possible but, as in all desert environments, close monitoring and careful management would be needed to prevent aquifer depletion. Field investigations including geologic mapping, geophysical surveys, and hydraulic well testing are needed to adequately characterize the extent and availability of groundwater resources in the AOI.

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