Chapter 8C. Geohydrologic Summary of the Katawas Gold Area of Interest

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8C.1 Introduction

This chapter describes the geohydrology of the Katawas gold area of interest (AOI) in southeast Afghanistan identified by Peters and others (2007). The AOI is located in the Giro, Miri (Andar), and Dih Yah Districts of Ghazni Province, and the Sharan District in Paktika Province (fig. 8C–1*a,b*). The Katawas gold subarea occupies 143 km^2 (square kilometers) of the 478-km^2 area of the AOI. The AOI is bounded by the Ghazni and Jilga Rivers on the northwest, the Park and Naharah Rivers on the southeast, and the Pulta River on the east. The Sardeh (Sarde) Reservoir is in the northeast corner of the AOI. The cities of Ghazni and Gardez are both about 40 km (kilometers) from the AOI. The AOI is characterized by a prominent northeast-trending ridge that terminates to the northeast at the flood plains of the Pulta and Jilga Rivers.

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. Where these data are available, the depth to water and height of static water in well casings are documented. 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 (2010), nongovernmental organizations (NGOs), foreign government agencies, and the Afghan government have begun water-resource investigations; 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.

8C.1.1 Climate and Vegetation

Climate information for the Katawas gold 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.

The Sharana Agromet station is located in Sharan Woluswali on the Pulta River, about 1 km upstream from the Sardeh Reservoir (fig. 8C–1*b*). Precipitation data are available for this station for the 2009–2010 water year (Ministry of Agriculture, Irrigation, and Livestock, 2010). The closest Agromet station to the AOI for which both precipitation and temperature data, including long-term averages (LTAs), are available is in the city of Ghazni, about 40 km northwest of the AOI. The total precipitation recorded at the Sharana and Ghazni Agromet stations for the 2009–2010 water year was 339.5 and 218.3 mm (millimeters), respectively; the LTA precipitation at Ghazni is 308 mm. No precipitation was recorded at either station during September and October 2009, but as the LTA monthly precipitation recorded at Ghazni for September and October is 0.2 and 1.3 mm, respectively, receiving no rain during these two months is not unusual. Rainfall was recorded in August 2010 at both stations (88 mm at Sharana and 22.8 mm at Ghazni), indicating that some monsoon precipitation fell in the AOI. The Ghazni Agromet station received 34 mm of precipitation in July 2010. The Afghanistan Agrometeorological Seasonal Bulletin (Ministry of Agriculture, Irrigation, and Livestock, 2010) states, “The southeast region experienced heavy rainfall during the (2009–2010) rainfall season especially during the monsoon season.” The LTA precipitation for the Ghazni Agromet station for July and August is 15.7 and 2.4 mm, respectively, indicating that the monsoon rains are not an annually recurring phenomenon in this part of Afghanistan. Precipitation and temperature data for the Ghazni Agromet station are shown in table 8C–1.

A total of 4 snow days was reported for the Sharana Agromet station—2 in December 2009 and 1 each in January and February 2010. The depth of the snow that fell at the Sharana station was not reported. The snow-depth maps for January 2010 and September 2010 (Ministry of Agriculture, Irrigation, and Livestock, 2010) show 2 to 10 cm (centimeters) of snow in the AOI in January.

Temperature data are available for the Agromet station located at Ghazni. The average monthly temperatures for the 2009–2010 season range from -1.1°C (degrees Celsius) for February 2010 to 23.5°C for July 2010. The LTA monthly low and high temperatures are -7.2°C for January and 23.3°C for July (Ministry of Agriculture, Irrigation, and Livestock, 2010).

The Map of Potential Natural Vegetation in Breckle (2007, fig. 2) depicts two vegetation zones in and around the AOI. The higher elevations (above 2,200 m (meters)) are classified as *Amygdalus* woodlands and the lower elevations (valley bottoms and river flood plains) are *Pistacia atlantica* woodlands. Aerial photographs of the AOI indicate that natural vegetation is sparse, especially in areas mapped as bedrock (Maldonado and Turner, 2005).

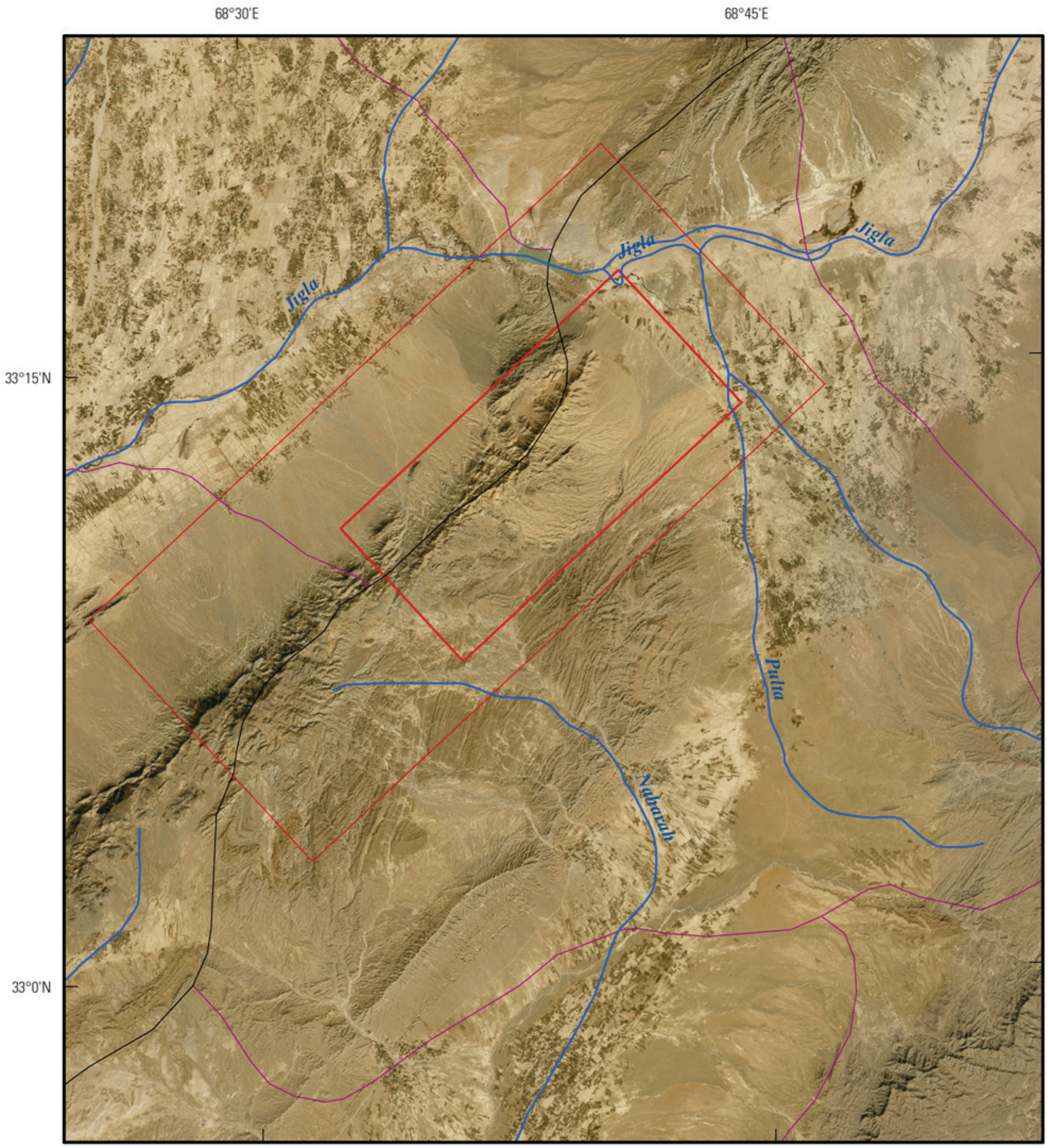
Table 8C–1. Annual, long-term annual average, and long-term average minimum and maximum precipitation and temperature at the Ghazni Agrometeorological (Agromet) station 40 kilometers northwest of the Katawas gold area of interest, Afghanistan.

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

Agromet station	Distance from AOI center (km)	Elevation (m)	Precipitation				Temperature		
			2009–2010 annual (mm)	Long-term average[1]			Long-term average[1]		
				Annual (mm)	Monthly minimum (mm) and month	Monthly maximum (mm) and month	Minimum (°C) and month	Monthly mean (°C)	Maximum (°C) and month
Ghazni	40	3,200	218.3	308	0.2 September	63.8 April	–7.2 January	7.3	23.3 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).

a



Base from U.S. Geological Survey Natural-Color Landsat Image Mosaic of Afghanistan Map Series, 2006,14.25-meter. Cultural data modified from Afghanistan Information Management System (www.aims.org).

0 2.5 5 10 KILOMETERS

EXPLANATION

Boundary of area of interest (AOI) or subarea

Province boundary line

District boundary line

Stream, generally perennial

b

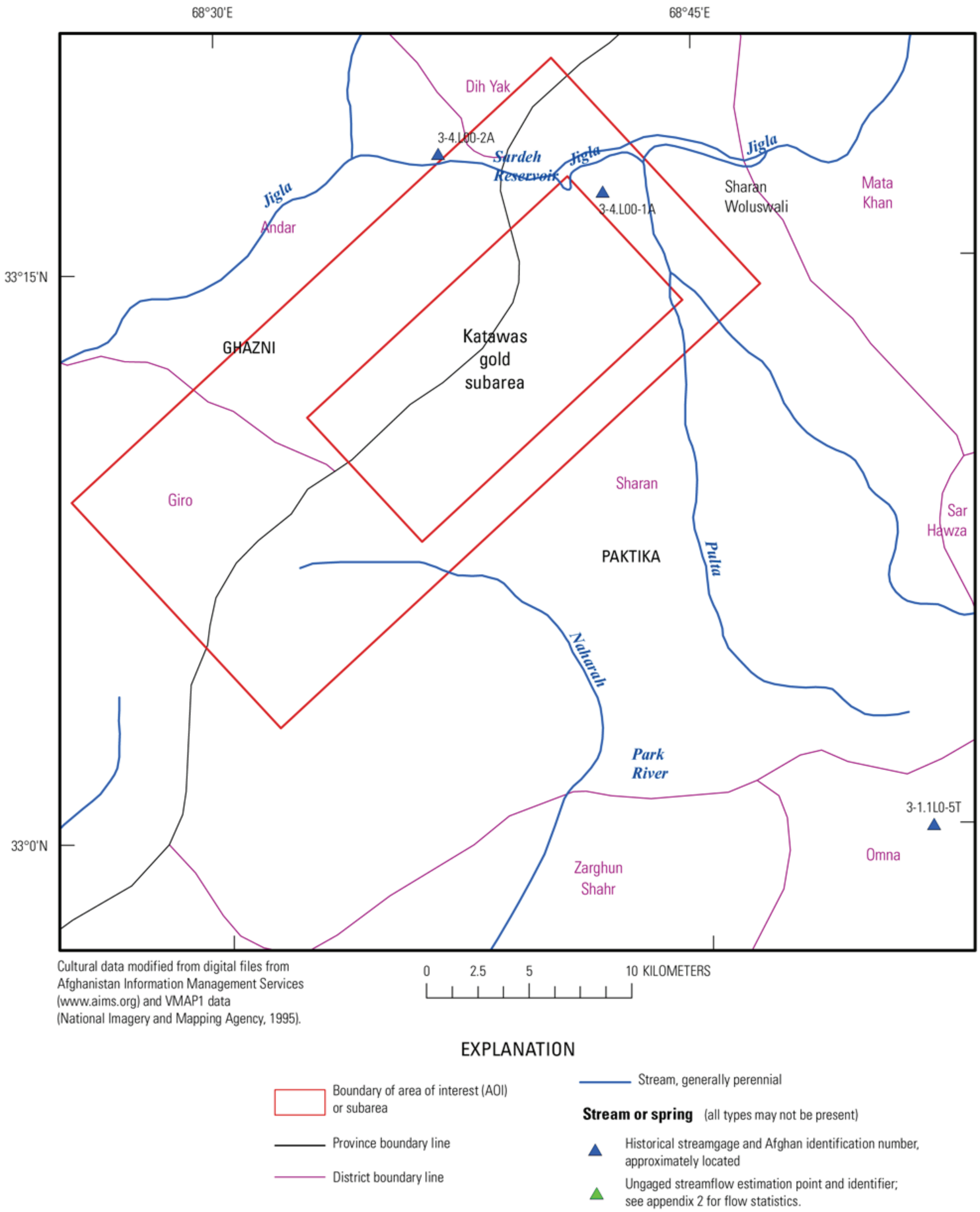


Figure 8C–1. *(a)* Landsat image showing the location of, and *(b)* place names, stream names, and streamgage station numbers in, the Katawas gold area of interest in southeastern Afghanistan.

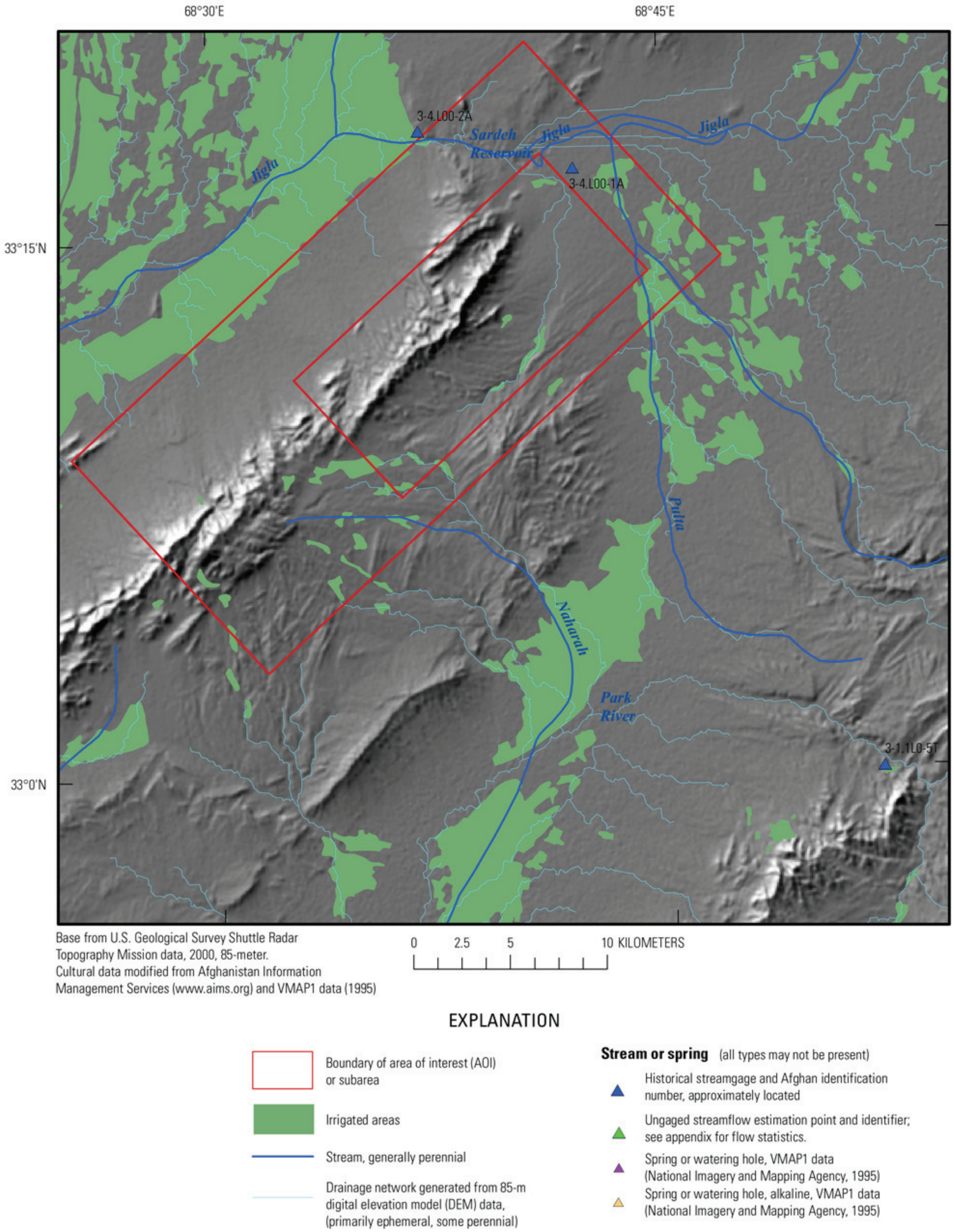


Figure 8C–2. Historical streamgage locations, digitally generated drainage network, and irrigated areas in the Katawas gold area of interest in southeastern Afghanistan.

8C.1.2 Demographics

The estimated population density in the Katawas gold AOI as mapped by LandScan (Oak Ridge National Laboratory, 2009) is shown in figure 8C–3. Population density in most areas in the AOI is less than 100/km^2. The largest settlement in the AOI is Sharan Woluswali, located in the northeast part of the AOI (fig. 8C–1*a*,*b*). In a few areas in the vicinity of Sharan Woluswali the estimated maximum population density is 501 to 2,500/km^2 (fig. 8C–3). The estimated population density in the southwestern part of the AOI is generally less than 25/ km^2. Areas where population density is higher are generally near streams. A few villages are present on the alluvial deposits formed at the mouths of ephemeral streams that drain the bedrock outcrop areas. There is limited development at the eastern edges of the AOI. The presence or absence of development in the AOI is probably related to the availability of water for domestic consumption and irrigation (fig. 8C–2). The population density shown in figure 8C–3 has a pixel resolution of about 1 km^2 (Oak Ridge National Laboratory, 2010). The roads within and around the AOI are mapped as "tracks" (Afghanistan Information Management Service, 2004). A secondary road connects Sharan Woluswali with the provincial capital of Ghazni.

The Ghazni and Jilga River valleys are located northwest of the AOI. These valleys exhibit considerable agricultural development as a result of the availability of water for irrigation (fig. 8C–2) (Afghanistan Information Management Service, 1997). Irrigation water is supplied from the Sardeh Reservoir through irrigation canals (U.S. Agency for International Development, 2003). Canals divert water directly from the Jilga River downstream from the Sardeh Dam for irrigation.

8C.3 Topography and Geomorphology

The topography of the Katawas gold AOI consists of a series of linear, northeast-trending ridges located in the middle of the AOI (figs. 8C–1b, 8C–4) (Davis, 2006). The ridges have a combined length of slightly more than 90 km. The location of ridges and valleys in the AOI is controlled by the location of faults and fault zones. The elevation of the bedrock outcrops gradually decreases to the southeast toward the valley formed by the Naharah River (fig. 8C–2). The northeast areas of the AOI are relatively flat, with an average elevation of 2,150 m above sea level (asl). This section of the AOI is dominated by the flood plains formed by the Pulta and Jilga Rivers. The sedimentary bedrock outcrops in and adjacent to the AOI display a complex pattern of shallow, linear valleys. The valleys could be controlled by steeply dipping, northeast-striking beds. There are two ephemeral streams in the bedrock outcrop that have large drainage basins. The larger drainage basin is about 31 km^2 in size and is in the northeast part of the AOI. This stream drains to the northeast into a splay of the Pulta River. The smaller basin is about 18 km^2 in size and is in the middle of the bedrock outcrop area. This stream drains to the southeast onto a large alluvial fan and then into the valley formed by the Naharah River.

8C.2 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 Katawas gold AOI is in the Katawas (Katawaz) Artesian Basin, located in the northeast part of the South Afghanistan Artesian Region. The Katawas Artesian Basin is a geosynclinal trough of the same name filled with a thick sequence, as much as 6,000 m, of sedimentary and volcanic rocks. The Katawas Artesian Basin is described by Safi (2007) as having potential for groundwater development but also having a range of thicknesses, hydraulic properties, and water qualities.

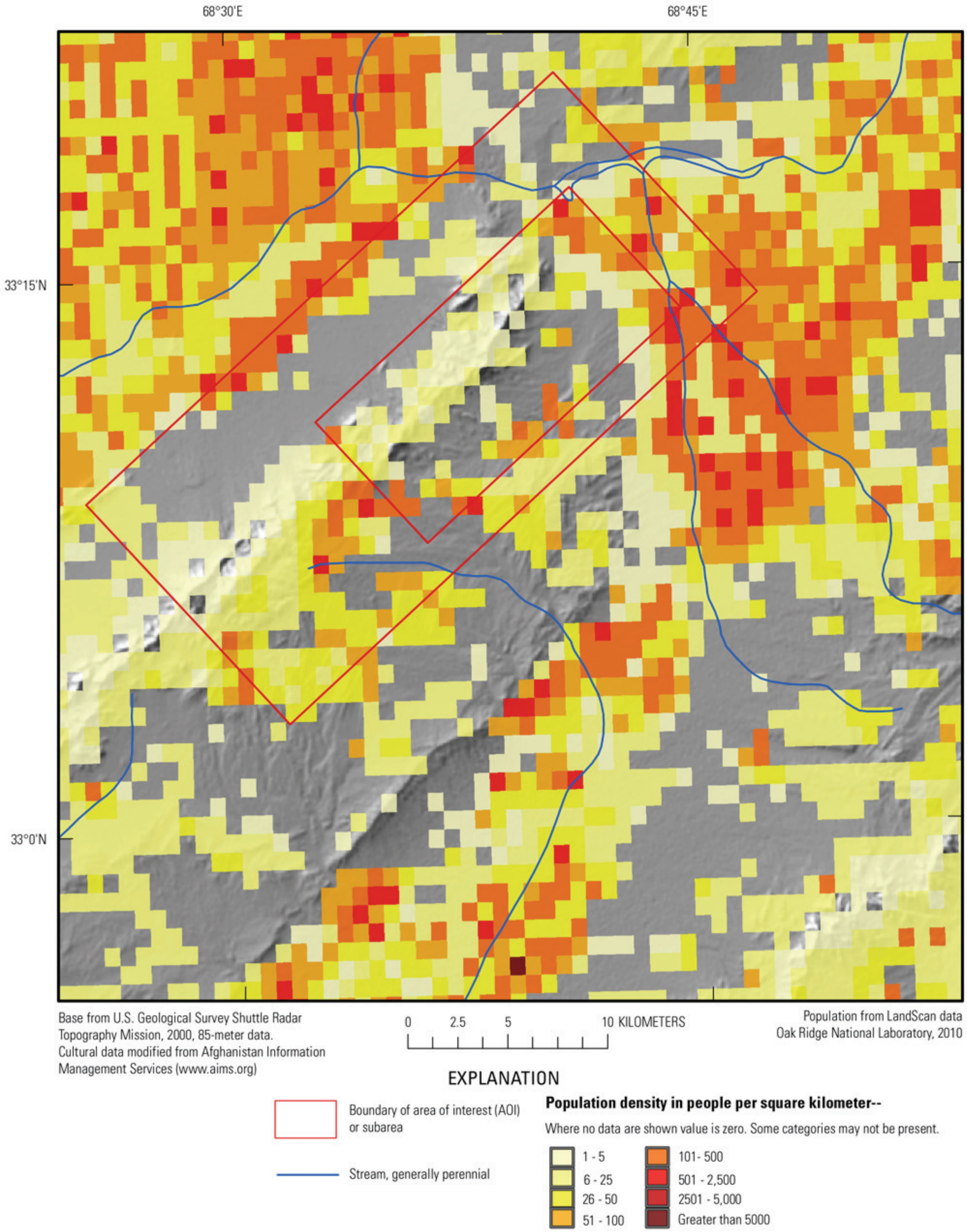


Figure 8C–3. Population density of the Katawas gold area of interest in southeastern Afghanistan.

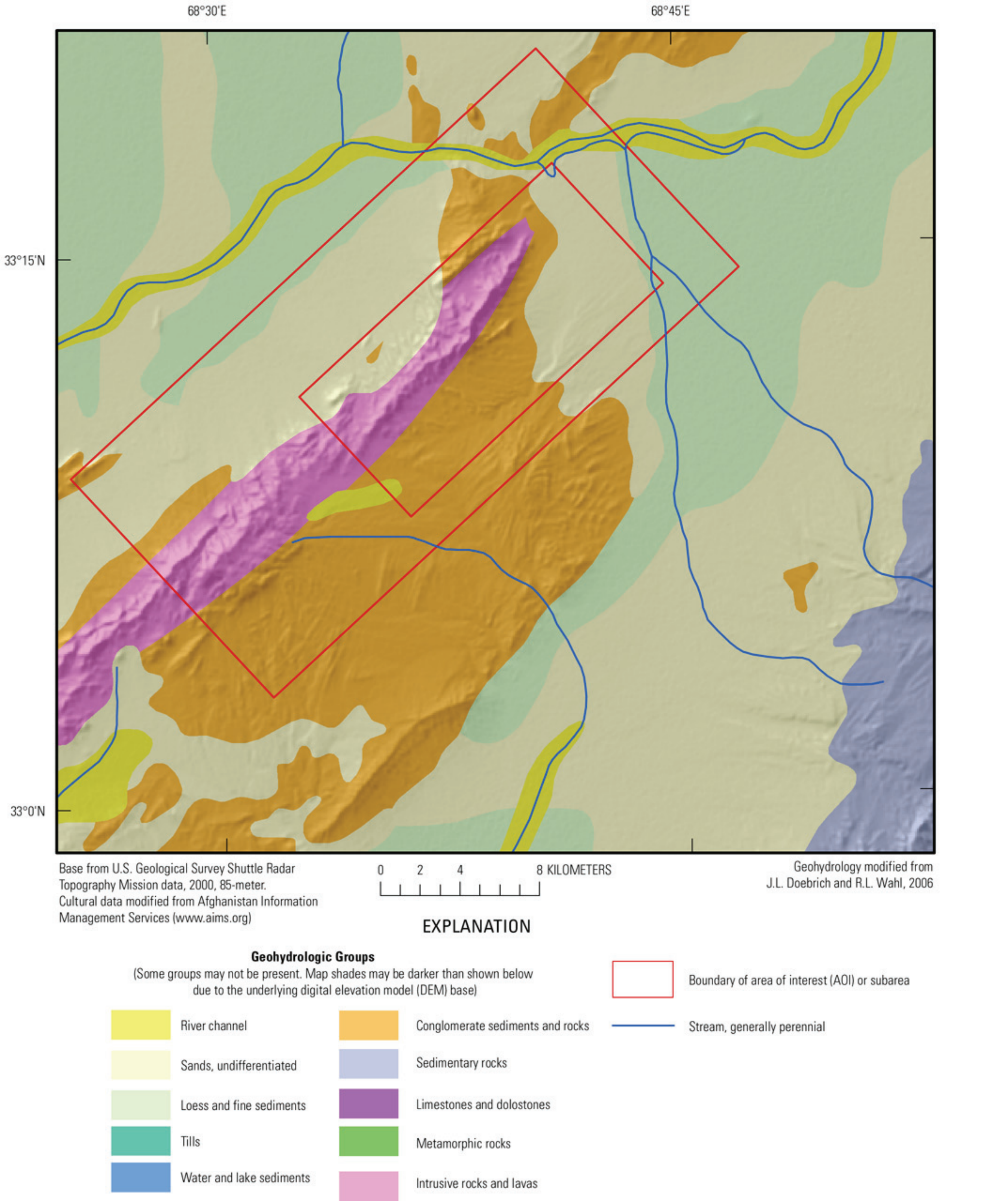


Figure 8C–4. Topography and generalized geohydrology in the Katawas gold area of interest in southeastern Afghanistan.

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 8C–4 with the underlying topography to allow examination of the geohydrology in the context of relief. Figure 8C–

5*a*,*b* shows the generalized geohydrology without topography for a clearer depiction of the geohydrologic units. Wells present in the map area (discussed in the Groundwater section) are shown in figure 8C–5*a*,*b*. 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; loess and fine sediments; and conglomerate sediments and rocks; sedimentary rocks; and intrusive rocks and lavas" (figs. 8C–4 and 8C–5*a*). 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 map that covers this AOI is provided by Maldonado and Turner (2005). Information about the hydraulic properties of the geohydrologic groups in the AOI is extremely limited. Additional field work including geologic mapping, geophysical surveys, and borehole drilling and testing would be needed to determine the groundwater potential of the geohydrologic groups in the AOI.

The unconsolidated units consist of the sands, undifferentiated and loess and fine sediments geohydrologic groups along the southeastern border of the AOI; the river channel, sands undifferentiated, and loess and fine sediments geohydrologic groups in the Ghazni and Jilga River valleys; the river channel and sands, undifferentiated deposits in the Naharah River valley; and the sands, undifferentiated and loess and fine sediments around Sharan Woluswali in the northern part of the AOI (fig. 8C–4). The area covered by the sands, undifferentiated geohydrologic group is fairly extensive within and adjacent to the AOI. Depending on the thickness of this group, it is possible that this unit could be a groundwater resource in and adjacent to the AOI.

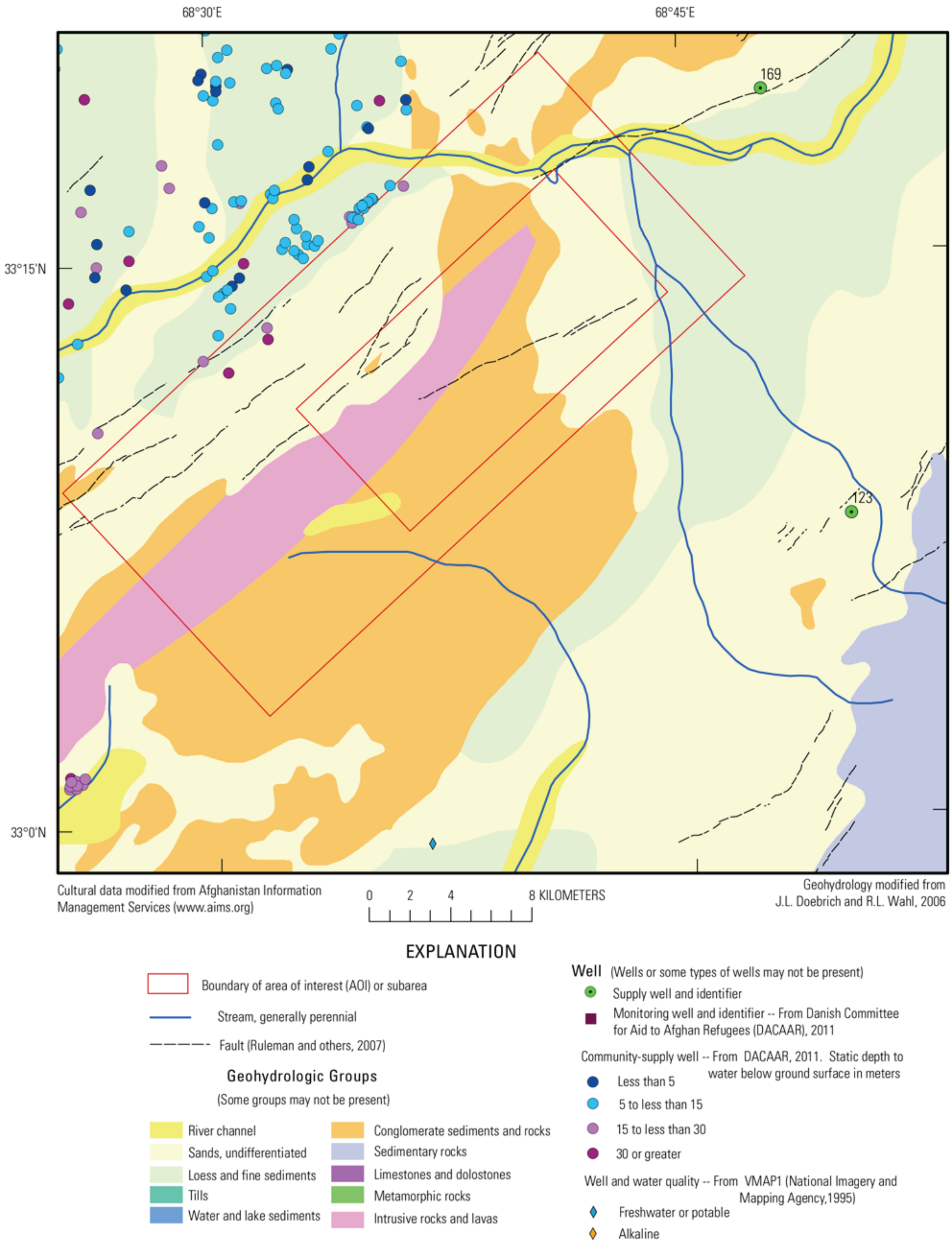
The conglomerate sediments and rocks geohydrologic group is present along the flanks of the northeast-trending ridge in the AOI (fig. 8C–4). These rocks appear to have been deposited on the intrusive rocks and lavas geohydrologic group. There are no mapped wells in these rocks in the AOI, and no information is available on the thickness of this group in the AOI. The limited areal extent and outcrop distribution of the conglomerate sediments and rocks group adjacent to the intrusive rocks and lavas geohydrologic group probably limits the amount of groundwater that is present in and can be extracted from the conglomerate sediments and rocks.

The outcrops of the intrusive rocks and lavas geohydrologic group form the northeast-trending ridge in the AOI (fig. 8C–4). If these rocks are unfractured intrusive rocks, their hydraulic conductivity and storage capacity will be small and it is unlikely that appreciable quantities of groundwater are present. However, if the outcrops consist of fractured intrusive rocks or fractured lavas, some groundwater could be present; the amount would depend on the amount of primary and secondary fracturing and the geometry of the fracture network.

8C.2.1 Surface Water

The Katawas gold AOI is between the Ghazni and Jilga Rivers on the northwest and the Naharah and Pulta Rivers on the southeast and south (figs. 8C–1*b,* 8C–2). A network of major, mostly perennial streams, modified from AIMS (Afghanistan Information Management Services, 1997) and VMAP1 (National Imagery and Mapping Agency, 1995), is shown in figure 8C–2. A network representing likely ephemeral streams, generated with a digital elevation model (DEM), also is shown in figure 8C–2. Names of major streams and identification numbers for any streamgages and ungaged streamflow estimation sites in the AOI are shown in figure 8C–1*b*. The Sardeh Reservoir is in the northern corner of the AOI and is formed by a dam on the Jilga River. The Pulta River runs through the AOI and empties into the Sardeh Reservoir. The Park River, southeast of the AOI, is ephemeral with sustained flow only during the spring runoff. Two large, unnamed ephemeral streams drain the bedrock outcrops in the AOI; the longer of the two is about 16 km in length and drains to the northeast, whereas the shorter is about 8 km long and drains to the south (fig. 8C–2). Both of these ephemeral streams have formed alluvial fans where settlements and agriculture have developed.

a



68°30'E
68°45'E
33°15'N
33°0'N
169
123
Cultural data modified from Afghanistan Information Management Services (www.aims.org)
0 2 4 8 KILOMETERS
Geohydrology modified from J.L. Doebrich and R.L. Wahl, 2006
EXPLANATION
Boundary of area of interest (AOI) or subarea
Stream, generally perennial
Fault (Ruleman and others, 2007)
Geohydrologic Groups
(Some groups may not be present)
River channel
Sands, undifferentiated
Loess and fine sediments
Tills
Water and lake sediments
Conglomerate sediments and rocks
Sedimentary rocks
Limestones and dolostones
Metamorphic rocks
Intrusive rocks and lavas
Well (Wells or some types of wells may not be present)
Supply well and identifier
Monitoring well and identifier -- From Danish Committee for Aid to Afghan Refugees (DACAAR), 2011
Community-supply well -- From DACAAR, 2011. Static depth to water below ground surface in meters
Less than 5
5 to less than 15
15 to less than 30
30 or greater
Well and water quality -- From VMAP1 (National Imagery and Mapping Agency,1995)
Freshwater or potable
Alkaline

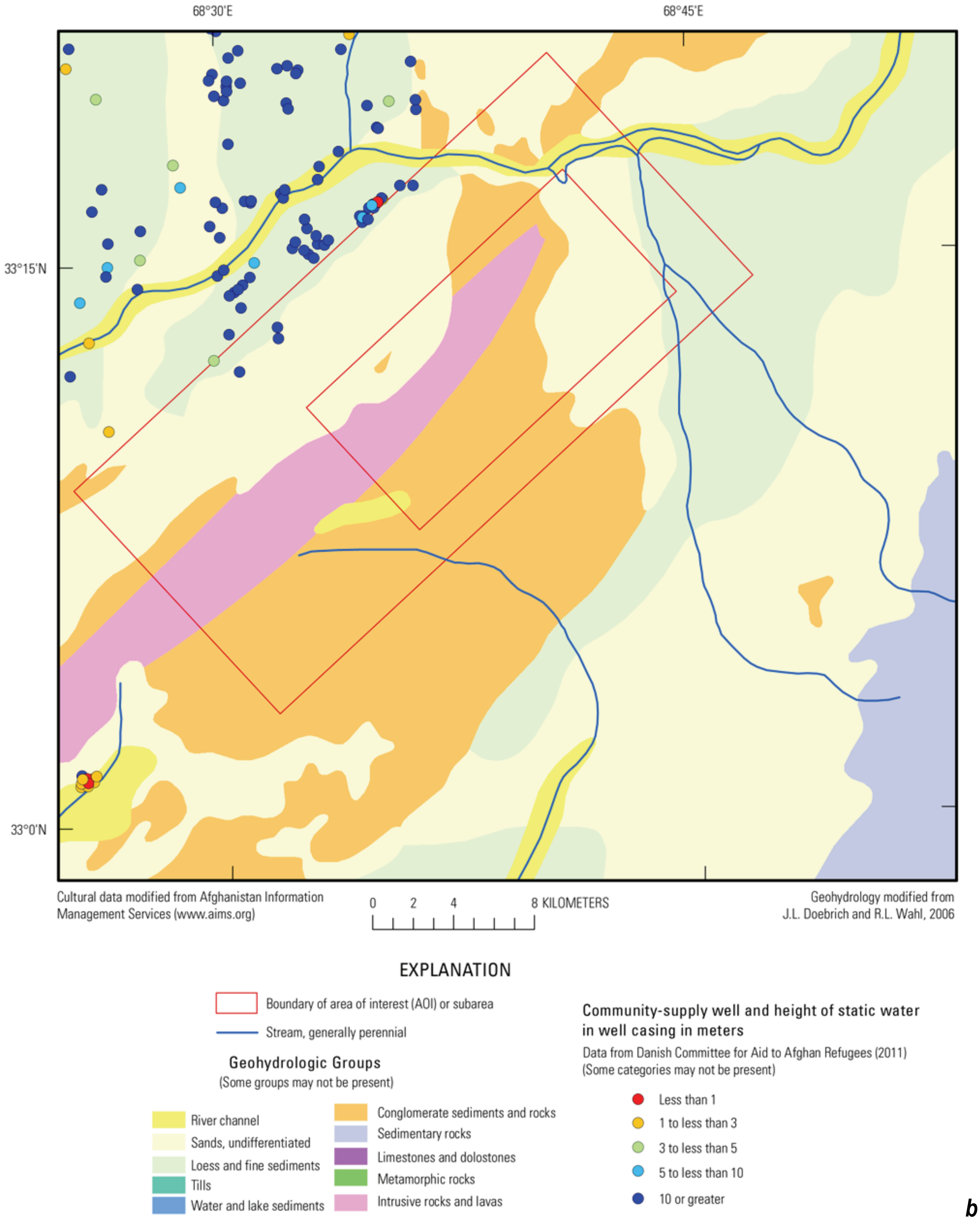


Figure 8C–5. *(a)* Generalized geohydrology, mapped faults, well locations, and depth to water, and *(b)* geohydrology and height of static water in well casings in community supply wells in the Katawas gold area of interest in southeastern Afghanistan.

Historical streamflow data are available from one streamgage station in and two streamgage stations near the AOI (Williams-Sether, 2008) (fig. 8C–2). The station on the Pulta River, above the Sardeh Reservoir (Afghan identification number 3–4.L00–1A), has a drainage area of 805 km^2 and is at an elevation of 2,115 m asl. The period of record is from 6 May, 1969, to 30 September, 1980. The annual mean streamflow per unit area for this station is 0.0007 $m^3/s/km^2$ (cubic meters per second per square kilometer). Mean streamflow was highest (2.45 m^3/s (cubic meters per second)) in April and lowest (0.0 m^3/s) in October; mean streamflow in both September and November was 0.05 m^3/s. The maximum monthly mean streamflow was 8.14 m^3/s during April 1976. With the exception of January, February, and March, no flow was recorded at this station during 1 or more years during the period of record. A statistical summary of monthly and annual mean streamflows for this station (Williams-Sether, 2008) is shown in table 8C–2. Statistical summaries of streamflow data for all available historical gages in Afghanistan can be accessed at *http://afghanistan.cr.usgs.gov/water.php*.

The streamgage station located on the Jilga River below Sardeh Reservoir (Afghan identification number 3–4.L00–2A, fig. 8C–2) has a drainage area of 4,340 km^2, is at an elevation of 2,086 m asl, and has a period of record that extends from 8 April, 1969, to 30 September, 1979. Some historical streamgage stations were imprecisely located, and this gage is likely about 3 km north of its location in figure 8C–2. The annual mean streamflow per unit area for this station is 0.0002 $m^3/s/km^2$. Mean streamflow for the period of record was highest (4.04 m^3/s) in April and lowest (0.21 m^3/s) in November, December, and January. The maximum monthly mean streamflow was 21.9 m^3/s during April 1976 and the minimum monthly mean streamflow was 0.039 m^3/s during October 1972. The streamflow from the Sardeh Reservoir is probably controlled to provide irrigation water to downstream settlements; this regulation could affect the flow at this streamgage station. A statistical summary of monthly and annual mean streamflows for this station (Williams-Sether, 2008) is shown in table 8C–3.

Characteristics of streamflow (per square kilometer) in topographically high areas of the AOI may be similar to those at the streamgage station on the Park River near Park Dasht (Afghan identification number 3–4.1L0–5T, Williams-Sether, 2008), approximately 25 km southeast of the AOI (figs. 8C-1b, 8C–2). This streamgage station has a small drainage area (260 km^2) at an elevation that is similar to the elevation of the AOI. The annual mean streamflow per unit area for this station is 0.0015 $m^3/s/km^2$. A statistical summary of monthly and annual mean streamflows for this station (Williams-Sether, 2008) is shown in table 8C–4.

The largest body of surface water near the AOI is the Sardeh Reservoir, created by the construction of the Sardeh Dam on the Jilga River. The Sardeh Dam was constructed by Soviet engineers and completed in 1967. The water in the Sardeh Reservoir is used to irrigate an area of about 15,280 hectares downstream from the dam (U.S. Agency for International Development, 2003). The volume of water in the reservoir varies seasonally, with the maximum probably coinciding with the spring runoff in the Jilga and Pulta Rivers. The U.S. Agency for International Development (2003) states that “Silt and sediment during periods of peak runoff partially fill the reservoir which results in a decrease in its storage capacity.” Whether the silt and sediment are or were removed to restore the reservoir to pre-peak runoff capacity is unknown. The water-surface area of the Sardeh Reservoir is about 15 km^2. The reservoir has a maximum capacity of 259 Mm^3 (million cubic meters) and a normal capacity of 165 Mm^3 (U.S. Agency for International Development, 2003). Water levels in the Sardeh Reservoir probably fluctuate considerably with the capture of meltwater in the spring and the release of water for irrigation during the drier months.

Table 8C–2. Statistical summary of monthly and annual mean streamflows for the Pulta River above Sardeh Reservoir streamgage station, Afghanistan (Williams-Sether, 2008).

[m^3/s, cubic meters per second; m, more than 2 years of occurrence; ng, no data]

3–4.L00–1A Paltu River above Sardeh Reservoir								
	Maximum		Minimum		Mean			
Month	Streamflow (m^3/s)	Water year of occurrence	Streamflow (m^3/s)	Water year of occurrence	Streamflow (m^3/s)	Standard deviation (m^3/s)	Coefficient of variation	Percentage of annual streamflow
October	0	m	0	m	0	0	ng	0
November	0.404	1978	0	m	0.05	0.12	2.63	0.72
December	0.167	1979	0	1972	0.06	0.06	0.95	1.03
January	0.271	1979	0.010	m	0.13	0.11	0.89	2.02
February	2.32	1973	0.010	1974, 1975	0.50	0.70	1.40	7.95
March	3.15	1980	0.091	1977	1.53	1.26	0.82	24.2
April	8.14	1976	0	1970, 1971	2.45	2.72	1.11	38.8
May	3.13	1976	0	m	0.67	1.14	1.70	10.6
June	0.219	1972	0	m	0.02	0.06	3.46	0.29
July	3.15	1978	0	m	0.39	0.91	2.37	6.11
August	2.54	1978	0	m	0.48	0.77	1.60	7.63
September	0.324	1976	0	m	0.05	0.11	2.38	0.73
Annual	**1.33**	**1976**	**0.073**	**1970**	**0.53**	**0.41**	**0.77**	**100**

Table 8C–3. Statistical summary of monthly and annual mean streamflows for the Jilga River below Sardeh Reservoir streamgage station.

[m^3/s, cubic meters per second]

3–4.L00–2A Jilga River below Sarde Reservoir								
	Maximum		Minimum		Mean			
Month	Streamflow (m^3/s)	Water year of occurrence	Streamflow (m^3/s)	Water year of occurrence	Streamflow (m^3/s)	Standard deviation (m^3/s)	Coefficient of variation	Percentage of annual streamflow
October	0.393	1977	0.039	1972	0.22	0.11	0.51	2.05
November	0.324	1977	0.070	1970	0.21	0.09	0.44	1.93
December	0.320	1977	0.067	1972	0.21	0.09	0.42	1.92
January	0.301	1979	0.050	1972	0.21	0.09	0.44	1.94
February	0.786	1973	0.074	1972	0.28	0.21	0.72	2.67
March	18.5	1973	0.191	1972	2.59	5.74	2.22	24.3
April	21.9	1976	0.210	1971	4.04	7.09	1.76	37.8
May	7.98	1972	0.104	1971	1.56	2.45	1.57	14.6
June	1.47	1972	0.108	1971	0.50	0.39	0.79	4.65
July	0.675	1973	0.108	1971	0.36	0.19	0.51	3.39
August	0.477	1974	0.052	1971	0.27	0.14	0.49	2.58
September	0.361	1976	0.100	1970	0.23	0.10	0.41	2.20
Annual	**2.90**	**1973**	**0.115**	**1971**	**0.90**	**0.97**	**1.07**	**100**

Table 8C–4. Statistical summary of monthly and annual mean streamflows for the Park River near Park Dasht streamgage station, Afghanistan.
[m^3/s, cubic meters per second]

3–1.1L0–5T Park River near Park Dasht

Month	Maximum		Minimum		Mean			
	Streamflow (m^3/s)	Water year of occurrence	Streamflow (m^3/s)	Water year of occurrence	Streamflow (m^3/s)	Standard deviation (m^3/s)	Coefficient of variation	Percentage of annual streamflow
October	0.091	1976	0.040	1978	0.06	0.02	0.32	1.12
November	0.104	1979	0.048	1978	0.06	0.02	0.33	1.19
December	0.133	1969	0.043	1970	0.09	0.03	0.35	1.72
January	0.149	1977	0.041	1970	0.11	0.04	0.37	1.98
February	1.13	1976	0.070	1969	0.32	0.37	1.17	5.85
March	3.58	1968	0.144	1969	1.48	1.26	0.85	27.2
April	3.83	1979	0.552	1969	1.89	1.41	0.75	34.8
May	1.42	1976	0.088	1978	0.46	0.55	1.18	8.52
June	0.272	1976	0.057	1978	0.13	0.09	0.68	2.33
July	1.97	1978	0.042	1968	0.55	0.82	1.48	10.2
August	0.447	1976	0.039	1969	0.20	0.20	0.97	3.72
September	0.172	1976	0.030	1968	0.08	0.06	0.79	1.44
Annual	**0.829**	**1976**	**0.136**	**1969**	**0.40**	**0.32**	**0.80**	**100**

8C.2.2 Groundwater

The nature of groundwater resources in the Katawas gold AOI, particularly groundwater in deeper aquifers, is not well known. The presence of agricultural development in the northeastern part of the AOI indicates that shallow groundwater resources may be sufficient for domestic consumption and limited irrigation, especially around Sharan Woluswali, where the unconsolidated sediments are probably recharged by infiltrating surface and irrigation water in areas near the Pulta and Jilga Rivers. Seasonal recharge from winter and spring precipitation events is likely; however, the shallow groundwater is vulnerable to contamination, especially in areas where population density is high and agricultural development is present, such as north of the AOI.

Many shallow (about 30 m deep or less) community water-supply wells were installed in the Ghazni and Jilga River valleys northwest of the AOI (fig. 8C–5*a*) by NGOs (Danish Committee for Aid to Afghan Refugees, 2011). Several of the wells are within or immediately adjacent to the AOI. The three NGO wells inside the northwest border of the AOI are from 32 to 56 m deep, with water levels from 24 to 38 m below ground surface (bgs). Most of the NGO wells are tube wells with hand pumps that are used to supply water for domestic consumption. This is the most common type of NGO well construction and completion in Afghanistan. The shallow wells are generally driven pipe that taps the first groundwater encountered and may only access the upper few meters of the aquifer. Figure 8C–5*b* shows the height of static water in the water-supply-well casings (well depth minus static depth to water). This type of well is commonly affected by seasonal water-level fluctuations and is vulnerable to drying out for extended periods, or even permanently, in areas where groundwater use is increasing (Mack and others, 2010). Most wells appear to have sufficient static water (10 m or greater) for use; however, many wells, particularly those at high elevations (fig. 8C–4) or far from streams, contain little static water (less than 3 m) (fig. 8C–5*b*). Additionally, the potential for well-to-well interference is great, and any new withdrawals, whether shallow or deep, have the potential to lower water levels in the existing supply wells..

Three groundwater-monitoring wells (GWMs) operated by the Danish Committee for Aid to Afghan Refugees (DACAAR) are located about 30 km from the AOI (Danish Committee for Aid to Afghan Refugees, 2011). Hydrographs provided by DACAAR for these wells (Danish Committee for Aid to Afghan Refugees, 2011) display water-level and specific-conductance data (app. 3). The hydrographs show the date in week number and year, groundwater specific conductance in microsiemens per centimeter at 25° Celsius (µS/cm), and depth to water in meters below ground surface. GWMs 5 and 171 are located in the city of Ghazni about 40 km northwest of the AOI. GWM 7 is in the settlement of Walikay, 50 km west of the AOI. The hydrographs for these wells record the fluctuations in water level that result from the seasonal variability in recharge. Recharge to the shallow alluvial aquifers that supply water to these wells generally occurs during the spring and early summer, coinciding with the seasonal runoff. If long-term trends in water levels are present, they could reflect the effects of groundwater withdrawals or climatic variables.

The geologic map of the area (Maldonado and Turner, 2005) indicates that GWM well 5 is located in late Pleistocene loess, and the underlying unit is probably late Pleistocene alluvium composed of gravel and sand. This well is located between the Ghazni River, about 1 km west, and an ephemeral stream about 0.6 km to the east. The land surface slopes from east to west with a gradient of about 0.01 m/m. The water-level hydrograph for this well has a period of record from 9 May, 2005, to 21 July, 2008. The hydrograph shows that the maximum water level (39.8 m bgs) occurred in August 2005. This high water level most likely coincided with high surface-water flow in the Ghazni River and the ephemeral stream to the east, appears to have occurred later than the expected spring and early summer snowmelt and runoff, and may be the result of late summer rains. The typical pattern of the spring to early summer seasonal recharge events is shown on the hydrograph. The water level in this well generally declined from the 2005 maximum until the 2008 spring recharge event. The lowest water level recorded, 43 m bgs, occurred in September 2007. The water level rose substantially from September 2007 until the April 2008 high of 40 m bgs (app. 3).

GWM 171 is located in Holocene alluvium described as “gravel and sand, more abundant than silt and clay” (Maldonado and Turner, 2005). This well is described as being at the Qarabagh bus station and is 115 m west of the Ghazni River. The period of record for this well is from 26 January, 2009, to 22 November, 2010. The hydrograph has two distinct peaks, both during the spring and early summer. The minimum water levels occurred in November 2009 and November 2010, although the water-level hydrograph ends in November 2010 and the water level was still declining at that time. The proximity of this well to the Ghazni River and the type of alluvial material mapped at the surface indicates that the potential for surface-water recharge to the aquifer is good.

GWM 7 is located in the settlement of Walikay on an alluvial fan approximately 350 m from the center of an ephemeral stream channel. The geologic map of the area (Maldonado and Turner, 2005) shows this area as being late Pleistocene loess that is probably underlain by late Pleistocene alluvium composed of gravel and sand. 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) with irrigation canals located in the ephemeral stream near this well. The water-level hydrograph for this well shows distinct peaks and lows that represent annual water-level highs and lows. The highs generally occur during the spring and summer, probably representing times of flow in the ephemeral stream. The maximum water level was 3.8 m bgs in June 2006. The water-level lows occur during the winter months. The minimum water level was about 6.6 m bgs in December 2007 and January 2009. There was a general water-level decline in the well during the period of record.

The U.S. government drilled water-supply wells at two sites just outside the AOI (fig. 8C–5*a*). Site 123 is about 12 km southeast of the AOI and is located near the Pulta River. Site 123 consists of two wells (1 and 2) approximately 650 m apart; both wells are located in alluvium. Well 1 was drilled to 123 m bgs and the static water level was 68 m bgs. The water-level elevation in well 1 was 2,152.8 m asl. Well 2 was drilled to 112 m bgs and the static water level was 56 m bgs. The water-level elevation in well 2 was 2,151.6 m asl. Both wells were constructed in unconsolidated materials variously described as breccia, clay, conglomerate, sand, quartz, and rock. In well 1, the “water-bearing zone” is described in drillers’ logs as a conglomerate that is either clast or matrix supported. The reported depth interval for the water-bearing zone is 96 to 113 m bgs. The static water level in the well was reported as 68 m bgs. The water level in this well rose above the top of the aquifer to 68 m bgs, indicating that artesian conditions exist in the aquifer.

The U.S. government also drilled a well at site 169 (fig. 8C–5*a*). This well is believed to be deep (deeper than 30 m), but no information other than a static water level of 9.45 m bgs is known. The lateral extent of the deep aquifer penetrated by well 1 is unknown, but it could underlie much of the alluvium-filled valley around Sharan Woluswali and possibly the valley formed by the Naharah River. In a preliminary analysis of historical and recent aeromagnetic data (Sweeney and others, 2006; Shenwary and others, 2011), Drenth (2009) estimated the thickness of sediments overlying basement rock in the sedimentary basin 10 km southeast of the AOI to be at least 1,000 m, and possibly more than 2,000 m. It is possible that alluvial aquifers are present within this thick sequence of sediments; however, as a result of the low precipitation and high evaporation rates that characterize this region, deep groundwater could be recharged very slowly and may be as much as thousands to tens of thousands of years old (Mack and others, 2010).

It is possible that properly located and constructed wells in the deeper alluvial aquifers may be able to supply water for mining activities without causing adverse effects on local water resources. Site-specific hydrologic investigations would help to determine the properties, extent, and thickness of any aquifers, which would need to be known prior to extracting water. Siting wells so as to avoid interference with existing water-supply wells and other natural or manmade water sources, such as springs and karezes, would help to minimize any adverse effects of additional groundwater withdrawals.

No information was available on the occurrence of groundwater in the sedimentary or volcanic rocks in the AOI; therefore, depth to groundwater in these rocks is unknown. No water wells appear to be constructed directly on the bedrock outcrops, likely because of the expense of drilling wells in bedrock. Vegetated areas are visible on aerial images of the bedrock outcrops in the AOI. The vegetated areas occur within incised stream valleys and could indicate that sediments in these valleys form alluvial aquifers of limited extent. The presence of vegetation near the heads of ephemeral streams in the bedrock outcrops indicates that groundwater may be discharged from bedrock at these locations. The amount of water being discharged probably depends on local recharge conditions and could fluctuate seasonally in response to changes in precipitation.

8C.2.3 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 Katawas gold AOI (B.E. Hubbard, T.J. Mack, and A.L. Thompson, unpub. data, 2011) were conducted using DEM and natural-color satellite imagery (fig. 8C–6) and Advanced Spaceborne Thermal Emission and Reflection Radiometry (ASTER) satellite imagery (fig. 8C–7*a*, *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 8C–6 were delineated visually, whereas those in figure 8C–7 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. 8C–6 and 8C–7*a*, *b*) 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. 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.

Analysis of lineaments in the AOI was limited because of the exposed bedrock. Northeast-trending features (figs. 8C–6 and 8C–7*a*) indicate a possible pervasive fracture pattern in the intrusive rocks (fig. 8C–4). Bedrock wells installed near or in line with such features may have greater yields than wells in other areas. Where these patterns intersect, there may be a potential for enhanced secondary porosity and transmissivity of the rock.

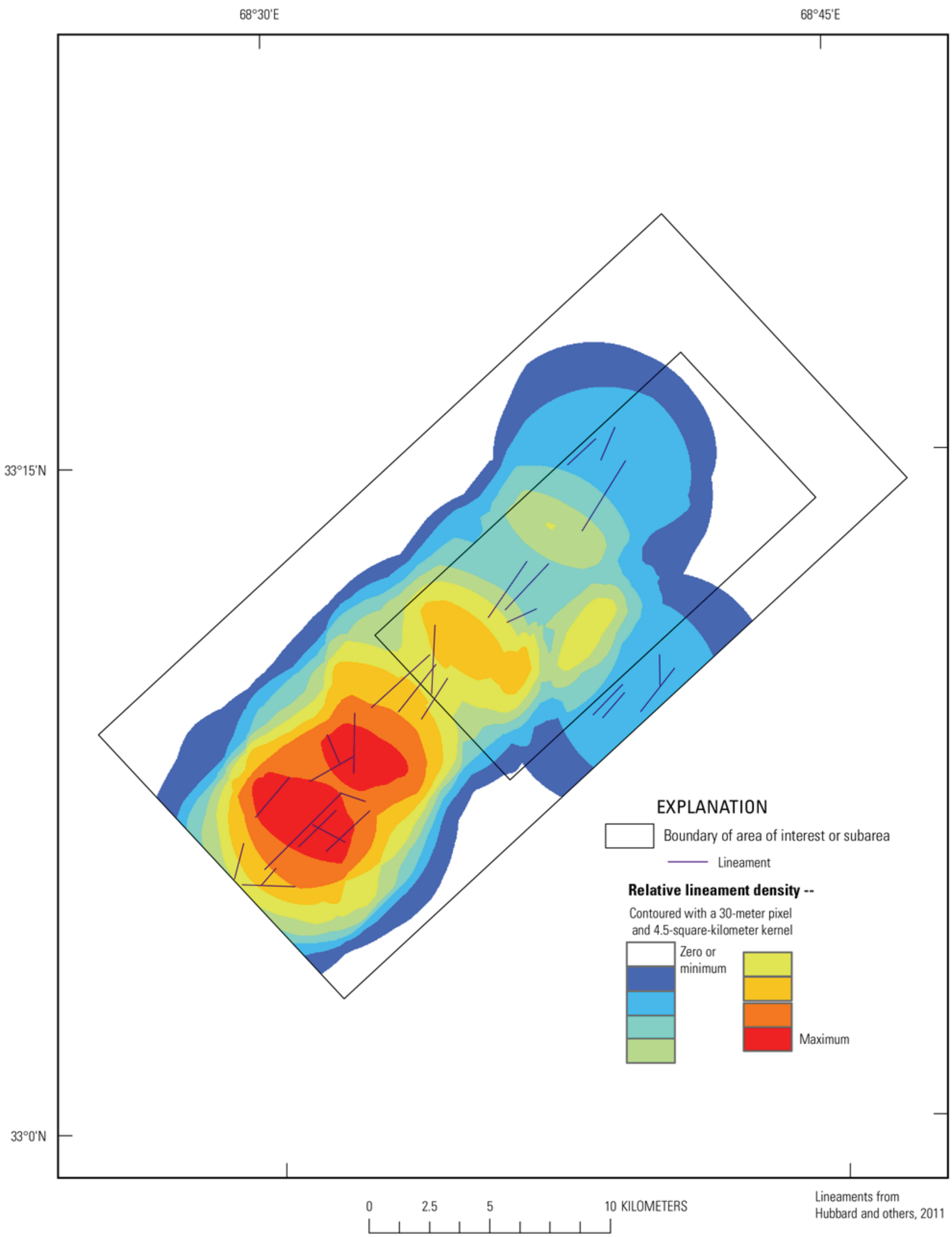
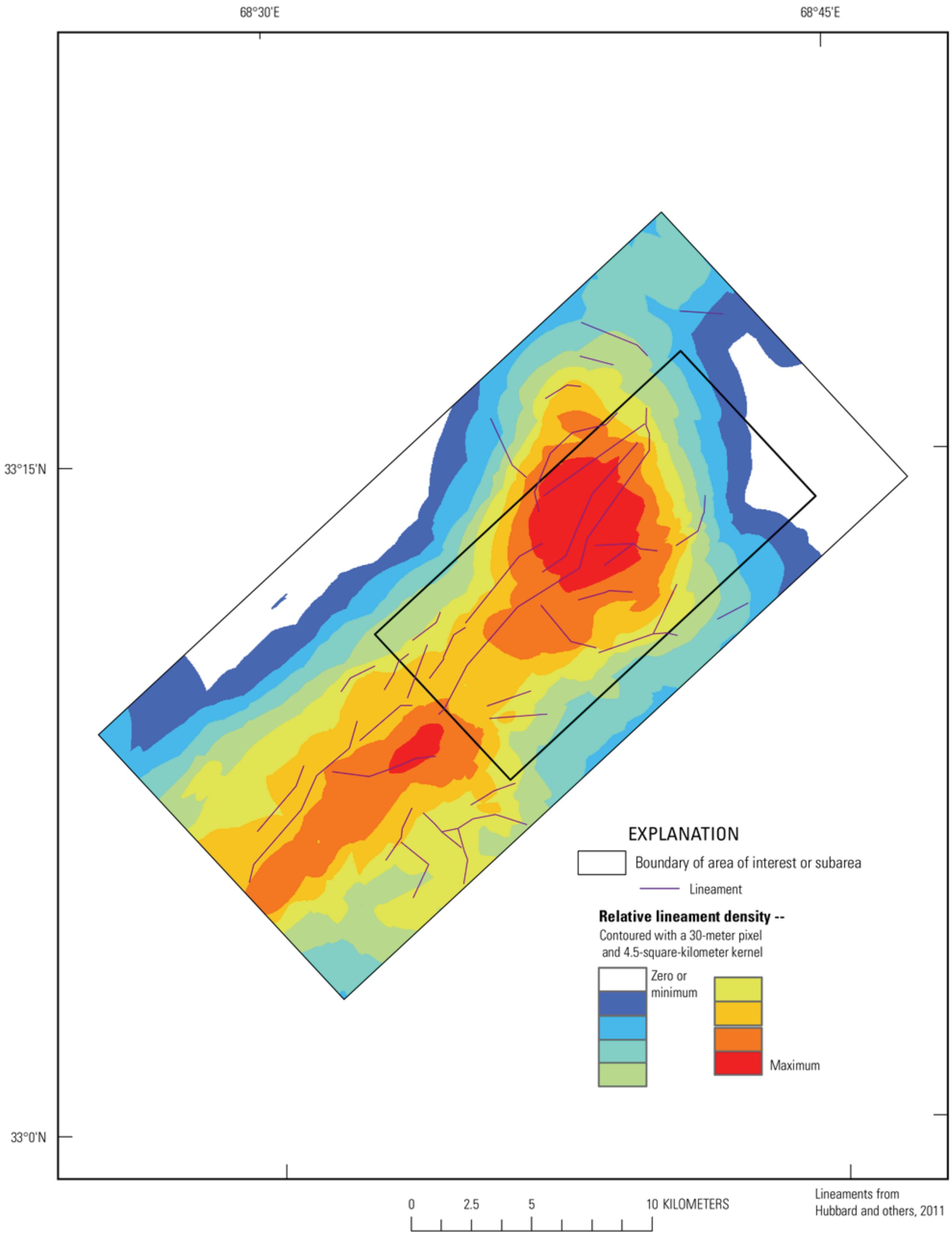


Figure 8C–6. (on previous page) Lineaments and lineament density based on 30-meter digital-elevation-model data and natural-color Landsat imagery in the Katawas gold area of interest in southeastern Afghanistan.

a



68°30'E
68°45'E
33°15'N
33°0'N
EXPLANATION
Boundary of area of interest or subarea
Lineament
Relative lineament density --
Contoured with a 30-meter pixel and 4.5-square-kilometer kernel
Zero or minimum
Maximum
0
2.5
5
10 KILOMETERS
Lineaments from Hubbard and others, 2011

b

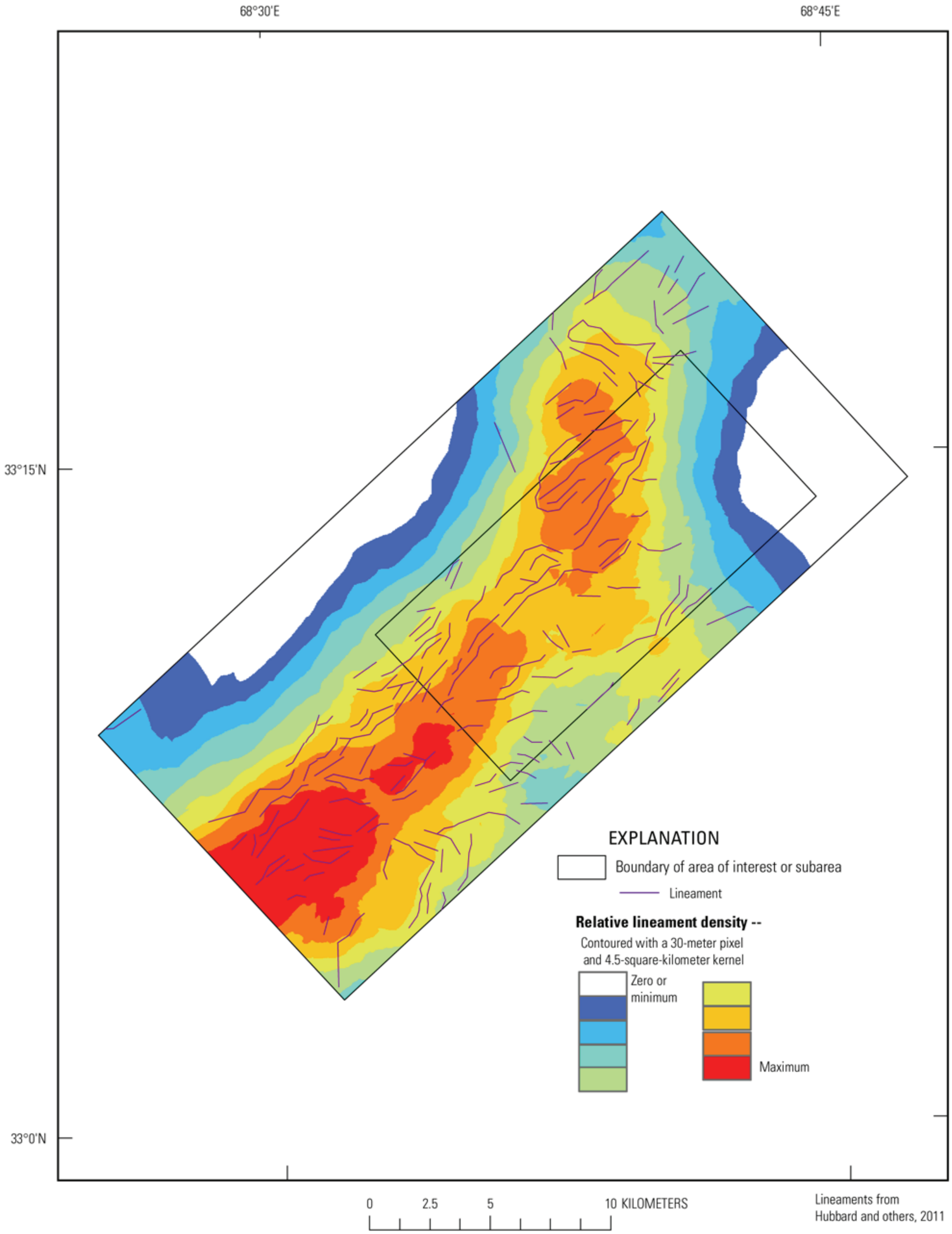


Figure 8C–7. *(a)* Lineaments and lineament density based on 30-meter multispectral Landsat imagery in the Katawas gold area of interest and *(b)* lineaments and lineament density based on 15-meter multispectral Landsat imagery in the Katawas gold area of interest in southeastern Afghanistan.

8C.3 Summary and Conclusions

Water resources are likely to be more available for mining and other uses in the Katawas gold area of interest (AOI) and surrounding area than in other areas of Afghanistan because of the proximity of the Sardeh Reservoir. The reservoir is the most readily available source of water in or near the AOI. The volume of water in the reservoir probably decreases during the summer and fall as water is used for irrigation and inflow from the rivers decreases. The reservoir has a maximum storage capacity of 259 Mm^3 (million cubic meters) and a normal capacity of 165 Mm^3. During periods of peak runoff, sediment is deposited in the reservoir, partially filling it and decreasing its storage capacity. Any use of water from the reservoir to support mining activities would need to be carefully balanced with water demands for irrigation, especially during times of decreased precipitation and flow in the rivers and streams.

Nongovernmental organizations have installed many shallow wells adjacent to the northwest border of the AOI. Most of these wells are probably tube wells with hand pumps that are used to supply water for domestic consumption. Information about deep groundwater in the AOI is very limited. Two deep water-supply wells just outside the AOI indicate that a deep alluvial aquifer is located in this area. This aquifer may be a considerable resource. It is possible that properly located and constructed wells in the deep alluvial aquifer may supply water for mining activities; however, because precipitation rates in the area are low, it is likely that deep groundwater is old water that is recharged very slowly. Siting wells so as to avoid interference with existing water-supply wells and other natural or manmade water sources such as springs and karezes would help to minimize any adverse effects related to the increase in withdrawals.

The long-term sustainability of groundwater resources in the AOI remains to be determined. Close monitoring by water managers to balance potential groundwater extraction with potential groundwater recharge would help to prevent dewatering of the aquifer and disruption of local groundwater supplies. Careful evaluation and management of potential new surface-water or groundwater withdrawals would help to protect the quantity and quality of the existing supply for current local water uses. A program of field investigations, including geologic mapping, geophysical surveys, and hydraulic well testing, is needed to adequately characterize the availability and extent of groundwater resources in the AOI.

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