Chapter 17C. Geohydrologic Summary of the Baghlan Clay and Gypsum Area of Interest

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17C.1 Introduction

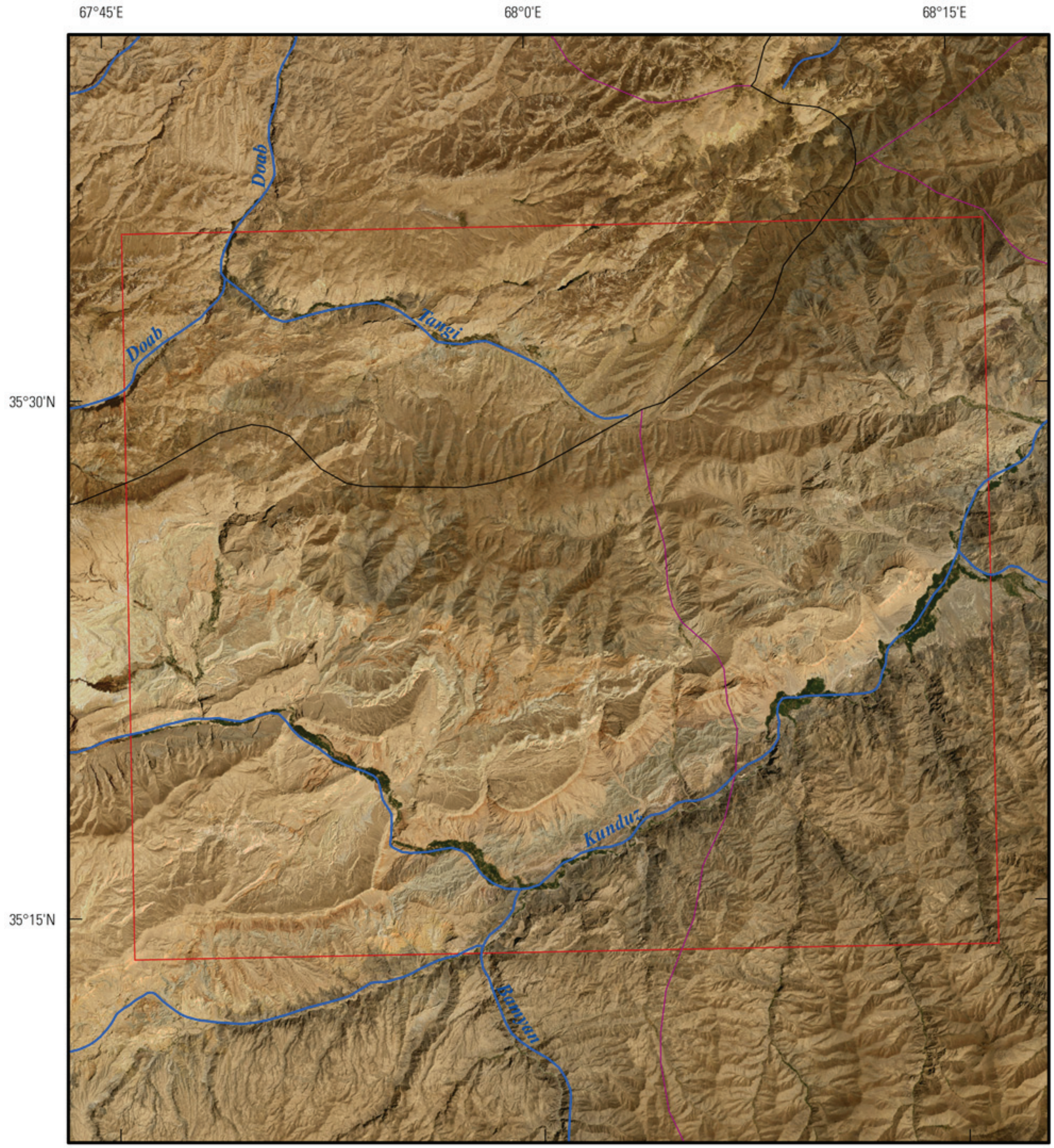
This chapter describes the geohydrology of the Baghlan clay-gypsum area of interest (AOI) in Afghanistan identified by Peters and others (2007) (fig. 17C–1*a*,*b*). The AOI is an 1,800-km^2 (square kilometer) area in northeast-central Afghanistan in the Ruyi Du Ab District in Samangan Province, and the Kahmard and Tala Wa Barfak Districts in Baghlan Province (fig. 17C–1*a*,*b*).

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 bedrock 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; 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.

17C.1.1 Climate and Vegetation

Climate information for the Baghlan clay-gypsum 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



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 3 6 12 KILOMETERS

EXPLANATION

Boundary of area of interest (AOI) or subarea

Stream, generally perennial

Province boundary line

District boundary line

b

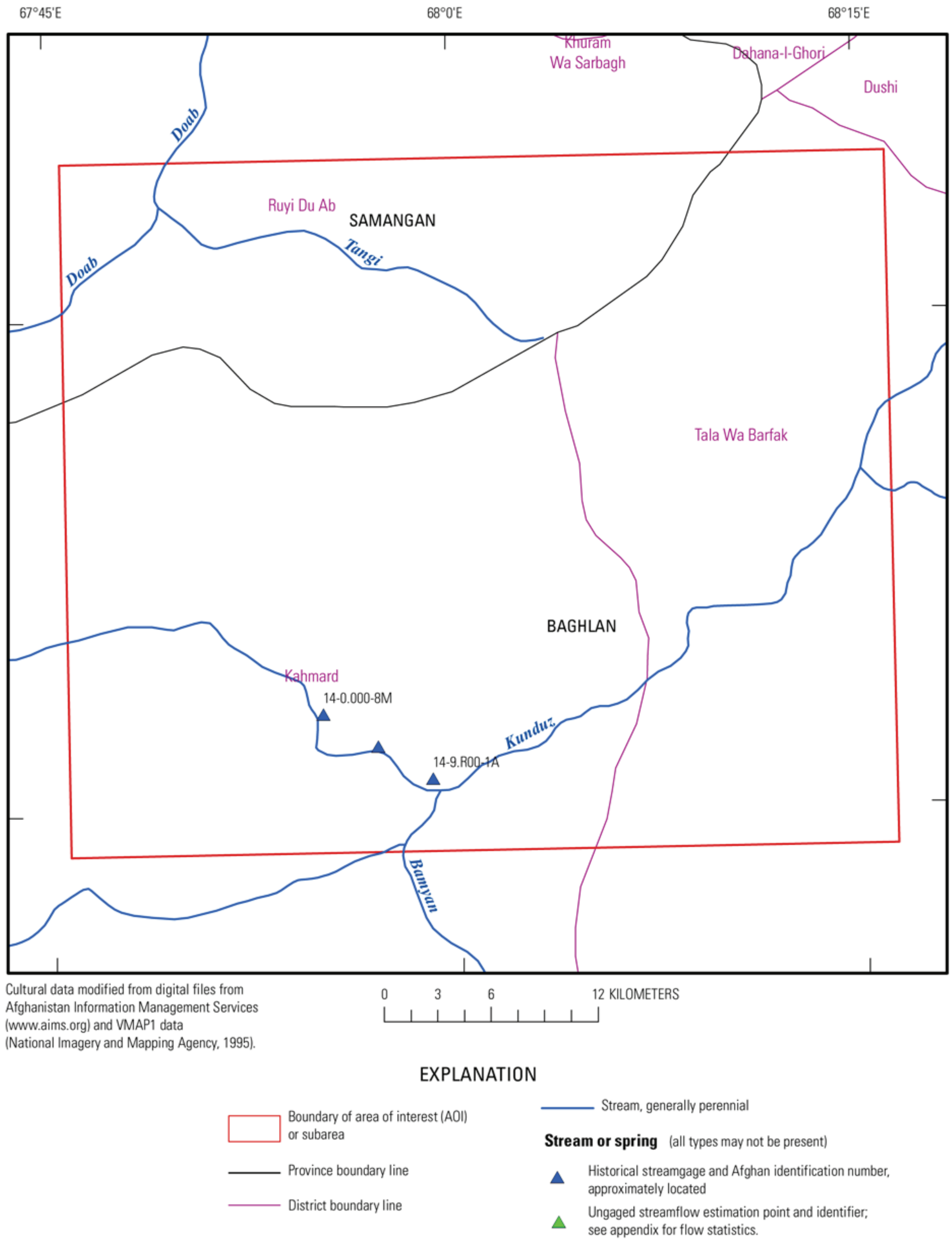


Figure 17C–1. (*a*) Landsat image showing the location of, and (*b*) place names, stream names, and streamgage station numbers in, the Baghlan clay-gypsum area of interest in Afghanistan.

The Dara-e-Soof Agromet station is located in Samangan Province in the northwest corner of the AOI. Data available for this station include 2009–2010 water year and long-term average (LTA) precipitation data. The station received 411 mm (millimeters) of precipitation during the 2009–2010 water year and has a LTA precipitation of 277.1 mm (Ministry of Agriculture, Irrigation, and Livestock, 2010). The AOI can be considered semiarid on the basis of this annual precipitation. Reported monthly precipitation was highest (148 mm) in May 2010. No precipitation was reported in September 2009 and August 2010. The LTA monthly high precipitation is 64.8 mm in March and the LTA monthly low is 0 mm in September and August.

The Agromet station located in the settlement of Bamyan, Bamyan Province, is the closest station to the AOI for which 2009–2010 water year and LTA precipitation and temperature data are available. The Bamyan Agromet station is about 100 km (kilometers) southwest of the center of the AOI. The average monthly high temperature at this Agromet station for the 2009–2010 water year was 19.5°C (degrees Celsius) in July 2010 and the average monthly low temperature was -4.51°C in January 2010. The LTA high and low temperatures at this station are 18.2°C for July and -6.8°C for January (Ministry of Agriculture, Irrigation, and Livestock, 2010). Table 17C–1 presents precipitation and temperature data for the Agromet station in Bamyan.

Table 17C–1. Annual, long-term annual average, and long-term average minimum and maximum precipitation and temperature at the Bamyan Agrometeorological (Agromet) station 100 km southwest of the Baghlan clay-gypsum area of interest, Afghanistan.

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

			Precipitation				Temperature		
				Long-term average[1]			Long-term average[1]		
Agromet Station	Distance from AOI center (km)	Elevation (m)	2009–2010 Annual (mm)	Annual (mm)	Monthly minimum and month (mm)	Monthly maximum and month (mm)	Minimum and month (°C)	Monthly mean (°C)	Maximum and month (°C)
Bamyan	100	3,100	207.4	142	0 August	34.3 April	–6.8 January	5.3	18.2 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).

The Bamyan Agromet station had a total of 17 reported snow days during the 2009–2010 water year with the following distribution: November 2009, 4 days; December 2009, 2 days; January 2010, 3 days; February 2010, 6 days; and March 2010, 2 days. A total snowfall of 99 cm (centimeters) was reported for Bamyan during the 2009–2010 water year. The snow-depth map for 17 January, 2010 (Ministry of Agriculture, Irrigation and Livestock, 2010, map 6), indicates a snow depth from 10 to 30 cm in the AOI, but this was before the snowfall in February. The snow-depth map for 30 September, 2010 (Ministry of Agriculture, Irrigation and Livestock, 2010, map 7), shows less than 2 cm of snow in the AOI.

The "Potential Natural Vegetation" described in Breckle (2007) is the vegetation cover that would be present if it had not been modified by human activity. It presents the natural vegetation potential and resources that would occur in the various regions of Afghanistan. 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.

The vegetation in the AOI is primarily "dwarf *Amygdalus*-semidesert" surrounded by a zone of "thorny cushions, subalpine and alpine semi deserts and meadows" as classified by Breckle (2007, p. 161). Much of the upland surface of the AOI is bedrock outcrop with thin alluvial cover. Azonal riverine vegetation likely was present in the stream valleys, but the trees have been harvested for fuel and building materials. Most land suitable for farming has been plowed and planted, especially along major stream valleys and some of the ephemeral tributary stream valleys. Irrigated fields are present in the perennial stream valleys and a few ephemeral stream valleys in the AOI (fig. 17C–2).

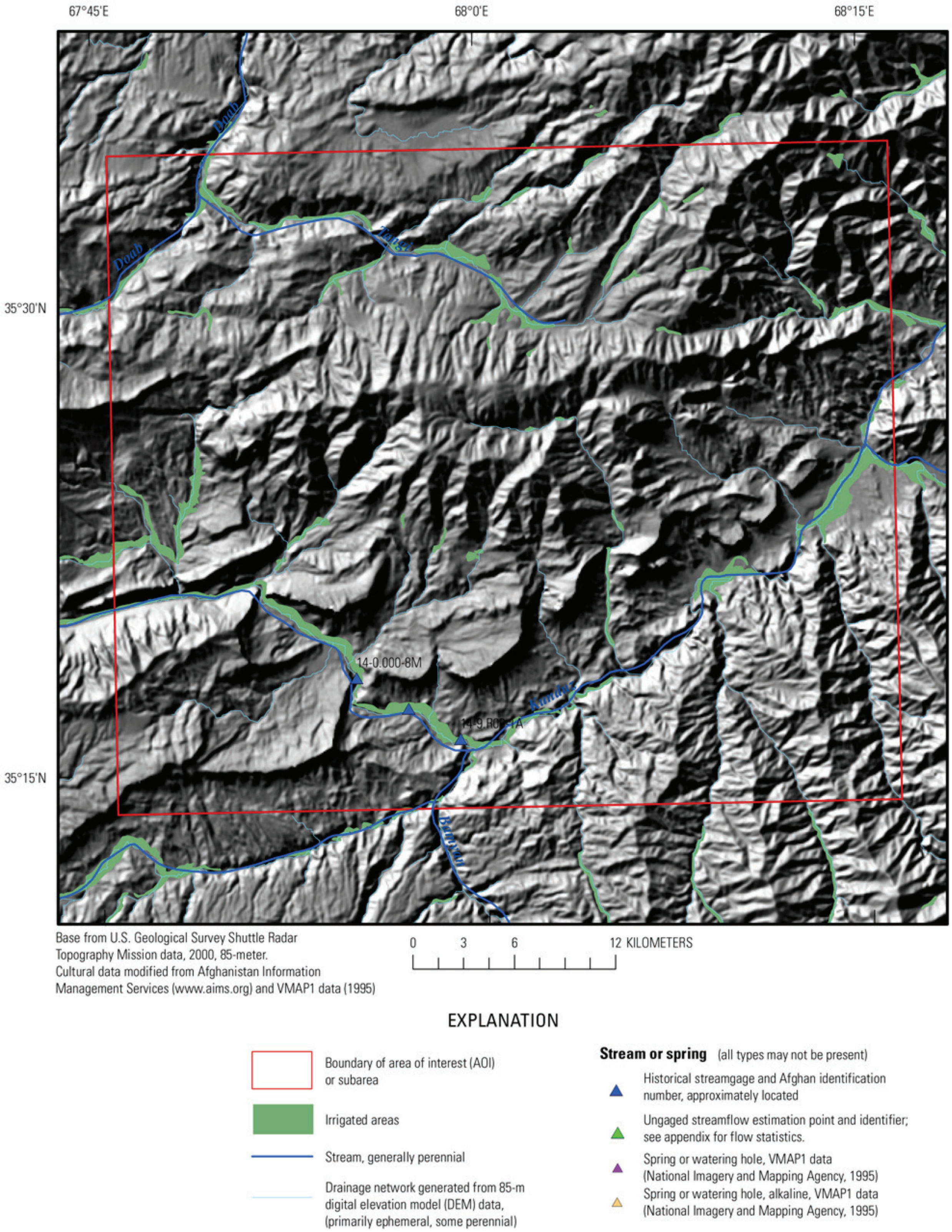


Figure 17C–2. Historical streamgage locations, digitally generated drainage network, and irrigated areas in the Baghlan clay-gypsum area of interest in Afghanistan.

17C.1.2 Demographics

The Baghlan clay-gypsum AOI is sparsely populated, with most areas having 1 to 25 inhabitants per square kilometer as mapped by LandScan (Oak Ridge National Laboratory, 2010) (fig. 17C–3). The mapped population density exceeds 50/km^2 in only a few places; these areas are mostly along the perennial streams. Some of the more mountainous areas are estimated to be uninhabited as indicated by the gray shading in figure 17C–3. The population density shown in figure 17C–3 has a pixel resolution of about 1 km^2 (Oak Ridge National Laboratory, 2010).

17C.1.3 Topography

The topography of the Baghlan clay-gypsum AOI is very mountainous with very little area suitable for agriculture as indicated by irrigated land (figs. 17C–2 and 17C–4). A high, mountainous ridge in the northeast corner of the AOI is more than 3,500 m (meters) above sea level (asl) for a distance of 9 km (Bohannon, 2005). Another high ridge, more than 3,000 m asl, trends east-west in the central part of the AOI (Davis, 2006). The perennial streams that flow through the AOI have formed deeply incised valley with more than 1,000 m of relief. There are also several deeply incised ephemeral stream valleys.

17C.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 Baghlan clay-gypsum AOI is in the transition area between the Northern Afghanistan Artesian Region and the Central Afghanistan Hydrogeological Folded Region. 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 17C–4 with the underlying topography to allow examination of the geohydrology in the context of relief. Figures 17C–5*a* and *b* show 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 figures 17C–5*a* and *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 “sands, undifferentiated; conglomerate sediments and rocks; limestones and dolostones; sedimentary rocks; and intrusive rocks and lavas” (figs. 17C–4, 17C–5*a*,*b*). 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 Lindsay and others (2005) and Turner (2005).

The mapped outcrops of sands are confined to three relatively small areas along the Kunduz River. Although water-supply wells have been constructed in the sediments of this geohydrologic group, it is unlikely that sufficient groundwater is present to support additional withdrawals for uses such as mining activities (fig. 17C–5*a*,*b*). The conglomerate sediments and rocks geohydrologic group forms a fairly large outcrop in the western part of the AOI. Where this unit is exposed in stream valleys, it appears to be as much as 1,000 m thick. Some wells have been constructed in the areas mapped as conglomerate (fig. 17-5*a*); however, wells are more likely to have been constructed in unmapped alluvium. Additional work would be needed to determine whether the conglomerate constitutes an aquifer that could supply groundwater for mining activities. The sedimentary rocks and the limestones and dolostones geohydrologic groups have a limited outcrop area. A few wells are located in the sedimentary rocks geohydrologic group in the Kunduz River valley (fig. 17C–5*a*,*b*); however, they are also likely to be completed in the overlying alluvium.

At least one third of the AOI is included in the intrusive rocks and lavas geohydrologic group. In the absence of fractures, the hydraulic conductivity and storage capacity of this geohydrologic group are likely to be low. If these rocks are highly fractured and the fracture network is extensive, there is the potential for limited groundwater availability. The intrusive rocks and lavas geohydrologic group forms much of the higher elevation areas and may have considerable recharge potential from snow melt. Additional work is needed to adequately characterize the groundwater potential of this and all other geohydrologic groups in the AOI.

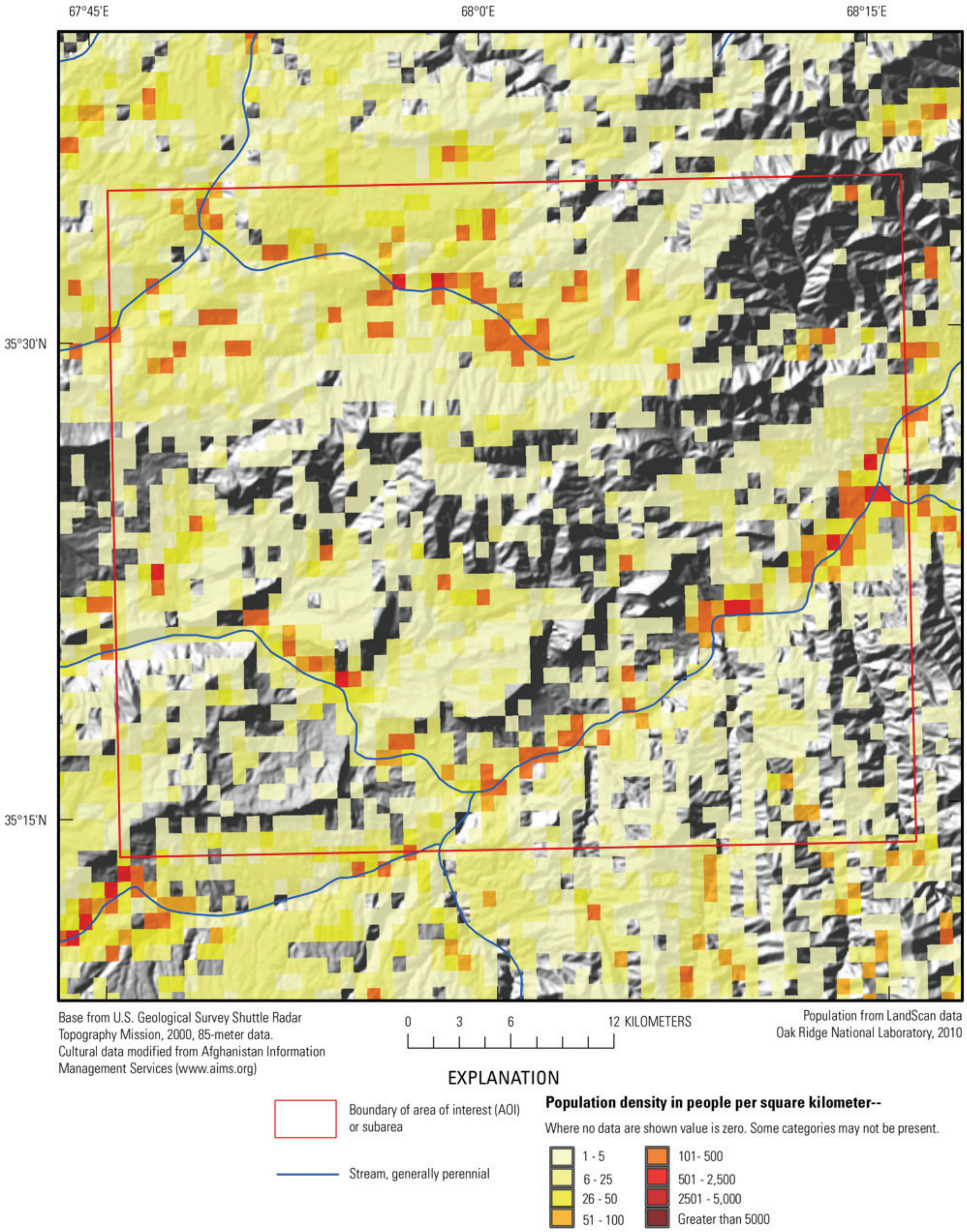


Figure 17C–3. Population density of the Baghlan clay-gypsum area of interest in Afghanistan.

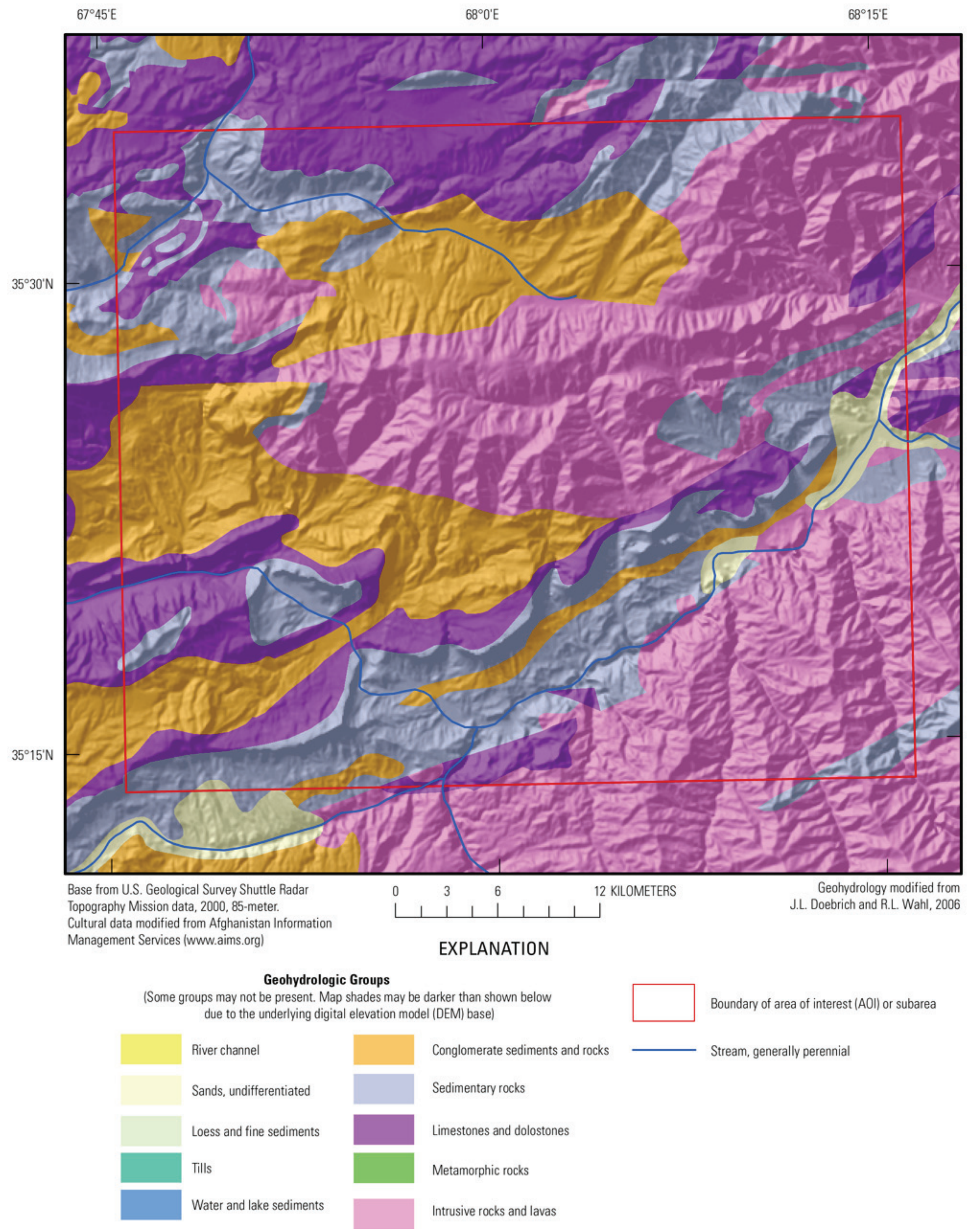
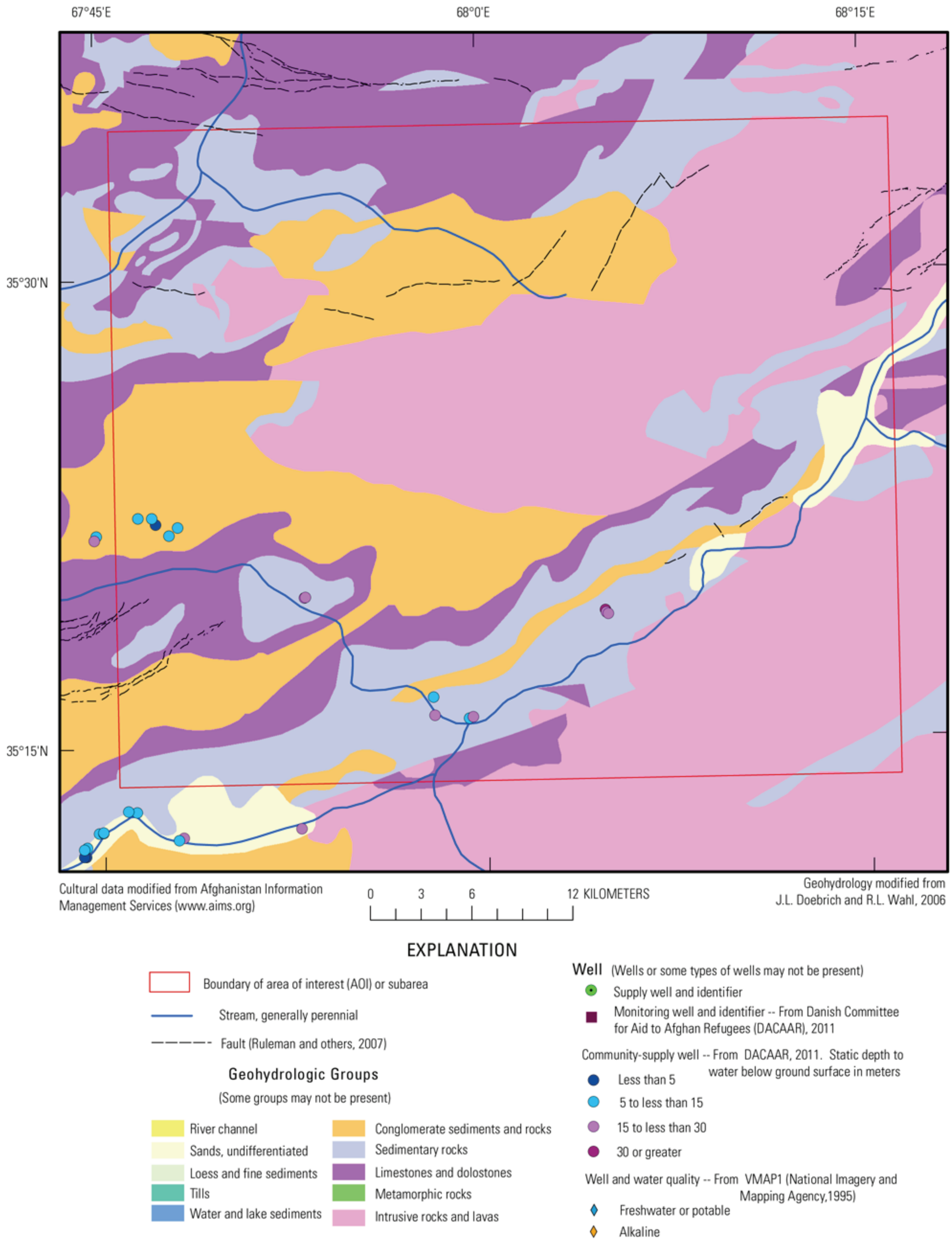


Figure 17C–4. Topography and generalized geohydrology of the Baghlan clay-gypsum area of interest in Afghanistan.

a


67°45'E
68°0'E
68°15'E
35°30'N
35°15'N
Cultural data modified from Afghanistan Information Management Services (www.aims.org)
0 3 6 12 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

b

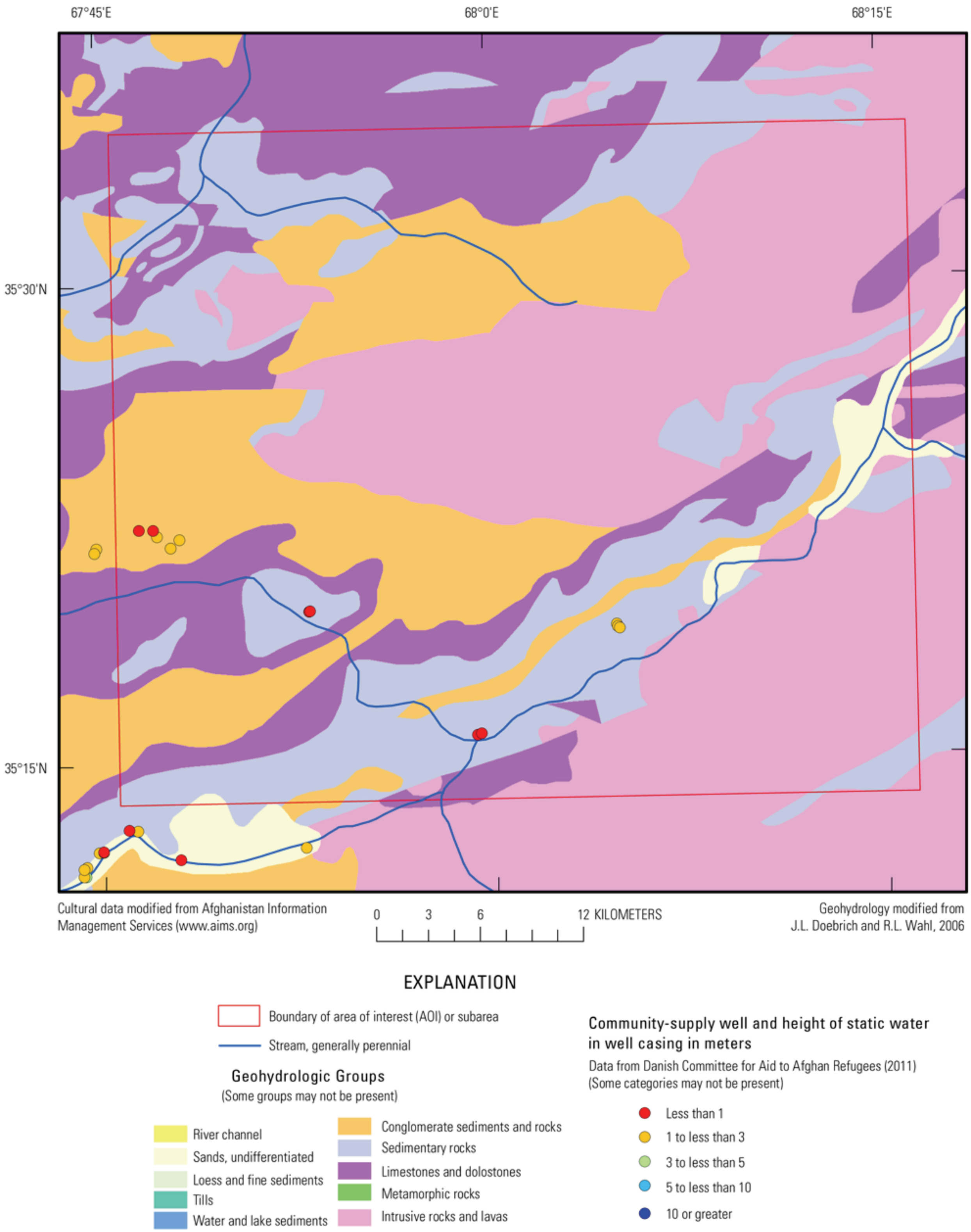


Figure 17C–5. (a) Generalized geohydrology, mapped faults, well locations, and depth to water, and (b) geohydrology and height of static water in well casings in community-supply wells in the Baghlan clay-gypsum area of interest in Afghanistan.

17C.2.1 Surface Water

A network of major, mostly perennial streams, in the Baghlan clay-gypsum AOI, modified from AIMS (Afghanistan Information Management Services, 1997) and VMAP1 (National Imagery and Mapping Agency, 1995), is shown in figure 17C–2. A network representing likely ephemeral streams, generated with a digital elevation model (DEM), also is shown in figure 17C–2. Names of major streams and identification numbers for any streamgages and ungaged streamflow estimation sites in the AOI are shown in figure 17C–1b.

The three streamgage stations in the AOI are shown in figures 17C–1*b* and 17C–2. The unlabeled streamgage station is identified as the Kunduz River at Doab; however, no additional information is available for that streamgage. The Bamyan River at Doab streamgage station (Afghan identification number 14-9.R00-1A) is at an elevation of 1,468 m asl and has a drainage area of 5,005 km^2 and a period of record that extends from 1 October, 1967, to 30 September, 1978 (Olson and Williams-Sether, 2010). The annual mean streamflow per unit area for this station is 0.0018 $m^3/s/km^2$ (cubic meters per second per square kilometer). The seasonal timing of maximum and minimum monthly streamflow is high flows in the late spring and early summer and low flows in late winter and early spring. A statistical summary of monthly and annual mean streamflows for this station is presented in table 17C–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 other station in the AOI is the Kunduz River at Dasht-i-Safed streamgage station (Afghan identification number 14-90.000-8M). This station is at an elevation of 1,588 m asl and has a drainage area of 3,795 km^2 and a period of record that extends from 12 October, 1967, to 5 May, 1975; 13 August, 1977, to 30 September, 1978; and 1 October, 1967, to 30 September, 1978 (Olson and Williams-Sether, 2010). The annual mean streamflow per unit area for this station is 0.0028 $m^3/s/km^2$. The seasonal timing of maximum and minimum monthly streamflow is high flows in the early summer and low flows in late winter and early spring, but the mean flow at this station is fairly consistent throughout the year. A statistical summary of monthly and annual mean streamflows for this station is presented in table 17C–3.

Table 17C–2. Statistical summary of monthly and annual mean streamflows for the Bamyan River at Doab streamgage station (Olson and Williams-Sether, 2010).

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

14-9.R00-1A BAMYAN RIVER AT DOAB

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	8.55	1970	3.10	1972	5.99	1.69	0.28	5.53
November	8.82	1970	3.26	1972	5.70	1.64	0.29	5.27
December	7.92	1970	2.98	1972	4.85	1.33	0.27	4.48
January	6.69	1970	2.70	1978	4.43	1.16	0.26	4.10
February	5.85	1969	2.46	1978	4.15	1.15	0.28	3.83
March	5.32	1968	2.82	1975	4.18	0.85	0.20	3.86
April	8.25	1968	3.06	1972	4.90	1.67	0.34	4.52
May	26.6	1973	10.4	1975	14.9	4.83	0.32	13.8
June	56.1	1969	9.35	1971	30.7	14.6	0.47	28.4
July	31.5	1969	2.66	1971	15.5	8.79	0.57	14.3
August	13.3	1969	2.65	1971	6.85	3.18	0.46	6.33
September	10.5	1969	1.97	1971	6.06	2.61	0.43	5.60
Annual	**14.4**	**1969**	**4.90**	**1971**	**9.03**	**2.92**	**0.32**	**100**

Table 17C–3. Statistical summary of monthly and annual mean streamflows for the Kunduz River at Dasht-i-Safed streamgage station (Olson and Williams-Sether, 2010).
[m^3/s, cubic meters per second]

14-0.000-8M KUNDUZ RIVER AT DASHT-I-SAFED

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	13.0	1970	8.78	1971	10.6	1.67	0.16	8.33
November	12.8	1970	7.91	1971	9.96	1.38	0.14	7.85
December	13.5	1970	7.64	1971	10.5	1.81	0.17	8.31
January	13.7	1969	9.37	1972	11.0	1.48	0.13	8.65
February	12.9	1969	8.22	1978	10.2	1.46	0.14	8.02
March	12.5	1969	7.07	1978	9.51	1.54	0.16	7.49
April	12.4	1969	7.64	1978	9.62	1.43	0.15	7.58
May	14.2	1972	8.13	1974	10.4	1.93	0.19	8.21
June	21.7	1972	7.32	1971	13.4	5.52	0.41	10.5
July	13.8	1968	8.31	1970	11.2	1.90	0.17	8.80
August	12.7	1968	8.82	1970	10.5	1.22	0.12	8.28
September	12.8	1969	8.49	1972	10.1	1.66	0.16	7.96
Annual	**12.6**	**1969**	**9.07**	**1978**	**10.5**	**1.21**	**0.12**	**100**

17C.2.2 Groundwater

Eighteen shallow community groundwater-supply wells have been installed in the Baghlan clay-gypsum AOI by NGOs. Information about these wells can be found in a database maintained by DACAAR (Danish Committee for Aid to Afghan Refugees, 2011). Well-depth and water-level information is available for 14 of the wells in this database (figs. 17C–5*a*,*b*). One supply well is 31.6 m deep and most (71 percent) are less than 20 m deep. The median well depth is 14 m. The depth to water in the supply wells in the AOI is generally less than 20 m (fig.17C–5*a*). The median depth to water is slightly less than the well depth, about 13.5 m.

The 14 wells for which construction information is available are reported to utilize concrete-ring casing. Wells are generally installed in unconsolidated sediments, completed a few meters below the depth at which water is first encountered, and equipped with a hand pump. Figure 17C–5b shows the height of static water in the casings of the water-supply wells (well depth minus static depth to water). The median height of static water in well casings is less than 1 m and all wells contained less than 3 m of static water. There are no groundwater-monitoring wells in or near the AOI; however, seasonal water-level fluctuations are typically at least 1 m and may be several meters. Such shallow wells with little static water are vulnerable to seasonal water-level fluctuations and becoming dry for extended periods of time, or even permanently, where groundwater withdrawals are increasing. Increases in groundwater withdrawals near existing wells in the AOI may disrupt the availability of groundwater supplies. There is no information on groundwater resources in bedrock aquifers in or near the AOI; however, limited groundwater resources may be available in the conglomerates and fractured intrusive rocks in the AOI. Groundwater may be more available in sedimentary rocks in the Kunduz River valley.

17C.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 Baghlan clay-gypsum AOI were conducted using DEM and natural-color satellite imagery (fig. 17C–6) and Advanced Spaceborne Thermal Emission and Reflection Radiometry (ASTER) satellite imagery (fig. 17C–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 17C–6 were delineated visually, whereas those in figure 17C–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).

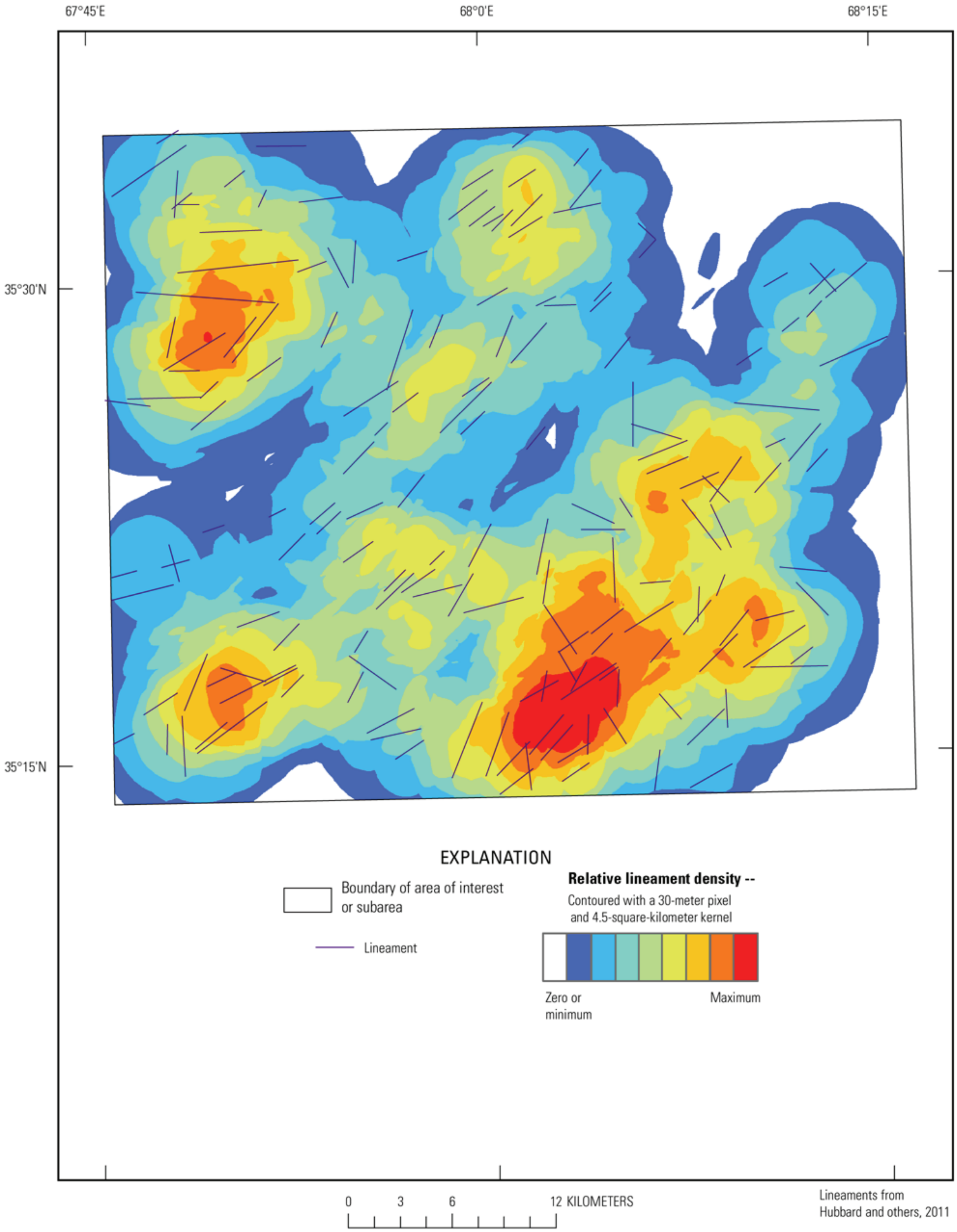
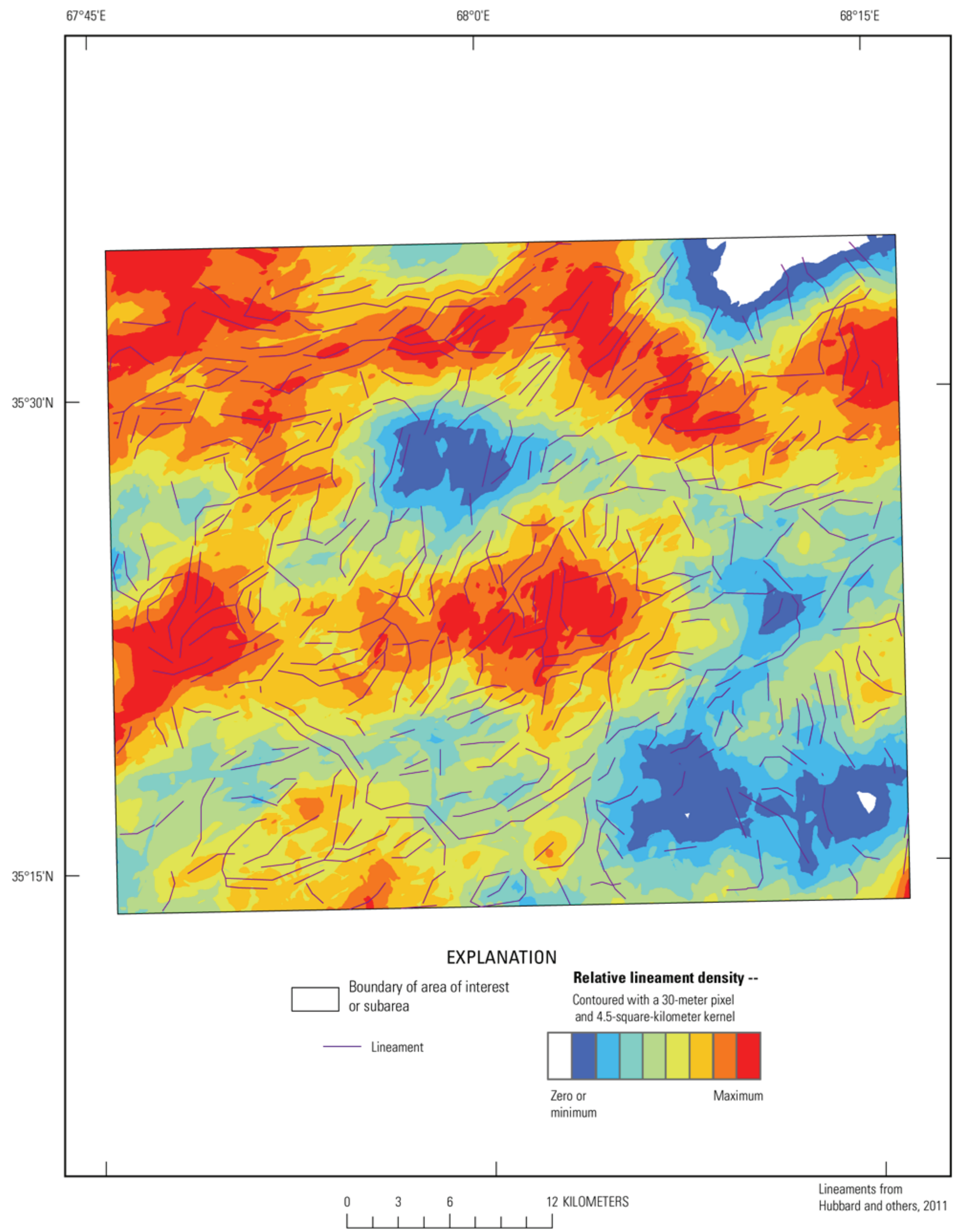


Figure 17C–6. Lineaments and lineament density based on 30-meter digital-elevation-model data and natural-color Landsat imagery in the Baghlan clay-gypsum area of interest in Afghanistan.

a


67°45'E
68°0'E
68°15'E
35°30'N
35°15'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 3 6 12 KILOMETERS
Lineaments from Hubbard and others, 2011

b

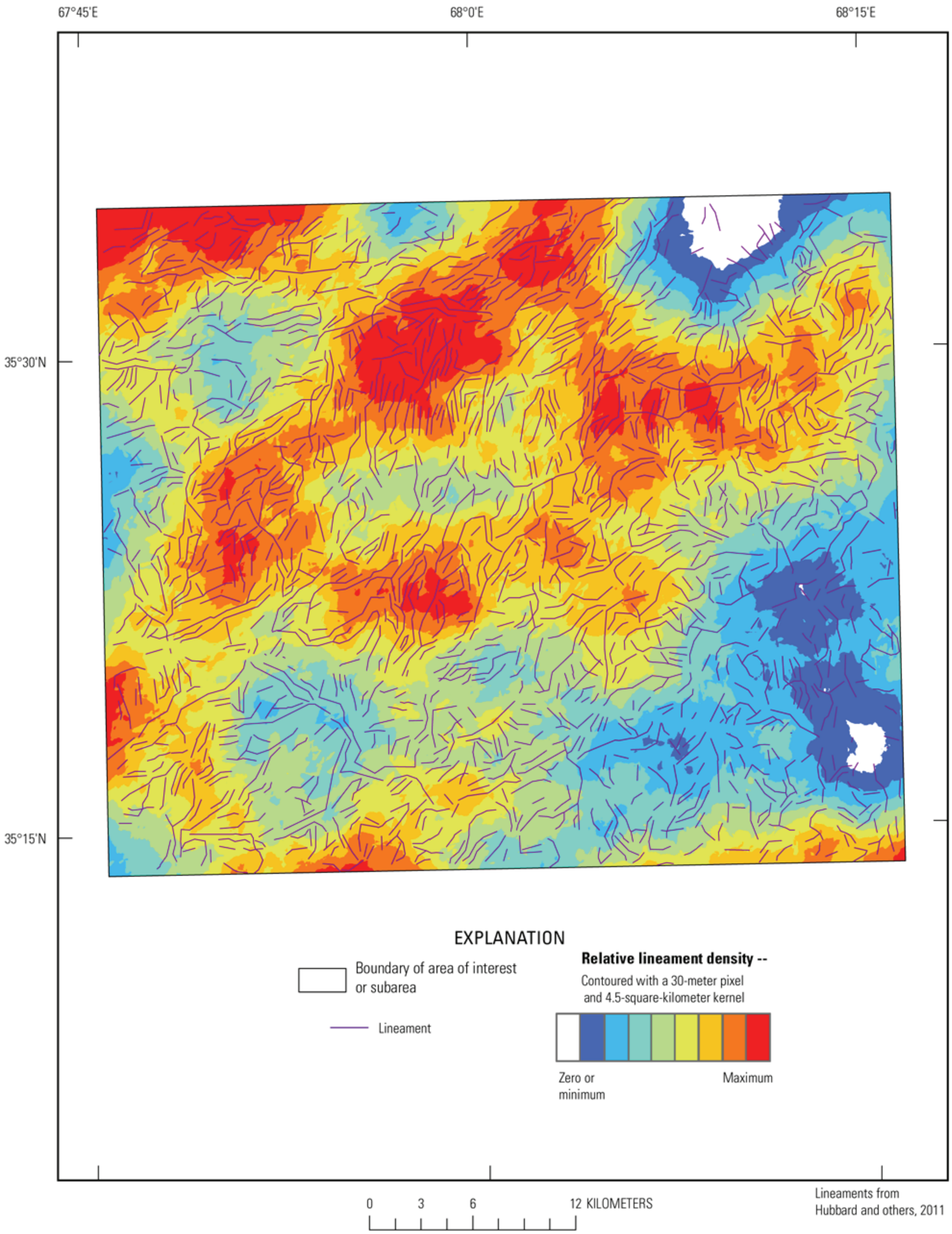


Figure 17C–7. (*a*) Lineaments and lineament density based on 30-meter multispectral Landsat imagery and (*b*) lineaments and lineament density based on 15-meter multispectral Landsat imagery in the Baghlan clay-gypsum area of interest in Afghanistan.

Water wells in bedrock aquifers generally are most productive where boreholes are located in areas of highly fractured bedrock. Lineaments in the AOI have a predominantly northeast trend, following the regional structure. Areas where lineament density is high (figs. 17C–6, 17C–7*a*, 17C–7*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.

17C.3 Summary and Conclusions

The availability of water resources for mining and other uses is likely to be greater in the Baghlan clay-gypsum area of interest (AOI) than in other areas of Afghanistan. Water resources in the AOI and surrounding area consist mainly of surface water, particularly the Kunduz River, but some of the geohydrologic groups may contain considerable groundwater resources. Field investigations are needed to determine the quantity and quality of any groundwater resources that currently are not being used. Some areas have shallow, valley-bottom alluvial aquifers that likely are a highly utilized groundwater resource. Most streams are also likely to be highly utilized by the local population and represent the primary source of water for irrigation. The diversion of water from the rivers to support mining activities would need to be closely monitored, particularly during low-flow periods, so that the quantity and quality of the surface water remains sufficient to supply water for irrigation and to provide recharge to the aquifers that supply groundwater to the shallow wells for domestic consumption.

There is no information about deep groundwater in the AOI or adjacent areas. Some areas of the AOI, as indicated by generalized geohydrologic maps and lineament analyses, are likely areas for further exploration for groundwater resources. The quality and sustainability of water resources in the AOI remain to be determined, however. Close monitoring and careful management of potential new surface-water or groundwater withdrawals would help to protect the quantity and quality of the existing supply for current local uses. 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.

17C.4 References Cited

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