Chapter 26C. Geohydrologic Summary of the Takhar Evaporite Area of Interest

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26C.1 Introduction

This chapter describes the geohydrology of the Takhar evaporite area of interest (AOI) in northeastern Afghanistan identified by Peters and others (2007) (fig. 26C–1*a*,*b*). The AOI is in the Bangi, Chal, Fakhar, Ishkamish, Kalafgan, and Taluqan (Taloqan) Districts in Takhar Province (fig. 26C–1*a*,*b*). The AOI covers an area of 6,128 km^2 (square kilometers).

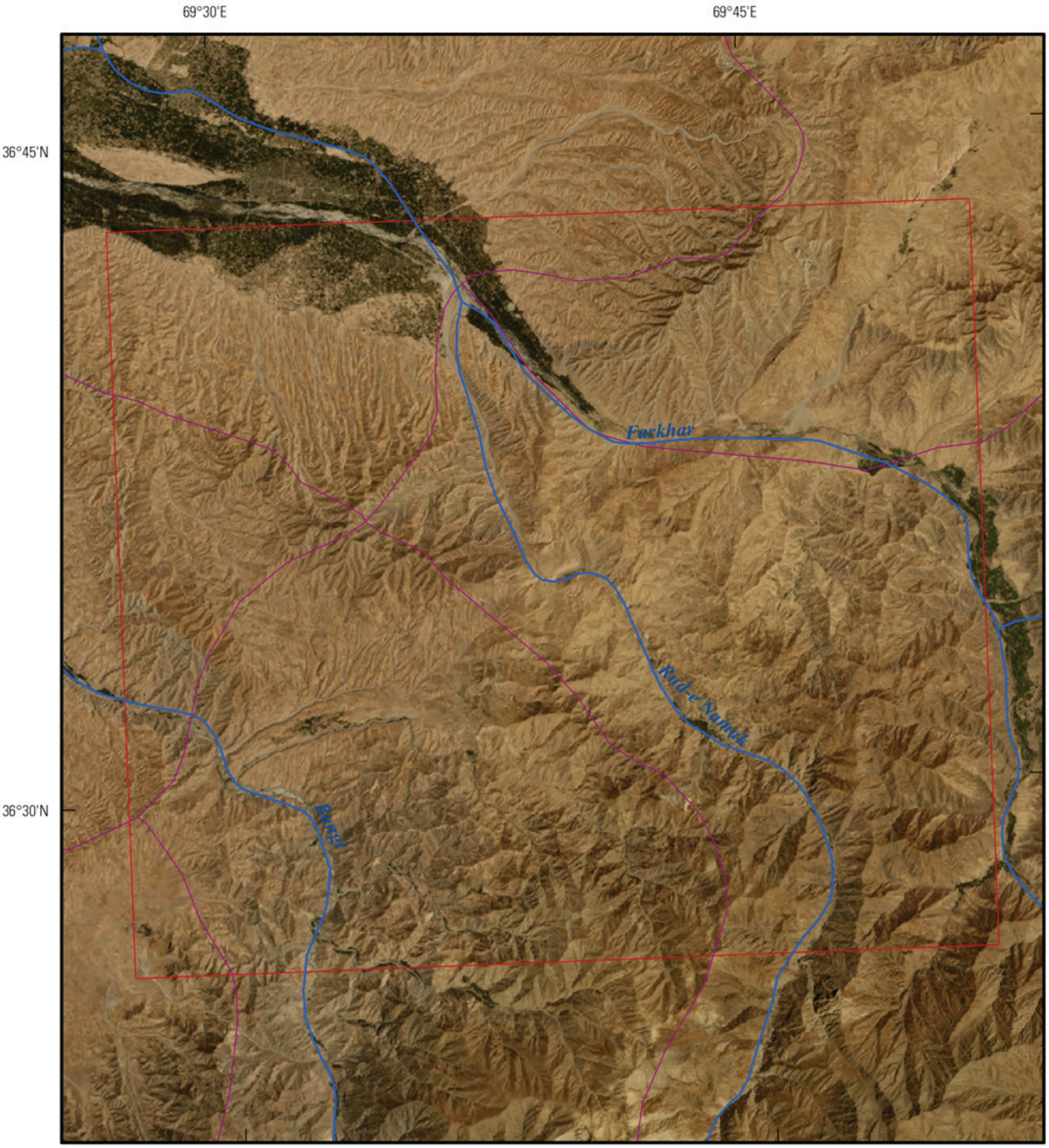
Water is needed not only to process mineral resources in Afghanistan, but also to supply existing communities and the associated community growth that may accompany a developing mining economy. Information on the climate, vegetation, topography, and demographics of the AOI is summarized to provide information 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 wells 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 (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.

26C.1.1 Climate and Vegetation

Climate information for the Takhar evaporite 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



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 4 8 KILOMETERS

EXPLANATION

Boundary of area of interest (AOI) or subarea

Stream, generally perennial

Province boundary line

District boundary line

b

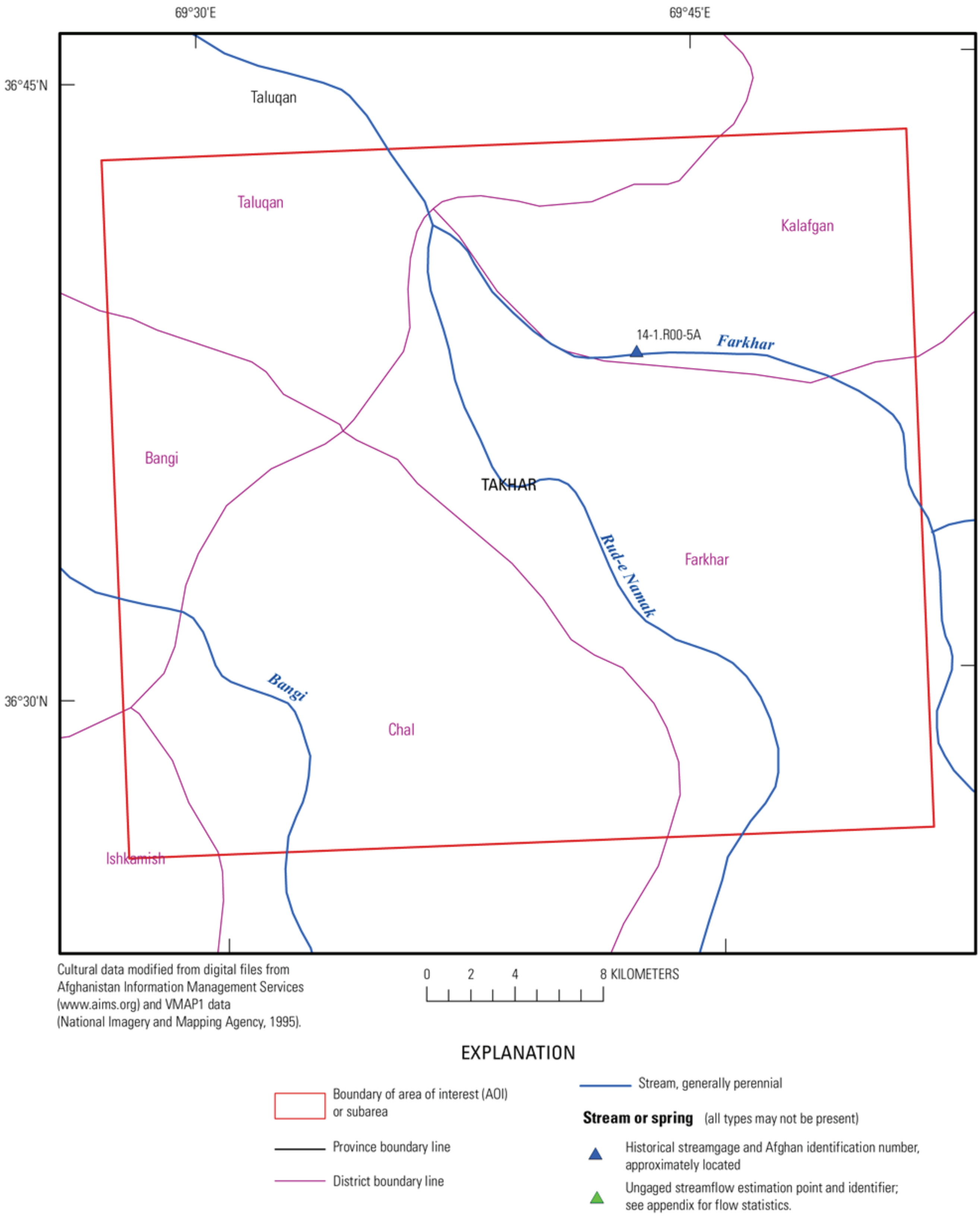


Figure 26C–1. (a) Landsat image showing the location of, and (b) place names, stream names, and streamgage station numbers in, the Takhar evaporite area of interest in Afghanistan.

The observed total precipitation for the AOI in the 2009–2010 water year, as published in the Seasonal Bulletin (Ministry of Agriculture, Irrigation, and Livestock, 2010, map 2), was about 518.5 mm (millimeters). The AOI received 61 to 80 mm of precipitation in February 2010, the month with the greatest precipitation (Ministry of Agriculture, Irrigation, and Livestock, 2010, map 3). The AOI received 34 to 47 mm of precipitation in October 2009, the month with the least precipitation (Ministry of Agriculture, Irrigation, and Livestock, 2010, map 4).

The Taluqan Agromet station is located in Takhar Province, approximately 18 km (kilometers) northwest of the center of the AOI, and is the only station that is near the AOI. The 2009–2010 water year and the long-term average (LTA) precipitation at this station are more than 500 mm/yr, indicating that this is one of the few areas of Afghanistan that is not classified as arid or semi-arid. The precipitation data for the Taloqan Agromet station (Ministry of Agriculture, Irrigation, and Livestock, 2010) are shown in table 26C–1. The total snowfall reported for the 2009–2010 water year at the Taloqan Agromet station was 74 cm (centimeters). For comparison, snowfall in the 2008–2009 water year was 127 cm.

Table 26C–1. Annual, long-term annual average, and long-term average minimum and maximum precipitation and temperature at the Taluqan Agrometeorological (Agromet) station in the Takhar evaporite area of interest, Afghanistan.

[LTA, long-term average; AOI, area of interest; km, kilometers; m, meters; mm, millimeters; °C, degrees Celsius; nr, not reported]

			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)
Taloqan	18	820	518.5	563	0.1 June 0.3 August	131.1 March	nr	nr	nr

[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 "Potential Natural Vegetation" (PVN) described in Breckle (2007) is the vegetation cover that would be present 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.

The PNV at the lower elevations in the western part of the AOI as classified by Breckle (2007, p. 161) is mostly *Pistacia vera*-Woodlands. The PNV in areas above 2,000 m (meters) above sea level (asl) is *Juniperus*-Woodlands. These areas are in the eastern part of the AOI. Much of the upland surface of the AOI is bedrock outcrop with thin alluvial cover, particularly in the southeast corner. 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 many of the valleys in the AOI (fig. 26C–2).

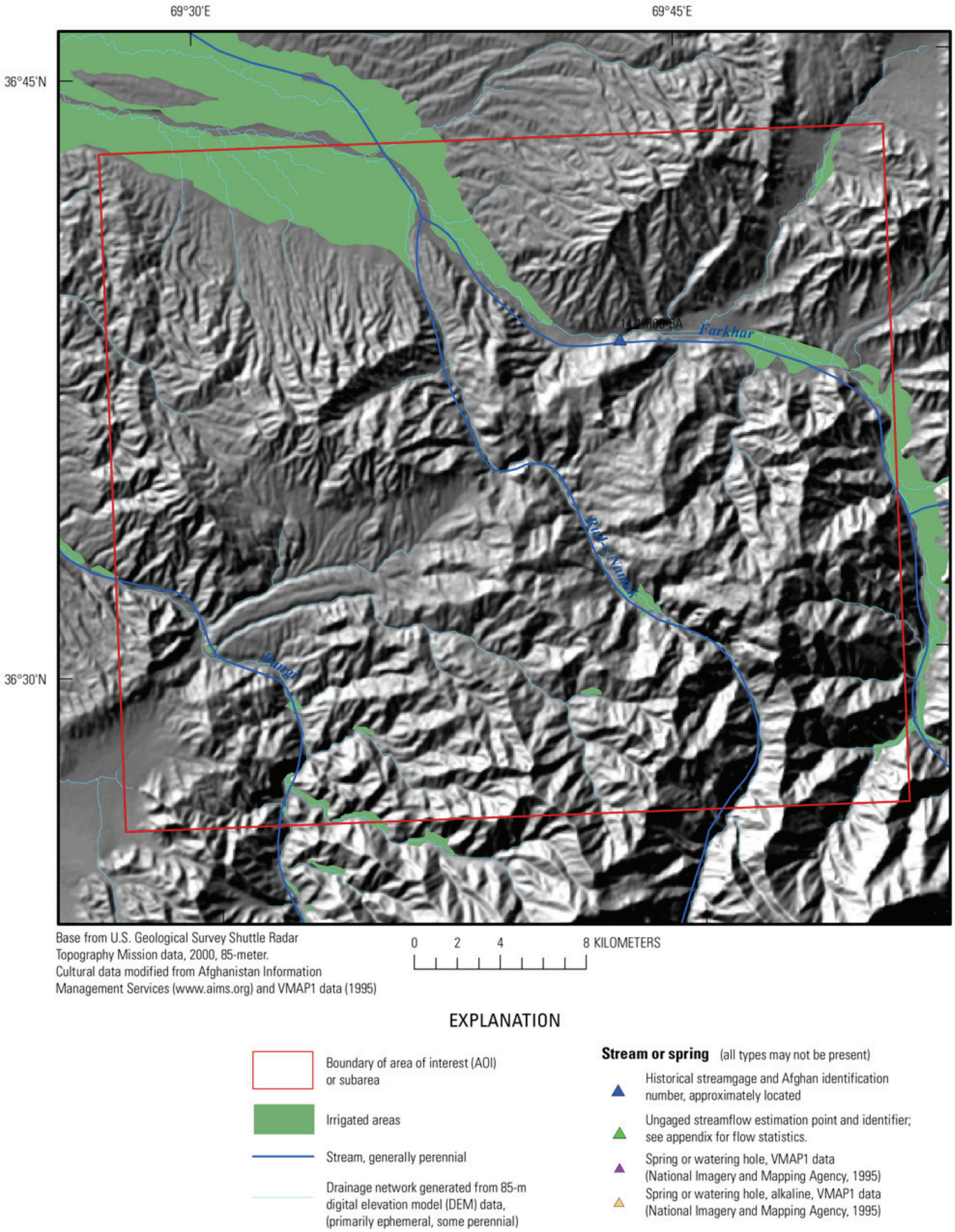


Figure 26C–2. Historical streamgage locations, digitally generated drainage network, and irrigated areas in the Takhar evaporite area of interest in Afghanistan.

26C.1.2 Demographics

The Takhar evaporite AOI ranges from uninhabited to densely populated, with the population density in most areas being from 26 to 50 inhabitants per square kilometer as mapped by LandScan

(Oak Ridge National Laboratory, 2010) (fig. 26C–3). The population is more concentrated along the Farkhar and Bangi Rivers (fig. 26C–3), and is most concentrated in the city of Taluqan adjacent to the northwest corner of the AOI (fig. 26C–1*b*), where the population density is greater than 5,000/km^2 (fig. 26C–3). The areas surrounding this city have a population density of about 101 to 2,500/km^2. These areas of concentrated population also have a large amount of irrigation (fig. 26C–2). The mountainous areas at the southern boundary of the AOI are mostly uninhabited. The population density shown in figure 26C–3 has a pixel resolution of about 1 km^2 (Oak Ridge National Laboratory, 2010).

26C.1.3 Topography and Geomorphology

The topography of the Takhar evaporite AOI transitions from lower elevations (900 m asl) in the Farkhar River valley in the northwest corner to mountainous in the remaining areas (Davis, 2006) (figs. 26C-1*a* and *b*). The two highest peaks in the AOI are in the southeast corner; the higher of the two peaks is 3,138 m asl and the lower peak is 2,861 m asl (Bohannon, 2005). The valley bottom of the Farkhar River is about 1,200 m asl where the river flows along the eastern border of the AOI. The Bangi River valley is about 2,000 m asl where the valley runs through the mountain in the AOI. Relief between the peaks and valleys in the AOI averages 800 m.

The perennial and ephemeral stream valleys are deeply incised in the mountainous parts of the AOI. There is a conspicuous northeast-trending valley in the middle of the AOI. The wide valley in the northwest corner of the AOI was probably formed by the Farkhar River.

26C.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 Takhar evaporite AOI is in the North Afghanistan Artesian Region. The North Afghanistan Artesian Region is located in the northern part of the country. 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 26C–4 with the underlying topography to allow examination of the geohydrology in the context of relief. Figure 26C–5 shows the generalized geohydrology without topography for a clearer depiction of the geohydrologic units and mapped faults. 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; loess and fine sediments; conglomerate sediments and rocks; limestones and dolostones; sedimentary rocks; and intrusive rocks and lavas” (figs. 26C–4, 26C–5). 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 cover this AOI is provided by Fridrich and others (2005).

26C.2.1 Surface Water

A network of major, mostly perennial streams, modified from AIMS (Afghanistan Information Management Services, 1997) and VMAP1 (National Imagery and Mapping Agency, 1995), in the Takhar evaporite AOI is shown in figure 26C–2. A network representing likely ephemeral streams, generated with a digital elevation model (DEM), also is shown in figure 26C–2. Names of major streams and identification numbers for any streamgages and ungaged streamflow estimation sites in the AOI are shown in figure 26C–1*b*.

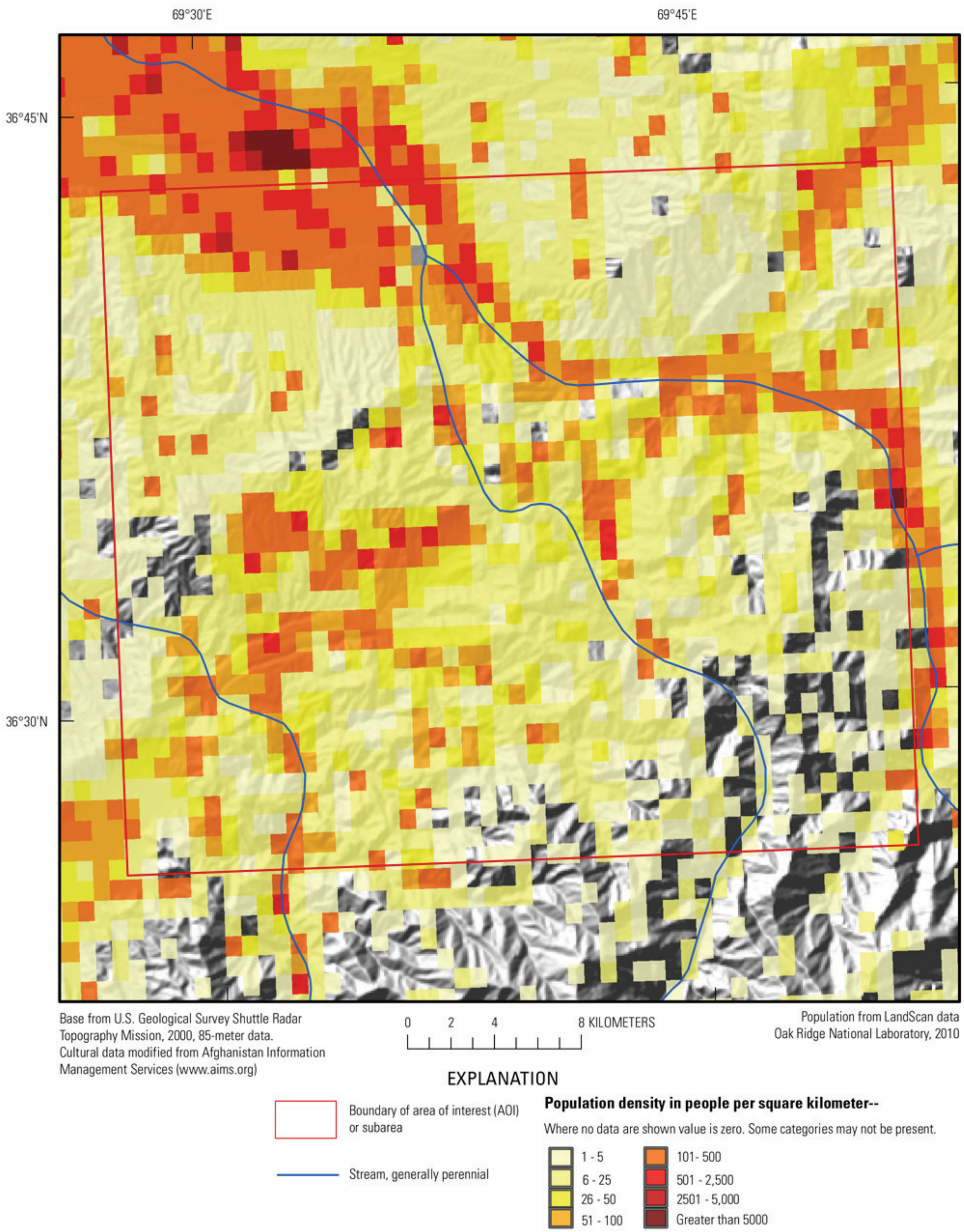


Figure 26C–3. Population density of the Takhar evaporite area of interest in Afghanistan.

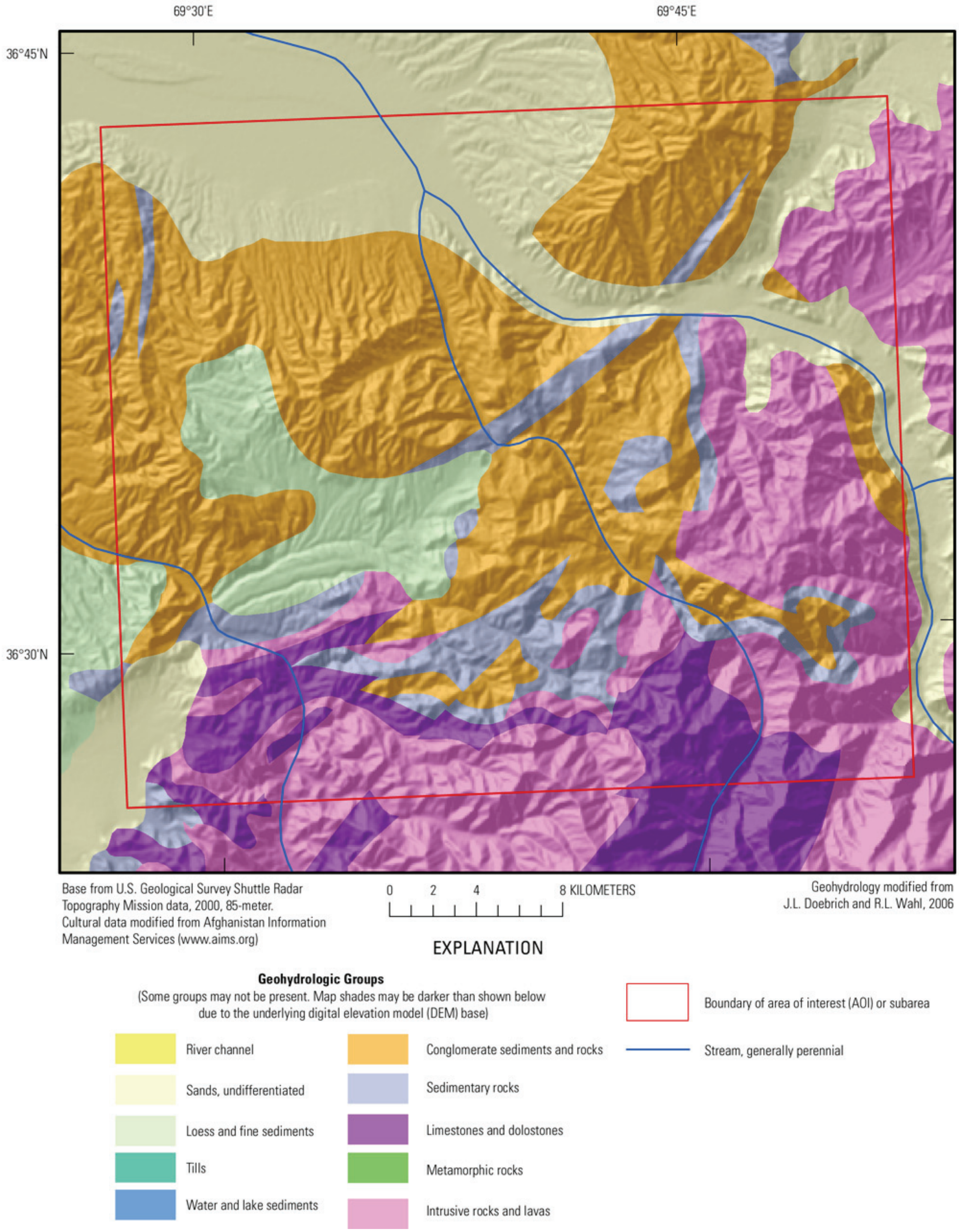


Figure 26C–4. Topography and generalized geohydrology of the Takhar evaporite area of interest in Afghanistan.

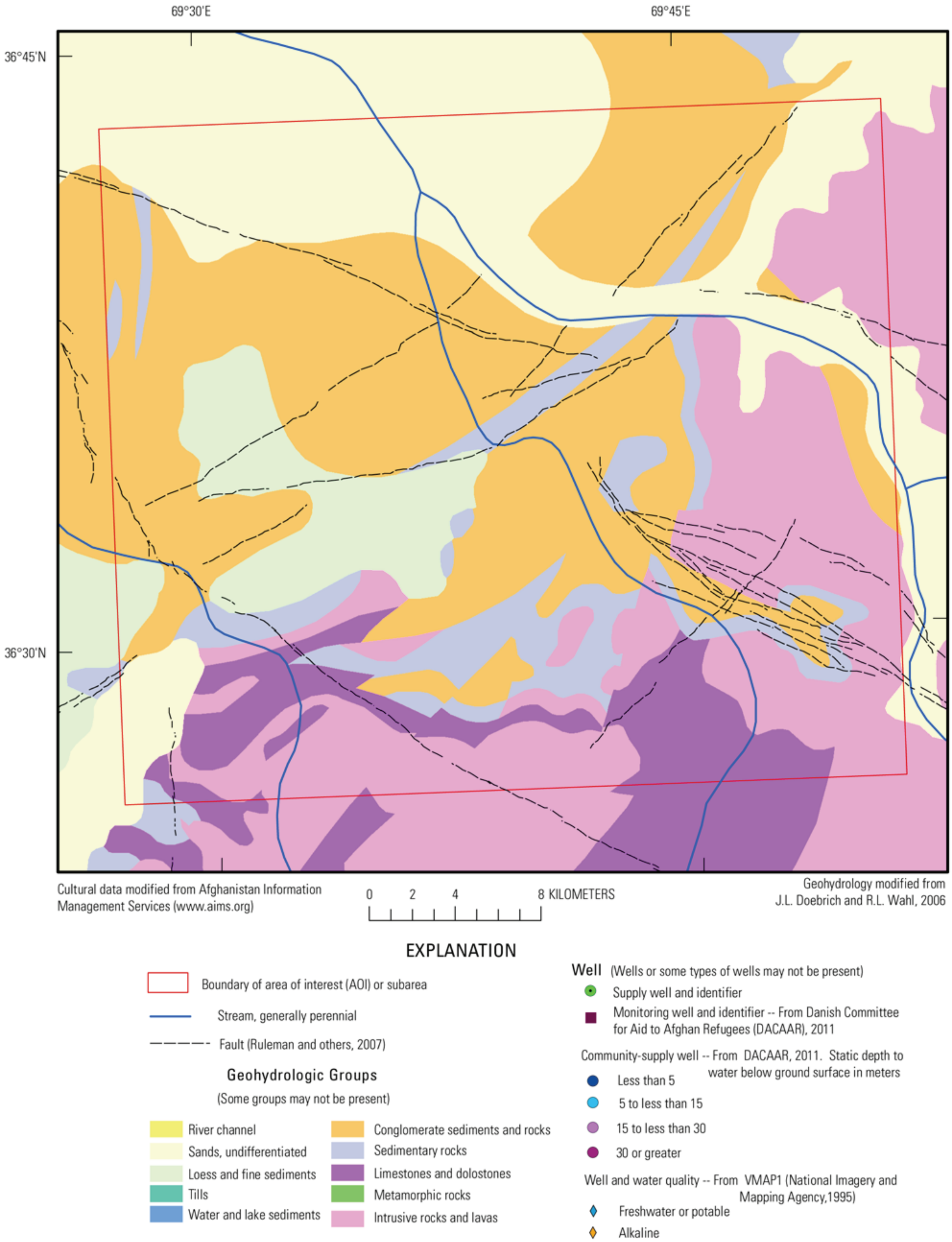


Figure 26C–5. Generalized geohydrology and mapped faults in the Takhar evaporite area of interest in Afghanistan.

The Farkhar River near Taloqan streamgage station (Afghan identification number 14-1.R00-5A) is near the center of the AOI (figs. 26C–1*b*, 26C–2). This station is at an elevation of 991 m asl, has a drainage area of 4,110 km^2, and has a period of record that extends from 22 November, 1966, to

30 September, 1978 (Olson and Williams-Sether, 2010). The annual mean streamflow per unit area for this station is 0.01 $m^3/s/km^2$ (cubic meters per second per square kilometer). High flows generally occur in the early to mid summer and low flows occur in winter. A statistical summary of monthly and annual mean streamflows for this station is presented in table 26C–2. Statistical summaries of streamflow data for all available historical gages in Afghanistan can be accessed at *http://afghanistan.cr.usgs.gov/water.php*.

Table 26C–2. Statistical summary of monthly and annual mean streamflows for the Farkhar River near Taloqan streamgage station (Olson and Williams-Sether, 2010).

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

14-1.R00-5A FARKHAR RIVER NEAR TALOQAN

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	24.5	1970	15.9	1972	20.1	2.74	0.14	3.95
November	18.2	1970	12.6	1975	15.7	1.74	0.11	3.08
December	18.4	1969	11.6	1972	13.4	1.88	0.14	2.63
January	14.7	1969	10.2	1971	11.7	1.56	0.13	2.30
February	14.1	1973	8.83	1971	11.1	1.67	0.15	2.18
March	20.4	1969	9.49	1967	12.8	3.32	0.26	2.51
April	82.0	1969	14.0	1977	29.0	17.9	0.62	5.70
May	123	1969	35.4	1974	59.8	22.1	0.37	11.8
June	184	1969	85.0	1974	124	30.5	0.25	24.4
July	182	1969	56.1	1971	113	38.8	0.34	22.3
August	110	1969	47.2	1974	65.1	17.9	0.28	12.8
September	48.7	1970	24.0	1973	32.5	7.36	0.23	6.39
Annual	**69.5**	**1969**	**33.4**	**1974**	**43.1**	**10.0**	**0.23**	**100**

26C.2.2 Groundwater

No NGO-installed community groundwater-supply wells in the Takhar evaporite AOI are found in a database maintained by DACAAR (Danish Committee for Aid to Afghan Refugees, 2011); however, shallow dug wells likely are present in alluvial sediments, particularly near perennial or ephemeral streams. Such wells are likely to be installed 1 m or less below the water surface and may be vulnerable to seasonal water-level fluctuations.

The hydraulic properties of the unconsolidated sediments in the AOI are likely to be favorable for groundwater availability. Sands are mapped in most of the lower elevation areas, particularly in the Farkhar River valley (fig. 26C–4). There is no information on the thickness of this unit but, in areas where the river valley is wide, the unit could be tens of meters thick. Where this unit is thick, especially near perennial streams, it has the potential to supply limited quantities of groundwater. This unit is probably being used at least to supply groundwater to the population of the AOI for domestic consumption. The loess and fine sediments geohydrologic group is present in the upland valley in the midwestern part of the AOI. This unit probably consists of wind-blown sediments that form a thin deposit on the underlying units with little or no groundwater storage. The conglomerate sediments and rocks geohydrologic group is fairly extensive in the AOI. Outcrops of the group appear to overlie the sedimentary rocks and possibly the intrusive rocks and lavas group. No information is available about the thickness of the conglomerate sediments and rocks geohydrologic group, but most outcrops of this group appear to be in mountainous areas (fig. 26C–4). These rocks and sediments could be a source of groundwater, but it is unlikely that the quantities would be large.

The outcrops of the consolidated rocks in the AOI form the higher elevations areas. The outcrops of the sedimentary rocks geohydrologic group are limited in the AOI. If this group underlies the conglomerate sediments and rocks group, it could be a potential source of groundwater. The limited area and the location of the limestones and dolostones geohydrologic group in the AOI make it an unlikely target for groundwater exploration. With the exception of an area of closely spaced faults (fig. 26C–5), the presence of substantial groundwater resources in the intrusive rocks and lavas geohydrologic group is also unlikely. No information is available about potential groundwater resources in bedrock aquifers of the AOI; however, groundwater is likely to be available in fracture zones. 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.

26C.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 Takhar evaporite AOI (B.E. Hubbard, T.J. Mack, and A.L. Thompson, unpub. data, 2011) were conducted using DEM and natural-color satellite imagery (fig. 26C–6) and Advanced Spaceborne Thermal Emission and Reflection Radiometry (ASTER) satellite imagery (fig. 26C–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). There are many northeast-, and conjugate northwest-, trending lineaments and mapped faults (fig 26C–5) in the AOI. The lineaments shown in figure 26C–6 were delineated visually, whereas those in figure 26C–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. 26C–6, 26C–7*a*, 26C–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.

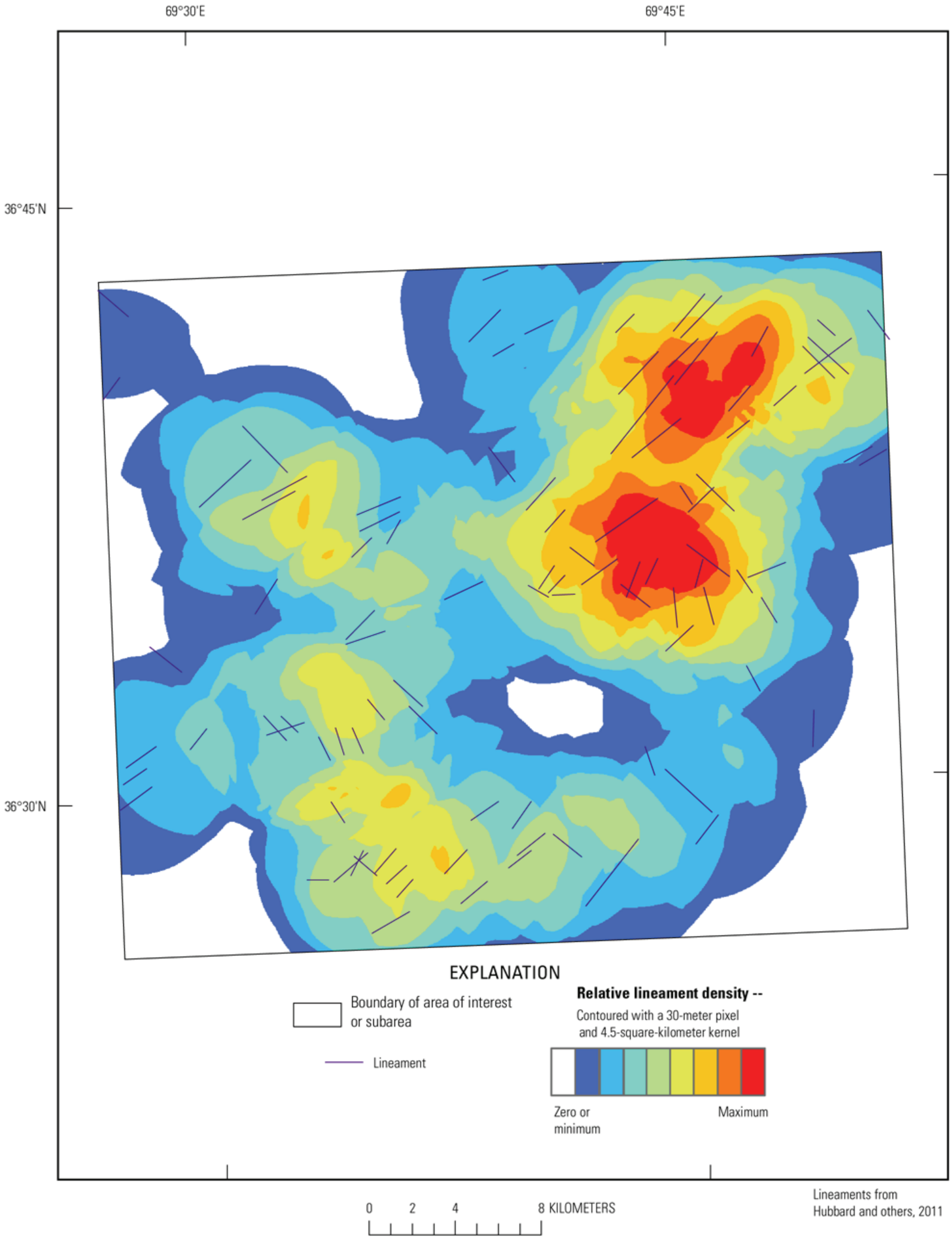
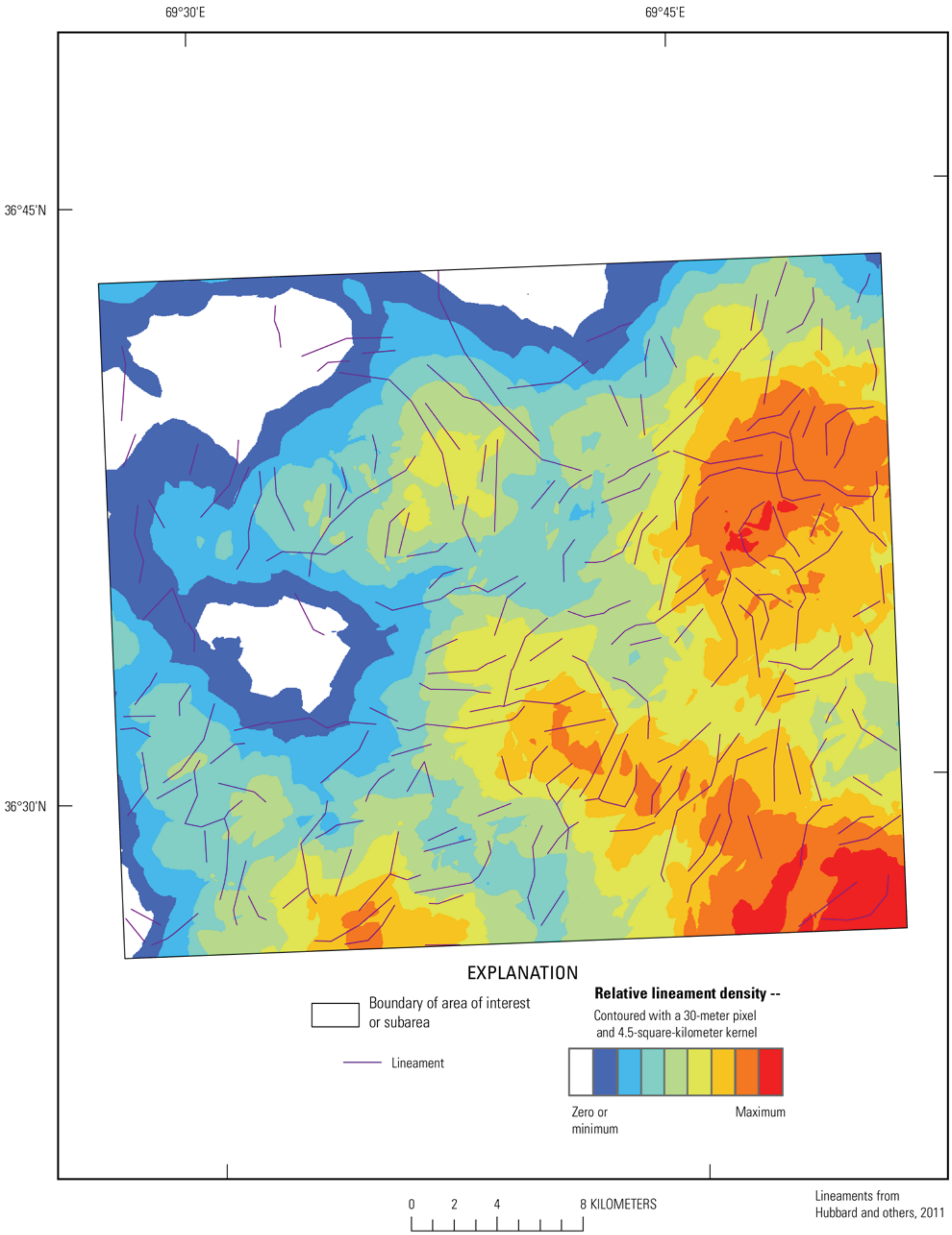


Figure 26C–6. Lineaments and lineament density based on 30-meter digital-elevation-model data and natural-color Landsat imagery in the Takhar evaporate area of interest in Afghanistan.

a



69°30'E
69°45'E
36°45'N
36°30'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 4 8 KILOMETERS
Lineaments from Hubbard and others, 2011

b

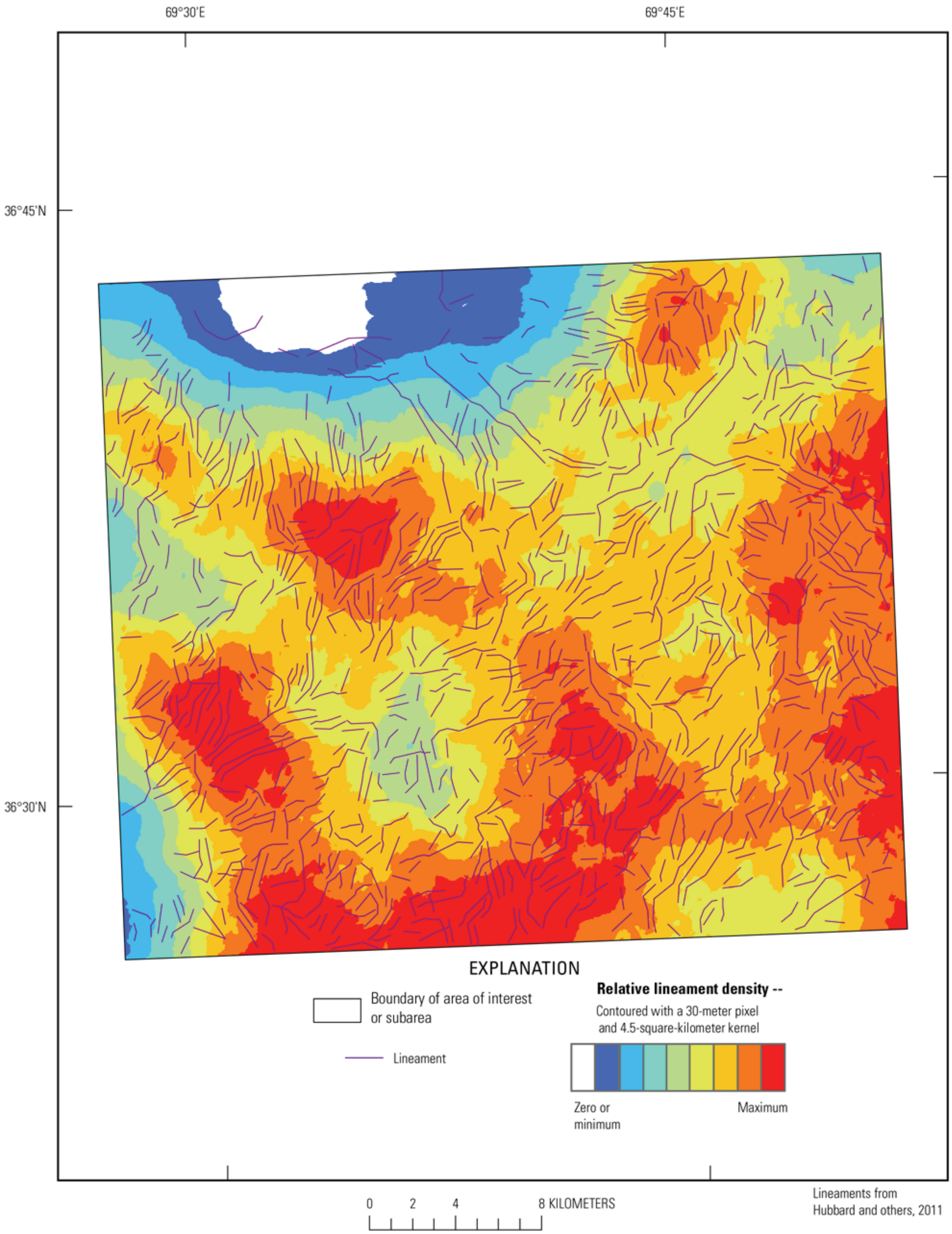


Figure 26C–7. (a) Lineaments and lineament density based on 30-meter multispectral Landsat imagery and (b) lineaments and lineament density based on 15-meter multispectral Landsat imagery in the Takhar evaporite area of interest in Afghanistan.

26C.3 Summary and Conclusions

The availability of water resources for mining and other uses is likely to be greater in the Takhar evaporite area of interest (AOI) than in other areas in Afghanistan. The AOI receives more precipitation and has a higher streamflow per unit area than most areas of Afghanistan, which indicates that the AOI may receive considerable groundwater recharge. Water resources in the AOI and surrounding area appear to consist mainly of surface water, although no information on groundwater resources is available. The mean monthly streamflow in the Farkhar River is reported to be greater than 11 cubic meters per second. The amount of irrigated land along the Farkhar River indicates that the river is highly utilized by local farmers. Most smaller streams also likely are highly utilized by the local population and represent the primary source of water for irrigation. It is likely there are shallow alluvial aquifers in the valley bottoms of the AOI that are a highly utilized groundwater resource. The diversion of water from the rivers to support mining activities would need to be closely monitored, particularly during low-flow periods, if the quantity and quality of the water resource are to be preserved so that surface-water flow remains sufficient to supply water for irrigation and to provide recharge to the aquifers that supply groundwater to the shallow wells for domestic consumption.

No subsurface hydraulic information is available for bedrock aquifers in the AOI or adjacent areas, but bedrock aquifers may be a source of considerable groundwater. 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 water 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.

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