Chapter 24B. Geohydrologic Summary of the Nuristan Pegmatite Area of Interest

By Michael P. Chornack and Thomas J. Mack

24B.1 Introduction

This chapter describes the geohydrology of the Nuristan pegmatite area of interest (AOI) in northeastern Afghanistan identified by Peters and others (2007) (fig. 24B–1a,b). The AOI is located in northeastern Afghanistan in the Bargi Matal, Kamdesh, Wama, Waygal, and Nuristan Districts in Nuristan Province, and the Pech and Chapa Dara Districts in Kunar Province (fig. 24B–1a,b). The area of the AOI is 3,489 km^2 (square kilometers).

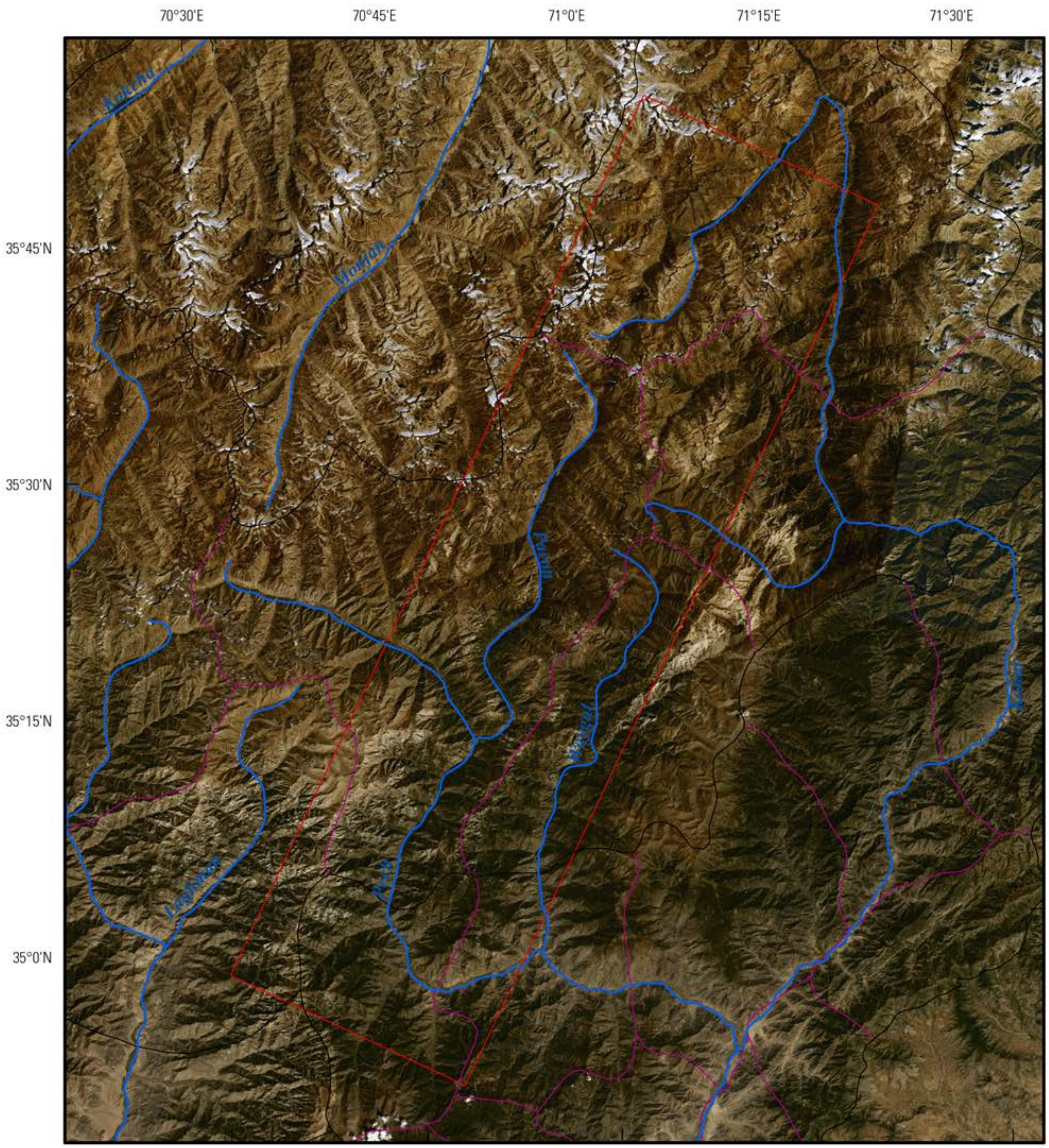
Water is needed not only to process mineral resources in Afghanistan, but also to supply existing communities and the associated community growth that may accompany a developing mining economy. Information on the climate, vegetation, topography, and demographics of the AOI is summarized to provide information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

24B.1.1 Climate and Vegetation

Climate information for the Nuristan pegmatite 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 5 10 20 KILOMETERS

EXPLANATION

Boundary of area of interest (AOI) or subarea

Stream, generally perennial

Province boundary line

District boundary line

b

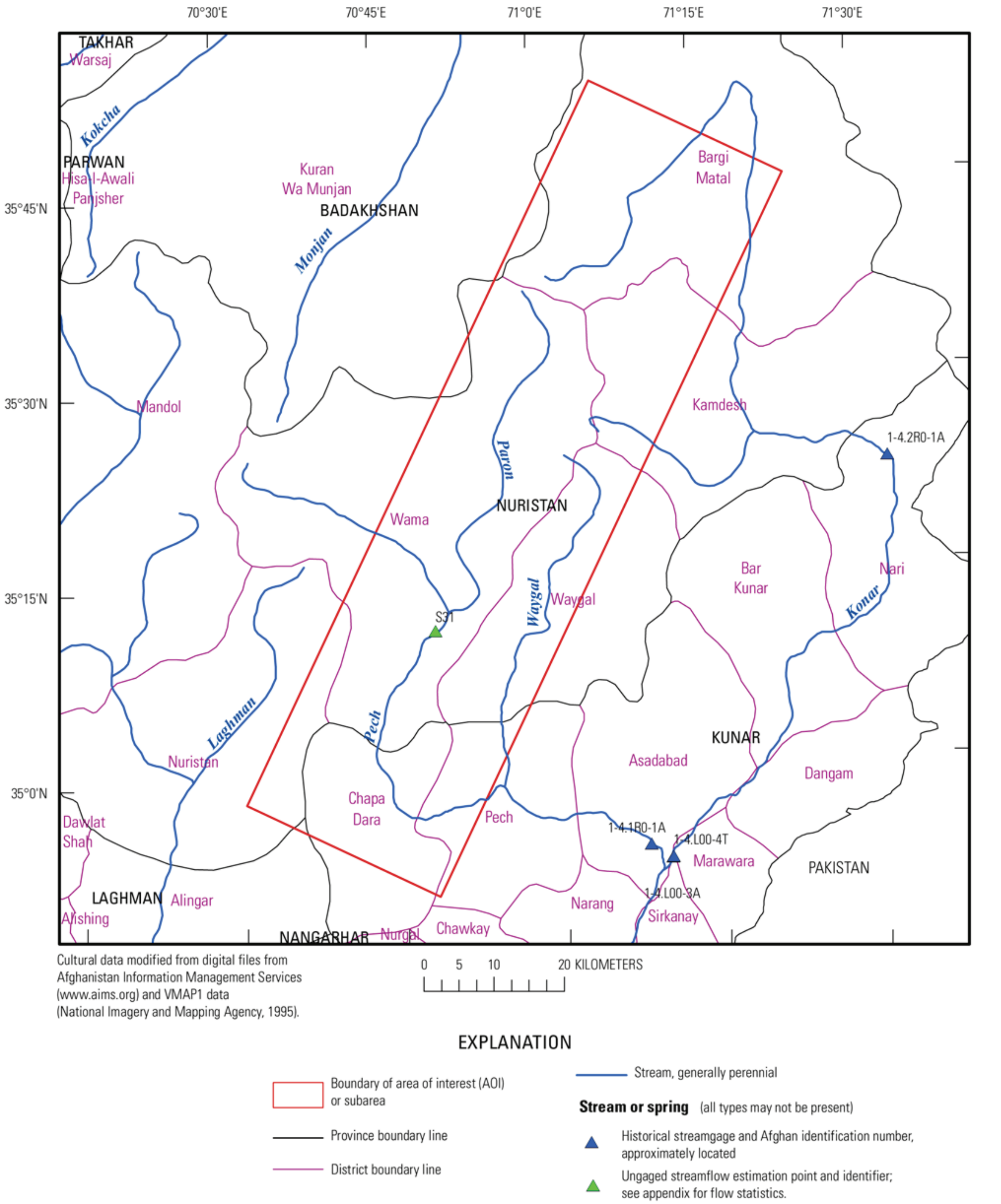


Figure 24B–1. (a) Landsat image showing the location of, and (b) place names, stream names, and streamgage station numbers in, the Nuristan pegmatite area of interest in northeastern Afghanistan.

The Paroon Agromet station is located in Nuristan Province approximately at the center of the AOI at an elevation of about 2,670 meters (m) above sea level (asl). Precipitation data for the 2009–2010 water year are available for this station. The total precipitation recorded at this station for the 2009–2010 water year was 1,354.5 mm (millimeters). The monthly high was 189 mm in February 2010 and the monthly low was 0.0 mm in October 2009 (Ministry of Agriculture, Irrigation, and Livestock, 2010).

The Asmar Agromet station is located in Kunar Province approximately 55km southeast of the center of the AOI. This station is the Agromet station that is closest to the AOI for which 2009–2010 water year long-term average (LTA) precipitation data are available. Precipitation data for this Agromet station (Ministry of Agriculture, Irrigation, and Livestock, 2010) are shown in table 24B–1.

The Dara Panjsheer Agromet station is located 120 kilometers (km) west of the center of the AOI at an elevation of about 2,050 m asl. Total snowfall at this station was 217 centimeters (cm) in the 2009–2010 water year and 370 cm in the 2008–2009 water year (Ministry of Agriculture, Irrigation and Livestock, 2010). Snowfall at this station probably can be assumed to be similar to snowfall in the AOI because of the large amount of precipitation recorded in the AOI in February 2010.

Table 24B–1. Annual, long-term annual average, and long-term average minimum and maximum precipitation and temperature at the Asmar Agrometeorological (Agromet) station approximately 55 km southeast of the center of the Nuristan pegmatite area of interest, Afghanistan.

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

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 and month (mm)	Monthly maximum and month (mm)	Minimum and month (°C)	Monthly mean (°C)	Maximum and month (°C)
Asmar	55	910	977	540.2	13.1[2] December	107 April	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).

[2] Precipitation in June and July 2010 was 13.5 and 13.7 mm, respectively.

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. 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 mostly thorny cushions, subalpine and alpine semi-deserts, and meadows as classified by Breckle (2007, p. 161). This vegetation type is found at elevations above 3,300 m asl. Where the soil is sufficiently developed between 2,200 and 3,300 m asl, areas of conifer forests are present; however, much of the upland surface of the AOI is bedrock outcrop with thin alluvial cover and very sparse vegetation. The highest elevations are in the northern corner of the AOI, and nival vegetation (growing in snow) is found above 4,900 m asl. Azonal riverine vegetation likely was present in the lower elevation stream valleys, but the trees have been harvested for fuel and building materials. Some native riverine vegetation may exist in remote parts of the AOI. Most land suitable for farming has been plowed and planted, especially along major stream valleys and some of the ephemeral tributary stream valleys, although little land in the AOI is irrigated (fig. 24B–2).

24B.1.2 Demographics

The Nuristan pegmatite AOI is sparsely populated, with most populated areas having from 1 to 5 inhabitants per square kilometer range as mapped by LandScan (Oak Ridge National Laboratory, 2010) (fig. 24B–3). In a few areas concentrated in stream valleys, population density is between 51 and 500/km^2 (fig. 24B–3). More than half the area of the AOI is unpopulated as indicated by the gray shading in figure 24B–3. The population density shown in figure 24B–3 has a pixel resolution of about 1 km^2 (Oak Ridge National Laboratory, 2010).

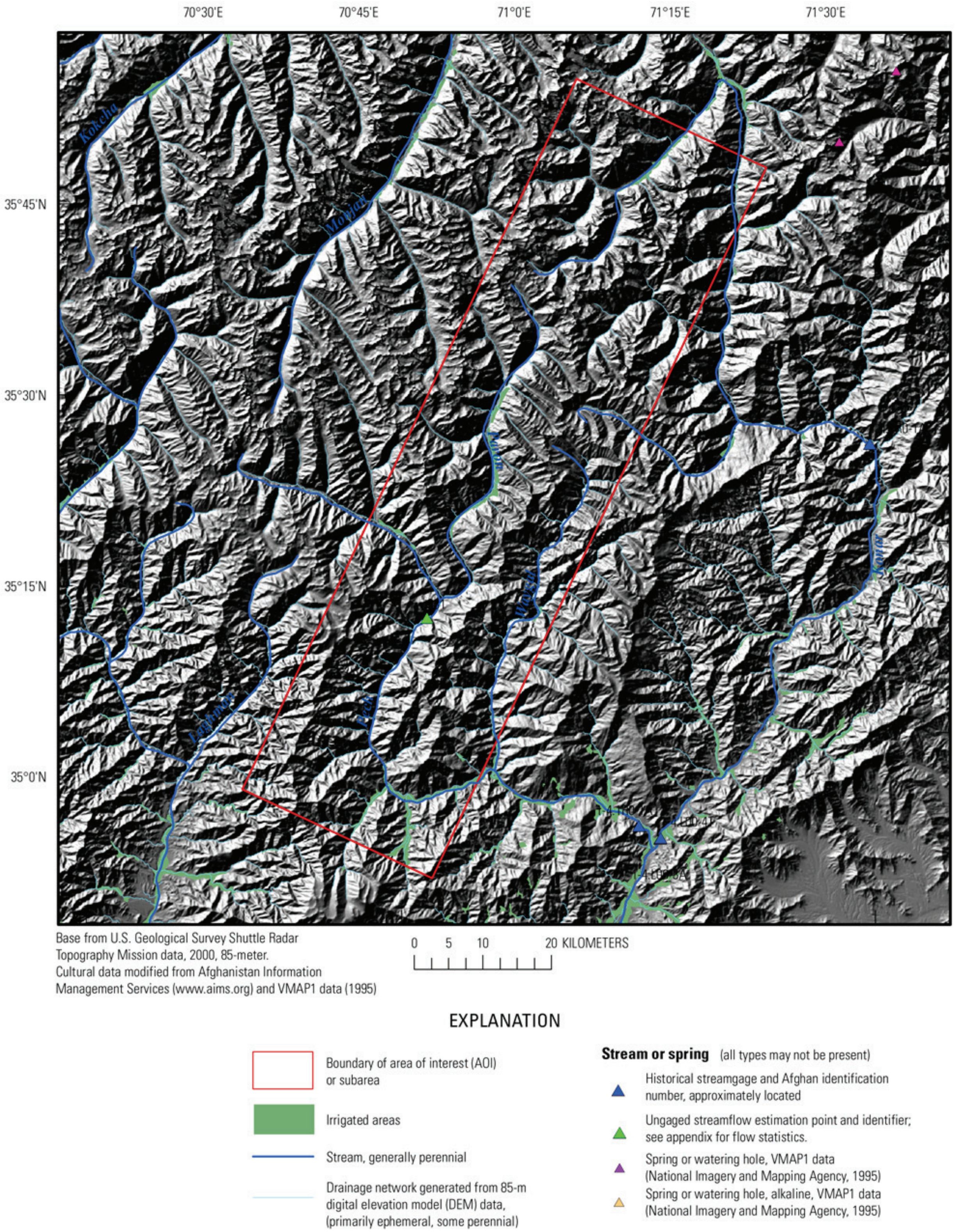


Figure 24B–2. Historical streamgage locations, digitally generated drainage network, and irrigated areas in the Nuristan pegmatite area of interest in northeastern Afghanistan.

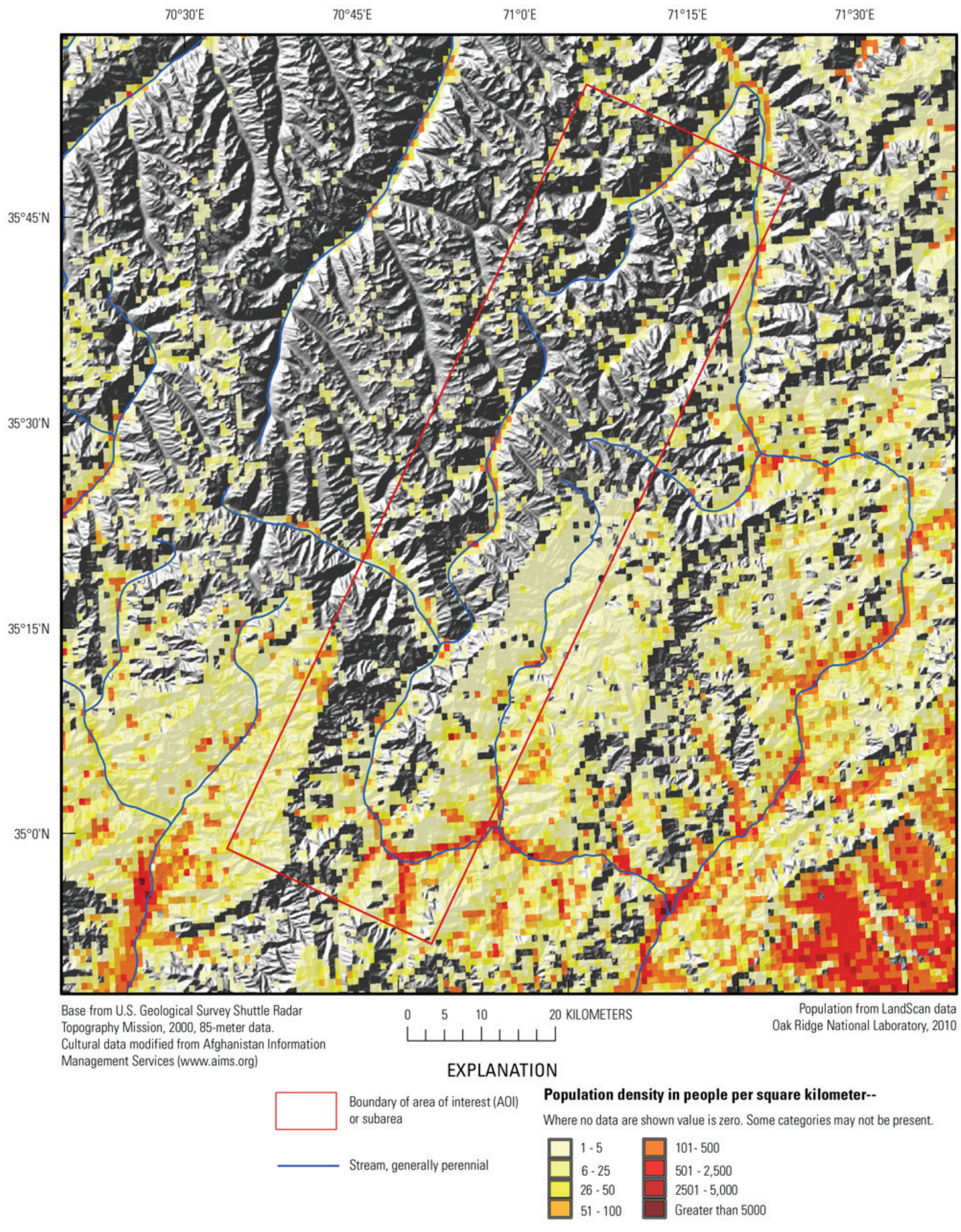


Figure 24B–3. Population density of the Nuristan pegmatite area of interest in northeastern Afghanistan.

24B.1.3 Topography and Geomorphology

The topography of the Nuristan pegmatite AOI is very mountainous (fig. 24B–4). A mountain range with peaks that range from 4,800 to more than 6,000 m asl runs along the northwest border of the

AOI (Bohannon, 2005; Davis, 2006). The major stream valleys range in elevation from about 1,000 m asl in the southern part of the AOI to 3,500 m asl in the north. The stream valleys are deeply incised with very steep sides and, in some areas, the relief is as much as 1,500 m. The geomorphology of the AOI is dominated by glacial features in the higher elevations and continuing erosion by the streams, which maintains the V-shaped valleys.

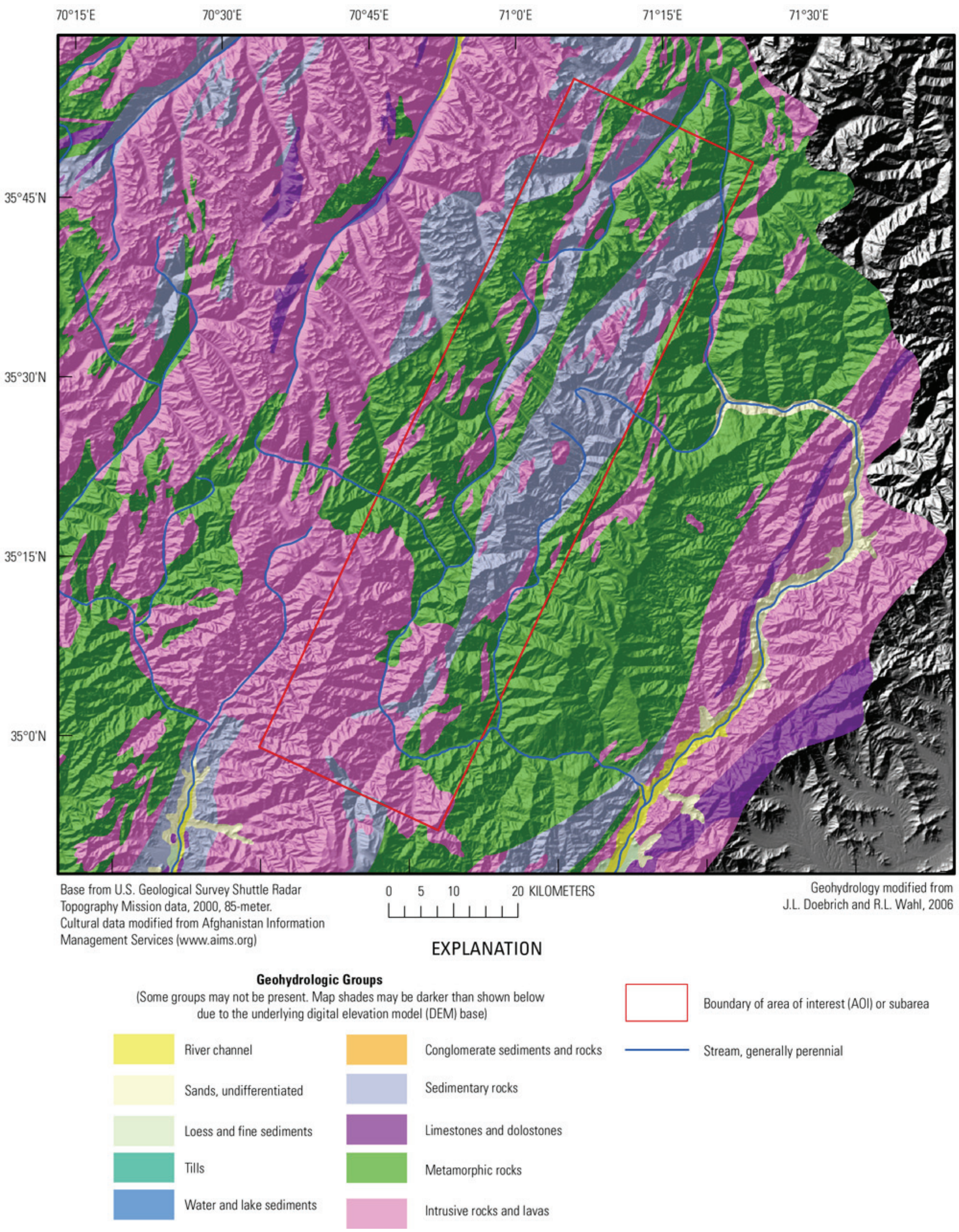


Figure 24B–4. Topography and generalized geohydrology of the Nuristan pegmatite area of interest in northeastern Afghanistan.

24B.2 Geohydrology

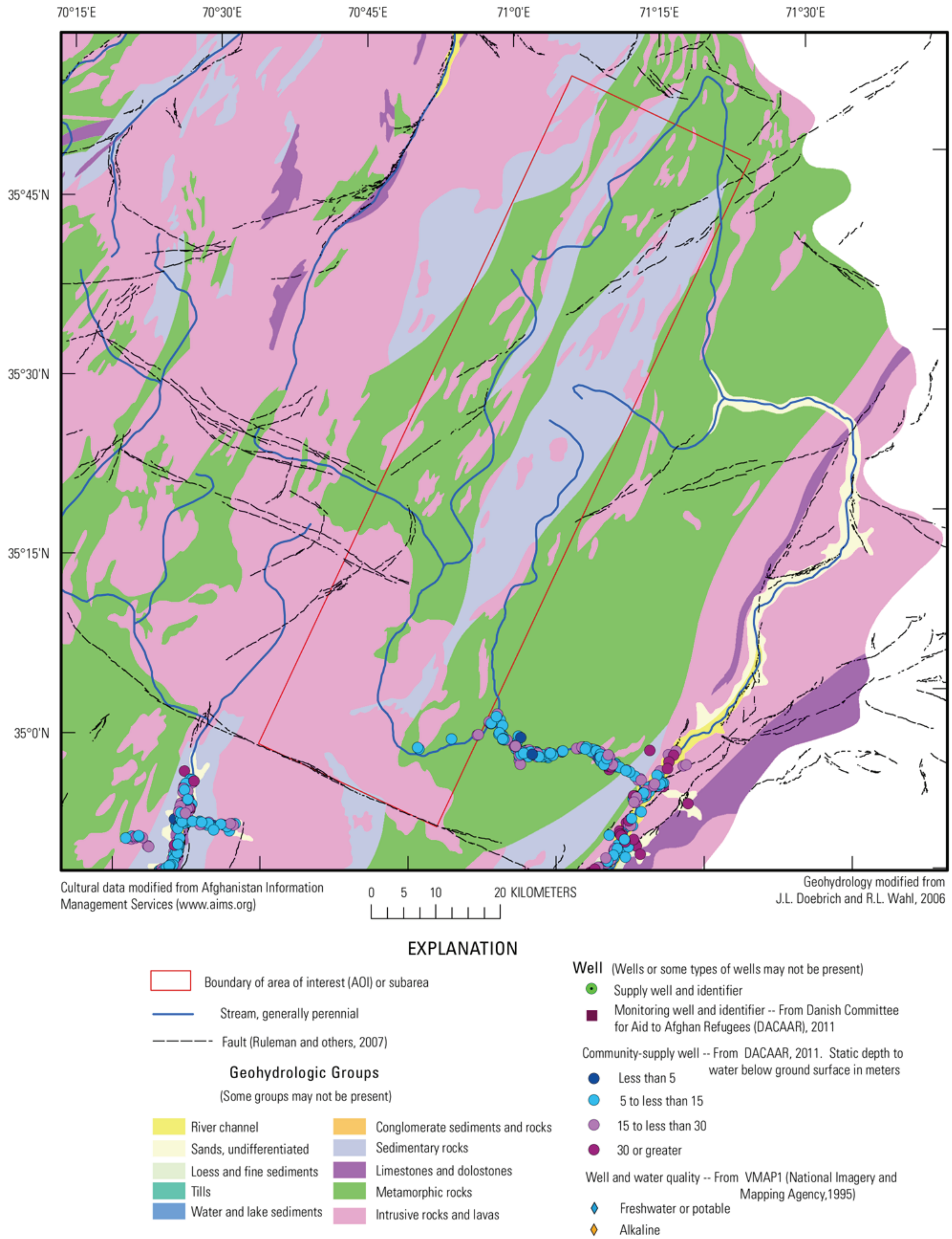
The geohydrology of Afghanistan has been described in general terms by Abdullah and Chmyriov (1977, book 2). As defined in their "Geology and mineral resources of Afghanistan," the Nuristan pegmatite AOI is in the "Central Afghanistan Hydrogeological Folded Region that occupies the central part of the country with a predominantly mountain climate." 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 24B–4 with the underlying topography to allow examination of the geohydrology in the context of relief. Figures 24B–5*a* and *b* show the generalized geohydrology without topography for a clearer depiction of the geohydrologic units. Any wells present in the map area (discussed in the Groundwater section) are shown in figures 24B–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 "sedimentary rocks; metamorphic rocks; and intrusive rocks and lavas" (figs. 24B–4, 24B–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 Lindsay and others (2005).

The outcrops of the three geohydrologic groups cover areas of the AOI that are roughly similar in size. The intrusive rocks and lavas group crops out in the very high mountains along the northwest border of the AOI. The thickness of these rocks can be estimated from the amount of relief between valley bottoms and mountain tops. In some places, as much as 1,300 m of this unit is exposed. Faults have been mapped in this unit in the AOI (fig. 24B–5*a*); it is likely that other, unmapped faults are present in the rocks of this group as well. If the rocks of this geohydrologic group are highly fractured, they may make up a substantial groundwater resource, as inferred from the recharge potential in the high mountain areas.

An area composed mostly of metamorphic rocks, with a linear zone of the sedimentary rocks geohydrologic group and scattered outcrops of the intrusive rocks and lavas group, is present in the high mountains along the western border of the AOI (figs. 24B–5*a* and *b*). There are several mapped faults in this unit. The metamorphic rocks crop out over a very large area just outside the eastern border of the AOI (figs. 24B–5*a* and *b*). Mapped faults, and probably other, unmapped faults as well, are present in this area. The area is mountainous, with peaks whose elevations exceed 4,000 m asl. The recharge potential in this area is good. If these rocks are highly fractured, both outcrop areas of the metamorphic rocks potentially could contain groundwater resources. Field investigations would be needed to characterize the groundwater-resource potential of the intrusive rocks and lavas and the metamorphic rocks geohydrologic groups in and adjacent to the AOI. The mountainous terrain could complicate field studies, especially the drilling and testing of boreholes.

Outcrops of the sedimentary rocks geohydrologic group form two linear bands that parallel the long axis of the AOI (figs. 24B–5*a* and *b*). The larger of the two outcrops is located along the eastern border of the AOI. Much of the outcrop area of this group occurs at higher elevations and may have good recharge potential, particularly from snowmelt. Some northeast-trending faults are present near the northern end of the outcrops. If fractures or fracture zones are associated with the faulting, the potential for infiltration of precipitation would be high. Therefore, the sedimentary rocks geohydrologic group is a potential source of groundwater within the AOI. Field investigations would be needed to determine whether groundwater resources are in fact present in this unit. The mountainous terrain could complicate field studies here as well, especially the drilling and testing of boreholes.

a


70°15'E
70°30'E
70°45'E
71°0'E
71°15'E
71°30'E
35°45'N
35°30'N
35°15'N
35°0'N
Cultural data modified from Afghanistan Information Management Services (www.aims.org)
0 5 10 20 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

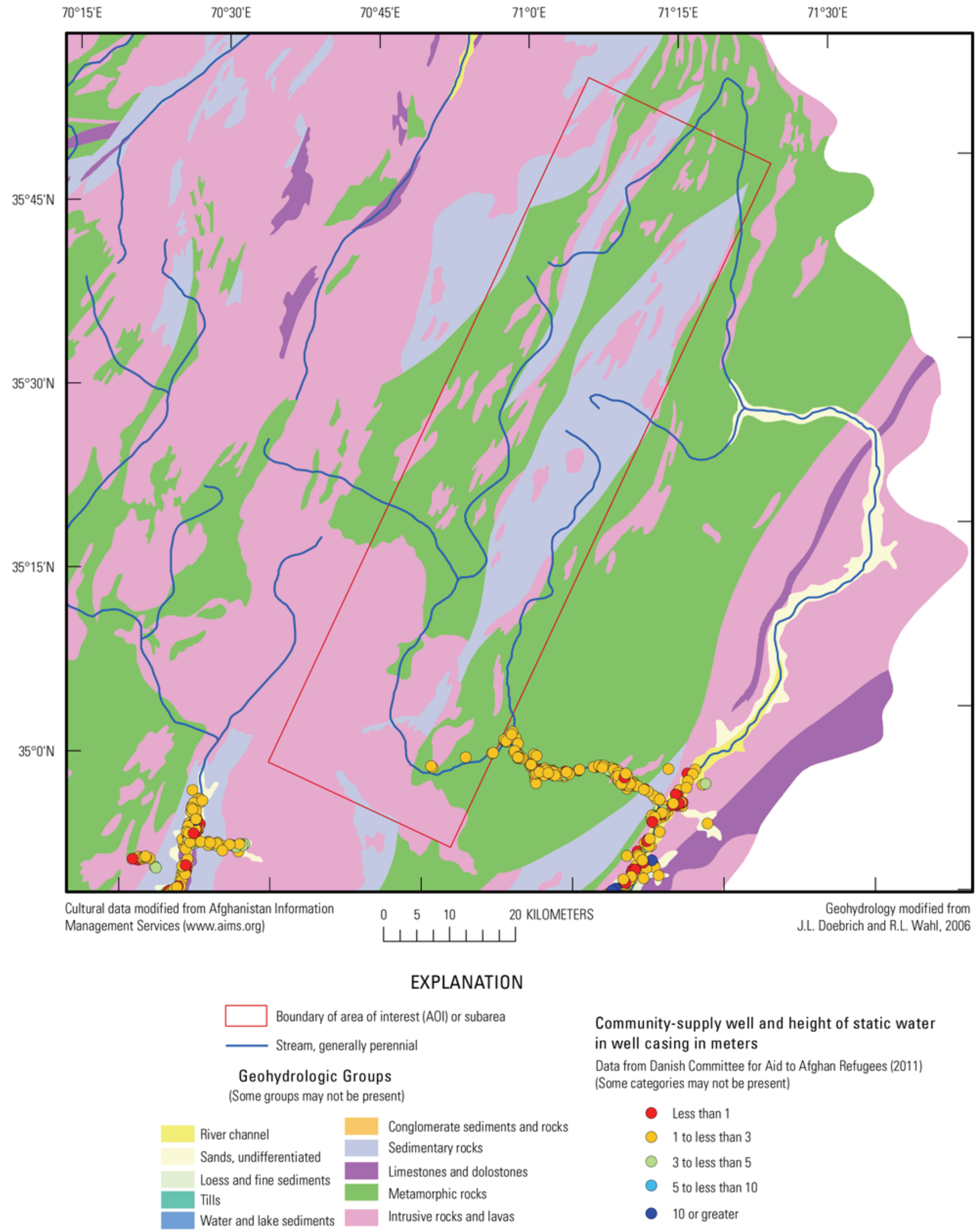


Figure 24B–5. (*a*) Generalized geohydrology, mapped faults, well locations, and depth to water, and (*b*) geohydrology and height of static water in well casings in community-supply wells in the Nuristan pegmatite area of interest in northeastern Afghanistan.

24B.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 Nuristan pegmatite AOI is shown in figure 24B–2. A network representing likely ephemeral streams, generated with a digital elevation model (DEM), also is shown in figure 24B–2. Names of major streams and identification numbers for any streamgages and ungaged streamflow estimation sites in the AOI are shown in figure 24B–1*b*.

Three streamgaging stations are about 20 to 50 km east of the AOI. All three stations are located on streams that originate within the AOI. The streamgage nearest to the AOI is located in Kunar Province approximately 50 km east of the center of the AOI. The Landaisin River near Gawardesh streamgage station (Afghan identification number 1-4.2R0-1A) (figs. 24B–1*b*, 24B–2) is at an elevation of 1,135 m asl and has a drainage area of 3,130 km^2 and a period of record that extends from 1 May, 1975, to 22 July, 1978 (Olson and Williams-Sether, 2010). The Landaisin River is a tributary of the Konar River, and the streamgage station is located approximately 10 km upstream from the confluence of the two streams. The annual mean streamflow per unit area for this station is 0.0170 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 through early summer (due to snowmelt) and low flows in winter. A statistical summary of monthly and annual mean streamflows for this station is presented in table 24B–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 Konar River near Asmar streamgage station (Afghan identification number 1-4.L00-4T) is about 75 km downstream from the confluence of the Landaisin River and the Konar River (figs. 24B–1b, 24B–2). This station is at an elevation of 795 m asl and has a drainage area of 19,960 km^2 and a period of record that extends from 23 February, 1960, to 30 September, 1971 (Olson and Williams-Sether, 2010). The annual mean streamflow per unit area for this station is 0.0184 m^3/s/km^2. The seasonal timing of maximum and minimum monthly streamflow is high flows in the late spring and summer (due to snowmelt) and low flows in winter. A statistical summary of monthly and annual mean streamflows for this station is presented in table 24B–3.

The Pech River at Chaghasarai streamgage station (Afghan identification number 1-4.1R0-1A) is about 3.5 km upstream from the confluence of the Pech and Konar Rivers (figs. 24B–1*b*, 24B–2). This station is at an elevation of 790 m asl and has a drainage area of 3,855 km^2 and a period of record that extends from 23 February, 1960, to 28 February, 1979 (Olson and Williams-Sether, 2010). The annual mean streamflow per unit area for this station is 0.0152 m^3/s/km^2. The seasonal timing of maximum and minimum monthly streamflow is high flows in the late spring through mid-summer (due to snowmelt) and low flows in winter. A statistical summary of monthly and annual mean streamflows for this station is presented in table 24B–4.

Streamflow statistics were estimated for selected ungaged streams that may be prominent in the AOI to provide some probable estimates of flow for these locations. Streamflow statistics, presented in appendix 2, were calculated for point S31 (figs. 24B–1*b* and 24B–2) on a selected stream in the AOI using a drainage-area-ratio method (Olson and Mack, 2011) based on historical flows at the Pech River at Chaghasarai streamgage station (Afghan identification number 1-4.1R0-1A) (Olson and Williams-Sether, 2010). The Pech River at Chaghasarai streamgage station was selected as the most representative historical gage for use with this method on the basis of drainage area and location in Afghanistan. The estimated mean annual streamflow for point S31 (app. 2), with a drainage area of 1,533.2 km^2, is about 22.48 m^3/s (cubic meters per second). The seasonal timing of maximum and minimum monthly streamflow at this station, high flows in late spring through mid summer and low flows in winter (app. 2), probably is similar to that at the Pech River at Chaghasarai station.

Table 24B–2. Statistical summary of monthly and annual mean streamflows for the Landaisin River near Gawardesh streamgage station (Olson and Williams-Sether, 2010).
[m^3/s, cubic meters per second]

1-4.2R0-1A LANDAISIN RIVER NEAR GAWARDESH

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	23.6	1976	21.8	1978	23.0	1.01	0.04	3.38
November	16.4	1977	15.6	1978	16.1	0.44	0.03	2.37
December	13.0	1977	11.4	1978	12.4	0.87	0.07	1.83
January	12.1	1976	9.7	1978	11.0	1.21	0.11	1.61
February	11.9	1976	10.3	1978	10.9	0.90	0.08	1.60
March	19.7	1977	14.1	1976	16.4	2.93	0.18	2.41
April	53.4	1976	44.4	1977	49.8	4.76	0.10	7.33
May	169	1975	80.0	1977	124	36.4	0.29	18.2
June	175	1978	150	1977	162	11.9	0.07	23.9
July	144	1976	112	1977	129	16.0	0.12	19.0
August	99.0	1975	69.9	1977	82.5	15.0	0.18	12.1
September	47.2	1975	35.5	1977	43.0	6.49	0.15	6.33
Annual	**57.4**	**1976**	**49.0**	**1977**	**53.2**	**5.94**	**0.11**	**100**

Table 24B–3. Statistical summary of monthly and annual mean streamflows for the Konar River near Asmar streamgage station (Olson and Williams-Sether, 2010).
[m^3/s, cubic meters per second]

1-4.L00-4T KONAR RIVER NEAR ASMAR

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	251	1961	144	1963	194	35.2	0.18	4.38
November	176	1970	107	1964	135	26.9	0.20	3.06
December	161	1970	88.9	1964	112	21.2	0.19	2.53
January	137	1970	75.4	1966	97.7	16.2	0.17	2.21
February	123	1970	75.6	1966	89.7	13.0	0.14	2.03
March	167	1960	95.3	1963	121	22.2	0.18	2.73
April	373	1968	157	1962	263	65.7	0.25	5.96
May	593	1965	236	1962	437	94.4	0.22	9.88
June	1070	1968	503	1962	760	158	0.21	17.2
July	1200	1967	674	1962	925	155	0.17	20.9
August	1040	1970	644	1962	831	144	0.17	18.8
September	583	1961	361	1963	454	79.4	0.18	10.3
Annual	452	1968	277	1962	367	53.2	0.14	100

Table 24B–4. Statistical summary of monthly and annual mean streamflows for the Pech River at Chaghasarai streamgage station (Olson and Williams-Sether, 2010).
[m^3/s, cubic meters per second]

1-4.1R0-1A PECH RIVER AT CHAGHASARAI

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	30.1	1970	6.74	1972	14.4	6.30	0.44	2.05
November	23.1	1970	5.94	1972	11.3	4.21	0.37	1.62
December	13.1	1973	4.01	1972	8.59	2.39	0.28	1.22
January	13.2	1973	3.50	1971	7.68	2.19	0.28	1.09
February	16.9	1973	4.24	1971	9.78	3.30	0.34	1.39
March	54.7	1969	11.4	1975	24.9	13.0	0.52	3.55
April	174	1973	42.7	1977	82.7	29.3	0.35	11.8
May	278	1973	75.8	1962	150	42.3	0.28	21.3
June	331	1972	96.4	1971	206	64.5	0.31	29.4
July	219	1965	33.5	1970	118	51.5	0.44	16.9
August	84.5	1968	17.0	1974	46.5	17.6	0.38	6.62
September	33.8	1967	9.17	1971	21.8	6.65	0.31	3.10
Annual	**92.4**	**1973**	**31.8**	**1971**	**58.7**	**16.4**	**0.28**	**100**

The number of perennial streams that either originate in or flow through the AOI indicates that surface-water resources probably are sufficient to supply the water needed to support mining activities. Determination of the water needs of downstream users would help to effectively manage the withdrawal of surface water for mining. The timing and amount of surface-water withdrawals would need to be closely monitored and carefully managed to protect the access of downstream users to adequate resources.

24B.2.2 Groundwater

Approximately 234 shallow community groundwater-supply wells have been installed in the Nuristan pegmatite 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 static-water-level information is available for only five of the wells in the AOI in this database (fig. 24B–5*a*,*b*). Nearly 600 supply wells are in the villages within 30 km of the southeast border of the AOI, and well-depth and water-level information is available for about half those wells. The hydrogeologic settings of and well characteristics in the two areas are likely to be similar; therefore, information for the wells in and just outside the AOI is summarized here. About 88 percent of the supply wells are less than 30 m deep, and 99 percent are less than 60 m deep. The median well depth is 16 m. The depth to water in 90 percent of the supply wells in the AOI is less than 30 m (fig. 24B–5*a*). The median depth to water is 13.9 m.

Available well-construction information is limited; however, most wells are likely to be "tube" wells (driven wells with steel or polyvinyl chloride (PVC) casing) or dug wells with 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 24B–5*b* 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 1.5 m. In the AOI and surrounding areas, less than 3 m of static water is present in 95 percent of the wells for which data are available. Such shallow wells were found to be vulnerable to seasonal water-level fluctuations and becoming dry for extended periods of time, or even permanently, in areas of the Kabul Basin where groundwater withdrawals are increasing (Mack and others, 2010). There are no groundwater-monitoring wells in the AOI.

There is no information on the availability of groundwater 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.

24B.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 Nuristan pegmatite AOI (B.E. Hubbard, T.J. Mack, and A.L. Thompson, unpub. data, 2011) were conducted using DEM and natural-color satellite imagery (fig. 24B–6) and Advanced Spaceborne Thermal Emission and Reflection Radiometry (ASTER) satellite imagery (fig. 24B–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 24B–6 were delineated visually, whereas those in figure 24B–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. Many northeast-trending lineaments and northeast-trending faults have been delineated in the AOI (fig. 24B–5*a*); east-trending lineaments and mapped faults have been identified in southern parts of the AOI. Areas where lineament density is high (figs. 24B–6, 24B–7*a*, 24B–7*b*) are areas where bedrock fractures are potentially more prevalent than in other areas of the AOI. Lineaments provide an indication of areas that may 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.

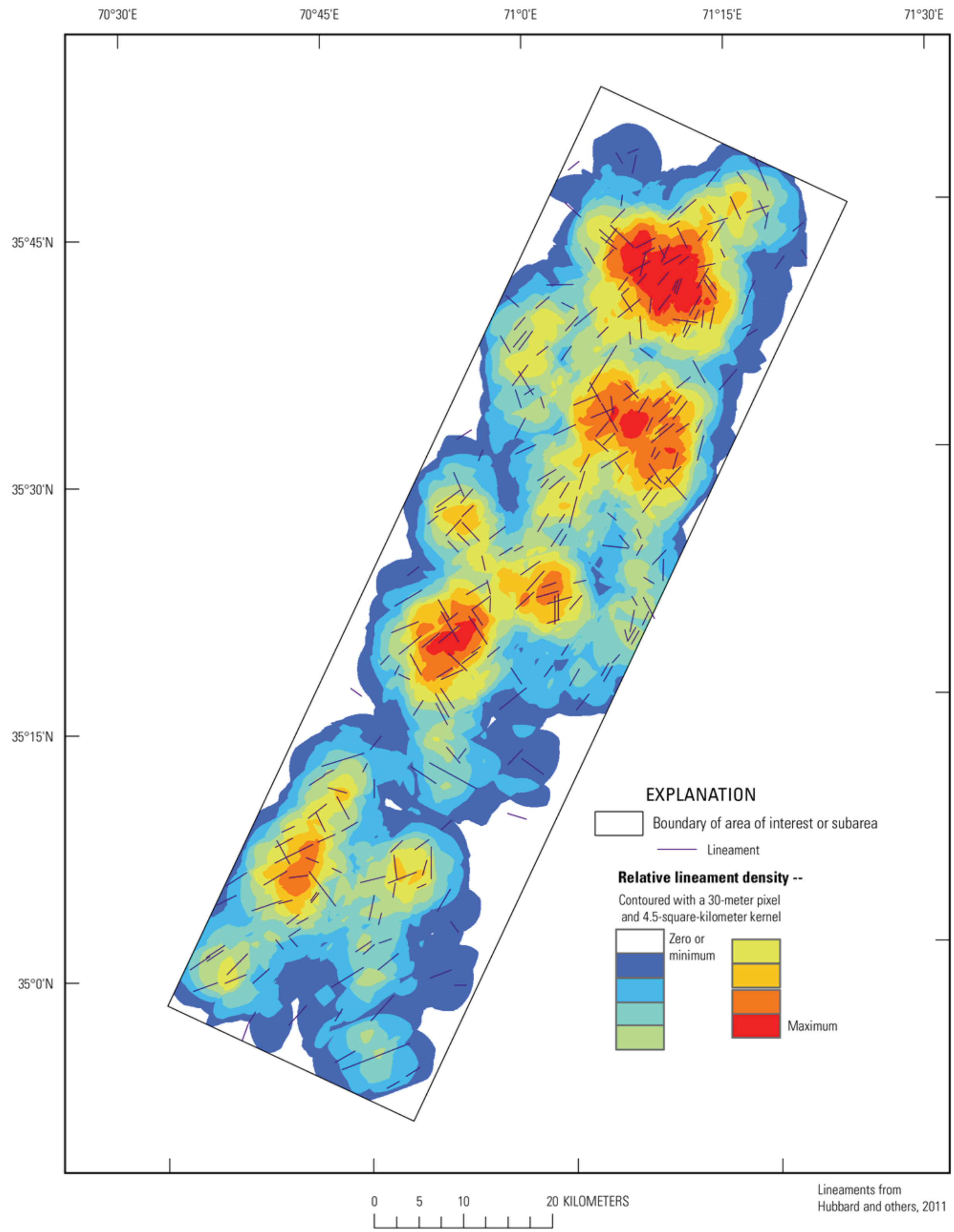
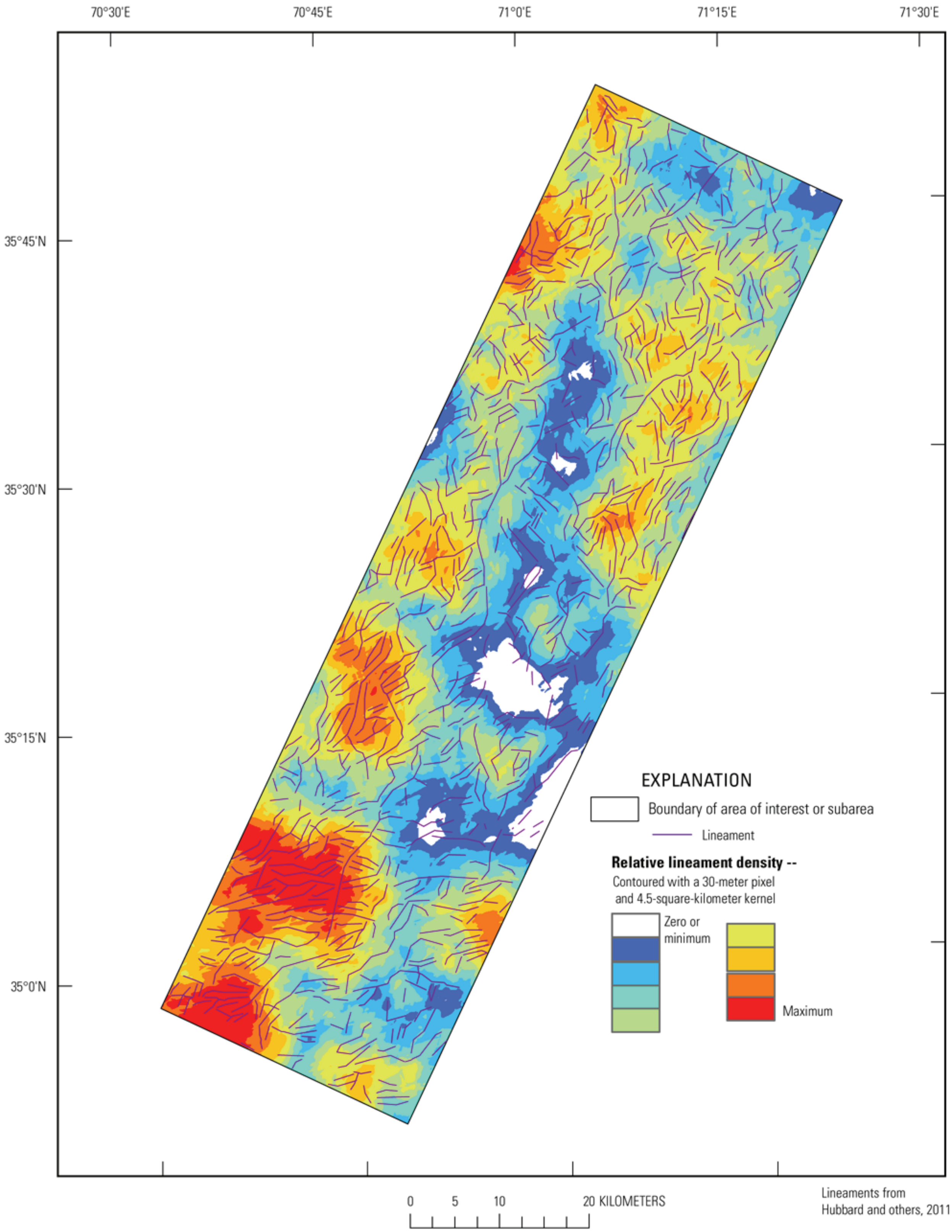


Figure 24B–6. Lineaments and lineament density based on 30-meter digital-elevation-model data and natural-color Landsat imagery in the Nuristan pegmatite area of interest in northeastern Afghanistan.

a


70°30'E
70°45'E
71°0'E
71°15'E
71°30'E
35°45'N
35°30'N
35°15'N
35°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
5
10
20 KILOMETERS
Lineaments from
Hubbard and others, 2011

b

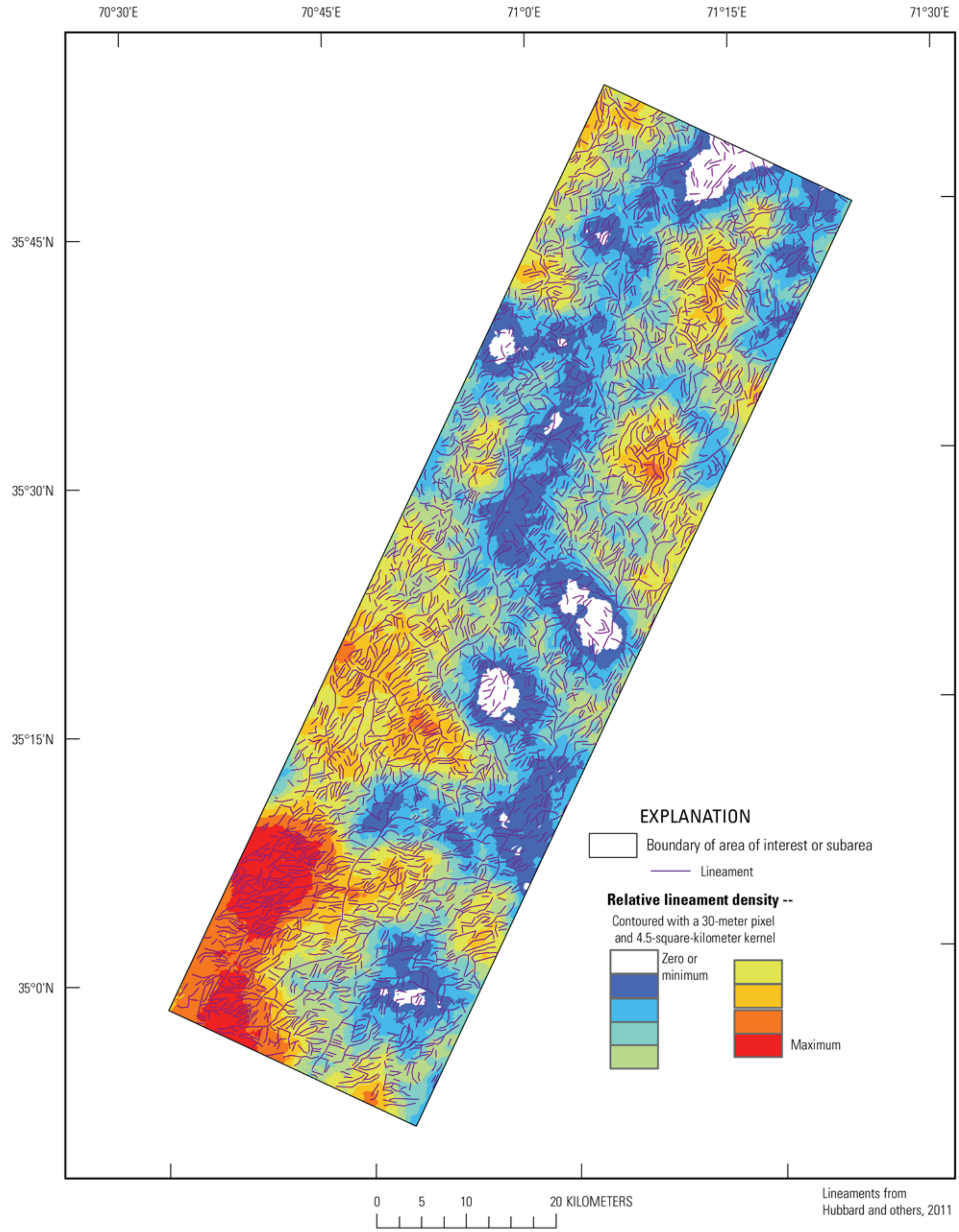


Figure 24B–7. (*a*) Lineaments and lineament density based on 30-meter multispectral Landsat imagery and (*b*) lineaments and lineament density based on 15-meter multispectral Landsat imagery in the Nuristan pegmatite area of interest in northeastern Afghanistan.

24B.3 Summary and Conclusions

The availability of water resources for mining and other uses is likely to be greater in the Nuristan pegmatite area of interest (AOI) than in other areas of Afghanistan on the basis of the relatively high precipitation and streamflow in the AOI. Water resources in the AOI and surrounding area consist mainly of surface water. Where shallow alluvial aquifers are present in the valley bottoms of the AOI, the groundwater is likely to be a highly utilized resource. Most streams are also 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, to ensure that the quantity and quality of the surface-water flow remain sufficient to supply water for irrigation and 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 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.

24B.4 References Cited

Abdullah, Sh., and Chmyriov, V.M., eds. in chief, 1977, Geology and mineral resources of Afghanistan, book 2: Afghanistan Ministry of Mines and Industries, Afghanistan Geological Survey, reprinted 2008, British Geological Survey Occasional Publications No. 15, 292 p.

Afghanistan Information Management Service, 1997, Irrigated areas: Afghanistan Information Management Service Afghanistan Shape Files, scale 1:250,000, accessed October 15, 2010, at *http://www.aims.org.af/*.

Bohannon, R.G., 2005, Topographic map of quadrangle 3570, Tagab-e-Munjan (505) and Asmar-Kamdesh (505) quadrangles, Afghanistan: U.S. Geological Survey Open-File Report 2005–1102B.

Breckle, S.W., 2007, Flora and vegetation of Afghanistan: Basic and Applied Dryland Research, v. 1, no. 2, p 155–194.

Danish Committee for Aid to Afghan Refugees, 2011, Update on “National groundwater monitoring wells network activities in Afghanistan” from July 2007 to December 2010: Kabul, Afghanistan, Danish Committee for Aid to Afghan Refugees (DACAAR), 23 p.

Davis, P.A., 2006, Calibrated Landsat ETM+ Mosaics of Afghanistan: U.S. Geological Survey Open-File Report 2006-1345, 18 p., also at *http://pubs.usgs.gov/of/2006/1345/*.

Doebrich, J.L., and Wahl, R.R., comps., *with contributions by* Doebrich, J.L., Wahl, R.R., Ludington, S.D., Chirico, P.G., Wandrey, C.J., Bohannon, R.G., Orris, G.J., Bliss, J.D., ____, and ___, 2006, Geologic and mineral resource map of Afghanistan: U.S. Geological Survey Open File Report 2006–1038, scale 1:850,000, available at *http://pubs.usgs.gov/of/2006/1038/*.

Freeze, R.A., and Cherry, J.A., 1979, Groundwater: Englewood Cliffs, N.J., Prentice-Hall, 604 p.

Lattman, L.H., and Parizek, R.R., 1964, Relationship between fracture traces and the occurrence of ground water in carbonate rocks: Journal of Hydrology, v. 2, p. 73–91.

Lindsay, C.R., Snee, L.W., Bohannon, R.G., Wahl, R.R., and Sawyer, D.A., 2005, Geologic map of quadrangle 3568, Polekhomri (503) and Charikar (504) quadrangles, Afghanistan: U.S. Geological Survey Open-File Report 2005–1101A.

Mabee, S.B., 1999, Factors influencing well productivity in glaciated metamorphic rocks: Groundwater, v. 37, no. 1, p. 88–97.

Mack, T.J., _____, ______, Chornack, M.P., and others, 2010, Conceptual model of water resources in the Kabul Basin, Afghanistan: U.S. Geological Survey Scientific Investigations Report 2009-5262, 240 p.

Ministry of Agriculture, Irrigation and Livestock and the Afghan Meteorological Authority of the Ministry of Transport, 2010,The Afghanistan Agrometeorological Seasonal Bulletin, issue no. 7, 2009–2010, 26 p., available at *http://afghanistan.cr.usgs.gov/documents.php*.

Moore, R.B., Schwarz, G.E., Clark, S.F., Jr., Walsh, G.J., and Degnan, J.R., 2002, Factors related to well yield in the fractured-bedrock aquifer of New Hampshire: U.S. Geological Survey Professional Paper 1660, 51 p., 2 pl.

National Imagery and Mapping Agency, 1995, Vector map (VMAP1): National Imagery and Mapping Agency database, available at *http://geoengine.nga.mil/geospatial/SW_TOOLS/NIMAMUSE/webinter/rast_roam.html*.

Oak Ridge National Laboratory, 2010, LandScan global population database 2009: Oak Ridge National Laboratory, accessed February 1, 2011, at *http://www.ornl.gov/sci/landscan/*.

Olson, S.A., and Mack, T.J., 2011, Technique for estimation of streamflow statistics in mineral areas of interest in Afghanistan: U.S. Geological Survey Open-File Report 2011–1176, 18 p., available at *http://pubs.usgs.gov/of/2011/1176/*.

Olson, S.A., and Williams-Sether, T., 2010, Streamflow characteristics of streamgages in northern Afghanistan and selected locations: U.S. Geological Survey Data Series 529, 512 p.

Peters, S.G., Ludington, S.D., Orris, G.J., Sutphin, D.M., Bliss, J.D., and Rytuba, J.J., eds., and the U.S. Geological Survey-Afghanistan Ministry of Mines Joint Mineral Resource Assessment Team, 2007, Preliminary non-fuel mineral resource assessment of Afghanistan: U.S. Geological Survey Open-File Report 2007–1214, 810 p., 1 CD–ROM. (Also available at *http://pubs.usgs.gov/of/2007/1214/*.)

Ruleman, C.A., Crone, A.J., Machette, M.N., Haller, K.M., and Rukstales, K.S., 2007, Map and database of probable and possible Quaternary faults in Afghanistan: U.S. Geological Survey Open-File Report 2007–1103, 39 p., 1 pl.

Siddiqui, S.H., and Parizek, R.R., 1971, Hydrogeologic factors influencing well yields in folded and faulted carbonate rocks in central Pennsylvania: Water Resources Research, v. 7, no. 5, p. 1295–1312.