10.0 Deposits related to surficial processes and unconformities.

In Afghanistan, mineral occurrences and deposits related to surficial processes and unconformities are bauxite alumina (section 10.1), alluvial placer gold (section 10.2), and sand and gravel (section 10.3). Preliminary resources were estimated by Russian workers for the Obato-Shela and Nalag (Tala) bauxite deposits and four placer gold deposits in northern Takhar Province and a number of sand and gravel deposits in Badakhshan Province. Sand and gravel is abundant in the country. Additional probabilistic estimates are made here for undiscovered sand and gravel deposits throughout the country.

10.1 Bauxite

Bauxite occurrences are present locally in Afghanistan. The largest known deposits is the Obatu-Shela deposit that has measured resources of 2.5 to 3 million metric tons of bauxite at 50 wt. percent alumina in place, and the surrounding area may contain as much as 35 million metric tons of bauxite. If the speculative resources in the graben-syncline are in fact real, then Obatu-Shela would be an above average size karst-type bauxite deposit and could attract international investment. Geologic conditions are permissive for additional deposits, particularly in geologic environments similar to that which Obatu-Shela formed.

Aluminum is the third most abundant element in the Earth's crust behind only oxygen and silicon. It is an important constituent in all clays and soil and of the silicates of common rocks (Jensen and Bateman, 1981). It occurs in nature combined with other elements mostly in silicate minerals where it is difficult and expensive to extract. Bauxite, an ore of aluminum, is a complex impure mixture of aluminum minerals, chiefly aluminum hydroxides (Patterson and Dyni, 1973). Bauxite is not a product of normal weathering in temperate regions (Jensen and Bateman, 1981). It forms in tropical and subtropical regions as a constituent of lateritic soils. Bauxite is an accumulated product of weathering of aluminum silicate rocks lacking much free quartz. The silicates are broken down, the silica is removed; iron is partly removed, water is added; and alumina, titanium, and ferric oxide and perhaps manganese oxide become concentrated in the residue (Jensen and Bateman, 1981). Gibbsite and boehmite are the principal minerals in bauxite. Gibbsite bauxites have low silica content and are the least expensive to process.

The necessary conditions for bauxite deposits to form are (1) humid tropical or subtropical climate, (2) rocks high in aluminum in a form susceptible to yielding bauxite, (3) available reagents including precipitation, to promote the chemical weathering of the silicates and solution of silica at a specific pH and Eh condition, (4) surfaces that permit a slow downward infiltration of meteoric water; (5) subsurface conditions that allow the removal of dissolved products, (6) long time of tectonic stability, and (7) the deposits must be preserved (Jensen and Bateman, 1981).

Known bauxite deposits of Afghanistan are of two basic types, those found in karst and those in laterite. They occur in two general areas; three laterite-type deposits are located northwest of Kabul in an area of small hard-coal deposits, and four karst-type deposits have been identified southwest of Kabul north of the Chaman fault.

10.1.1 Description of Bauxite Deposit Models

There are two bauxite deposit models applicable to Afghanistan, laterite-type and karst-type.

Laterite-type bauxite deposits (model 38b, Patterson, 1986a; Freyssinet and others, 2005), or alumina ore deposits, are composed of weathered residual material in subsoil that forms in any rock containing alumina. The deposits consist of weathered rock formed on aluminous silicate rocks and contain typical lateritic textures including pisolitic, massive, nodular, and earthy. Ages are mainly Cenozoic, but can be older. The depositional environment consists of surficial weathering on well-drained plateaus in regions with warm to hot and wet climates. Locally, deposits may be present in poorly drained areas where iron is removed by organic complexing. The deposits typically are present on plateaus in tectonically stable areas. Deposits may be overlain by thin "A" horizon soil and are usually underlain by saprolite (parent rock in intermediate stages of weathering). Mineralogy consists mainly of gibbsite and mixtures of gibbsite and boehmite. Gangue minerals are hematite, goethite, and anatase, as well as quartz. Intensive weathering is required to form bauxite. Bauxite continues to form in present weathering environments in most deposits. The geochemical signature is characterized by elevated concentrations of Al and Ga in parts of the lateritic profile. Residual kaolin deposits are associated bauxite deposits. Three laterite-type bauxite deposits are present in Afghanistan in Baghlan Province northwest of Kabul.

Compilation of grade and tonnage data for laterite-type bauxite deposits has shown that 90 percent of these deposits contain at least 870,000 t of material (figures 10.1-1 and 10.1-2). The median tonnage is 25 million metric tons, and 10 percent of deposits contain 730 million metric tons or more of material (Mosier, 1986a). Grades of laterite-type bauxite deposits have a median of 45 percent alumina (fig. 10.1-2). About 90 percent of deposits contain 35 percent or more alumina, and 10 percent contain 55 percent or more alumina.

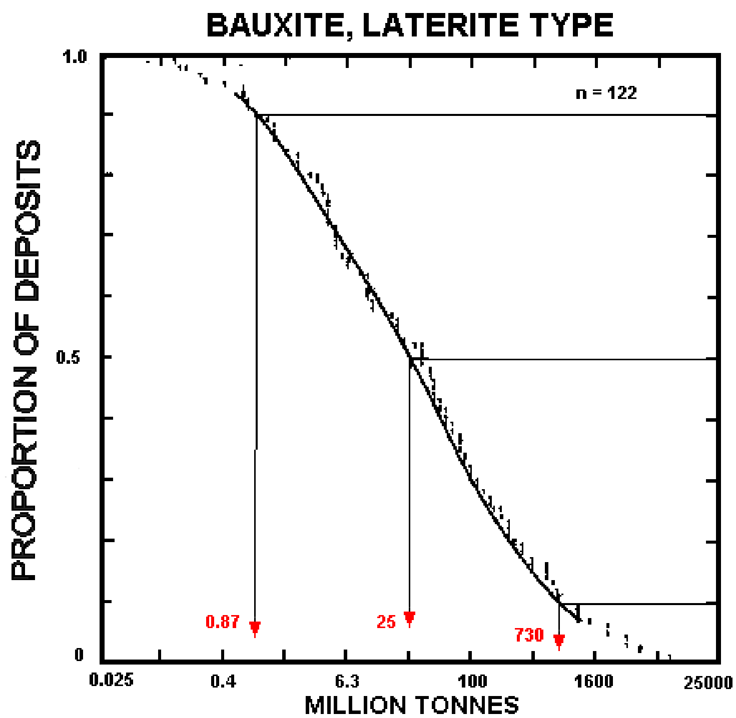

Figure 10.1-1. Tonnages of laterite-type bauxite deposits. Individual digits represent number of deposits (Mosier, 1986a). [Because of limitations on the reproduction of the original figure, these numbers cannot be distinguished in the figure.]

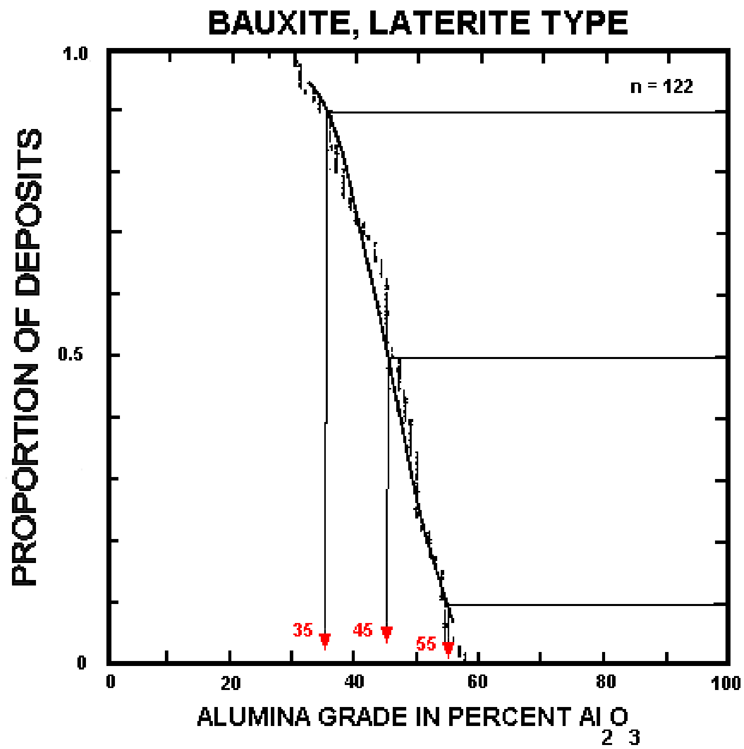

Figure 10.1-2 Alumina grades of laterite-type bauxite deposits. Individual digits represent number of deposits (Mosier, 1986a). [Because of limitations on the reproduction of the original figure, these numbers cannot be distinguished in the figure.]

The laterite-type bauxite occurrences are Eshpushta, Estoma, and Nalag, all in Baghlan Province. Light-grey, pinkish, and slightly ferruginous bauxite at Eshpushta occurs in Upper Triassic weathered volcanic rocks as a tabular body 300 to 400 m long and 1 to 3 m thick. At Estoma and Nalag, bauxite is located at the contact between Jurassic carbonaceous rocks and weathered Upper Triassic volcanic rocks (Mikhailov and others, 1967; Abdullah and others, 1977). Estoma has four tabular white bodies as much as 70 m long and 2 to 4 m thick, and the bauxite is grey, light pink, and oolitic. At Nalag, there are 10 tabular bauxite bodies as much as 200 m long and up to 4 m thick. The bauxite is grey, pinkish, and oolitic and assays more than 52 percent alumina, 19.05 percent silica, and 16.56 percent hematite. Speculative reserves at Nalag are estimated at 4.5 million metric tons bauxite (Mikhailov and others, 1967; Abdullah and others, 1977).

Karst-type bauxite deposits. This type of bauxite deposit (model 38c, Patterson, 1986a) is composed of residual and transported material on carbonate rocks. The material may be felsic volcanic ash from a distant source or any aluminous sediment washed into a depositional basin. The deposits range in age from the Paleozoic to Cenozoic. They form from intense surficial weathering mainly in wet tropical areas and tend to be concentrated in depressions on karst surfaces. These deposits require stable land areas allowing time for weathering and protection from erosion. Their textures are pisolitic, nodular, massive, and earthy. Gibbsite is the main mineral in Quaternary age deposits; older Cenozoic deposits have a mixture of gibbsite and boehmite; boehmite is the main mineral in Mesozoic and Paleozoic deposits. Gangue minerals are hematite, goethite, anatase, kaolin minerals, and minor amounts of quartz. Geochemically, these deposits are recognized by anomalous Al and Ga values.

Grade and tonnage models for karst-type bauxite deposits (Mosier, 1986b) indicate that typically these deposits are somewhat smaller than laterite-type deposits. The median deposit size is 23 million tonnes (fig. 10.1-3). Ten percent of the deposits contain 3.1 million metric tons or less and 10 percent contain 170 million metric tons or more. Grades of karst-type bauxite deposits are similar to those of laterite-type deposits; 90 percent of deposits contain at least 39 percent alumina (fig. 10.1-4). The median is 49 percent, and 10 percent of these deposits contain 59 percent alumina or more. Known karst-type bauxite occurrences in Afghanistan are Obatu-Shela deposit, Zabul Province; Kohe-Safed, Ghowr Province; and Char-Qala and Tangi, Ghazni Province.

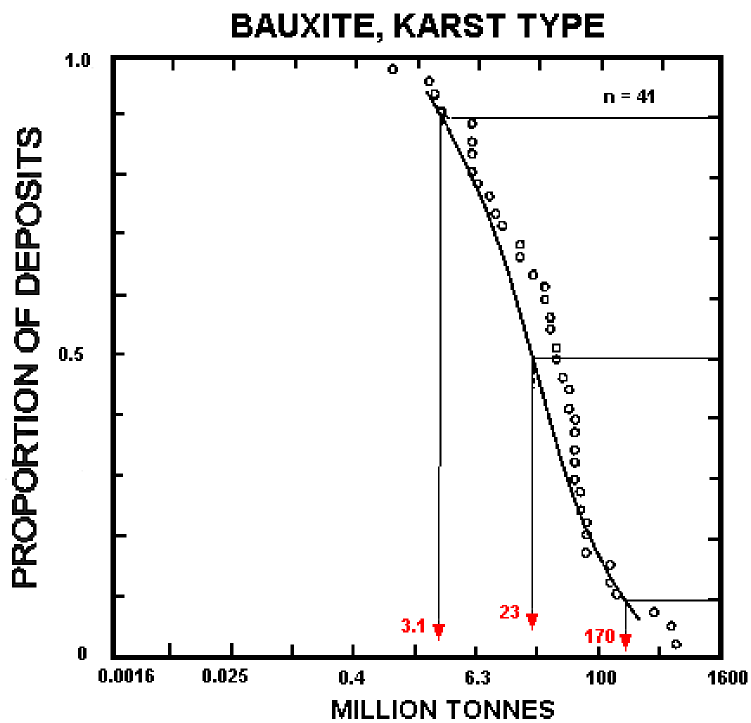

Figure 10.1-3 .Tonnages of karst-type bauxite deposits (Mosier, 1986b).

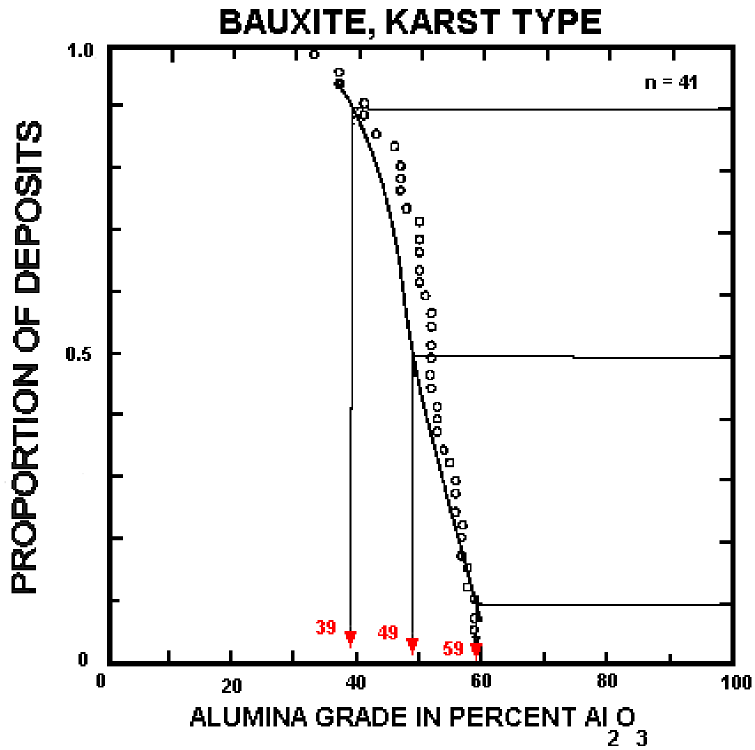

Figure 10.1-4. Alumina grades of karst-type bauxite deposits (Mosier, 1986b).

The Obatu-Shela bauxite deposit occurs as a bauxite-bearing bed in Middle to Upper Jurassic slightly weathered, white oolitic limestone overlain by Upper Jurassic to Lower Cretaceous calcareous sediments. The deposit is confined to a large graben-syncline extending over an area of more than 19 km^2 where bauxite-bearing lenses and interbeds as much as 250 long and 5 to 6 m thick occur. As of 1976, the better studied part of the deposits was on the east flank of the graben-syncline where it covers 2.28 km^2. The bauxite is green and grey; oxidized varieties are red, brown, and ashy colored with oolitic texture and chamosite-diaspore composition. Speculative reserves for the eastern part of the graben-syncline are 2.5 to 3.0 million tonnes bauxite assaying 50.0 wt. percent alumina and 11.5 wt. percent silica. Using the same criteria, speculative reserves for the entire graben-syncline are 30 to 35 million metric tons bauxite (Dovgal and others, 1971; Abdullah and others, 1977).

At Kohe-Safed, two bauxite lenses occur in Upper Permian limestone. The lenses are 15 to 20 m long and 1.5 to 2.5 m thick, assaying 40.10 to 48.68 wt. percent alumina 6.28 to 23.32 wt. percent silica, and 17.19 to 23.03 wt. percent Fe oxides (Abdullah and others, 1977). Char-Qala occurs as a Carboniferous to Lower Permian sequence of five bauxite lenses at the base of a Lower Permian limestone. The bauxite has a pisolitic texture, with red, dirty-green bauxite, occurs in lenses 10 to 30 m long and 8.0 to 25.0 m thick, and assays 40.37 to 49.95 wt. percent alumina and 2.74 to 5.88 wt. percent silica (Abdullah and others, 1977). The Tangi occurrence occurs as five bauxite lenses in karst cavities in a Permian limestone basal bed underlain by Proterozoic weathered dolomite. The lenses are 10 to 70 m long and 1.7 to 2.0 m thick. The bauxite is greenish-grey, ferruginous, massive, and pisolitic, and assays 11.57 to 46.72 wt. percent alumina and 11.28 to 66.79 wt. percent silica (Borozenets and others, 1972; Abdullah and others, 1977).

10.1.2 Description of Bauxite Assessment Areas

Two areas were selected by the USGS-AGS Assessment Team as having permissive geology for bauxite deposits. The first was in Triassic and Jurassic volcanic and sedimentary rocks in the central parts of the country permissive for laterite-type bauxite deposits (tract bxt01). The second area (tract bxt02) was identified as permissive for karst-type bauxite deposits, which may be paleo bauxite deposits along unconformities in Late Paleozoic calcareous rocks.

Tract ID: bxt01—Laterite-type bauxite areas

Deposit type—Laterite-type bauxite

Age of mineralization—Post Carboniferous?

Examples of deposit type—Eshpushta, Estoma, and Nalag

Exploration history—The three known deposits of this type have been identified and described in Abdullah and others (1977). One of those deposits, Nalag, has been assayed which indicates some exploration for bauxite deposits has taken place.

Tract boundary criteria—Triassic and Jurassic stratified rocks were identified as those most likely to contain laterite-type bauxite deposits, because the three Afghanistan examples are in Upper Triassic weathered volcanic rocks along the contact between Jurassic carbonaceous rocks and weathered Upper Triassic volcanic rocks The tract could be further defined by noting carbonaceous Jurassic rocks associated with Triassic volcanic rocks (fig. 10.1-5).

Important data sources—Geologic map, mineral deposit database (Doebrich and Wahl, 2006; Orris and Bliss, 2002; Abdullah and others, 1977).

Needs to improve assessment—Further exploration in Jurassic and Upper Triassic rocks for laterite-type bauxite deposits noting newly discovered occurrences would be helpful.

Optimistic factors—Although very large deposits are unlikely, geologic conditions are permissive for additional deposits, particularly in similar environments to that which the current deposits formed.

Pessimistic factors—Afghanistan lies in an active tectonic zone and has not experienced low latitude stable weathering.

Quantitative assessment—No estimate of the numbers of undiscovered laterite-type bauxite deposits was done, but the areas outlined above are the most likely in Afghanistan to contain such deposits.

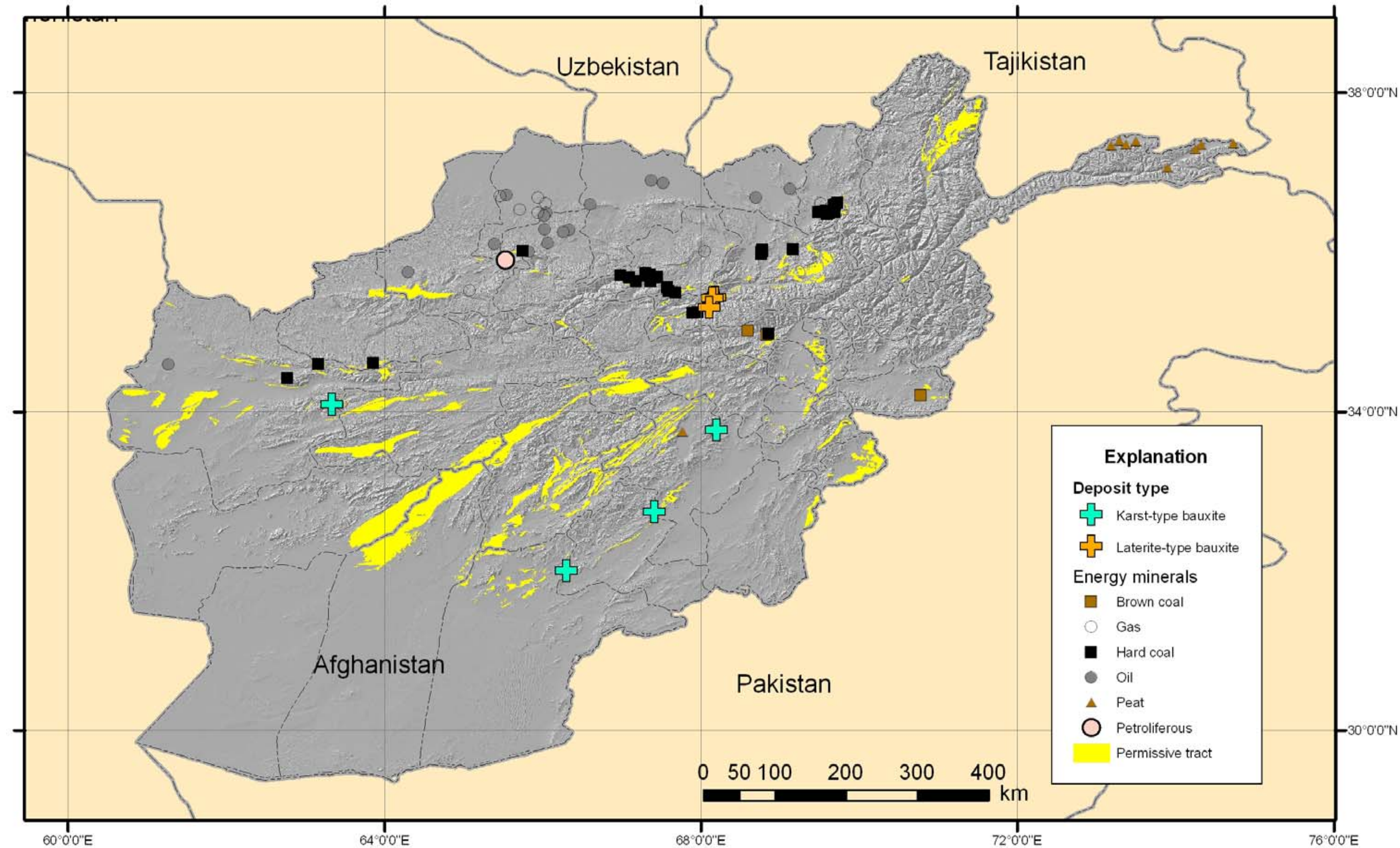

Figure 10.1-5. Tract bxt01, rocks permissive for the occurrence of laterite-type bauxite deposits in Afghanistan.

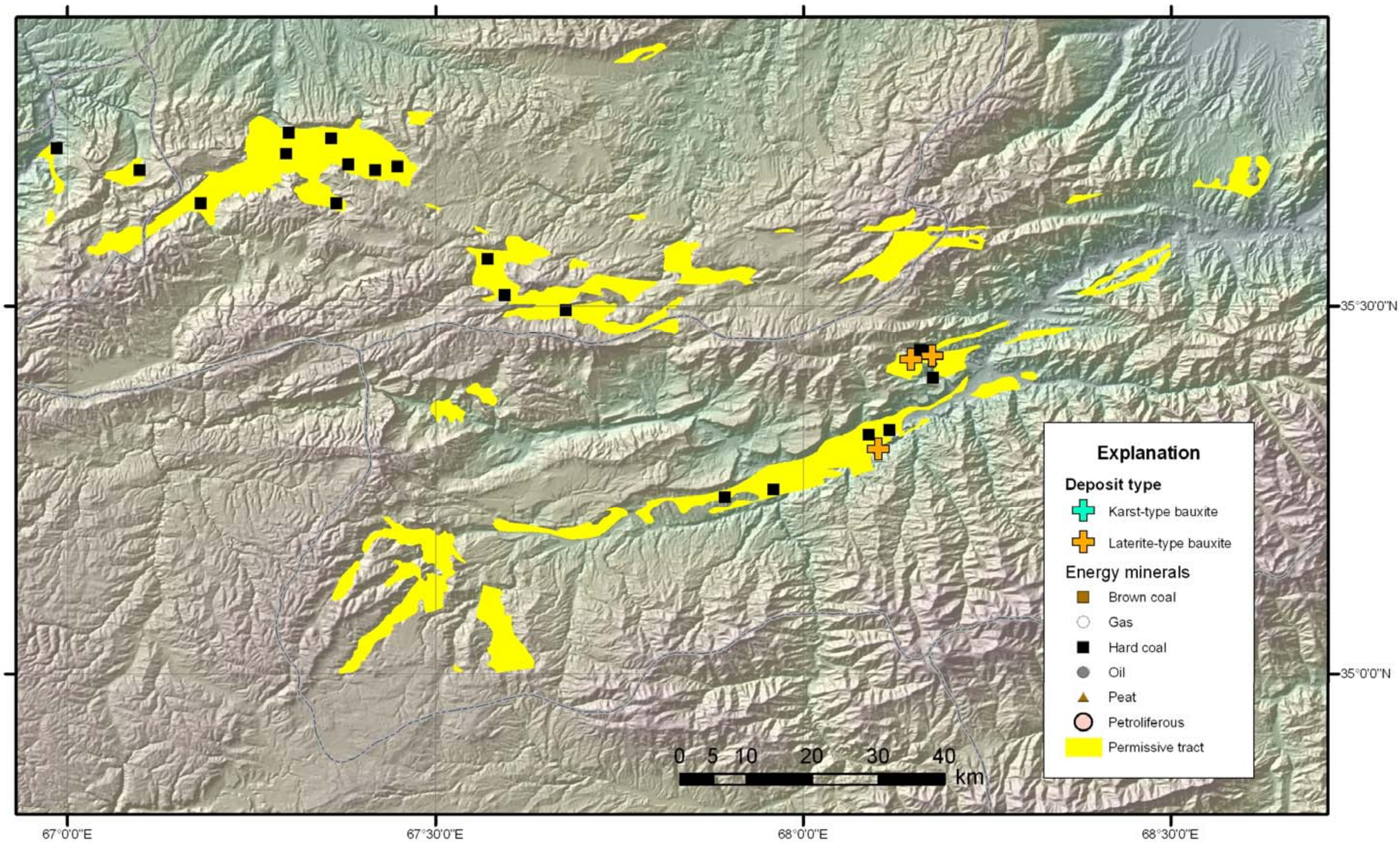

Figure 10.1-6. Parts of tract bxt01 showing areas in Baghlan and Samangan Provinces permissive for the occurrence of laterite-type bauxite deposits in Afghanistan.

Tract ID: bxt02—Karst-type bauxite areas

***Deposit type*—**Karst-type bauxite

***Age of mineralization*—**Cenozoic to Recent

***Examples of deposit type*—**Obatu-Shela, Kohe-Safed, Char-Qala, and Tanghi.

***Exploration history*—**Russian geologists examined, assayed, and estimated the reserves in the deposits in the 1970s.

***Tract boundary criteria*—**Rocks were selected on the basis of their rock descriptions containing the word "bauxite." Map units include Middle to Upper Jurassic limestone overlain by Upper Jurassic to Lower Cretaceous calcareous sediments, Upper Permian limestone, and Carboniferous to Lower Permian sequences at the base of a Lower Permian limestone. This criterion selected both limestones and red bed detrital rocks (fig., 10.1-7).

***Important data sources*—**Geologic map, mineral deposit database (Doebrich and Wahl, 2006; Orris and Bliss, 2002; Abdullah and others, 1977).

***Needs to improve assessment*—**Exploration dedicated to locating bauxite deposits would go a long way to determining the bauxite resources of the country. Discovery and exploitation of additional deposits or extensions of known resources will be aided by mapping and sampling using trenching and drilling. These activities would benefit by close attention to characteristics outlined in the descriptive mineral deposit model and other sources (Patterson, 1967; Patterson and others, 1986).

***Optimistic factors*—**The Obatu-Shela deposit has measured resources of 2.5 to 3 million metric tons of bauxite in place and the entire graben-syncline may contains as much as 35 million metric tons of bauxite. If the speculative resources in the graben-syncline are in fact real, than Obatu-Shela would be an above average size karst-type bauxite deposit and could attract international investment. Geologic conditions are permissive for additional deposits, particularly in similar geologic environments to that which the Obatu-Shela formed.

***Pessimistic factors*—**Large areas where the rocks are described as containing bauxite have no known bauxite occurrences. This may be from a lack of exploration or from a lack of mineralization. Extraction of aluminum from bauxite requires considerable amounts of electricity, something that remote regions do not have.

***Quantitative assessment*—**No estimate of the numbers of undiscovered karst-type bauxite deposits was done, but the areas outlined above are the most likely in Afghanistan to yield such deposits.

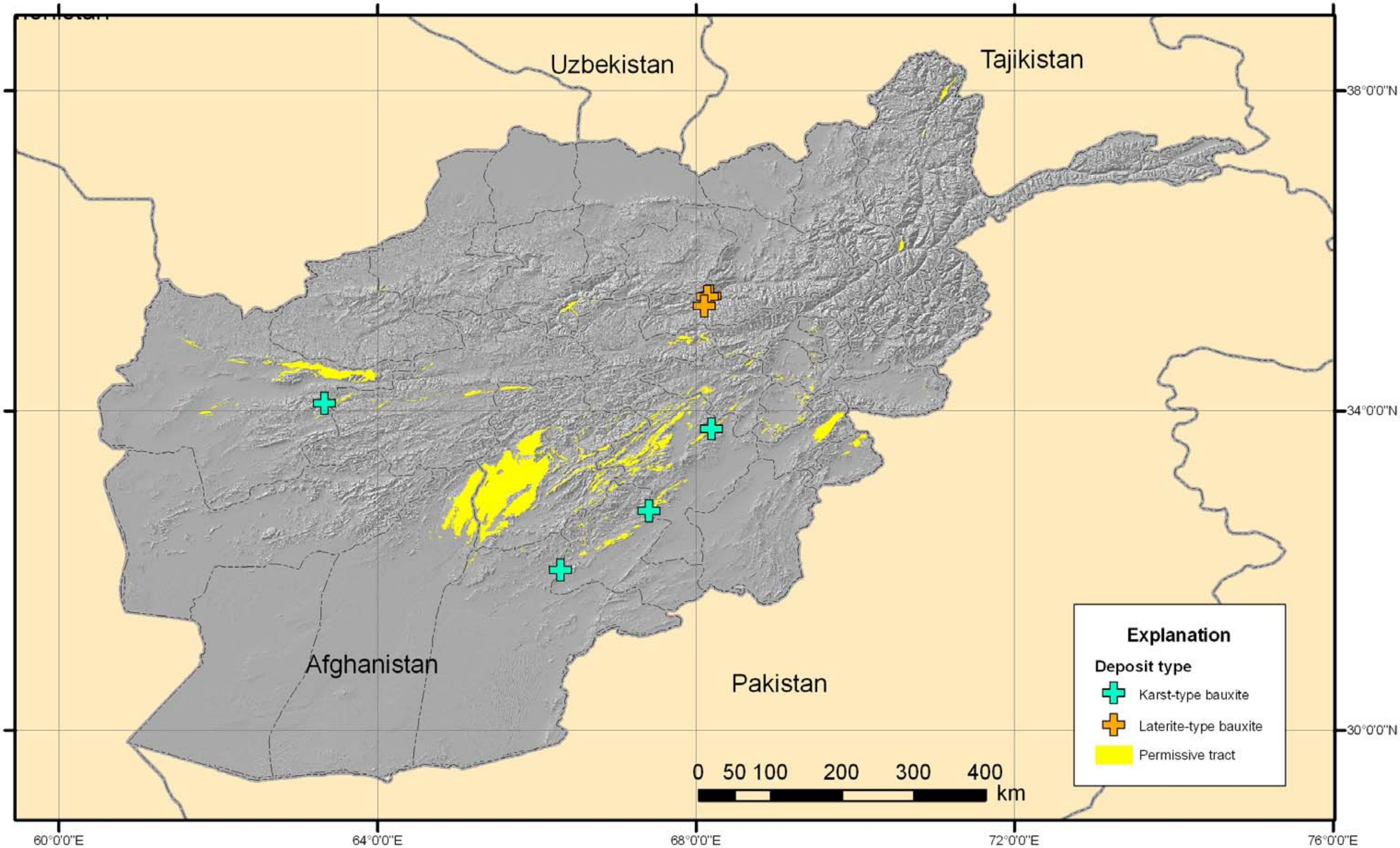

Figure 10.1-7. Known bauxite occurrences and tract bxt02, rocks permissive for the occurrence of karst-type bauxite deposits in Afghanistan.

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10.2 Placer gold deposits

Placer gold deposits are known from two main areas in Afghanistan. These and some additional areas may contain sufficient resources to provide a ready source of local industry and employment from small-scale mining. Identification and documentation of newly discovered gold placer occurrences should be conducted according the characteristics in the descriptive model.

The largest gold placer area is along the northern Takhar and Badakhshan Provinces border. It contains the Samty and Nooraba deposits in Chah Ab district where alluvial gold is present in an 8,000–m-long 900– to 1,700–m-wide valley containing unconsolidated sediments with an average depth of 27.9 m. The Samty placer comprises two sedimentary beds where the lower bed is 25 to 45 m thick and consists of pebble-, sand-, and boulder-sized material and the upper bed is 5 to 20 m thick and is composed of sandy loam. Sources of the gold are speculated to be reworking of Middle Pleistocene and Lower Pliocene coarse-grained sediments with the ultimate source possibly the Dawang Creek drainage. The other known area of placer deposits is in Moqur District in southern Ghazni Province in streams that drain the Zarkashan and Dynamite copper and gold lode deposits.

Resources estimated for placer gold deposits by Russian workers and tabulated in Abdullah and others (1977) (table 10.2-1).

Table 10.2-1. Gold placer deposits and estimated known resources of Afghanistan (Abdullah and others, 1977).

Deposit	Province	Resource Estimate
Zarkashan	Ghazni	116 kg Au
Anjir	Takhar	155 kg Au
Nooraba	Takhar	210 kg Au
Khasar	Takhar	437 kg Au

10.2.1 Description of placer gold deposit model

Placer gold deposits (model 39a, Yeend and Page, 1986) consist of elemental Au in grains and (rarely) nuggets in gravel, sand, silt, and clay, and their consolidated equivalents, in alluvial, beach, eolian, and (rarely) glacial deposits derived from ultramafic sources. The geological environment includes alluvial gravel and conglomerate and heavy minerals indicative of ultramafic rock sources and rocks in metamorphic terrane. Sand and sandstone are of secondary importance. Textures are coarse to fine clastic. Most deposits are Cenozoic in age. Older deposits may have been formed but their preservation is unlikely.

The depositional environment is marine (near shore), rivers and streams (medium to low gradient), desert (eolian) sand dunes, and in-situ weathering. The tectonic setting involves the generation of Tertiary conglomerates along major fault zones; low terrace deposits; high-level terrace gravels. Associated deposit types are primary PGE and Ni–Cu deposits, including Ni–laterite deposits, and other continental and shoreline placer deposits of Au, Ti, and diamonds.

Textures of grains and nuggets are flattened with rounded edges, flaky, flour-sized alloys and Au. Nuggets are very rarely equidimensional nuggets. Highest gold values are at the base of gravel deposits or on clay-rich beds within the gravel sequence; metal alloys concentrated in "traps" such as natural riffles in floor of river or stream, fractured, or foliated bedrock, dikes, bedding planes, and in structures trending transverse to direction of water flow. Geochemical signature consists of anomalously high concentrations of Ag, As, Cr, Cu, Fe, Hg, S, and Sb.

10.2.2 Description of placer gold tracts

Tracts permissive for the occurrence of undiscovered gold placer deposits were delineated in the north in Takhar and Badakhshan Provinces (pgold01) and in the south central part of Afghanistan in northeastern Kandahar (pgold02), Zabul and Ghanzi Provinces. Large areas of alluvial sedimentation were identified down stream from known lode gold occurrences by the USGS-AGS Assessment Team as being permissive for the occurrences of these deposits. In addition, a number of small drainages that feed into these larger sedimentation areas also were identified.

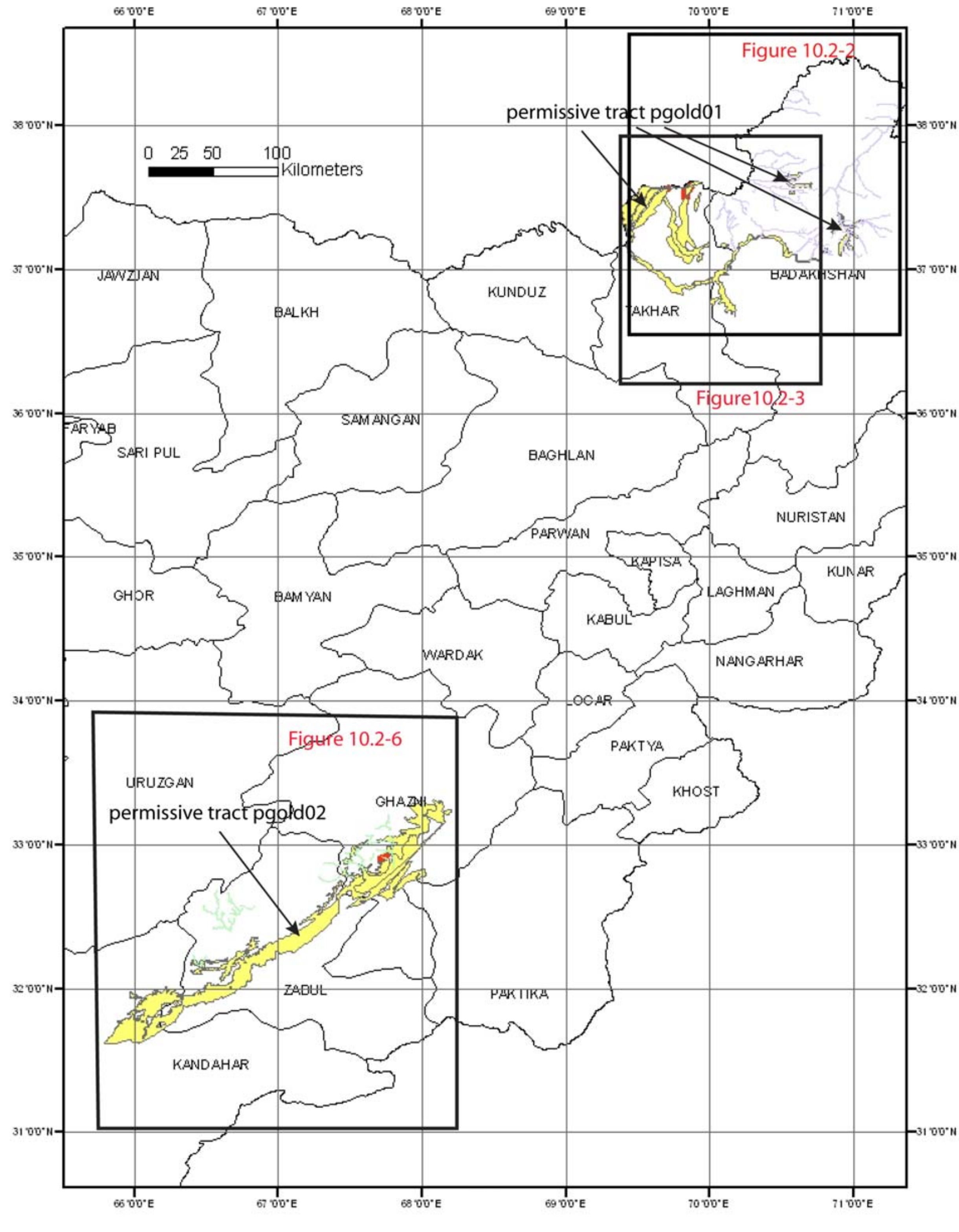

Figure 10.2-1. Locations of two tracts permissive for undiscovered placer gold deposits.

Permissive tract—pgold01 Takhar

Deposit types—Placer gold

Age of mineralization—Cenozoic

Examples of deposit type—Samty and Nooraba (Nooraba, Khasar, and Anjir Vallies) and the Jaz-Bashi gold placers deposits on the border of Takhar and Badakhshan Provinces.

Within the main known placer area there are three (3) commercially interesting areas with different placer gold concentrations (Galchenko and others, 1975a). The Nooraba placer deposit is similar to the Samty deposit and lies in box-shaped valleys with steep sides. The bottom width is 80 to 120 m in the Khasar Valley and 50 to 100 m in the Nooraba Valley, and 50 to 150 m in the Anjir Valley. The placers are composed of 7– to 14–m-thick sandy argillaceous rocks. The Khasar placer is 4,600 m long and 30 to 100 m wide. The Nooraba placer is 3,800 m long and 10 to 50 m wide, and the Anjir placer is 2,300 m long and 20 to 70 m wide. Gold distribution is irregular and ranges between 50 to 100 mg/m^3 gold and averages about 19 mg/m^3 gold. Fragmental deposits overlying the main gold-bearing sediments contain up to 200 to 300 mg/m^3. Resource calculations on the Khasar Placer are 437 kg gold, 210 kg at Nooraba, and 155 kg at Anjir placers (Popenko, 1970; Galchenko and others, 1975b). Additional placer deposits in the area are mentioned by Abdullah and others (1977).

Exploration history—Extensive exploration and mining has taken place on the Samty, Khasar Valley, Anjir Valley and Nooraba Valley placer deposits and Chah Ab District, Takhar Province.

Tract boundary criteria—A permissive placer tract with a number of separate areas was constructed in northern Afghanistan in Takhar and western Badakhshan Provinces by combining several Quaternary sedimentary units associated with the known placer deposits (map units Q_4q, Q_2a, $Q_{34}a$, and Q_1a from Doebrich and Wahl, 2006). In addition, favorable small surficial stream drainages were added to this permissive tract in active basins downstream from known lode gold occurrences and deposits (fig. 10.2-2). The main known placer deposits within the tract are the Samty, Khasar, Anjir, and Nooraba Valley deposits. The Samty placer deposit is spotty with the highest gold concentrations occurring in the middle parts. The gold-bearing formations are both on bedrock and on eluvial formations. Gold concentrations lie within a 0.25– to 4.0–m-thick sedimentary bed that has a grade range from 100 mg/m^3 to 30 to 40 mg/m^3 gold.

Important data sources—Geologic map and mineral occurrences data (Doebrich and Wahl, 2006; Abdullah and others, 1977; Orris and Bliss, 2002).

Needs to improve assessment—The area needs to be visited and sampled. Upstream and perched parts of the tract should be sampled and mapped.

Optimistic factors—Known placer deposits are present in the tract area. Significant lode gold occurrences and deposits are located up stream. Some mining and exploration activity is currently taking place there.

Pessimistic factors—The area is remote and no major reported placer activity is known upstream.

Quantitative assessment—No quantitative estimate was made by the USGS-AGS Assessment Team due to lack of information.

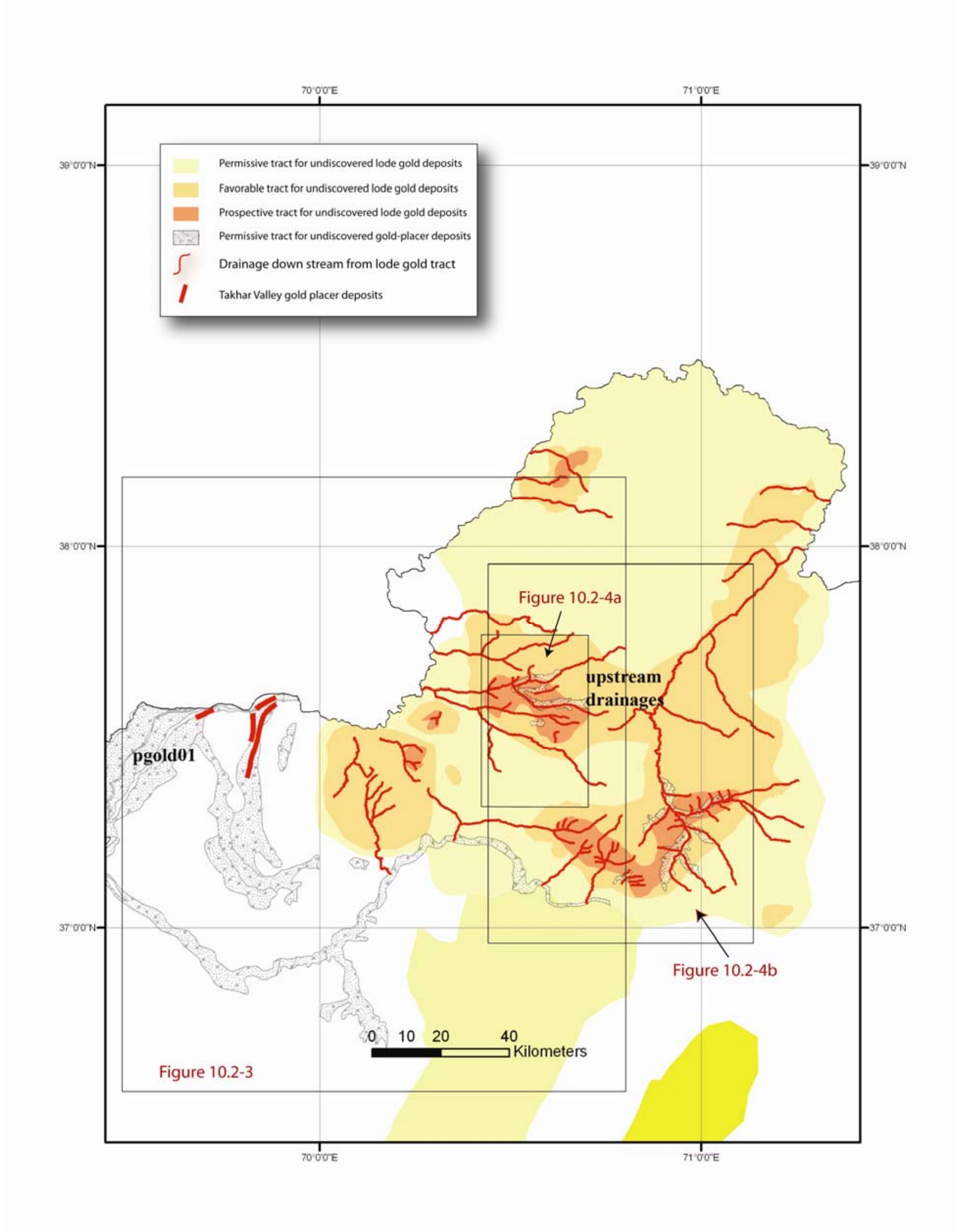

Figure 10.2-2. Map showing location of upper and lower parts of permissive tract pgold01 for undiscovered placer deposits in Takhar and Badakhshan Provinces. Both the downstream Quaternary sediments (lower part of tract) and the upstream gravels (upper part of tract) form part of the permissive tract. The colored areas represent the permissive, favorable, and prospective tracts for lode gold in Badakhshan Province.

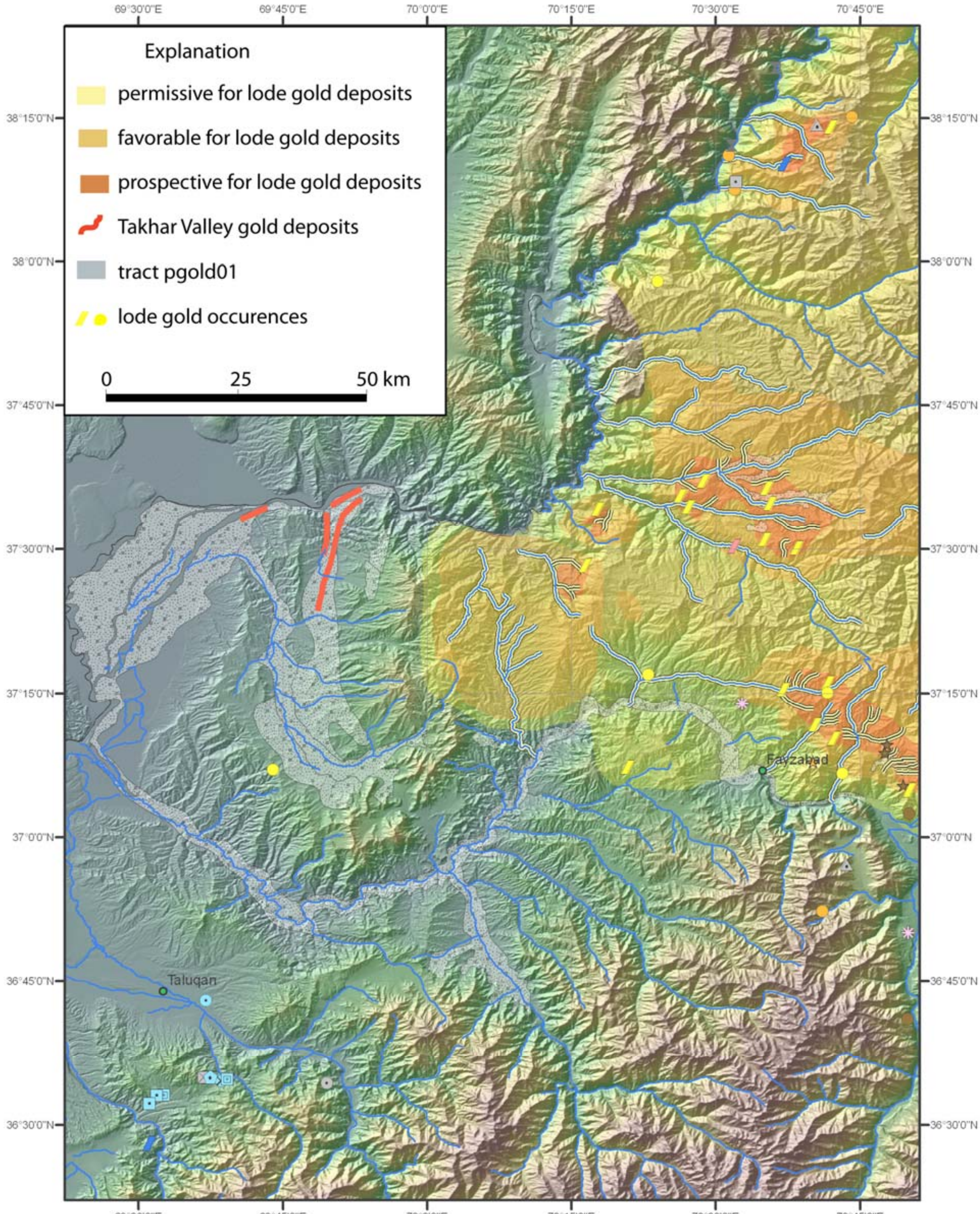

Figure 10.2-3. Map showing location of upper and lower parts of permissive tract pgold01 for undiscovered placer deposits in Takhar and Badakhshan Provinces on top of shaded relief and also showing the known lode gold deposits (section 9.1). Both the downstream Quaternary sediments and the upstream gravels form part of the permissive tract.

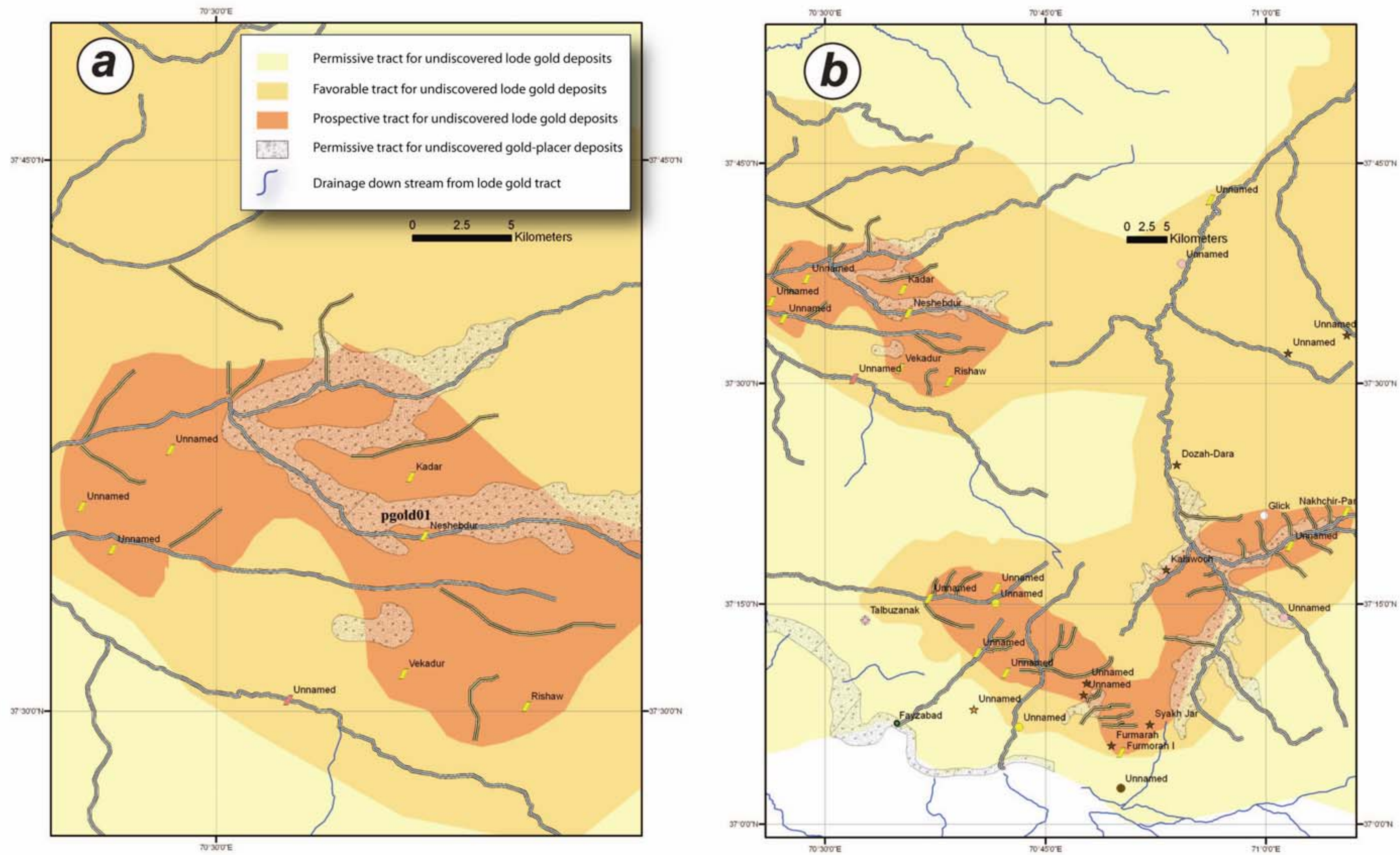

Figure 10.2-4. Maps showing location of parts of pgold01tract permissive for undiscovered placer gold deposits in the perched upper reaches of the tract in Badakhshan Province. (*a*) Map showing location of perched drainages and sediments around the Kadar and Neshebdur prospects. (*b*) Map showing two parts of pgold01tract permissive for undiscovered placer gold deposits in the perched upper reaches of the tract in Badakhshan Province. Gold vein deposits are shown as yellow bars.

Permissive tract—pgold02 Zarkashan

Deposit types—Placer gold

Age of mineralization—Cenozoic

Examples of deposit type—Zarkashan placer deposit (figure 10.2-6).

The Zarkashan placer deposit lies in the northern part of the area and is a 3,000–m-long, 200–m-wide valley that contains a 1.2– to 2.5–m-thick gold-bearing sedimentary bed near bedrock. The overburden is 1.5 to 11 m deep. Resources calculated over the main part of the placer are 116 kg gold, averaging 1,111 mg/m^3 gold. The gold bearing formation is 104,400 m^3 in size with an average 2.0 m thickness and is 1,000 m long (Meshcheryakov and Borozenets, 1970; Abdullah and others, 1977; Homilius, 1968 and 1970).

Exploration history—Hard-rock lode exploration upstream in the Zarkashan porphyry copper skarn occurrence and exploration in the non commercial gold placer deposits has led to resource calculations.

Tract boundary criteria—A tract was constructed in the 180–km-long valley and stream and fan sediments below the two favorable areas for pluton-related gold (fig. 10.2-5) in Kandahar, Zabul and Ghazni Provinces (map units $Q_{34}ac$, $Q_{31}oe$, and $Q_{3}c$ from Doebrich and Wahl, 2006). In addition, active placer areas in small streams were also designated as part of the tract (fig. 10.2-5).

Important data sources—Geologic map and mineral occurrences data (Doebrich and Wahl, 2006; Abdullah and others, 1977; Orris and Bliss, 2002).

Needs to improve assessment—The area should be visited and sampled. Upstream and perched parts of the tract should be sampled and mapped.

Optimistic factors—Known placer deposits are present in the tract. Significant lode deposits are adjacent to the tract. Geographically, Zarkashan is in a relatively accessible location, about 11 km north of Moqur and the road between Kabul and Kandahar (fig. 10.2-6). Tract pgold02 extends along much of the valley between Ghazni and Kandahar, which is a major transportation route between Kabul and Kandahar.

Pessimistic factors—The mountainous terrain is rugged, and no reported placer activity is known upstream. Availability of water may be a limiting factor for year-round placer mining.

Quantitative assessment—No quantitative estimate was conducted by the USGS-AGS Assessment Team due to the lack of information.

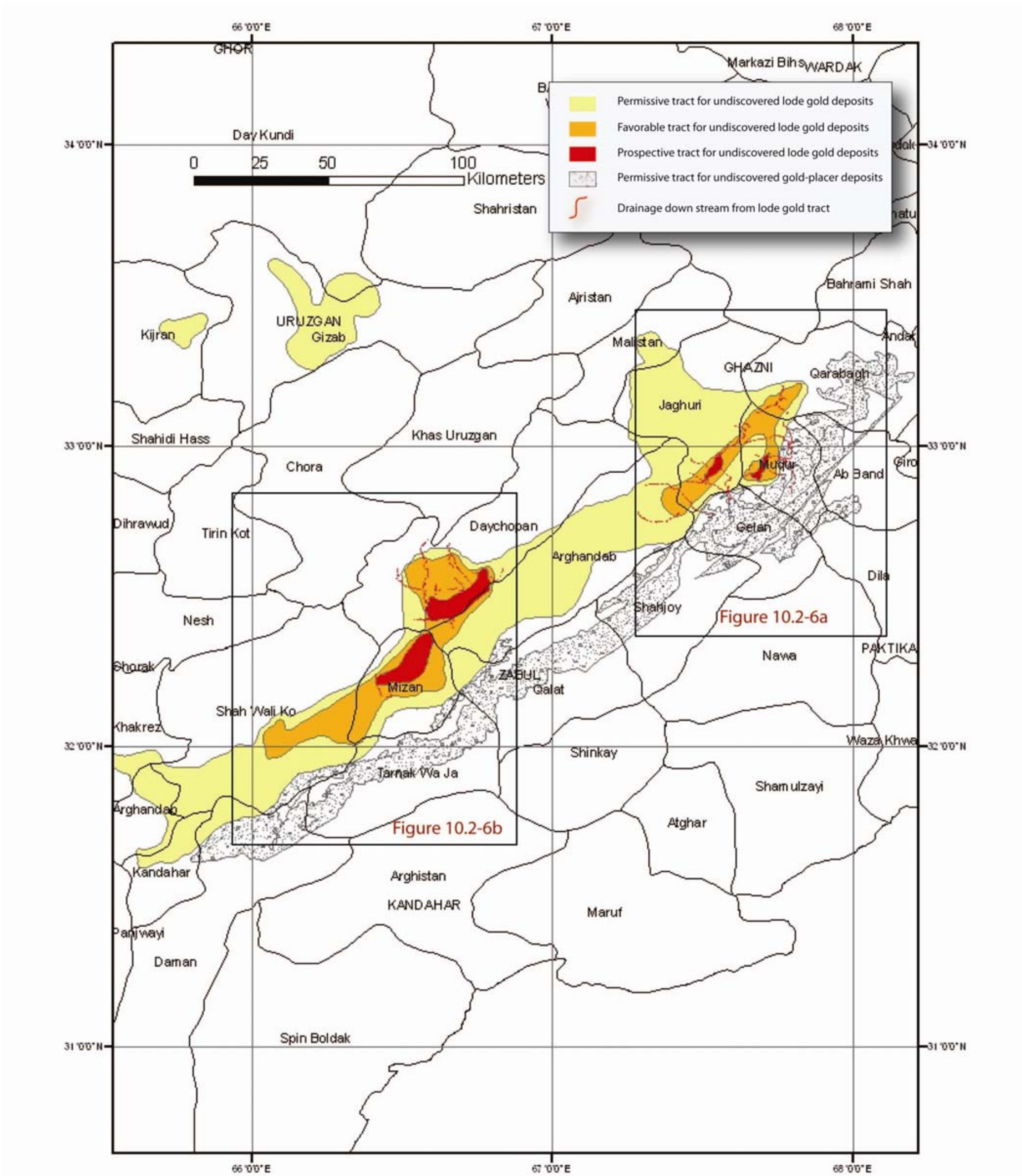

Figure 10.2-5. Map showing location of pgold02 permissive tract for undiscovered placer deposits in Kandahar, Zabul and Ghazni Provinces.

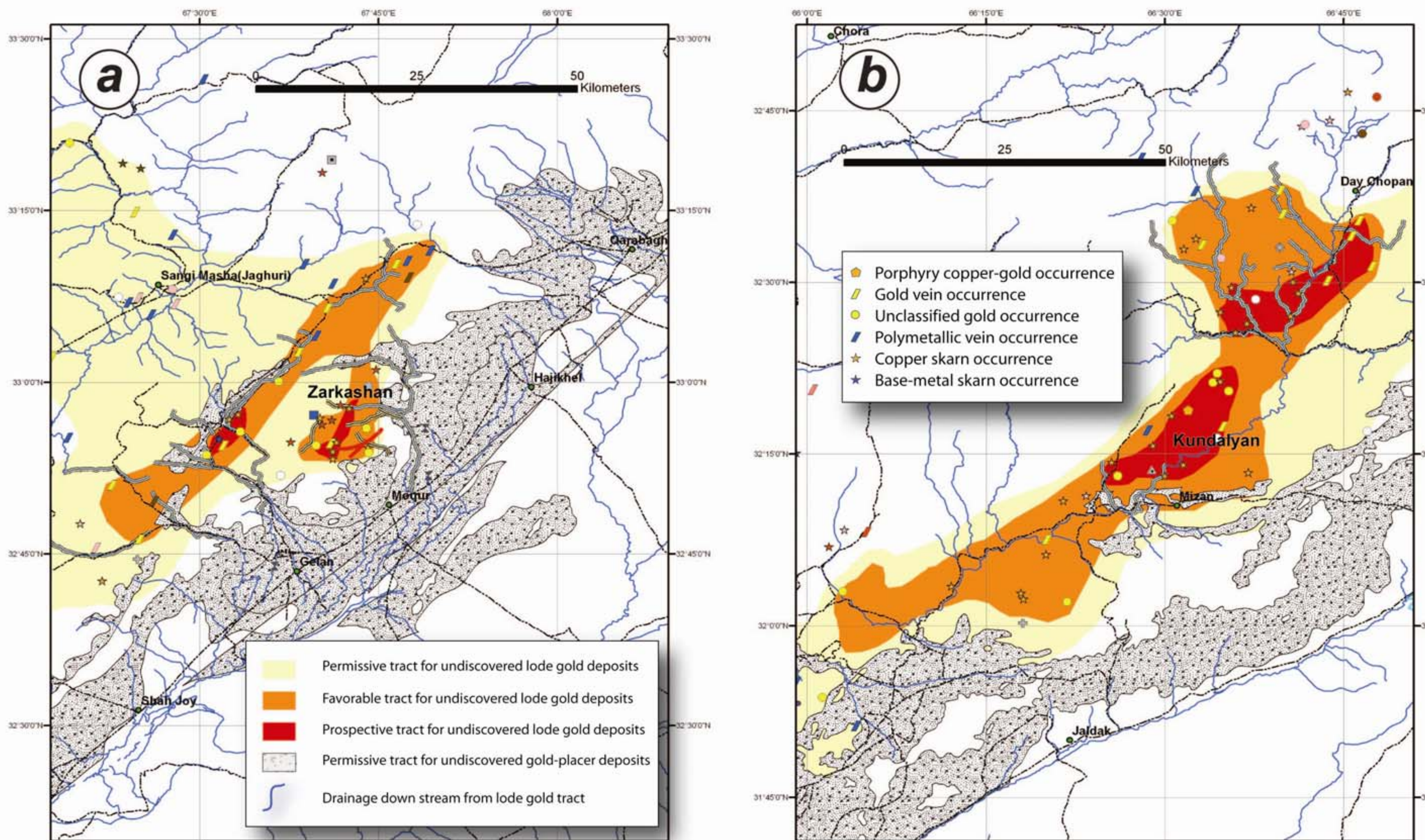

Figure 10.2-6. Maps showing location of southern parts of permissive tract pgold02. (*a*) Zarkashan area in Ghazni Province. (*b*) Kundalyan area in Kandahar and Zabul Provinces. The colored parts are the tracts for lode deposits, indicated by symbols.

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10.3 Preliminary assessment of sand and gravel resources of Afghanistan

Contribution by James D. Bliss and Karen S. Bolm

This assessment focuses on surficial fluvial sand and gravel resources along rivers and streams and on alluvial fans—the sand and gravel of the type appropriate for use as aggregate in infrastructure repair and in construction. In this assessment of surficial fluvial resources, predictions on sand and gravel resources are provided for two deposit types, (1) sand and gravel along or in fluvial stream and rivers and (2) sand and gravel in alluvial fans. The assessment uses models and Monte Carlo Simulations (MCS) to provide an estimate of how much sand and gravel may be present in a set of river basins as well as near roads and towns within each basin that may be more accessible for development.

10.3.1 Summary of Methodology

Mineral resource assessment may be considered to be a variety of regional mineral deposit exploration planning that is formalized. This mineral resource assessment of sand and gravel resources in Afghanistan is based on a modified version of a standard approach described by Singer (1993) that is conducted in three parts as given below. An expanded discussion of these parts and model requirements follow.

1. Define permissive areas or tracts boundaries according to geology, geomorphology and topography. Areas so delineated will contain areas with and without fluvial or alluvial fan sand and gravel deposits. For this particular assessment, zones around selected towns and along selected roads were also prepared. These areas are defined as “buffer zones” and are nested within permissive tracts. Buffer zones include areas within a radius of 25 km from towns or within 25 kilometers of major roads. The zones represent that part of the tract that are more accessible for development of fluvial sand and gravel deposits. The number of deposits expected to be present in the buffer zone are no different from the number of deposits in an area of comparable size elsewhere in the tract. Alluvial fan deposits are NOT assessed in the buffer zones.
2. Provide estimates of the numbers of undiscovered sand and gravel deposits with due consideration of exploration intensity and associated success and failures within the tracts. The deposits being estimated are expected to have a distribution of volumes consistent with those in the volume models referred to in part 3. In this study, two methods are used to estimate undiscovered deposits. A traditional subjective estimation methodology, as outlined by outlined by Singer (in press) is used to estimate numbers of undiscovered alluvial fan sand and gravel deposits. However, an alternative approach is used in this preliminary assessment to estimate of numbers of undiscovered fluvial sand and gravels, one of which uses a mineral deposit density (MDD) model, a type of spatial model. The latter is developed using counts of sand and gravel deposits per unit area occurring in areas that has been well-studied.
3. Provide estimates of the volume of sand and gravel that may be contained in the undiscovered deposits estimated in part 2. Models allow both interpolation and extrapolation from scant observations and data. In this application, models are given as distributions of frequency of volumes for the two sand and gravel deposit types considered. Adjustments to volumes can be made using distribution of frequency of waste material in fluvial or fan sand and gravel deposits types, and

Where fluvial sand and gravel resources are being estimated, data about tract areas identified in part 1 are multiplied by MDD values described in part 2 to produce probabilistic distributions of undiscovered sand and gravel deposits. The distributions of undiscovered deposits are combined with volume models in part 3 using MCS methods (see section 1.3). The results are probabilistic distributions of sand and gravel resources within tracts. Where resources in alluvial fan deposits are being estimated, the distribution of undiscovered deposits are subjectively estimated. Thereafter, the processing is the same.

Mineral resource assessments may include just one part of the three activities noted above. Some assessments may include just tract delineation (part 1) for specific deposit types that have grade and tonnage models (part 3); other assessments may also include estimate of undiscovered deposits by deposit types (parts 1-2). Given the requirements of all parts of the assessment are met; MCS may be run to give a probabilistic distribution of undiscovered materials, when both deposit estimates have been made and volume models are available.

The following preliminary quantitative assessment of sand and gravel resources of Afghanistan considers sand and gravel resources for 18 basins and 6 additional areas (hereafter both noted as basins) within the country (fig. 10.3-1). Minor departures from this approach have occurred and are noted as appropriate. In this study, sufficient data were developed during the assessment that a follow up MCS could also be run for most, but not all basins. This assessment should be considered as preliminary given both the lack of hard data and the very short timeframe in which it has been prepared.

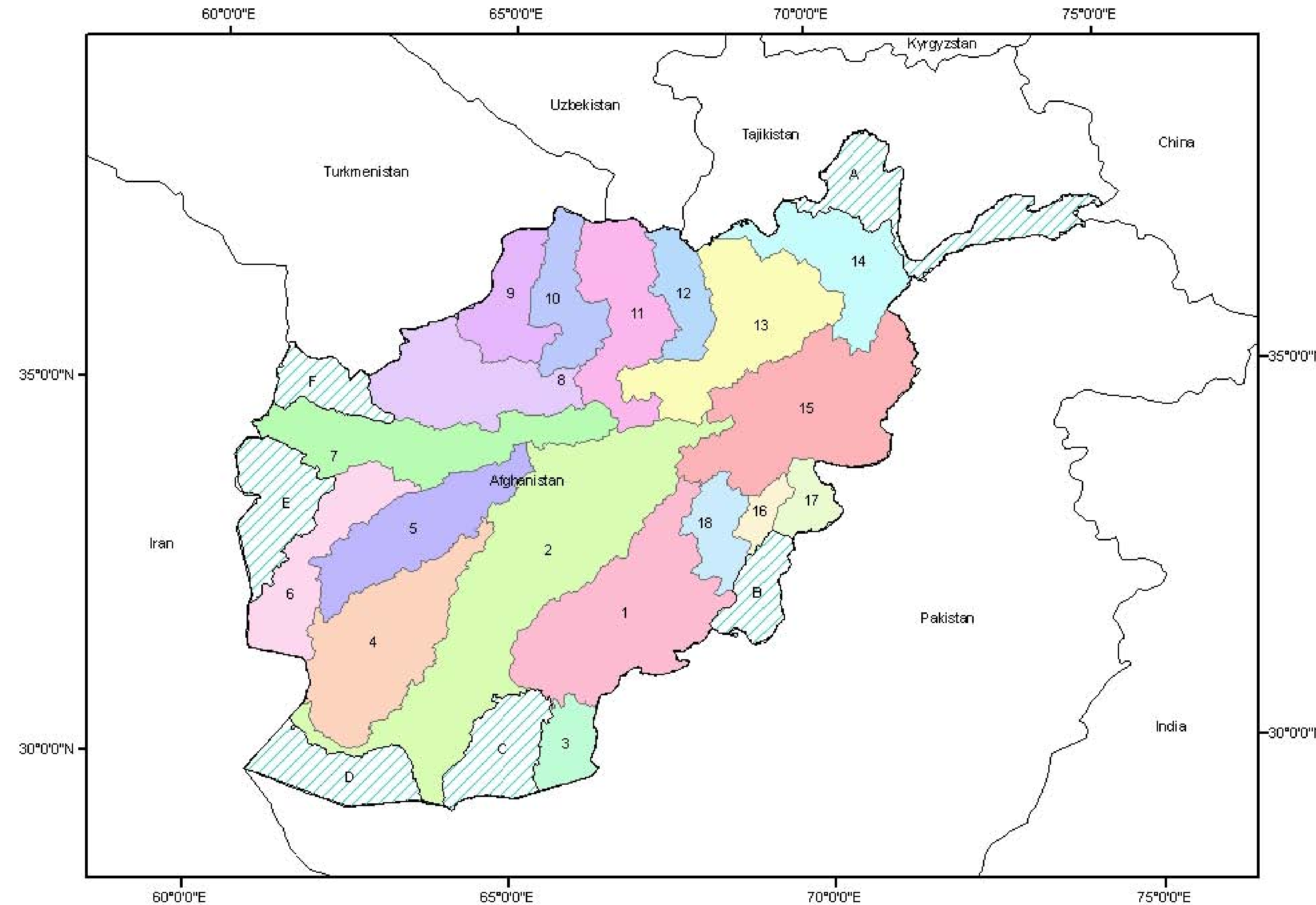

Figure 10.3-1. Basins and areas in Afghanistan used in assessment of sand and gravel resources. Identifying numbers and letters within each basin or area shown on the figure are used in the text.

Sand and gravel deposits types

Sand and gravel deposits can be grouped for assessment purposes into at least six deposits types of which two are addressed in this assessment. All deposit types that are currently recognized for purposes of assessment are as follows:

1. Fluvial sand and gravel deposits associated with rivers and streams in water sheds with or without glaciation,
2. Sand and gravel deposits in alluvial fans developed by streams as they leave mountainous areas into flatter areas,
3. Sand and gravel deposits associated with catastrophic flood discharges of all types,
4. Sand and gravel deposits associated with shorelines of inland lakes (Bliss and Bolm, 2001),
5. Sand and gravel deposits of a possible variety of types developed by marine processes either stranded above the shore, at the shoreline or below water, and
6. Sand and gravel lag deposits developed by deflation of desert surfaces by wind that are sufficient strong to remove silt and sand.

In this assessment, sand and gravel deposits for types 1 and 2 are addressed. There is a possibility that sand and gravel deposits associated with catastrophic flood discharges (type 3) are present particularly downstream from mountain valleys that were blocked either by glacial ice or large landslides. However, deposits of this type are most common when volcanic systems melt ice fields or very large continental-scale lakes rupture melting glacial dams. There is also some possibility that there may be shoreline sand and gravel deposits (type 4) associated with lakes that may have developed in the Helmand Basin area. The idea of deflation sand and gravel lag deposits (type 6) is new, and the character of this deposit type is unknown. Only a few of these deposit types listed above have models that allow quantitative assessment, and some deposit types are inappropriate for the Afghanistan assessment.

Models used for assessment

This assessment employs four models (or distributions) utilizing data that describe sand and gravel resources in studied areas throughout the world. It includes two sand and gravel deposit types and uses two different volume models for MCS (Bliss and Page, 1994). The first model is for volumes of fluvial sand and gravel deposits; the second is for volumes of sand and gravel in alluvial fans.

Waste model. A new third model used during MCS for both fluvial and alluvial fan deposit types has been developed and allows for estimates of how much waste, including bedded silt or overburden, may be present within the deposits (fig. 10.3-2). This model has been difficult to develop and it will be subject to updating for future assessments.

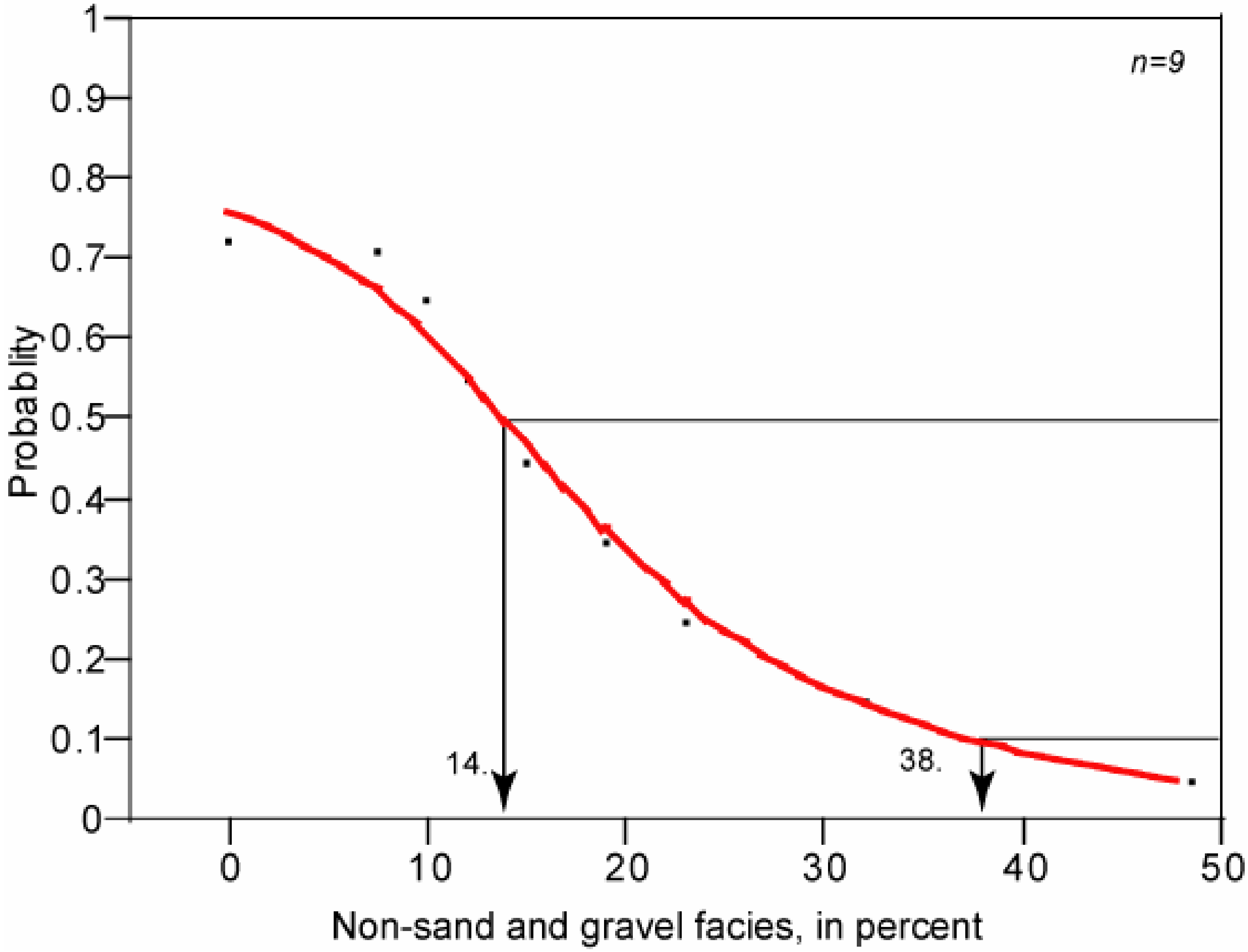

Figure 10.3.1-1. Empirical model of non-sand and gravel facies in sand and gravel deposits that can occur as interbedded silts and fine-grain overburden as well as other unsuitable materials (peat, etc)

Fluvial sand and gravel deposit spatial model. A newly developed spatial model (fig. 10.3-3) is also developed for use in the assessment. It is based on the distribution patterns of fluvial sand and gravel deposits in areas studied for sand and gravel resources. This model is applicable in estimating the number of deposits for sand and gravel deposits developed by fluvial streams and rivers. The spatial model is used to estimate how many deposits may be present given the size of the permissive area. The permissive area is those parts of the surface terrain that have slopes less than 10 degrees. Slopes with this angle or less are also used as a primary delineation criterion for tracts permissive for fluvial sand and gravel deposits. The spatial distribution model and the development of the delineation criteria using slope are based on data from nine regions with a composite area of 200,000 km^2 with diverse geology and climate.

All nine MDD values were used to convert each tract area to nine different estimated numbers of deposits. Each MDD value was set to be equally likely with a probability of 0.11. Delineated regions used for calculation of the MDD values also include areas that consist of bedrocks with low angle exposure slopes and other non-sand and gravel favorable areas including lakes, areas dominated with glacial silts, and so forth. In other words, the areas used to develop the model and the areas to which the model is applied in Afghanistan, it is hoped, have geomorphology and bedrock geology with comparable levels of variability and uncertainty.

Alluvial fan deposit models. Surface geomorphology and geology where used in a GIS to subjectively estimate the number of alluvial fans within each basin. The process of estimating the number of alluvial fans involved the integration and interpretation of data on surficial and bedrock geology, geomorphological and hydrological information. Additional guidance to estimation of number of deposits was using the presences of selected Quaternary units reported on the geologic map (Doebrich and Wahl, 2006). Alluvial fans are recognizable by there distinctive geomorphological setting as found within the permissive tracts. Fans were recognized along many mountain fronts and are expected to have an associated upstream basin within the mountain range. Permissive tracts that host alluvial fan deposits are defined using slope data. Essentially all alluvial fans have surfaces with slopes between 0.1 and 10 degrees based on data for 900 fans (Anstey, 1965 as cited by Cooke and Warren, 1973). Alluvial fans are found adjacent to much steeper mountains slopes to one side and shallower valley slopes beyond the fan toes. Fans with slopes between 0.1 degree and 1 degree are likely to have little sand and gravel. Therefore, sand and gravel deposits are expected to be found in alluvial fans in areas with slopes between 1 degree and 10 degree and have been used for tract delineations. The use of this slope interval is appropriate but permissive tracts so defined will also include considerable areas that lack appropriate geomorphology. Permissive tracts are defined using Quaternary units reported on the geologic map (Doebrich and Wahl, 2006). However, not all basins have the appropriate units shown. A review of topography and geomorphology suggest fans may be present in areas outside of the appropriate Quaternary units and have been considered during the estimate of numbers of undiscovered alluvial fan sand and gravel deposits. Note, this is a departure from the procedure described by Singer (1993) as deposits may be present outside of permissive tracts. No spatial model for this deposit type has been developed.

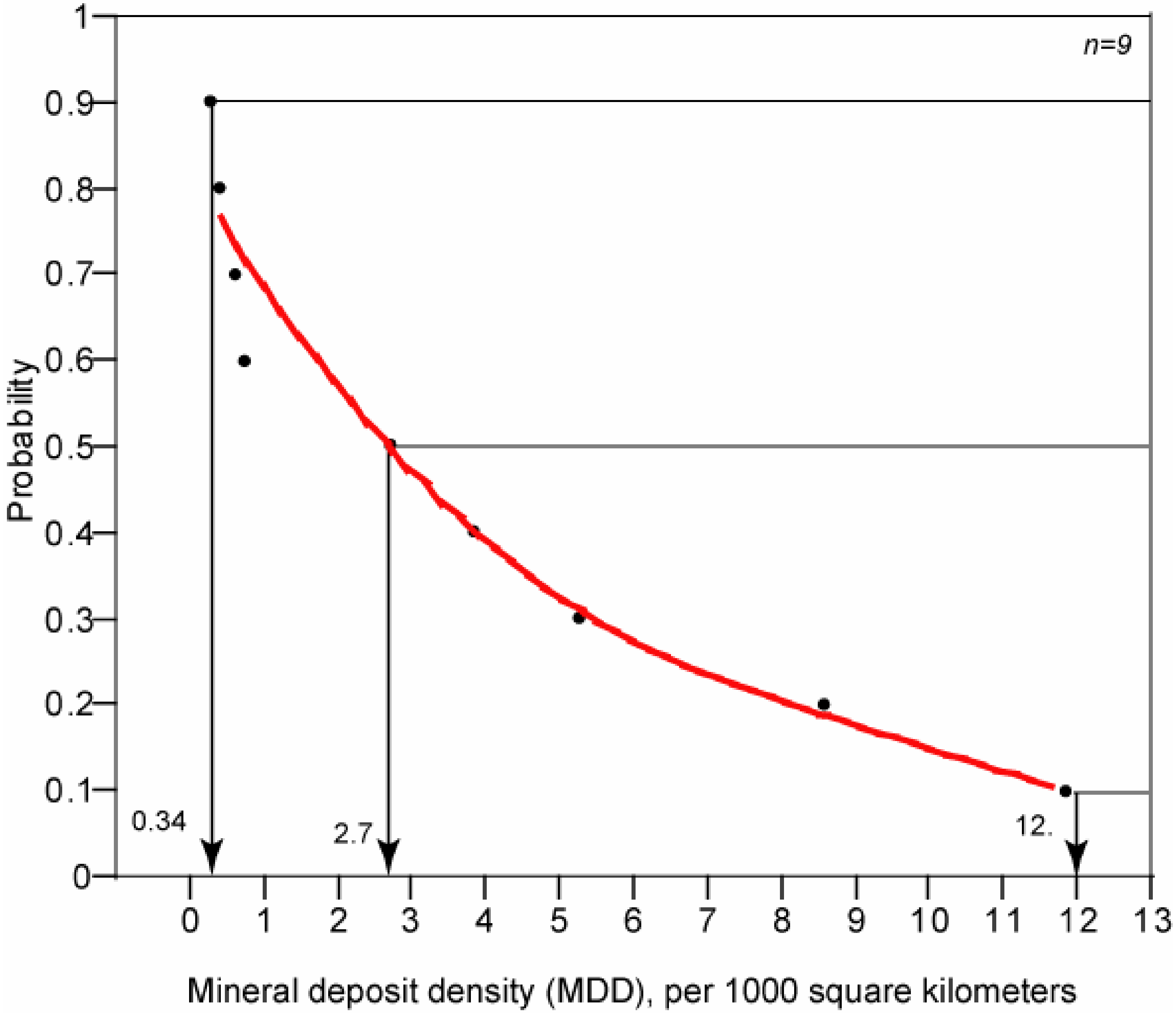

Figure 10.3.1-2. Empirical model of mineral deposit densities for fluvial sand and gravel deposits and sand deposits in areas that are expected to have been well explored

Monte Carlo Simulation (MCS)

The predicted amounts of sand and gravel resources are made by using MCS, a common procedure for combining mineral resource assessment results. The MCS program is written in SYSTAT[1], version 11, a statistical and graphical analysis package. MCS is a method that samples the quantitative models and manipulates the resulting values to permit the amount of sand and gravel to be estimated. Simulations were run to obtain three sets of assessment results—one set contained data about sand and gravel resources formed by fluvial stream and river systems, and a second set contained data about gravel resources in alluvial fans. In the third simulation, the entire MCS procedure is repeated for a second set of assessments addressing that part of the permissive tracts for fluvial type deposits within buffer zones in each basin. Buffer zones represent areas within a radius of 25 kilometers from towns or within 25 kilometers of major roads. However, alluvial fan deposits are NOT assessed in the subset tracts.

Sand and gravel resources are assessed in tracts using the topography of each basin. It is recognized that the geology of southwestern Afghanistan makes it unlikely that portions of the region contains significant sand and gravel deposits. A number of geologic units that are in areas expected to contain sand and gravel deposits are unlikely to contain resources. These units include glacial till, loess deposits, silt dominated units, and lake beds. The presence of these units is reported if given on the geologic map. The primary criteria for delineation of permissive areas include all cells with slopes equal to or less than 10 degrees, and they are shown in two parts—those slopes from 0 to 5 degrees and those slopes greater than 5 degrees up to 10 degrees. However, this is not a hard and fast rule. Some areas of southwest Afghanistan that meet the slope criteria—huge areas of nearly flat relief—are isolated from both known rivers and mountains ranges that are expected to be the source of fluvial sand and gravel deposits. These considerations as see below resulted in a considerable portion of the area of assessment of Area C that meets the slope criteria not being considered permissive outside the present of a sureficial geologic unit (Q2a). Absence of specific geologic map data resulted in nearly all of Area D being excluded from tract preparation. Slope criteria are also not used in Area E for the same reasons. However, geologic mapping suggest that 10% of the area with slopes less the 10 degrees is likely permissive. In summary, the development of permissive tracts involved the integration and interpretation of data on surficial and bedrock geology, geomorphological and hydrological information.

The results of the MCS are given for each basin. Each basin simulation generates a data set or distribution with 4,999 sand and gravel estimates. These estimates are ranked and the basin resource potential is characterized by reporting the sand and gravel totals for the 7^{th}, 50^{th}, and 25^{th} percentiles and the distribution mean. Two simulations are run. One gives the amounts of sand and gravel in fluvial sand and gravel deposits along streams and rivers and the second for sand and gravel deposits in alluvial fans. The volume of past sand and gravel production is unknown and may have reduced the sand and gravel resource by an unknown, but likely small, amount as compared to the total sand and gravel resource. Therefore, the assessment gives the volume of sand and gravel resources, both discovered and undiscovered.

Table 10.3-1 summarizes the results of the MCS for each basin and area in the assessment. Estimated resources are given for the 75 percent, 50 percent, and 25 percent levels of probability. The table shows that fluvial deposits in Area A, for example, have a 75 percent probability of containing 20 million m^3 of sand and gravel, a 50 percent probability of containing 150 million m^3 of sand and gravel, and a 25 percent probability of containing 510 million m^3 of sand and gravel. The mean estimate is Area A contains 330 million m^3 sand and gravel in fluvial deposits. The MCS finds that there is a 50 percent probability of fluvial deposits in Area A containing that mean value and a 3 percent chance of Area A containing no sand and gravel resources in fluvial deposits.

Table 10.3-1. Summary of the amount of sand and gravel (in million cubic meters) expected in both discovered and undiscovered deposits for the fluvial sand and gravel deposit type and the alluvial fan sand and gravel type for 24 river basins and other areas in Afghanistan. [Deposit type: FL—fluvial sand and gravel; AF—alluvial fan sand and gravel; BF—fluvial sand and gravel within buffer zones around towns and along roads; p(m)—probability of mean; p(0)—probability of zero or no sand and gravel resources; n/a—not available, see text for details. Amount of sand and gravel rounded to two significant figures.]

Basin or Area	Deposit type	Quantiles			Mean (m)	p(m)	p(0)
		0.75	0.50	0.25			
A	FL	20	150	510	330	0.50	0.03
A	BF	0	3.5	41	42	0.25	0.46
A	AF	n/a	n/a	n/a	n/a	n/a	n/a
B	FL	59	350	1,100	660	0.37	0.00
B	BF	0	15	76	68	0.27	0.26
B	AF	83	280	600	500	0.33	0.00
C	FL	2.2	34	140	110	0.30	0.19
C	BF	n/a	n/a	n/a	n/a	n/a	n/a
C	AF	n/a	n/a	n/a	n/a	n/a	n/a
D	FL	n/a	n/a	n/a	n/a	n/a	n/a
D	BF	n/a	n/a	n/a	n/a	n/a	n/a
D	AF	n/a	n/a	n/a	n/a	n/a	n/a
E	FL	7.0	59	220	160	0.32	0.07
E	BF	0	11	66	60	0.27	0.36
E	AF	0	0	0	49	0.13	0.83
F	FL	73	420	1,200	760	0.37	0.00
F	BF	23	180	560	370	0.35	0.03
F	AF	0	0	59	98	0.16	0.63
1	FL	470	2,300	5,400	3,500	0.38	0.00
1	BF	170	900	2,400	1,500	0.37	0.00
1	AF	220	550	920	800	0.30	0.00
2	FL	600	3,000	6,800	4,600	0.38	0.00
2	BF	230	1,200	2,300	1,500	0.40	0.00
2	AF	4.9	150	510	400	0.33	0.23
3	FL	4.2	44	180	130	0.32	0.00
3	BF	n/a	n/a	n/a	n/a	n/a	n/a
3	AF	0	4.9	110	160	0.20	0.41
4	FL	470	2,000	4,900	3,100	0.38	0.00
4	BF	77	470	1,300	830	0.37	0.00
4	AF	0.3	61	230	210	0.26	0.26
5	FL	170	870	2,300	1,400	0.37	0.00
5	BF	71	390	1,100	710	0.37	0.00
5	AF	2.8	110	460	350	0.32	0.20
6	FL	200	1,000	2,700	1,700	0.37	0.00
6	BF	51	300	940	590	0.36	0.00
6	AF	0	0	94	150	0.20	0.62
7	FL	210	1,100	2,800	1,800	0.37	0.00

Basin or Area	Deposit type	Quantiles			Mean (m)	p(m)	p(0)
		0.75	0.50	0.25			
7	BF	71	390	1,100	710	0.48	0.00
7	AF	160	500	920	760	0.31	0.02
8	FL	130	760	2,000	1,200	0.37	0.00
8	BF	7	70	250	180	0.32	0.07
8	AF	0	0	78	47	0.13	0.82
9	FL	99	540	1,500	950	0.36	0.00
9	BF	55	360	1,000	630	0.37	0.00
9	AF	0	13	180	200	0.24	0.43
10	FL	100	600	1,600	990	0.38	0.00
10	BF	81	400	1,100	710	0.38	0.00
10	AF	89	370	710	610	0.30	0.04
11	FL	600	900	2,300	1,400	0.38	0.00
11	BF	80	480	1,300	840	0.37	0.00
11	AF	77	210	550	440	0.34	0.03
12	FL	68	390	1,100	790	0.35	0.00
12	BF	30	220	680	430	0.35	0.00
12	AF	120	410	770	670	0.30	0.02
13	FL	150	790	2,000	1,300	0.36	0.00
13	BF	98	560	1,500	950	0.37	0.00
13	AF	43	130	460	360	0.33	0.05
14	FL	42	290	900	560	0.36	0.00
14	BF	32	210	640	420	0.35	0.00
14	AF	8	160	550	420	0.34	0.22
15	FL	160	850	2,200	1,400	0.37	0.00
15	BF	140	760	1,800	1,200	0.37	0.00
15	AF	420	810	1,500	1,200	0.32	0.00
16	FL	17	140	470	320	0.34	0.03
16	BF	11	110	330	240	0.33	0.00
16	AF	69	170	500	410	0.34	0.03
17	FL	11	100	350	240	0.34	0.05
17	BF	7	70	240	180	0.41	0.00
17	AF	0.3	60	180	200	0.25	0.27
18	FL	78	450	1,300	810	0.37	0.00
18	BF	42	270	850	540	0.36	0.00
18	AF	83	280	600	500	0.34	0.04

Sand and gravel assessment limitations

While sand and gravel resource estimates are provided by MCS, much of this resource will never be extracted for a number of reasons. Perhaps most important is that the areas underlain by sand and gravel deposits are the same areas in which farms and towns are located. Sand and gravel extraction can disrupt both irrigation systems and potable water sources, either directly or indirectly, when sand and gravel is removed from waterways channels. Sand and gravel has a low in place-value, and most of its cost is accrued in transportation. Therefore, deposits far removed from developed transportation corridors can be expected not to be used, while deposits near roads and towns are far more likely to be used.

Another major concern is aggregate quality. All aggregate including sand and gravel are expected to be inert and bind well with either cement or asphalt if these materials are used during construction. Aggregate that lacks certain characteristics performs poorly in roads and in other structures built following accepted civil engineering practices and quality controls. A partial list of issues that may need to be addressed include particle geometry, chemical reactivity, weathering susceptibility, presence of soft or friable fragments or other contaminates including clays, or clay films on aggregate particles, polish, solubility, toughness, alkali-silica reactivity, and material consistency. Climate and other site specific requirements can also influence where a specific sand and gravel may be used. Therefore, this sand and gravel assessment is a starting point that will require detailed evaluation of sand and gravel resources that are targeted for use to insure that they provide an aggregate that has a reasonable service life when used in roads and other structures.

10.3.2 Sand and Gravel Assessment by Basins in Afghanistan

Tracts permissive for fluvial sand and gravel deposits in Afghanistan are prepared using the slope of all cells within a basin. Each cell is square and 85 m on a side and was created using a digital elevation model (DEM) of Afghanistan. The permissive tracts are groupings of cells shown in two parts; all slopes less than 5 degrees that are shown in yellow and those greater than 5 degrees to 10 degrees are shown in red on the figures that follow. Using these two slope groupings helps to give a better idea of the nature of slopes within the permissive areas. Those areas in the basins with slopes greater than 10 degrees are shown in blue and are not considered to be permissive for fluvial sand and gravel deposits. Some permissive cells are isolated from others and would not be considered permissive under closer inspection as the areas and geomorphologic situations are unsuitable for sand and gravel deposits. These cells will inflate the total size of the areas of the permissive tracts in a basin but likely not greatly for most basins. On the other hand, some non-permissive cells are also likely isolated from others and would be considered permissive under closer inspection. However, this may be less of problem than suggested given that the isolated cell phenomenon is also present in the control areas used to develop the spatial model used to predict the number of deposits in this assessment.

The focus of this preliminary assessment is the 18 numbered basins shown on figure 10.3-1. Also considered are 6 non-basin areas along the border of Afghanistan identified by letter on figure 10.3-1. These areas have not been studied in the same detail as the basins. Differences in approach include 1) not reviewing geomorphology and geology to estimate the number of alluvial fans and 2) not preparing buffer zones around town and along roads, which are far less common in these outlying areas than in the basins.

Alluvial fans are separately studied with and without using tracts within basins. Recognition of fans consistent with the alluvial fan model also involved using data about the distribution of fan widths and lengths that was recognized in the volume model (Bliss and Page, 1994). In this assessment, fans were identified using geomorphology as seen on a DEM and geology data for each basin using a GIS.

Note that the results of MCS with 4,999 iterations are reported in billion cubic meters of sand and gravel, which is equivalent to one cubic kilometer.

Assessment of fluvial sand and gravel resources in Basin 1

Introduction**—**Basin 1 is located in southeastern Afghanistan along the Pakistan border (fig. 10.3-1). Within the basin is the Tarnak River, which runs down a valley near the center of the basin. The town of Ghazni is in the northeast, and Kandahar is in the southwest.

Deposit type**—**Fluvial sand and gravel

Age of mineralization**—**Quaternary; as a rule, better quality material is in younger fluvial sand and gravel deposits.

Example deposits types**—**There are records of sand and gravel deposits in tracts in Basin 1. Usually, no official records of work in sand and gravel deposits are kept, and this is also true in Afghanistan. Basin 1 contains the Tarnak River and its tributaries, and fluvial sand and gravel deposits can be expected to be present there.

Exploration history**—**Three sites have been reported as sources of sand and gravel in Basin 1 (fig. 10.3-2). The presence of roads and other infrastructure suggests that sand and gravel has been previously identified elsewhere in the basin and that production likely has been wide spread. A major highway (A1) runs down the middle of the basin, and some deposits are highly likely to have been worked for sand and gravel during its construction and ongoing maintenance. However, neither the intensity nor the extent of sand and gravel exploration is known. Exploitation of deposits near major roads is expected given that both the U.S. Corp of Engineers and the former Soviet Union has historically been involved in developing roads in Afghanistan. Sand and gravel is produced near the point of consumption, so locations in regions at some distance from existing roads and towns are likely untouched. Deposits within buffer zones (as defined below), which are near towns and roads are more likely to have been explored.

Tract boundary criteria in basins**—**See uniform tract boundary criteria based on topographic slope used for both basins and buffer zones as noted in the introductory discussion above. The size of the area that met these criteria within this basin is 77 percent of the basin area (fig. 10.3-2) or 41,000 km^2.

Buffer zone criteria**—**Buffer zones in tracts are defined as extending 25 km around towns and along both sides of major roads. Buffered zones (fig. 10.3-2b) with slopes, less than 10 degrees have a cumulative area of 18,000 km^2 within permissive tracts.

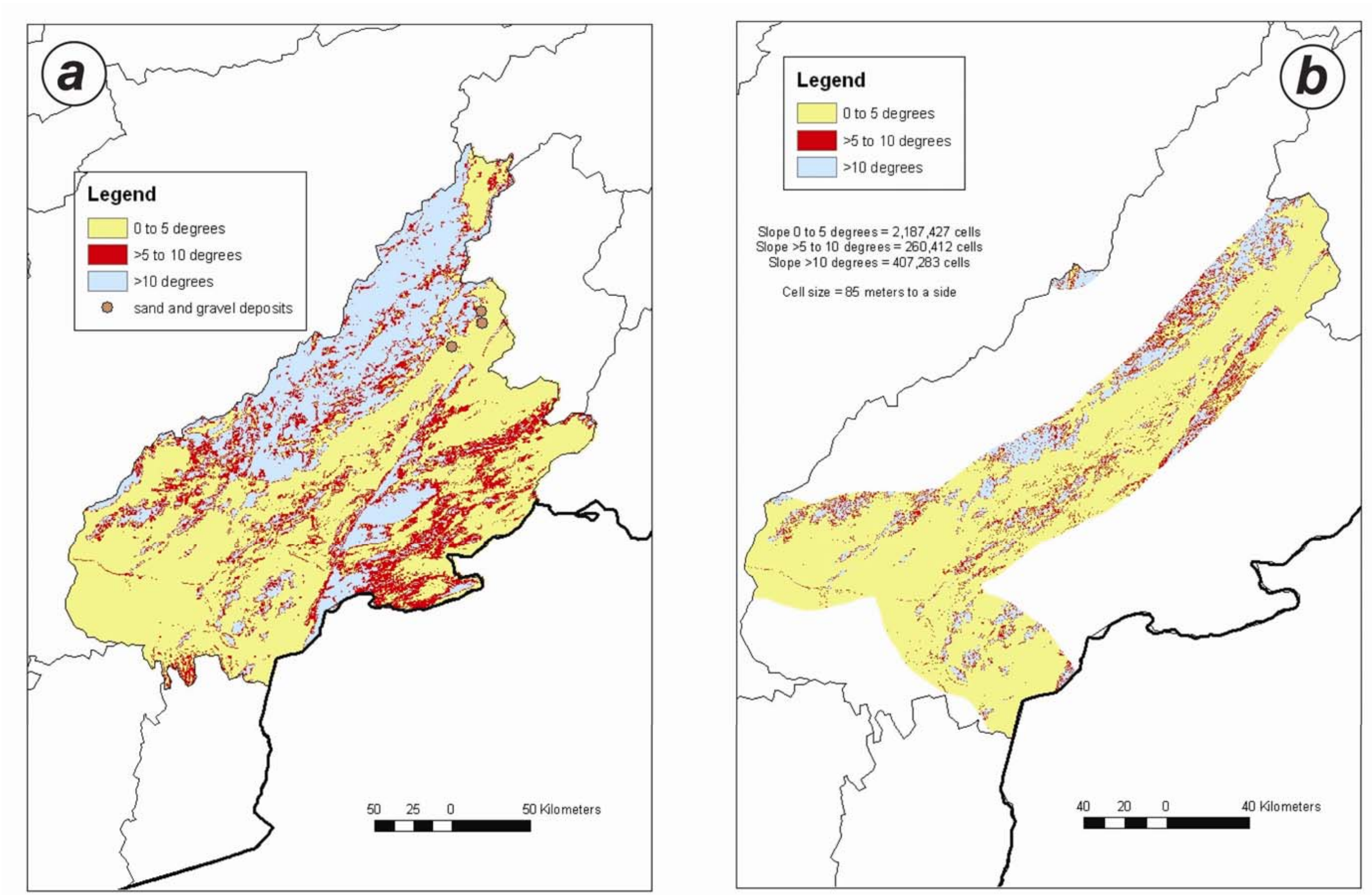

Figure 10.3-2. Outline of Basin 1 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits. Areas with slopes greater than 10 degrees (blue) .are non-permissive. (*a*) sand and gravel in the entire basin. (*b*) areas within 25 kilometer buffer zone around towns and along roads. Slopes between 0-5 degrees (yellow), and 5-10 degrees (red) are permissive for fluvial sand and gravel deposits and those greater than 10 degrees (blue) are not permissive.

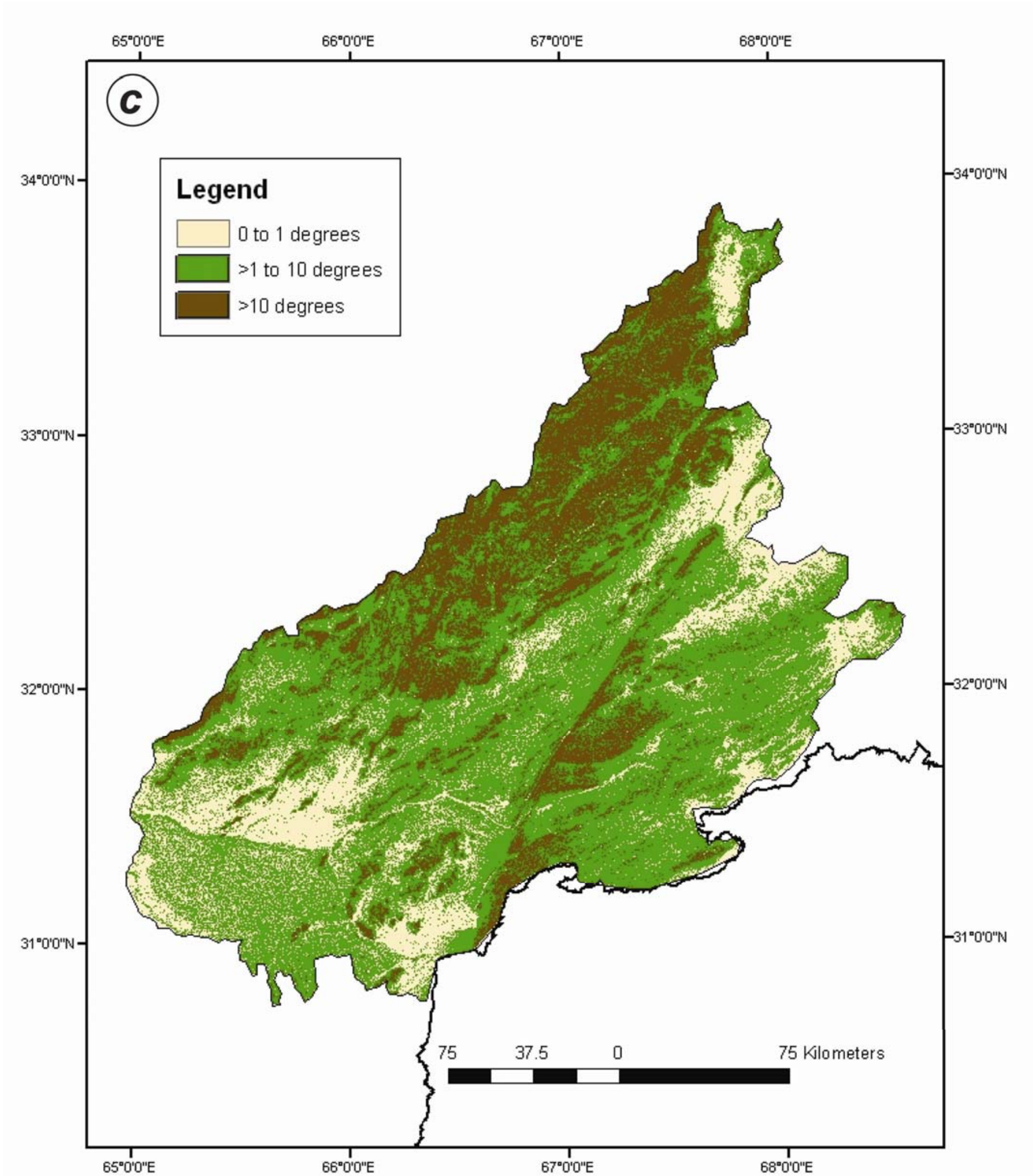

Figure 10.3-2*c*. Outline of Basin 1 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

***Needs to improve assessment*—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

***Optimistic factors*—**Of the Quaternary sediments in tracts in this basin, 16 percent are defined as an alluvium unit in which the gravel content is greater than the silt or clay content. This unit is highly likely the host of readily recognizable fluvial sand and gravel deposits. Alluvial fans and colluvium with gravel and sand volume greater than silt and clay volume along mountain fronts is in 46 percent of the tract and can also be a source of fluvial sand and gravel deposits downstream from these features. However, alluvial fan sand and gravel deposits are separately assessed (see below.)

***Pessimistic factors*—**Application of the uniform tract boundary criteria based on topographic slope to this basin resulted in 43 percent of the cells being on non-Quaternary rocks. This indicates that we may have produced a cumulative permissive tract area that is too large. The alluvium unit that is likely to contain readily identifiable sand and gravel makes up a small part of the basin. Quaternary sediments in this tract include units that are 1) highly unlikely sources of sand and gravel or 2) overburden that may obscure sand and gravel deposits at depth. These units include those dominated by loess (14 percent of the tract areas), sand (21 percent); mud, silt and clay greater than sand (2.2 percent), and playas (0.8 percent).

***Estimated number of undiscovered deposits*—**For the assessment of the slope-defined tracts in Basin 1 (fig. 10.3-2), a mineral deposit density model (MDD), as described previously, is used to provide an estimate of undiscovered deposits (table 10.3-2) All tracts, which have a total cumulative area of 41,000 km^2 within the basin, are evaluated simultaneously. Because information about discovered deposits is limited, the estimated number of deposits and their associated probability given in the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-2. Estimated number of fluvial sand and gravel deposits in Basin 1, both discovered and undiscovered, calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	14
80 % chance of at least	18
70 % chance of at least	27
60 % chance of at least	33
50 % chance of at least	113
40 % chance of at least	161
30 % chance of at least	219
20 % chance of at least	356
10 % chance of at least	492

***Monte Carlo Simulation (MCS) results*—**There are three chances in four that the sand and gravel resources in Basin 1 in fluvial sand and gravel deposits will be equal to or greater than 470 million m^3 and there is an even chance that there will be equal to or greater than 2,300 million m^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 5,400 million m^3 (fig. 10.3-2 and table 10.3-1).

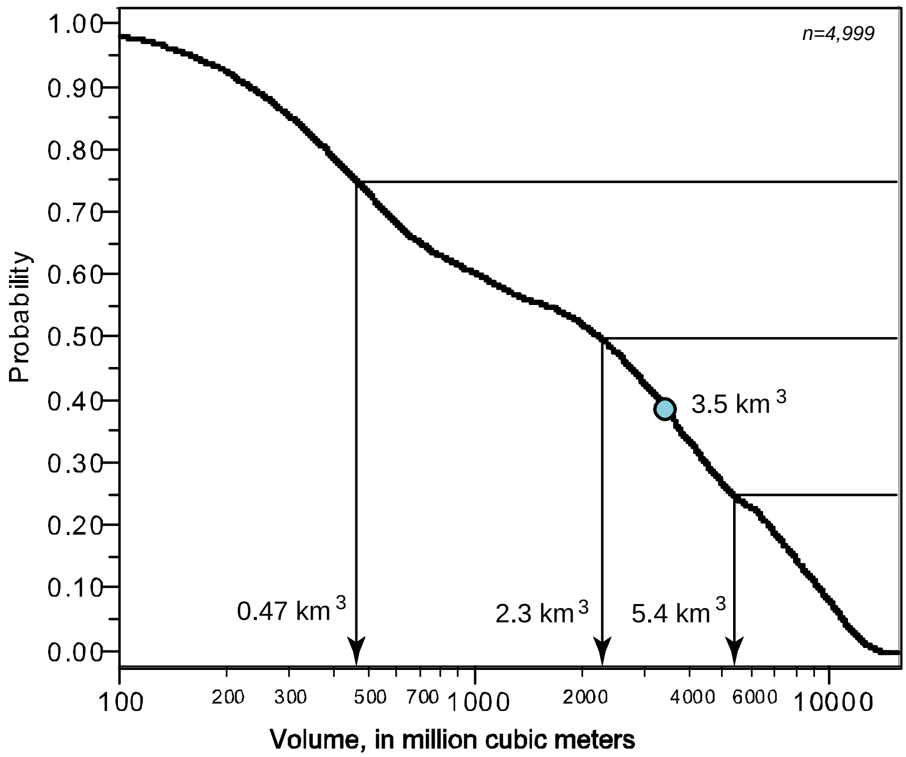

Figure 10.3-3. Distribution of sand and gravel resources in fluvial sand and gravel deposits in tracts in Basin 1. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

***Estimated number of undiscovered deposits in buffer zones*—**For the assessment of the slope-defined tracts in Basin 1 buffer zones (fig. 10.3-2b), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-3) from the permissive area of 18,000 km^2. All parts of the buffer zone in the basin are evaluated simultaneously. Because information about the three known sand and gravel occurrences is not available, the estimated number of deposits and their associated probability given by the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-3. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zone tracts calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	6
80 % chance of at least	8
70 % chance of at least	12
60 % chance of at least	14
50 % chance of at least	48
40 % chance of at least	69
30 % chance of at least	94
20 % chance of at least	152
10 % chance of at least	211

***Monte Carlo Simulation (MCS) result for buffer zone tracts*—**There are three chances in four that the sand and gravel resources in Basin 1 in fluvial sand and gravel deposits will be equal to or greater than

170 million m^3 (fig. 10.3-4). There is also an even chance that there will be sand and gravel resources equal to, or greater than, 900 million m^3 and one chance in four that the amount will equal or be greater than 2,400 million m^3. Proximity to towns and major roads suggests a portion of the estimated sand and gravel resources may have already been consumed.

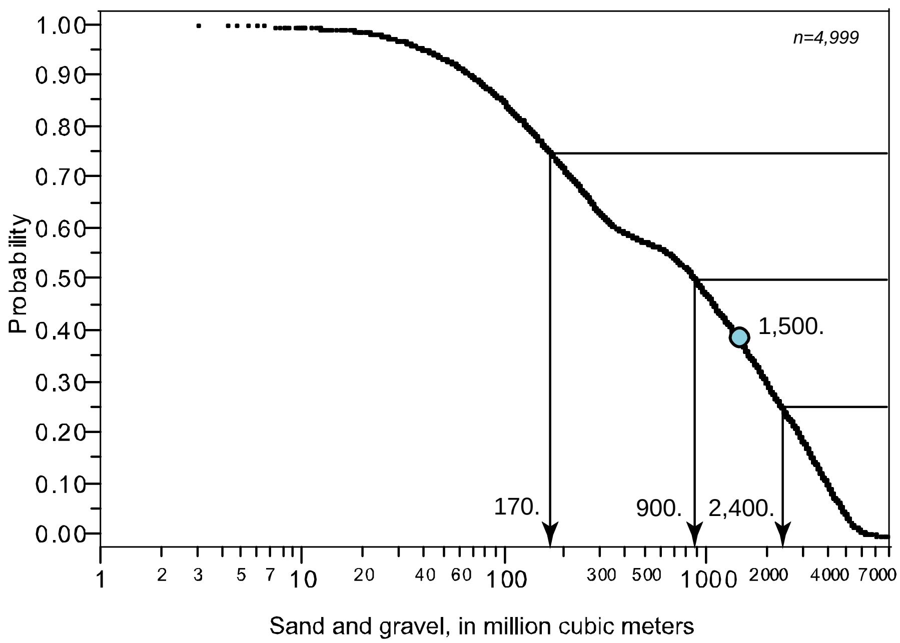

Figure 10.3-4. Distribution of sand and gravel resources in fluvial sand and gravel deposits in buffer zones in Basin 1 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of alluvial fan sand and gravel resources in Basin 1

***Deposit type*—**Alluvial fan sand and gravel

Age of mineralization—Quaternary, better quality material is in younger alluvial fan sand and gravel deposits.

***Example deposits types*—**There are no reported examples of alluvial fan sand and gravel deposits in tracts in this basin. However, 11,000 km^3 of the basin is mapped as fan alluvium and colluvium with gravel, sand, and clay. Most alluvial fan sand and gravel deposits are worked without record in many part of the world, and this is also true in Afghanistan.

***Exploration history*—**The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified and produced in the tracts in this basin. Alluvial fan sand and gravel deposits are usually not near towns unless a roadway passes up the fan slope into the stream basin in the adjacent mountains. Neither the intensity nor the extent of sand and gravel exploration is known. However, exploitation of deposits near major roads is expected given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. However, alluvial sand and gravel deposits are likely positioned away from most roads and other points of consumption, so those deposits are likely untouched. Deposits of this type are likely rare within buffer zones (as defined below) which are located near towns and roads and are not considered in this assessment.

Tract boundary criteria**—**Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-2*c*).

Needs to improve assessment**—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, the former USSR engineers, and construction contractors who have built roads in Afghanistan would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors**—**Alluvial fan and colluvium with gravel and sand volume greater than that for silt and clay include an area of 11,000 km^2 on the geologic map (Doebrich and Wahl, 2006). It comprises 46 percent of the Quaternary units described in Basin 1. Alluvial fans are also clearly recognized on topographic sheets (scale 1:200,000).

Pessimistic factors**—**Alluvial fans are often problematic as they are commonly poorly sorted with large amounts of unsuitable clay and silt interbedded or directly mixed with the sand and gravel. While a large number of fans may be present, only a few are likely to contain sand and gravel deposits suitable for development.

Estimated number of undiscovered deposits**—**The number of alluvial fans was subjectively estimated. Because information about discovered deposits is not available, the estimated number of deposits and their associated probability for MCS are for both discovered and undiscovered deposits and are given together with an associated probability (table 10.3-4).

Table 10.3-4. Estimated number of sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 1.

Probability level	Number of deposits
90 % chance of at least	2
70 % chance of at least	2
50 % chance of at least	3
30 % chance of at least	4
10 % chance of at least	5

Monte Carlo Simulation results for alluvial fan deposits**-—**There are three chances in four that the sand and gravel resources in Basin 1 in alluvial fan sand and gravel deposits will be equal to or greater than 220 million m^3. There is also an even chance that there will be equal to or greater than 550 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 920 million m^3 (fig. 10.3-5 and table 10.3-1).

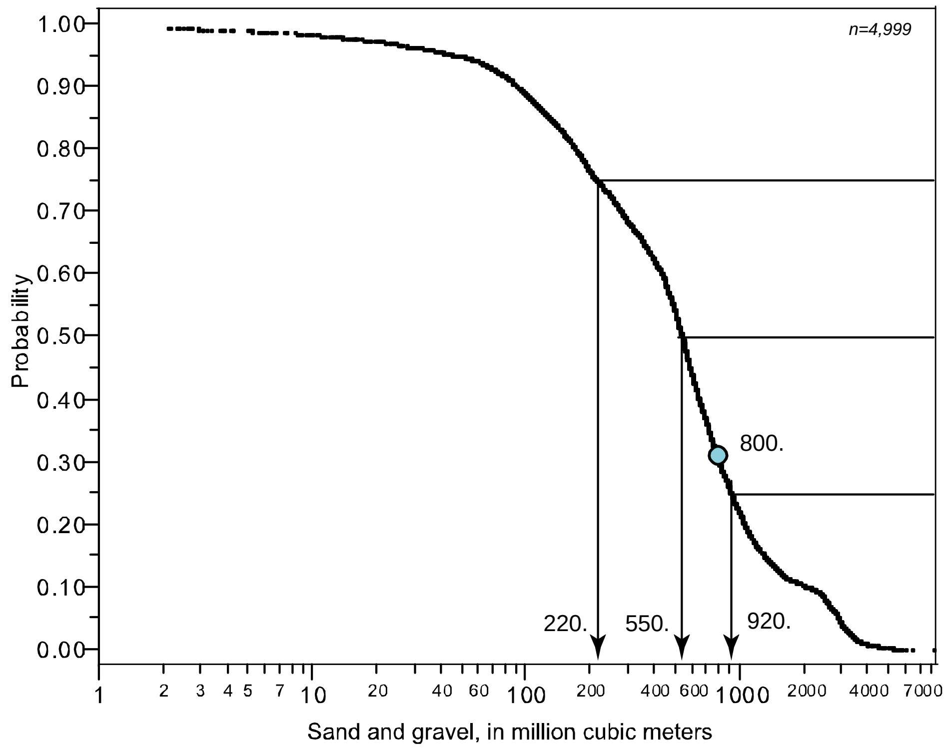

Figure 10.3-5. Distribution of sand and gravel resources in deposits in alluvial fans in Basin 1. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of fluvial sand and gravel resources in Basin 2

Introduction—Basin 2 (fig. 10.3-6) is located in south central Afghanistan (fig. 10.3-1). It includes the Hilmand (Helmand, Helmund) River. The basin extends to both the borders of Iran and Pakistan. The basin includes two distinct areas, 1) over half of the northeast part that is dominated by a series of mountain ranges of the Central Highlands, and 2) the southeast part that includes a considerable part of the relatively flat large basin located on the arid Helmand Basin. The Helmund River crosses the plateau and terminates in the basin in a series of playa lakes on both sides of the Iran-Afghanistan border.

Deposit type**—**Fluvial sand and gravel

Age of mineralization**—**Quaternary; as a rule, better quality material is in younger fluvial sand and gravel deposits.

Example deposits types**—**There are no reported examples of sand and gravel deposits in tracts in Basin 2. No official records of work in sand and gravel deposits are kept in many parts of the world, and this is also true in Afghanistan. Basin 2 contains one of Afghanistan's major internal river systems, the Helmund River and its tributaries, and fluvial sand and gravel deposits can be expected to be present along those waterways.

Exploration history—The presence of roads and other infrastructure suggests that sand and gravel has been previously identified and produced in the tracts in this basin. Neither the intensity nor the extent of sand and gravel exploration is known. However, exploitation of deposits near major roads is likely given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. Sand and gravel is produced near the point of consumption, so locations in regions at some distance from existing roads and towns are likely untouched. Deposits within buffer zones (as defined below), which are near towns and roads are more likely to have been explored.

Tract boundary criteria in basins—See uniform tract boundary criteria based on topographic slope used for both basins and buffer zones as noted in the introductory discussion above. The size of the area that met these slope criteria within this basin is 58 percent of the basin area (fig. 10.3-6a) or 54,000 km^2.

Buffer zone criteria—Buffer zones in tracts are defined as extending 25 km around towns and along both sides of major roads. Buffered areas (fig. 10.3-6b) with slopes less than 10 degrees have a cumulative area of 16,000 km^2 within permissive tract

Needs to improve assessment—Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors—Of the Quaternary sediments in tracts in this basin, 67 percent are defined as alluvium in which the gravel content is greater than silt or clay content. This unit is highly likely to be the host of readily recognizable fluvial sand and gravel deposits. Whitney (2006) reports that the Neogene coarse gravel in the Helmand Basin can have a thickness from less than a meter to exceeding 15 m. Neogene gravels appear to be widespread in many parts of the basin (Whitney, 2006, fig. 6).

Alluvial fans and colluvium with gravel and sand content greater than silt and clay content along mountain fronts is found in 14 percent of the tract areas and can also be a source of fluvial sand and gravel deposits downstream from these features. However, alluvial fan sand and gravel deposits are separately assessed (see below).

Pessimistic factors—Application of the uniform tract boundary criteria based on topographic slope to this basin resulted in 38 percent of the cells being on non-Quaternary rocks. This indicates that we may have produced a cumulative permissive tract area that is too large. Quaternary sediments in this tract include units that are 1) highly unlikely sources of sand and gravel or 2) overburden that may obscure sand and gravel deposits at depth. These units include those dominated by loess (3 percent of the tract areas), sand (16 percent); mud, silt and clay greater than sand (0.3 percent), and playas (0.11 percent).

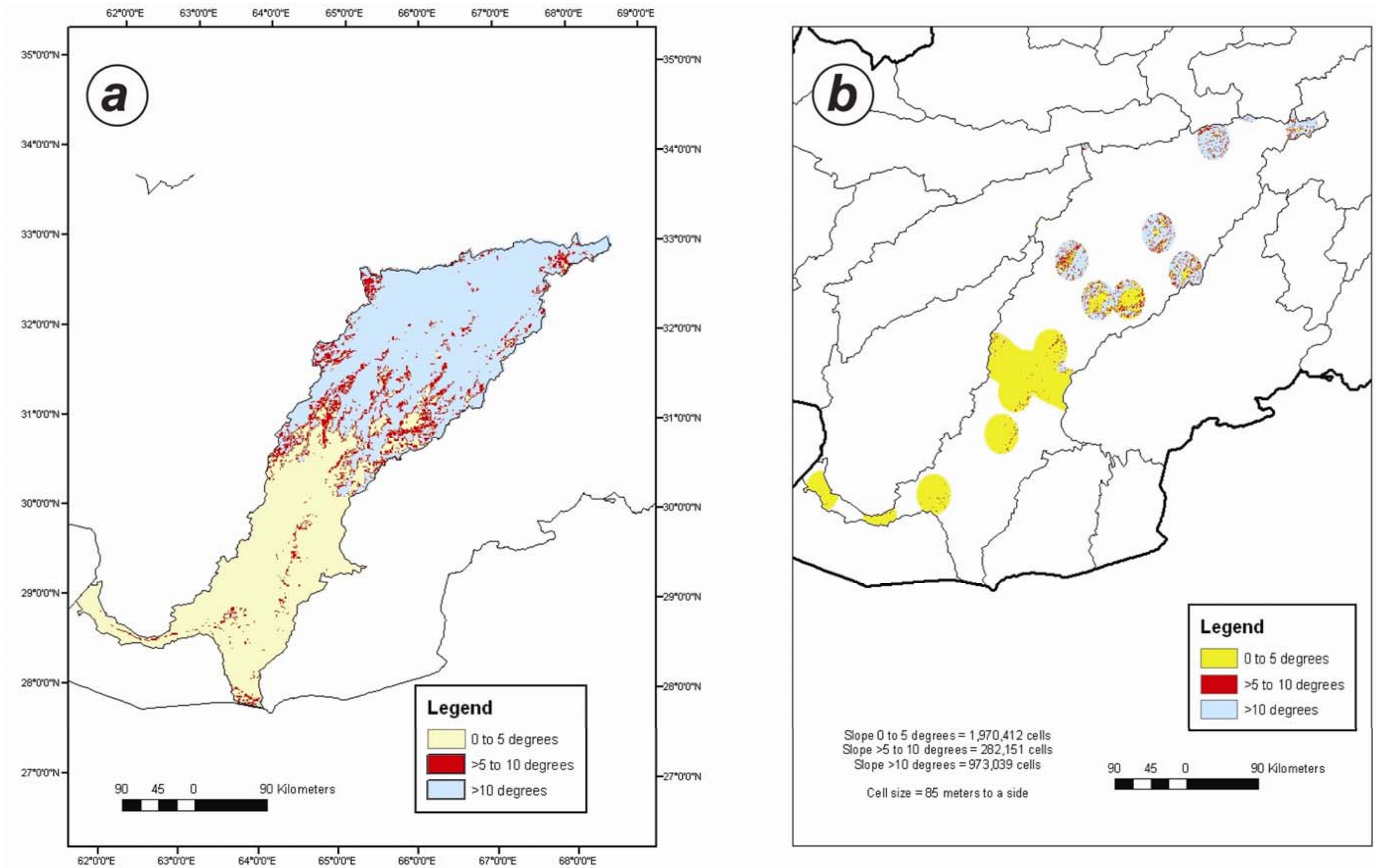

Figure 10.3-6. Outline of Basin 2 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits. Areas with slopes greater than 10 degrees (blue) are non-permissive..(*a*) total basin. (*b*) areas within 25 kilometer buffer zone around towns and along roads. Slopes between 0-5 degrees (yellow), and 5-10 degrees (red) are permissive for fluvial sand and gravel deposits and those greater than 10 degrees (blue) are not permissive.

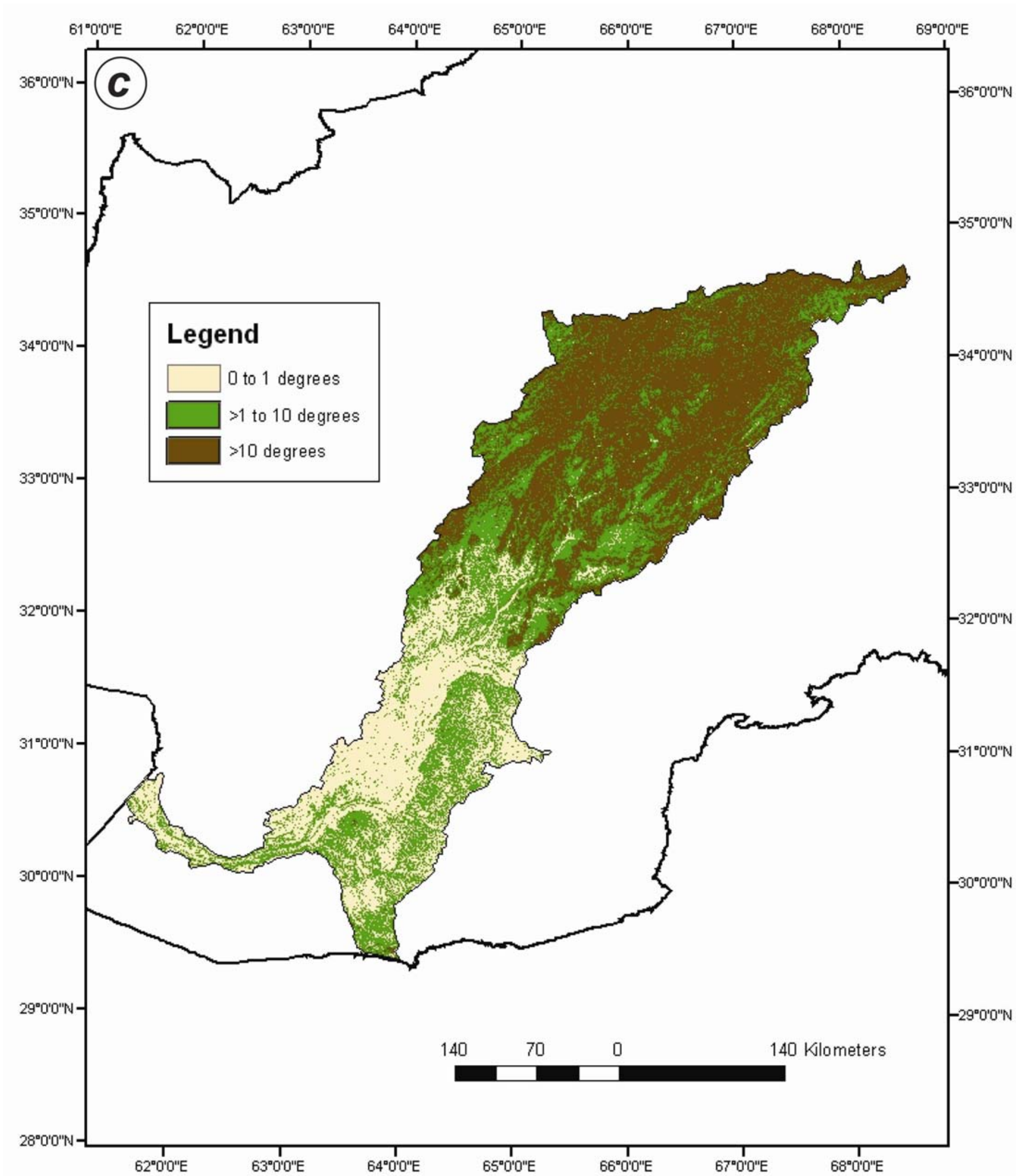

Figure 10.9-6*c*. Outline of Basin 2 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

***Estimated number of undiscovered deposits*—**For the assessment of the slope-defined Basin 2 buffer zones in tracts (fig. 10.3-6), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-5). All tracts, which have a total area of 55,000 km^2 within the basin, are evaluated simultaneously. Because information about known deposits is not available, the estimated number of deposits and their associated probability given in the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-5. Estimated number of fluvial sand and gravel deposits in Basin 2, both discovered and undiscovered, calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	19
80 % chance of at least	23
70 % chance of at least	36
60 % chance of at least	44
50 % chance of at least	149
40 % chance of at least	213
30 % chance of at least	289
20 % chance of at least	470
10 % chance of at least	650

***Monte Carlo Simulation (MCS) results*—**There are three chances in four that the sand and gravel resources in Basin 2 in fluvial sand and gravel deposits will be equal to or greater than 0.6 km^3, and there is an even chance that there will be equal to or greater than 3.0 km^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 6.8 km^3 (fig. 10.3-7).

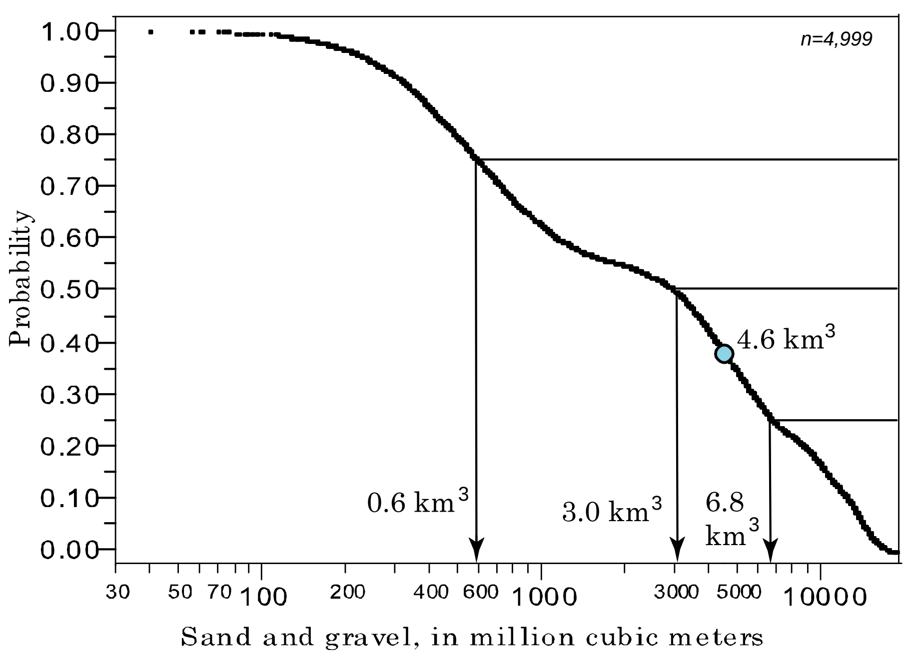

Figure 10.3-7. Distribution of sand and gravel resources in fluvial sand and gravel deposits in buffer zones in Basin 2 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Estimated number of undiscovered deposits in buffer zones—For the assessment of the slope-defined tracts in Basin 2 buffer zones (fig. 10.3-6*b*), an MDD model, as described previously, is used to provide an estimate of undiscovered deposits (table 10.3-6) from the permissive area of 16,000 km^2. All tracts within the buffer zone in the basin are evaluated simultaneously. Note that all issues described under optimistic and pessimistic factors are still applicable. Because information about discovered deposits is not available, the estimated number of deposits and their associated probability given by the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-6. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zone tracts calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	6
80 % chance of at least	7
70 % chance of at least	11
60 % chance of at least	13
50 % chance of at least	45
40 % chance of at least	63
30 % chance of at least	86
20 % chance of at least	140
10 % chance of at least	194

Monte Carlo Simulation (MCS) result for buffer zone tracts—There are three chances in four that the sand and gravel resources in Basin 2 in fluvial sand and gravel deposits will be equal to or greater than 0.6 km^3. There is also an even chance that there will be equal to or greater than 1.2 km^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 2.3 km^3. Proximity to towns and major roads suggests a portion of the estimated sand and gravel resources may have already been consumed (fig. 10.3-6*b*).

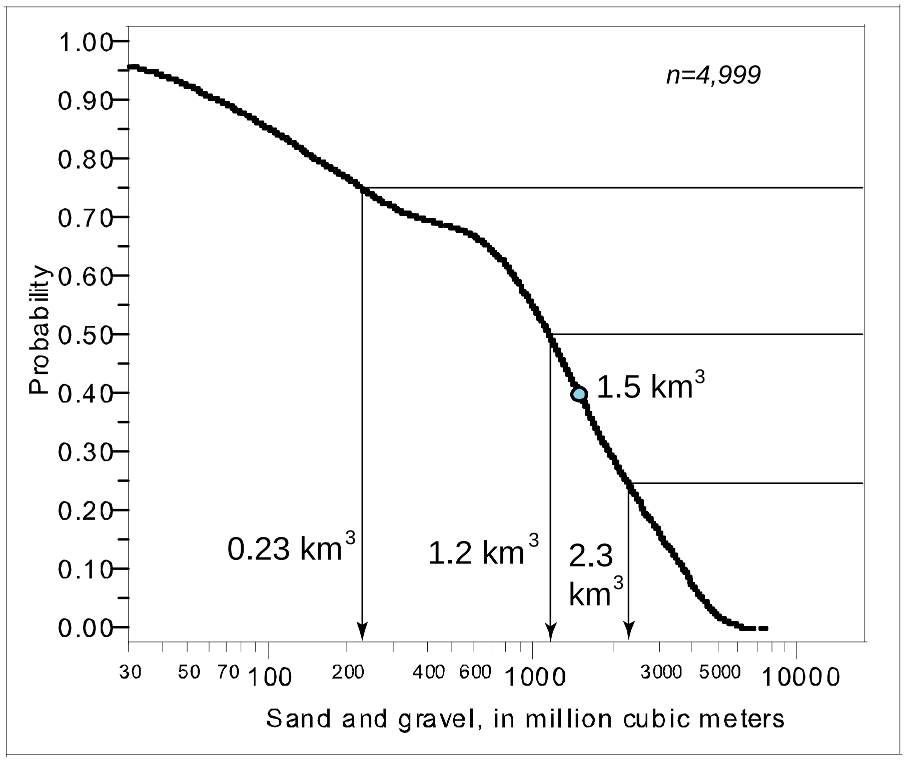

Figure 10.3-8. Distribution of sand and gravel resources in fluvial sand and gravel deposits in tracts in Basin 2 buffer zones. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of alluvial fan sand and gravel resources in Basin 2

Deposit type—Alluvial fan sand and gravel

Age of mineralization—Quaternary, better quality material is in younger alluvial fan sand and gravel deposits.

Example deposits types—There are no reported examples of alluvial fan sand and gravel deposits in tracts in this basin. No official records of work in sand and gravel deposits are kept in many parts of the world, and this is true in Afghanistan.

Exploration history—The presence of roads and other infrastructure suggests that sand and gravel has been previously identified and produced in the tracts in this basin. Alluvial fan sand and gravel deposits are usually not found near towns unless a roadway passes up the fan slope into the stream basin in the adjacent mountains. Neither the intensity nor the extent of sand and gravel exploration is known. However, exploitation of deposits near major roads is likely given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. However, alluvial sand and gravel deposits are likely positioned away for most roads and other points of consumption, so those deposits are likely untouched. Deposits of this type are likely rare within buffer zones (as defined below), which are found near towns and roads and are not considered in this assessment.

Tract boundary criteria—Tracts are defined by Quaternary unit described as alluvial fan and colluvium on the geologic map. Alluvial fans were also recognized on topographic sheets (scale 1:200,000).

Needs to improve assessment—Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, former USSR engineers, and construction contractors who have built roads in Afghanistan would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors—Alluvial fan and colluvium with gravel and sand content greater than silt and clay content include an area of 4,900 km^2 of Basin 2 without regard to topographic slope, and alluvial fans are clearly recognized on topographic sheets (scale 1:200,000.)

Pessimistic factors—Alluvial fans are often problematic as they are commonly poorly sorted with large amounts of unsuitable clay and silt interbedded or directly mixed with the sand and gravel. While a large number of fans may be present, only a few are likely to contain sand and gravel deposits suitable for development.

Estimated number of undiscovered deposits—The number of alluvial fans was subjectively estimated. Because information about discovered deposits is not available, the estimated number of deposits and their associated probability for MCS are for both discovered and undiscovered deposits and are given together with an associated probability (table 10.3-7).

Table 10.3-7. Estimate number of sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 2.

Probability level	Number of deposits
90 % chance of at least	0
70 % chance of at least	1
50 % chance of at least	2
30 % chance of at least	2
10 % chance of at least	3

Monte Carlo Simulation results for alluvial fan deposits—There are three chances in four that the sand and gravel resources in Basin 2 in alluvial fan deposits will be equal to or greater than 4.9 million m^3. There is also an even chance that sand and gravel resources will be equal to or greater than 147 million m^3 and one chance in four that the amount will equal or be greater than 512 million m^3 (fig. 10.3-9).

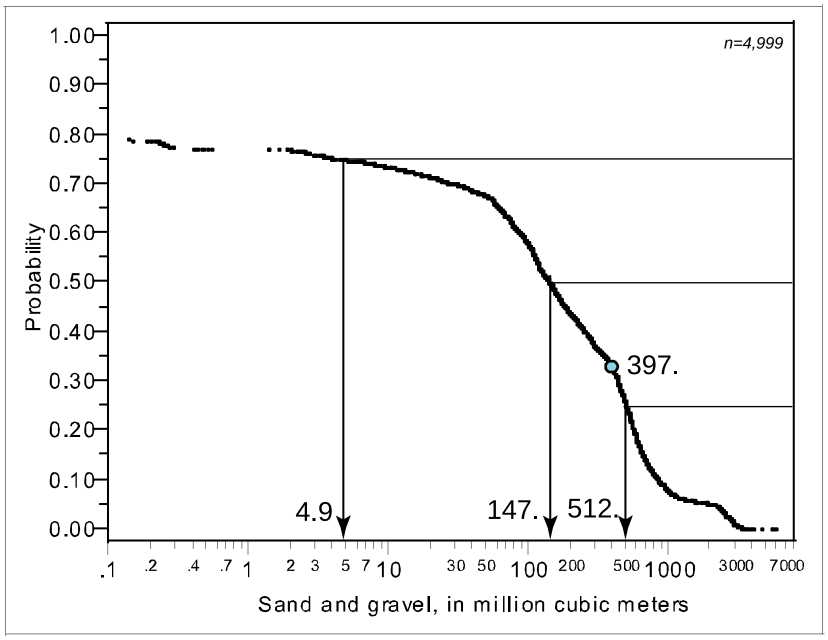

Figure 10.3-9. Distribution of sand and gravel resources in alluvial fans in Basin 2. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of fluvial sand and gravel resources in Basin 3

Introduction—Basin 3 is located in southeastern Afghanistan along the Pakistan border (fig. 10.3-1) in the region of the Lora River and Jale Westa (not shown) The 9,800 km^2 basin also includes a considerable area of sand dunes (Registan, “land of sand”) that will mask former fluvial systems as well as sand and gravel-bearing lacustrine deposits if present. Neither of these two possible occurrences is addressed in this assessment.

Deposit type—Fluvial sand and gravel

Age of mineralization—Quaternary; as a rule, better quality material is in younger fluvial sand and gravel deposits.

Example deposits types—There are no reported eamples of sand and gravel deposits in tracts in Basin 3. No official records of work in sand and gravel deposits are kept in many parts of the world, and this is true in Afghanistan. Basin 3 contains no notable river and readily recognizable deposits will be along the mountain ranges in a zone of an area about 1,900 km^2 along the border (fig. 10.3-10).

Exploration history—The presence of roads and other infrastructure suggest that sand and gravel has been previously identified and produced in a small portion of this basin. Neither the intensity nor the extent of sand and gravel exploration is known. However, exploitation of deposits near major roads is expected given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. Sand and gravel is produced near the point of consumption, so locations in regions at some distance from existing roads and towns are likely untouched. Only a small portion of the basin is found in buffer zones and have not been evaluated.

Tract boundary criteria in basins—See uniform tract boundary criteria based on topographic slope used for both basins and buffer zones as noted in the introductory discussion above. The assessment addresses just the zone along the east edge of the basin where the other boundaries were subjectively located. The area to the west is part of an area called Registan (“land of sand”) (Whitney, 2006) that includes two generations of sand dunes both active and inactive. The size of the area that met these criteria within the zone along the east edge of basin is 1,600 km^2 or 84 percent of the zone (fig. 10.3-10*a*).

Buffer zone criteria—Buffer zones in tracts are defined as extending 25 km around towns and along both sides of major roads. Buffered areas fall outside of the assessment zone (fig. 10.3-10*b*) and not addressed.

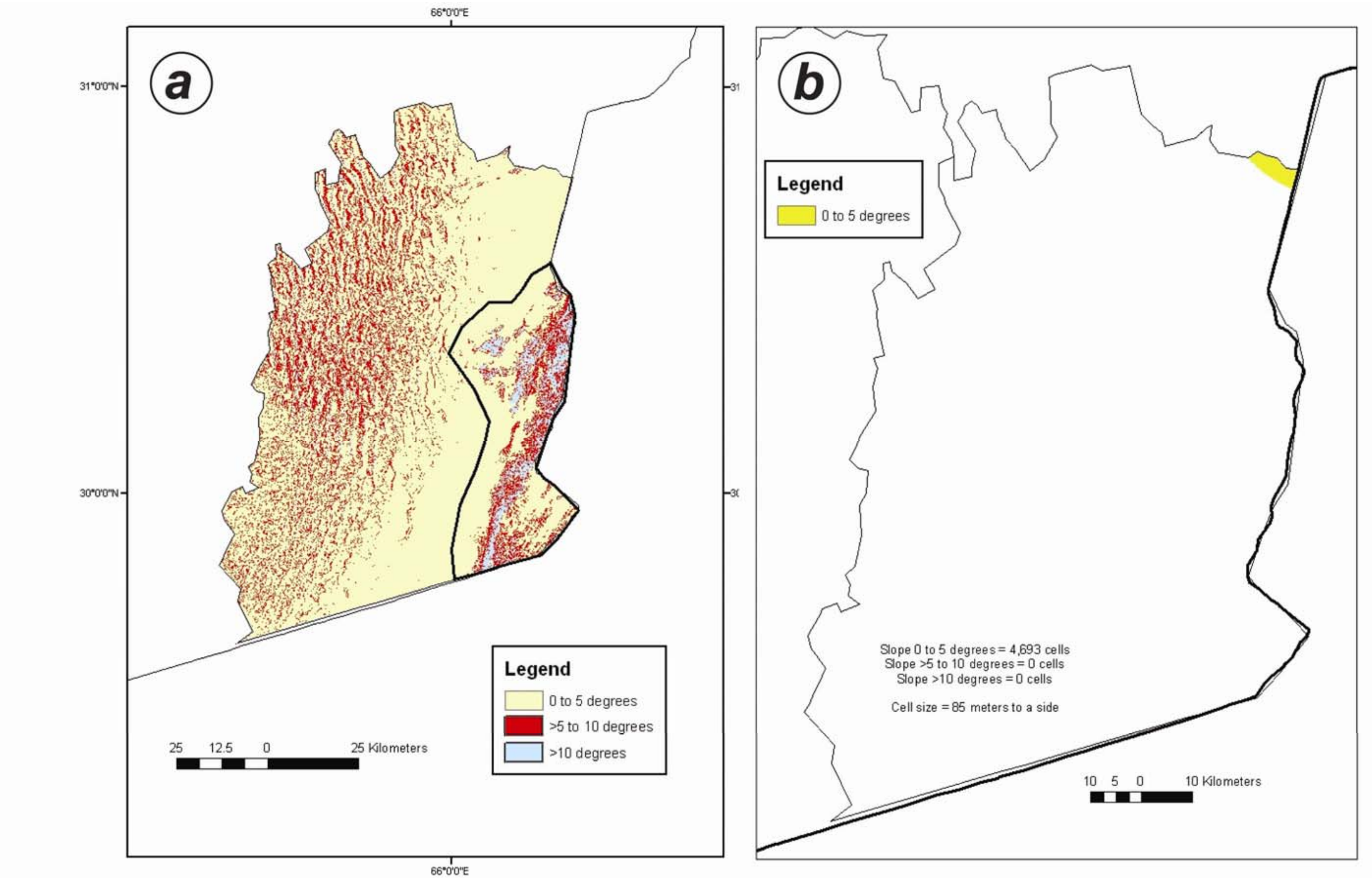

Figure 10.3-10. Outline of Basin 3 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits. Areas with slopes greater than 10 degrees (blue) are non permissive. (*a*) The area outlined in black is the assessment zone or sub-basin that is assessed for discovery of accessible sand and gravel deposits at the surface. (*b*) areas within 25 kilometer buffer zone around towns and along roads and are located outside the basin.

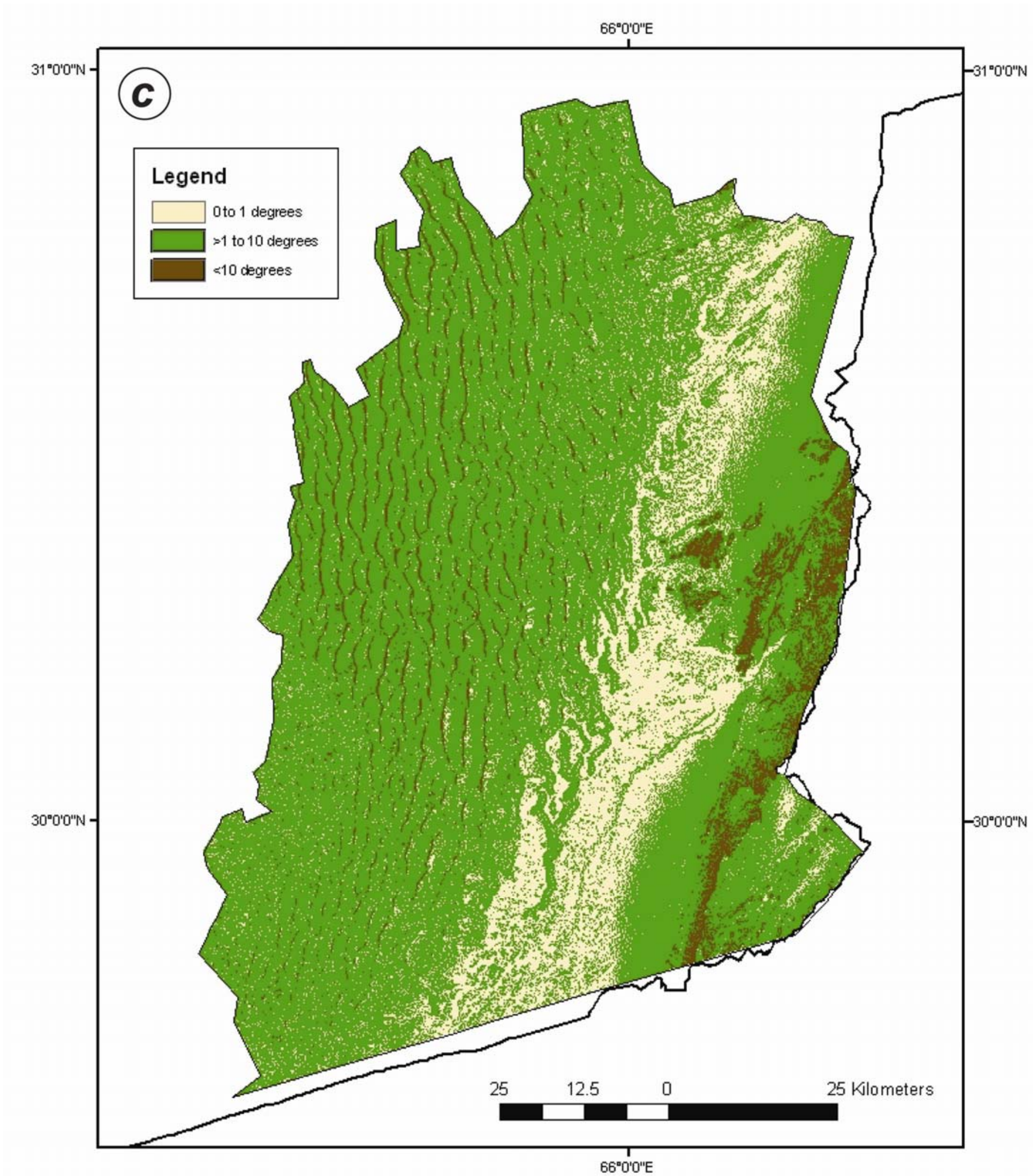

Figure 10.3-10*c*. Outline of Basin 3 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

Needs to improve assessment**—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors**—**Of the Quaternary sediments in tracts in the in the sub-basin or assessment zone in this basin, 38 percent are defined as an alluvium unit in which the gravel content is greater than silt or clay. This unit is highly likely to be the host of readily recognizable fluvial sand and gravel deposits. Alluvial fans and colluvium with gravel and sand greater than silt and clay along mountain fronts make up a considerable portion of surface alluvium and is found in 38 percent of the tract areas and can also be a source of fluvial sand and gravel deposits downstream from these features. However, alluvial fan sand and gravel deposits are separately assessed (see below.)

Pessimistic factors**—**Application of the uniform tract boundary criteria based on topographic slope was applied to the assessment zone (fig. 10.3-10) resulted in 40 percent of the cells being on Non-Quaternary rocks. This indicates that we may have produced tracts that are too large. Quaternary sediments in the assessment zone include units that are 1) highly unlikely sources of sand and gravel or 2) overburden that may obscure sand and gravel deposits at depth. These units include those dominated by loess (6.2 percent of the tract areas), and sand (18 percent). Alluvial fan and colluvium also make of the 38 percent of the permissive tracts and are separately assessed (see below).

Estimated number of undiscovered deposits**—**For the assessment of the slope-defined tracts in Basin 3 assessment zone or sub-basin (fig. 10.3-10*b*), an MDD is used to provide an estimate of undiscovered deposits (table 10.3-8). All tracts within the assessment zone, which have a total area of 1,600 km^2 within the basin, are evaluated simultaneously. Because information about discovered deposits is not available, the estimated number of deposits and their associated probability given in the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-8. Estimated number of fluvial sand and gravel deposits in Basin 3 assessment zone, both discovered and undiscovered, calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	1
80 % chance of at least	1
70 % chance of at least	1
60 % chance of at least	1
50 % chance of at least	4
40 % chance of at least	6
30 % chance of at least	9
20 % chance of at least	14
10 % chance of at least	19

Monte Carlo Simulation (MCS) results**—**There are three chances in four that the sand and gravel resources in Basin 3 in fluvial sand and gravel deposits will be equal to or greater than 4.2 million m^3, and there is an even chance that there will be equal to or greater than 44 million m^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 180 million m^3 (fig. 10.3-11).

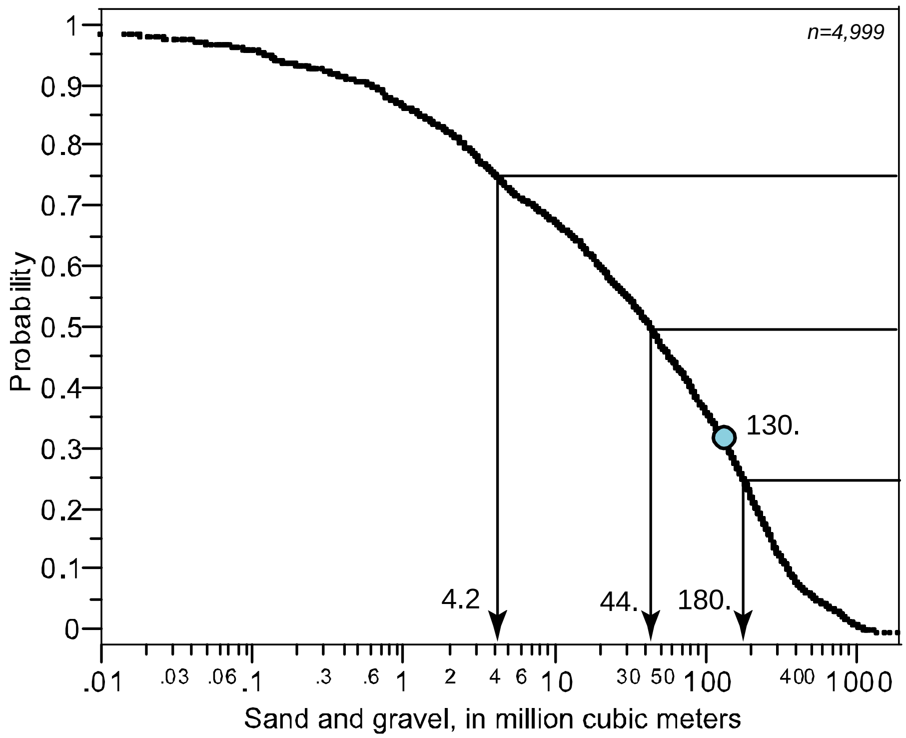

Figure 10.3-11. Distribution of sand and gravel resources in fluvial sand and gravel deposits in tracts in the assessment zone in Basin 3. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of alluvial fan sand and gravel resources in Basin 3

***Deposit type*—**Alluvial fan sand and gravel

***Age of mineralization*—**Quaternary, better quality material is in younger alluvial fan sand and gravel deposits.

***Example deposits types*—**There are no reported examples of alluvial fan sand and gravel deposits in tracts in this basin. Most alluvial fan sand and gravel deposits are worked without record in many part of the world, and this is true in Afghanistan.

***Exploration history*—**The presence of roads and other infrastructure suggests that sand and gravel has been previously identified and produced in the tracts in this basin. Alluvial fan sand and gravel deposits are usually not found near towns unless a roadway passes up the fan slope into the stream basin in the adjacent mountains. Neither the intensity nor the extent of sand and gravel exploration is known. However, exploitation of deposits near major roads is expected given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. However, alluvial fan sand and gravel deposits are likely positioned away for most roads and other points of consumption, so those deposits are likely untouched. Deposits of this type are likely rare within buffer zones (as defined below), which are found near towns and roads, and are not considered in this assessment.

***Tract boundary criteria*—** Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-10*c*).

***Needs to improve assessment*—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, the former USSR engineers, and construction contractors who have built roads in Afghanistan would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

***Optimistic factors*—**Alluvial fan and colluvium with gravel and sand greater than silt and clay include an area of 370 km^2 on the geologic map (Doebrich and Wahl, 2006) for Basin 3. Alluvial fans are clearly recognized on topographic sheets (scale 1: 200,000).

***Pessimistic factors*—**The area of the permissive zone is small. Alluvial fans are often problematic as they are commonly poorly sorted with large amounts of unsuitable clay and silt interbedded or directly mixed with the sand and gravel. While a large number of fans may be present, only a few may contain sand and gravel deposits suitable for development.

***Estimated number of undiscovered deposits*—**The number of alluvial fans was subjectively estimated. Because information about discovered deposits is not available, the estimated number of deposits and their associated probability for MCS are for both discovered and undiscovered deposits and are given together with an associated probability (table 10.3-9).

Table 10.3-9. Estimate number of sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 3.

Probability level	Number of deposits
90 % chance of at least	0
70 % chance of at least	0
50 % chance of at least	1
30 % chance of at least	1
10 % chance of at least	1

***Monte Carlo Simulation results for alluvial fan deposits*—**There are three chances in four that the sand and gravel resources in Basin 3 in alluvial fan sand and gravel deposits will be zero. There is an even chance that there will be equal to or greater than 4.9 million m^3 (fig. 10.3-12) and one chance in four that the amount of sand and gravel resources will equal or be greater than 110 million m^3.

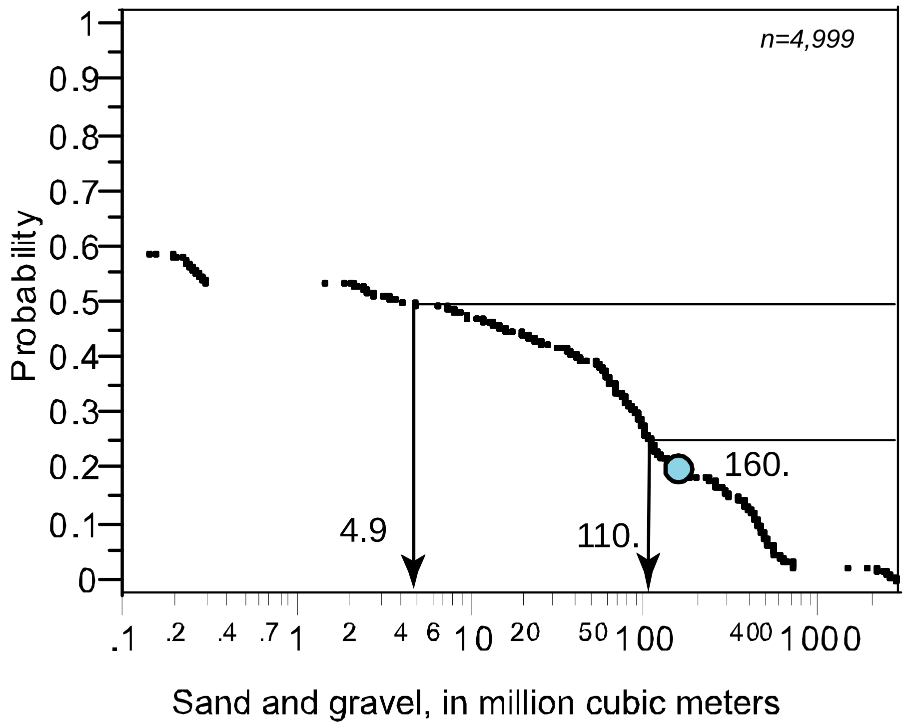

Figure 10.3-12. Distribution of sand and gravel resources in sand and gravel deposits in alluvial fans in Basin 3. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of fluvial sand and gravel resources in Basin 4

Introduction**—**Basin 4 is in southwest Afghanistan in the Region of Khash Rud and extends to the border of Iran (fig. 10.3-1) The 42,000 km^2 basin also includes a considerable area of low lying land of the Khash Desert of Helmand Basin. Basin 4 extends into the area of the southwest Sistan playas a part of which are found in Iran. Evidence of fluvial activity is visible on the basin map (fig. 10.3-13) and suggests that fluvial deposits may be present in all parts of the basin. Whitney (2006) also notes that Neogene coarse gravels are wide spread in the downstream part of the basin. However, the steeper terrain usually associated with alluvial fans is restricted to the northeast part of the basin in areas along the mountain front. Southwestern parts of this basin may include lacustrine sand and gravel deposit type that is not consider in this assessment.

Deposit type**—**Fluvial sand and gravel

Age of mineralization**—**Quaternary; as a rule, better quality material is in younger fluvial sand and gravel deposits.

Example deposits types**—**There are no examples of sand and gravel deposits in tracts in Basin 4. No official records of work in sand and gravel deposits are kept in many parts of the world, and this is true in Afghanistan. Basin 4 contains the Khash River and its tributaries, and fluvial sand and gravel deposits can be expected to be present along those waterways.

Exploration history**—**No sites have been reported as sources of sand and gravel in Basin 4. The presence of roads and other infrastructure suggests that sand and gravel has been previously identified in the basin and that production likely has been wide spread. A major highway (A1) runs across the basin from the southeast to the northwest along the front of the mountains where some deposits are highly likely to have been worked for sand and gravel during its construction and ongoing maintenance. However, neither the intensity nor the extent of sand and gravel exploration is known. Exploitation of deposits near major roads is expected, given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. Sand and gravel is produced near the point of consumption, so tracts in regions at some distance from existing roads and towns are likely untouched. Deposits within buffer zones (as defined below), which are near towns and roads are more likely to have been explored.

Tract boundary criteria in basins—See uniform tract boundary criteria based on topographic slope used for both basins and buffer zones as noted in the introductory discussion above. Ninety percent of Basin 4, or 38,000 km^2, is permissive for fluvial sand and gravel (fig. 10.3-13*a*).

Buffer zone criteria—Buffer zones within the tracts are defined as extending 25 km around towns and along both sides of major roads. Buffered areas (fig. 10.3-13*b*) with slopes less than 10 degrees have a cumulative area of 9,800 km^2.

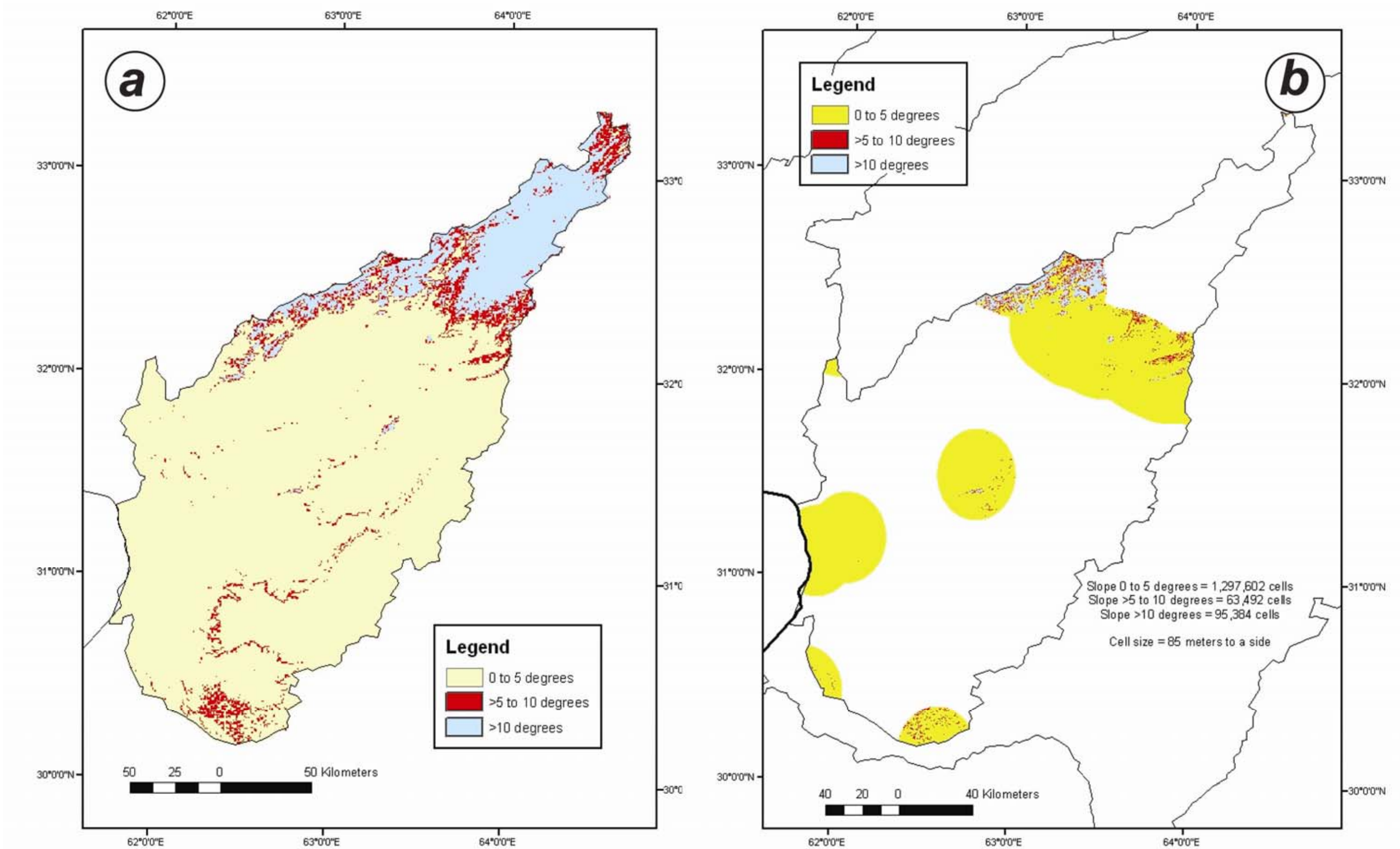

Figure 10.3-13. Outline of Basin 4 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits. Areas with slopes greater than 10 degrees (blue.) are non-permissive. (*a*) entire basin. (*b*) areas within 25 kilometer buffer zone around towns and along roads. Slopes between 0-5 degrees (yellow), and 5-10 degrees (red) are permissive for fluvial sand and gravel deposits and those greater than 10 degrees (blue) are not permissive.

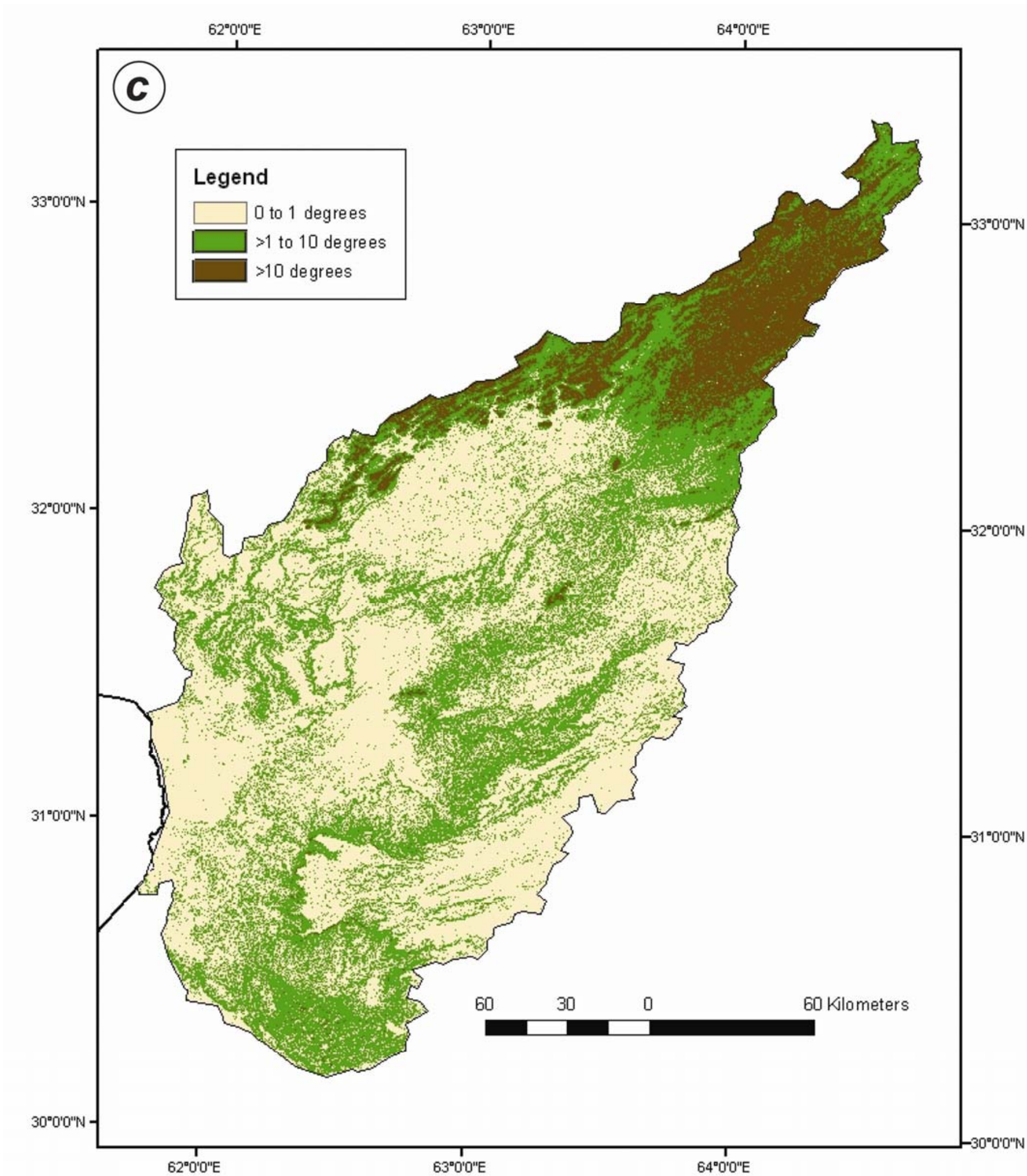

Figure 10.3-13*c*. Outline of Basin 4 showing areas with slopes of 0-5 degrees (tan), 1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

***Needs to improve assessment*—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

***Optimistic factors*—**Of the Quaternary sediments in tracts in this basin, 75 percent are defined as an alluvium unit in which the gravel content is greater than silt or clay content. This unit is highly likely to host readily recognizable fluvial sand and gravel deposits. Along mountain fronts, alluvial fans and colluvium with the amount of gravel and sand greater than the amount of silt and clay are in 6.7 percent of the tract areas. These fans can also be a source of fluvial sand and gravel deposits downstream from these features. However, alluvial fan sand and gravel deposits are separately assessed (see below.)

***Pessimistic factors*—**Application of the uniform tract boundary criteria based on topographic slope to this basin resulted in 8.9 percent of the cells being on non-Quaternary rocks. This indicates that we may have produced a cumulative permissive tract area of about the right size. One serious problem is that the alluvium as reported may be covered with desert pavement, the lag concentrate of gravel left behind with the removal of fine grain material including sand by wind. However, Whitney (2006, fig. 6) suggests that coarse Neogene gravels are widespread and are present in the lower part of the basin. Quaternary sediments in this tract include units that are 1) highly unlikely sources of sand and gravel or 2) overburden that may obscure sand and gravel deposits at depth. These units include those dominated by loess (2.3 percent of the tract areas), sand (9.3 percent); mud, silt and clay greater than sand (5.6 percent), and playas (1.2 percent).

***Estimated number of undiscovered deposits*—**For the assessment of the slope-defined tracts in Basin 4 (fig. 10.3-13), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-10) All tracts, which have a total cumulative area of 38,000 km^2 within the basin, are evaluated simultaneously. Because information about discovered deposits is limited, the estimated number of deposits and their associated probability given in the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-10. Estimated number of fluvial sand and gravel deposits in Basin 4, both discovered and undiscovered, calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	13
80 % chance of at least	16
70 % chance of at least	25
60 % chance of at least	30
50 % chance of at least	103
40 % chance of at least	147
30 % chance of at least	199
20 % chance of at least	324
10 % chance of at least	448

***Monte Carlo Simulation results*—**There are three chances in four that the sand and gravel resources in Basin 4 in fluvial sand and gravel deposits will be equal to or greater than 0.47 km^3, and there is an even chance that there will be equal to or greater than 2.0 km^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 4.9 km^3 (fig. 10.3-14).

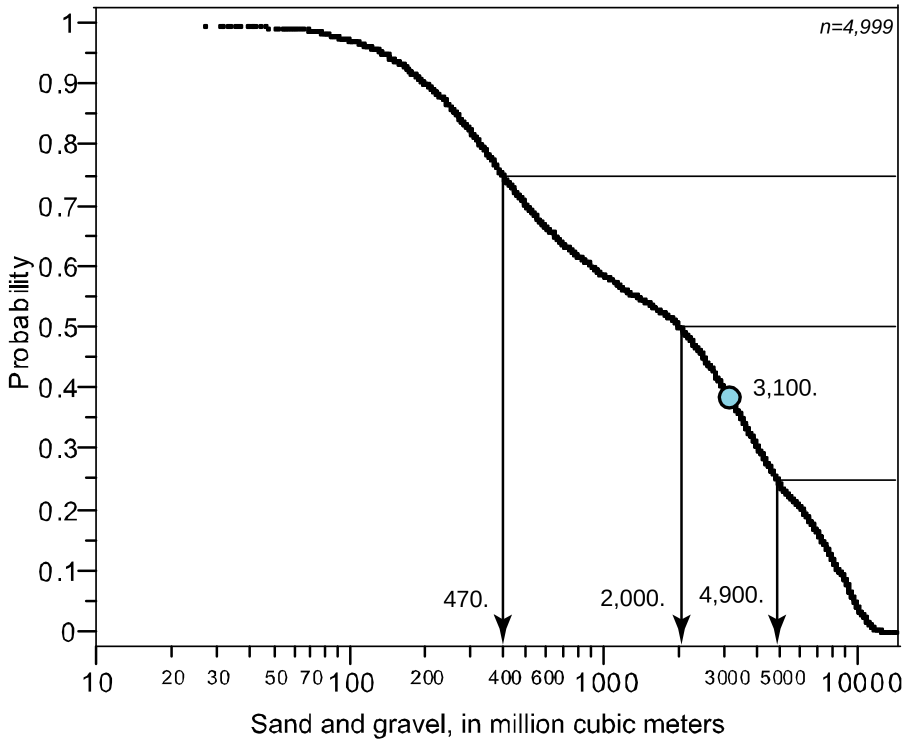

Figure 10.3-14. Distribution of sand and gravel resources in fluvial sand and gravel deposits in tracts in Basin 4. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Estimated number of undiscovered deposits in buffer zones—For the assessment of the slope-defined tracts in Basin 4 buffer zones (fig. 10.3-13*b*), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-11) from the permissive area of 18,000 km^2. All parts of the buffer zone in the basin are evaluated simultaneously. The estimated number of deposits and their associated probability given by the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-11. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zone tracts calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	3
80 % chance of at least	4
70 % chance of at least	6
60 % chance of at least	8
50 % chance of at least	27
40 % chance of at least	38
30 % chance of at least	52
20 % chance of at least	85
10 % chance of at least	117

Monte Carlo Simulation result for undiscovered deposits in buffer zones—There are three chances in four that the sand and gravel resources in Basin 4 in fluvial sand and gravel deposits will be equal to or greater than 77 million m^3. There are also an even chance that there will be equal to or greater than 470 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 1,300 million m^3 (fig. 10.3-15). Proximity to towns and major roads suggests a portion of the estimate sand and gravel resources may have already been consumed.

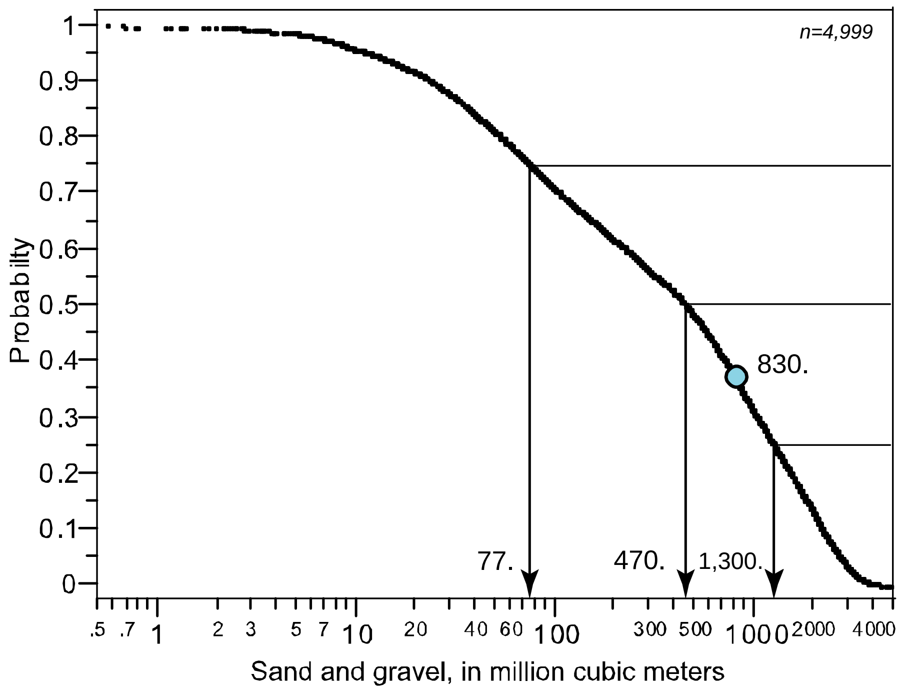

Figure 10.3-15. Distribution of sand and gravel resources in fluvial sand and gravel deposits in buffer zones of Basin 4 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of alluvial fan sand and gravel resources in Basin 4

Deposit type—Alluvial fan sand and gravel

Age of mineralization—Quaternary, better quality material is in younger alluvial fan sand and gravel deposits.

Example deposits types—There are no reported examples of alluvial fan sand and gravel deposits in tracts in this basin. However, 2,400 km^3 of the basin is mapped as fan alluvium and colluvium with gravel, sand and clay. This includes all areas without regard to slope. Most alluvial fan sand and gravel deposits are worked without record in many part of the world, and this is true in Afghanistan.

Exploration history—The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified and produced in the tracts in this basin. Alluvial fan sand and gravel deposits are usually not found near towns unless a roadway passes up the fan slope into the stream basin in the adjacent mountains. Neither the intensity nor the extent of sand and gravel exploration is known. However, exploitation of deposits near major roads is expected given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. Some of these alluvial sand and gravel deposits are near roads and other points of consumption, so they may have been exploited but most of the resource is likely untouched. Deposits of this type are likely rare within buffer zones (as defined below) found near towns and roads and are not considered in this assessment.

Tract boundary criteria—Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-13*c*).

Needs to improve assessment—Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, former USSR engineers, and construction contractors who have built roads in Afghanistan would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors—Alluvial fans and colluvium with gravel and sand greater than silt and clay comprise an area of 2,400 km^2 or 6.7 percent of the Quaternary units described in Basin 4 (Doebrich and Wahl, 2006) and alluvial fan are clearly recognized on topographic sheets (scale 1: 200,000).

Pessimistic factors—Alluvial fans are often problematic as they are commonly poorly sorted with large amounts of unsuitable clay and silt interbedded or directly mixed with the sand and gravel. While a large number of fans may be present, only a few are expected to contain sand and gravel deposits suitable for development.

Estimated number of undiscovered deposits—The number of alluvial fans was subjectively estimated. Because information about discovered deposits is not available, the estimated number of deposits and their associated probability for MCS are for both discovered and undiscovered deposits and are given together with an associated probability (table 10.3-12).

Table 10.3-12. Estimated number of sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 4.

Probability level	**Number of deposits**
90 % chance of at least	0
70 % chance of at least	1
50 % chance of at least	1
30 % chance of at least	1
10 % chance of at least	1

Monte Carlo Simulation results for alluvial fan deposits—There are three chances in four that the sand and gravel resources in Basin 4 in alluvial fan sand and gravel deposits will be equal to or greater than 0.3 million m^3. There is also an even chance that there will be equal to or greater than 61 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 230 million m^3 (fig. 10.3-16).

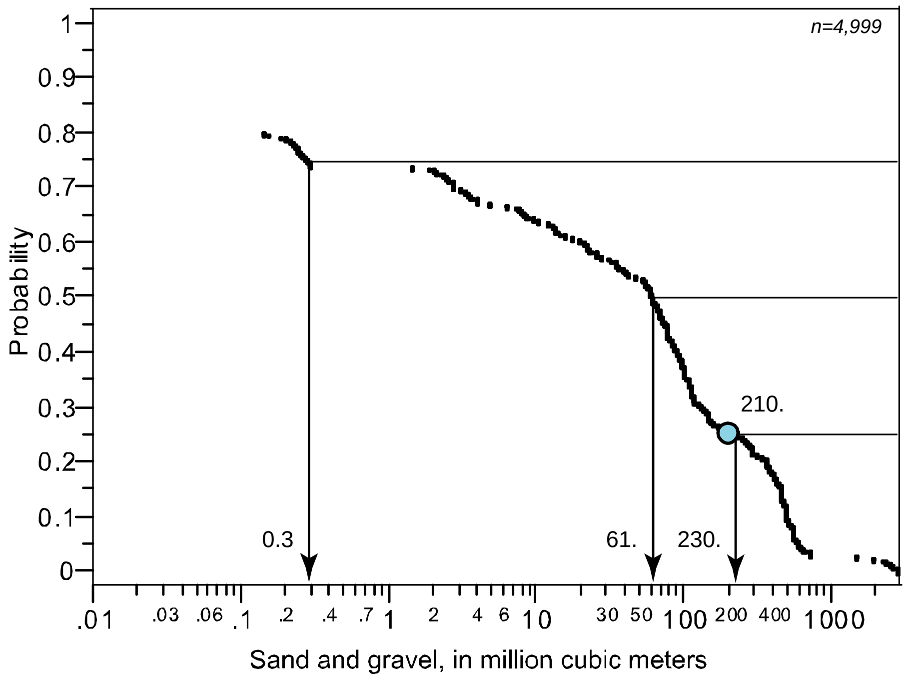

Figure 10.3-16 Distribution of sand and gravel resources in sand and gravel deposits in alluvial fans in Basin 4. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of fluvial sand and gravel resources in Basin 5

Introduction—Basin 5 is located in western central Afghanistan (fig. 10.3-1) in the Khash River Region. Evidence of fluvial activity in areas suitable for development of sand and gravel deposits like those in the volume model are likely limited to the western third of the basin (fig. 10.3-17). The steeper terrain and mountain fronts usually associated with alluvial fans are in the same area.

Deposit type—Fluvial sand and gravel

Age of mineralization—Quaternary; as a rule, better quality material is in younger fluvial sand and gravel deposits.

Example deposits types—There are no examples of sand and gravel deposits in tracts in Basin 5. No official records of work in sand and gravel deposits are kept in many parts of the world, and this is also true in Afghanistan. Basin 5 contains the Khash River and its tributaries where fluvial sand and gravel deposits can be expected to be present.

Exploration history—No sites have been reported as a sources of sand and gravel in Basin 5. The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified in the basin and that production likely has been wide spread. A major highway (A1) runs across the basin from southeast to northwest and some nearby deposits were highly likely to have been worked for sand and gravel during its construction and ongoing maintenance. However, neither the intensity nor the extent of sand and gravel exploration is known. Exploitation of deposits near major roads is expected given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. Sand and gravel is produced near the point of consumption, so locations in regions at some distance from existing roads and towns are likely untouched. Deposits within buffer zones (as defined below), which are near towns and roads are more likely to have been explored.

Tract boundary criteria in basins—See uniform tract boundary criteria based on topographic slope used for both basins and buffer zones as noted in the introductory discussion above. Fifty five percent of Basin 5, or 17,000 km^2, is permissive for fluvial sand and gravel (fig. 10.3-17.)

Buffer zone criteria—Buffer zones are defined as extending 25 km around towns and along both sides of major roads. Buffered areas (fig. 10.3-17*b*) with slopes less than 10 degrees have a cumulative area of 8,300 km^2.

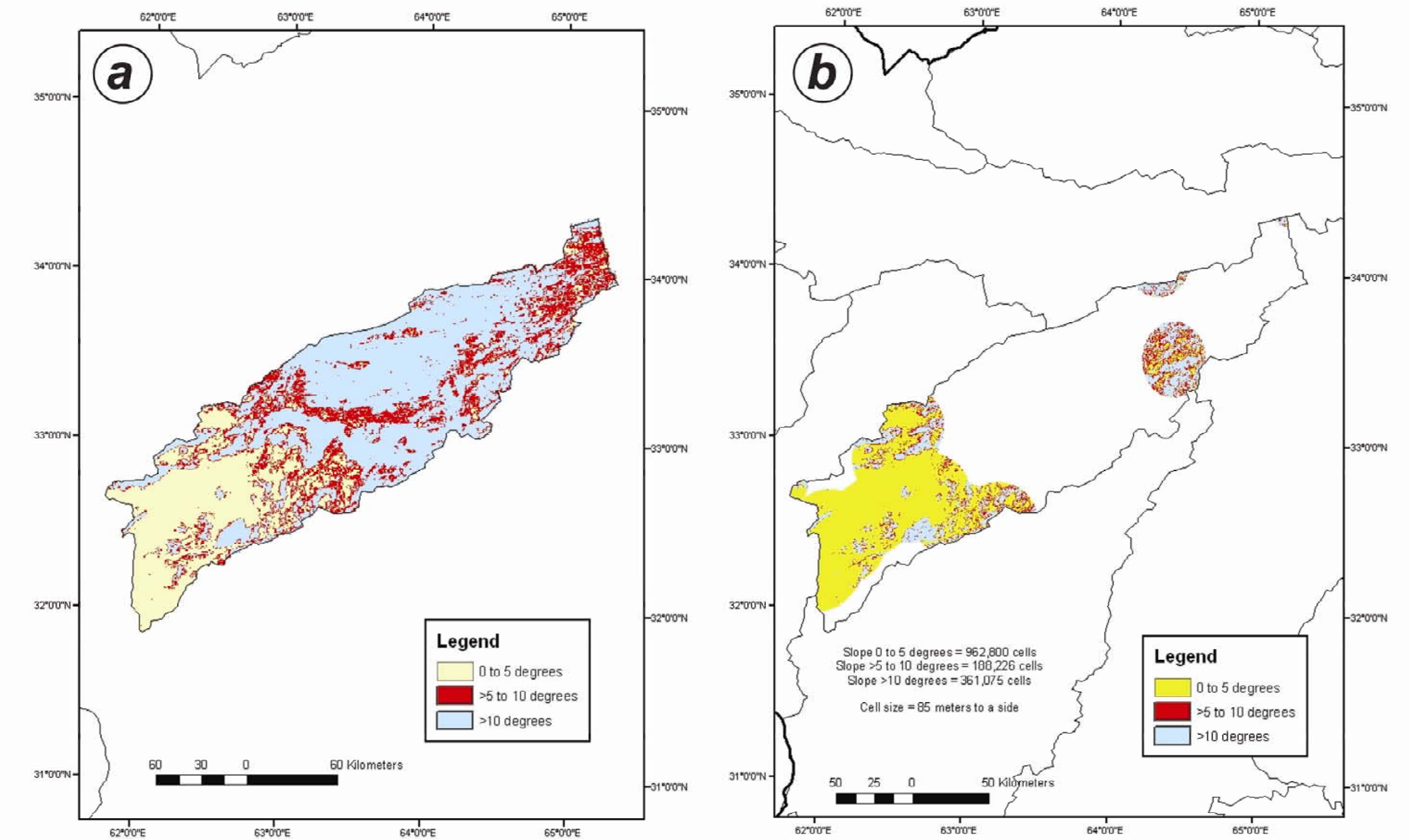

Figure 10.3-17. Outline of Basin 5 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits. Areas with slopes greater than 10 degrees (blue) are non-permissive. (*a*) entire basin. (*b*) areas within 25 kilometer buffer zone around towns and along roads. Slopes between 0-5 degrees (yellow), and 5-10 degrees (red) are permissive for fluvial sand and gravel deposits and those greater than 10 degrees (blue) are not permissive.

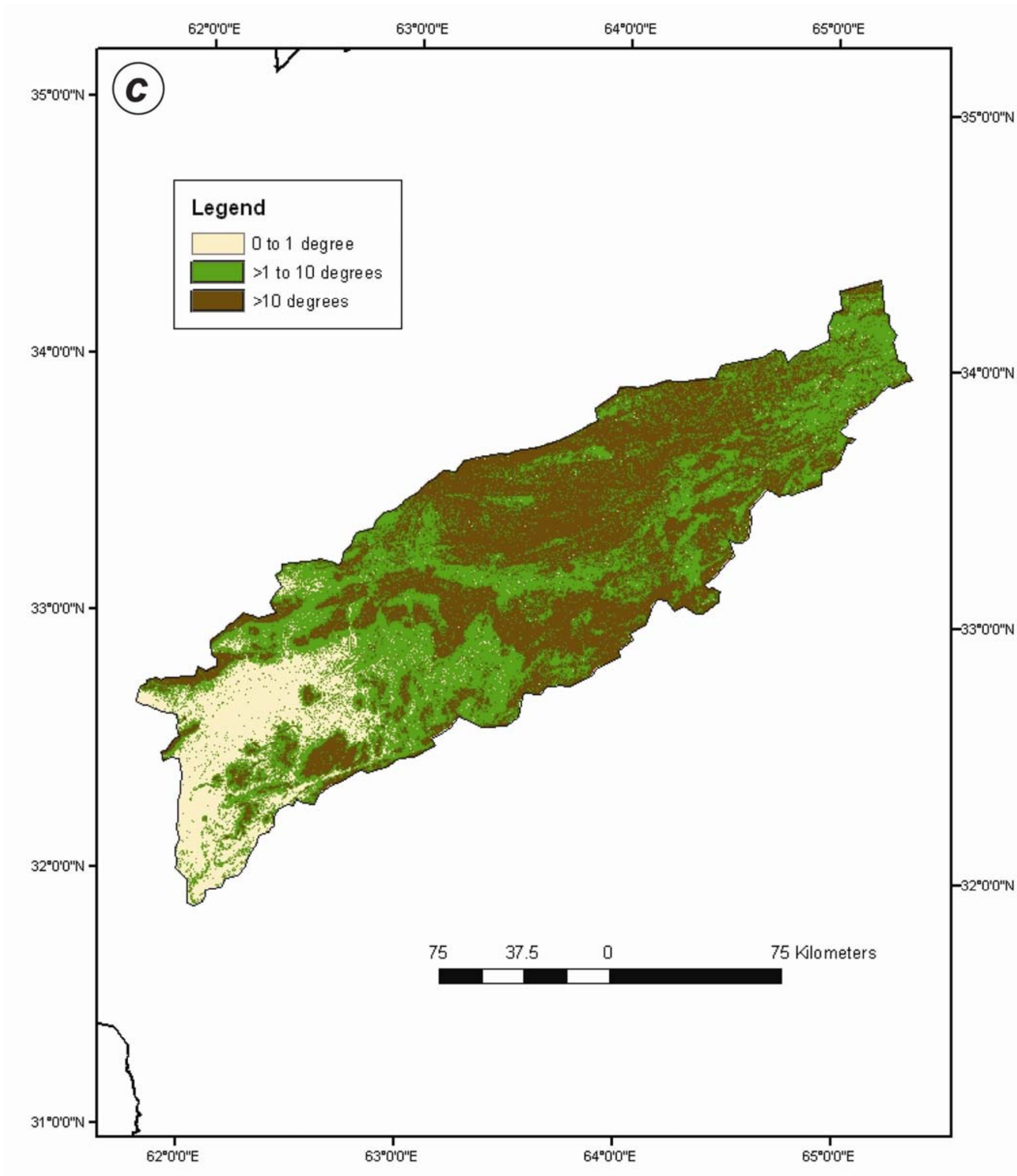

Figure 10.3-17*c*. Outline of Basin 5 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

Needs to improve assessment—Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors—Of the Quaternary sediments in tracts in this basin, 47 percent are defined as an alluvium unit in which the gravel content is greater than silt or clay content. This unit is highly likely to host readily recognizable fluvial sand and gravel deposits. Along mountain fronts, alluvial fans and colluvium with the amount of gravel and sand greater than the amounts of silt and clay are in 40 percent of the tract areas and can also be a source of fluvial sand and gravel deposits downstream from these features. However, alluvial fan sand and gravel deposits are separately assessed (see below).

Pessimistic factors—Application of the uniform tract boundary criteria based on topographic slope to this basin resulted in 64 percent of the cells being on non-Quaternary rocks. This indicates that we may have likely produced a cumulative permissive tract area that is too large. Quaternary sediments in this tract include units that are 1) highly unlikely sources of sand and gravel or 2) overburden that may obscure sand and gravel deposits at depth. These units include those dominated by loess (13 percent of the tract areas), and those with mud, silt and clay greater than sand (8.3 percent).

Estimated number of undiscovered deposits—For the assessment of the slope-defined buffer zones in Basin 5 tracts (fig. 10.3-17), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-13) All tracts, which have a total cumulative area of 17,000 km^2, are evaluated simultaneously. The estimated number of deposits and their associated probability given in the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-13. Estimated number of fluvial sand and gravel deposits in Basin 5, both discovered and undiscovered, calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	6
80 % chance of at least	7
70 % chance of at least	11
60 % chance of at least	13
50 % chance of at least	46
40 % chance of at least	65
30 % chance of at least	88
20 % chance of at least	144
10 % chance of at least	199

Monte Carlo Simulation results—There are three chances in four that the sand and gravel resources in Basin 5 in fluvial sand and gravel deposits will be equal to or greater than 170 million m^3, and there is an even chance that there will be equal to or greater than 870 million m^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 2,300 million m^3 (fig. 10.3-18).

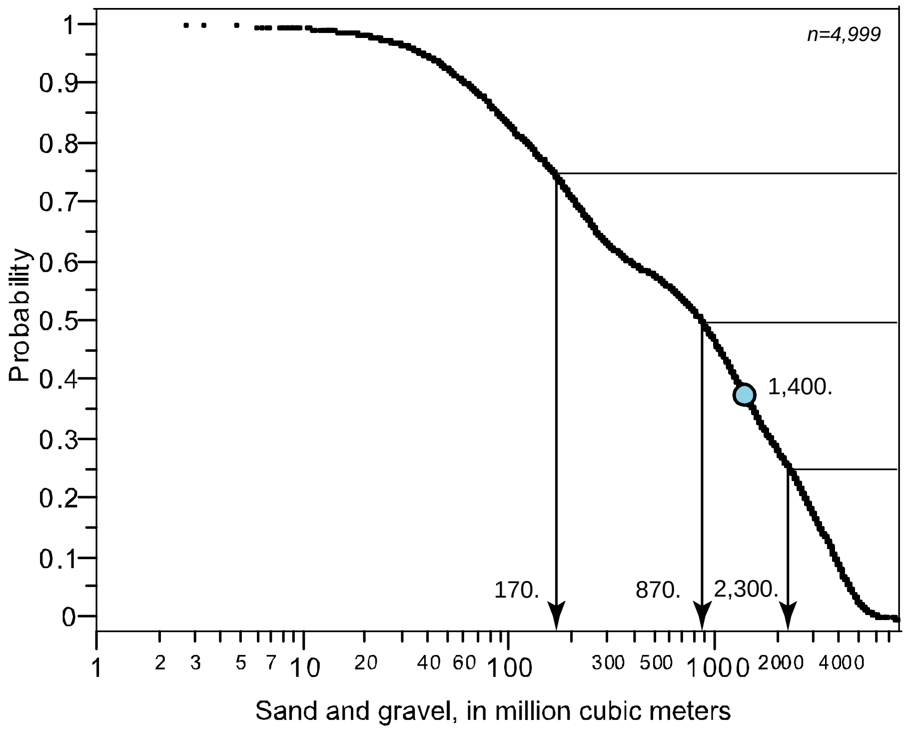

Figure 10.3-18. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 5 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Estimated number of undiscovered deposits in buffer zones—For the assessment of the slope-defined tracts in Basin 5 buffer zones (fig. 10.3-17*b*), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-14) from the permissive area of 8,300 km^2. All tracts within the buffer zone in the basin are evaluated simultaneously. The estimated number of deposits and their associated probability given by the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees. Note that the same limitation related to Quaternary geology is also applicable to tracts within buffer zones.

Table 10.3-14. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zone tracts calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	3
80 % chance of at least	4
70 % chance of at least	5
60 % chance of at least	7
50 % chance of at least	23
40 % chance of at least	32
30 % chance of at least	44
20 % chance of at least	72
10 % chance of at least	99

Monte Carlo Simulation result for undiscovered deposits in buffer zones—There are three chances in four that the sand and gravel resources in Basin 5 in fluvial sand and gravel deposits will be equal to or greater than 71 million m^3. There is also an even chance that there will be equal to or greater than 390 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 1,100 million m^3 (fig. 10.3-19). Proximity to towns and major roads suggests a portion of the estimated sand and gravel resources may have already been consumed.

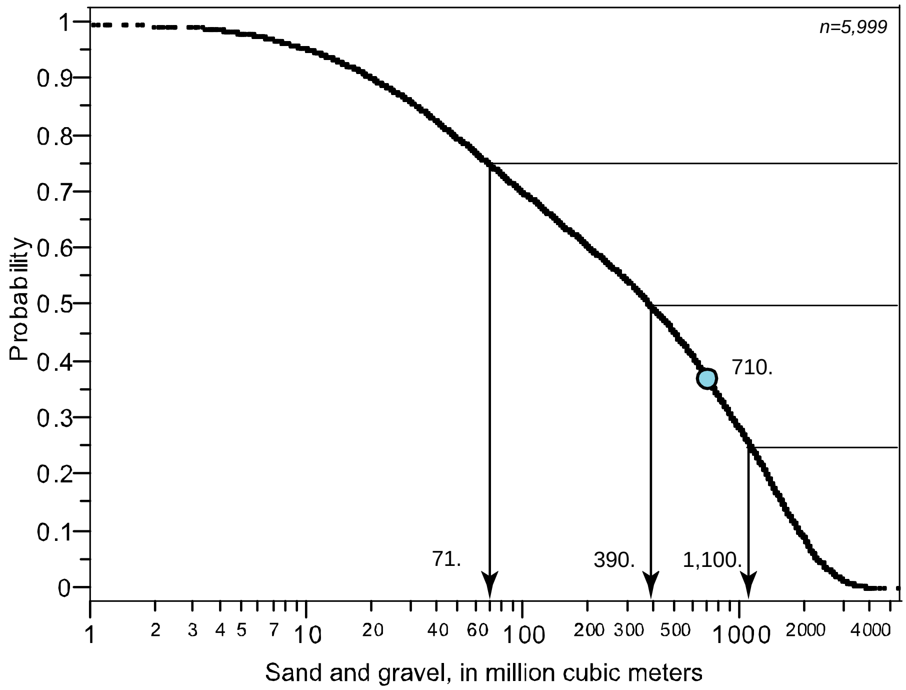

Figure 10.3-19. Distribution of sand and gravel resources in fluvial sand and gravel deposits in buffer zones in Basin 5 tracts. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of alluvial fan sand and gravel resources in Basin 5

***Deposit type*—**Alluvial fan sand and gravel

***Age of mineralization*—**Quaternary, better quality material is in younger alluvial fan sand and gravel deposits.

***Example deposits types*—**There are no reported examples of alluvial fan sand and gravel deposits in tracts in this basin. However, 2,400 km^3 of the basin is mapped as fan alluvium and colluvium with gravel, sand, and clay (Doebrich and Wahl, 2006). Most alluvial fan sand and gravel deposits are worked without record in many part of the world, and this is true in Afghanistan.

***Exploration history*—**The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified and produced in the tracts in this basin. Alluvial fan sand and gravel deposits are usually not found near towns unless a roadway passes up the fan slope into the stream basin in the adjacent mountains. Neither the intensity nor the extent of sand and gravel exploration is known. However, exploitation of deposits near major roads is expected given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. However, some of these alluvial sand and gravel deposits are near roads and other points of consumption, so some of these deposits may have been exploited but most of the resource is likely untouched. Deposits of this type are likely rare within buffer zones (as defined below) found near towns and roads and are not considered in this assessment.

Tract boundary criteria—Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-17*c*).

Needs to improve assessment—Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, former USSR engineers, and construction contractors who have built roads in Afghanistan would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors—Alluvial fan and colluvium with gravel and sand greater than silt and clay comprise an area of 2,900 km^2 in this basin or 40 percent of the Quaternary sediments in the basin. Alluvial fans are clearly recognized on topographic sheets (scale 1: 200,000).

Pessimistic factors—Alluvial fans are often problematic as they are commonly poorly sorted with large amounts of unsuitable clay and silt interbedded or directly mixed with the sand and gravel. While a large number of fans may be present, only a few are likely to contain sand and gravel deposits suitable for development.

Estimated number of undiscovered deposits—The number of alluvial fans was subjectively estimated. Because information about discovered deposits is not available, the estimated number of deposits and their associated probability for MCS are for both discovered and undiscovered deposits and are given together with an associated probability (table 10.3-15).

Table 10.3-15. Estimated number of sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 5.

Probability level	Number of deposits
90 % chance of at least	0
70 % chance of at least	1
50 % chance of at least	1
30 % chance of at least	2
10 % chance of at least	3

Monte Carlo Simulation results for alluvial fan deposits—There are three chances in four that the sand and gravel resources in Basin 5 in alluvial fan sand and gravel deposits will be equal to or greater than 2.8 million m^3. There is also an even chance that there will be equal to or greater than 110 million m^3 and one chance in four that the amount of sand and gravel resources will equal to or be greater than 460 million m^3 (fig. 10.3-20).

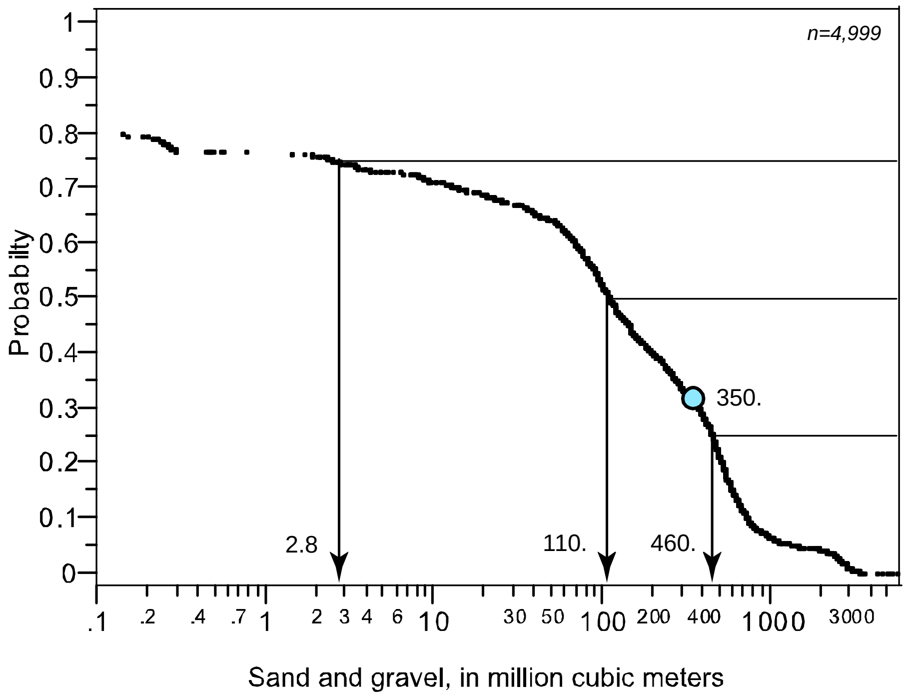

Figure 10.3-20. Distribution of sand and gravel resources in sand and gravel deposits in alluvial fans in Basin 5. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of fluvial sand and gravel resources in Basin 6

Introduction**—**Basin 6 is located in western Afghanistan (fig. 10.3-1) in the Region of Harut River and extends to border of Iran on the south. The southwest portion includes part of Helmund Basin and the basin is bounded on the west by Iran. The area includes a number of ephemeral stream and playas.

Deposit type**—**Fluvial sand and gravel

Age of mineralization**—**Quaternary; as a rule, better quality material is in younger fluvial sand and gravel deposits.

Example deposits types**—**No examples of sand and gravel deposits in tracts in Basin 6. No official records of work in sand and gravel deposits are kept in many parts of the world, and this is true in Afghanistan. Basin 6 contains the Harut River and its tributaries, and fluvial sand and gravel deposits can be expected to be present along those waterways.

Exploration history**—**No sites have been reported as a sources of sand and gravel in Basin 6. The presence of roads and other infrastructure suggests that sand and gravel has been previously identified in the basin and that production likely has been wide spread. A major highway (A1) runs across the basin from southeast to northwest and some nearby deposits are highly likely to have been worked for sand and gravel during its construction and ongoing maintenance. However, neither the intensity nor the extent of sand and gravel exploration is known. Exploitation of deposits near major roads is expected, given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. Sand and gravel is produced near the points of consumption, so locations in regions at some distance from existing roads and towns are likely untouched. Deposits within buffer zones (as defined below), which are near towns and roads are more likely to have been explored.

***Tract boundary criteria in basins*—**See uniform tract boundary criteria based on topographic slope used for both basins and buffer zones as noted in the introductory discussion above. Eighty two percent of Basin 6, or 20,000 km^2, is permissive for fluvial sand and gravel (fig. 10.3-21.)

***Buffer zone criteria*—**Buffer zones are defined as extending 25 km around towns and along both sides of major roads. Buffered areas (fig. 10.3-21*b*) with slopes less than 10 degrees have a cumulative area of 7,000 km^2.

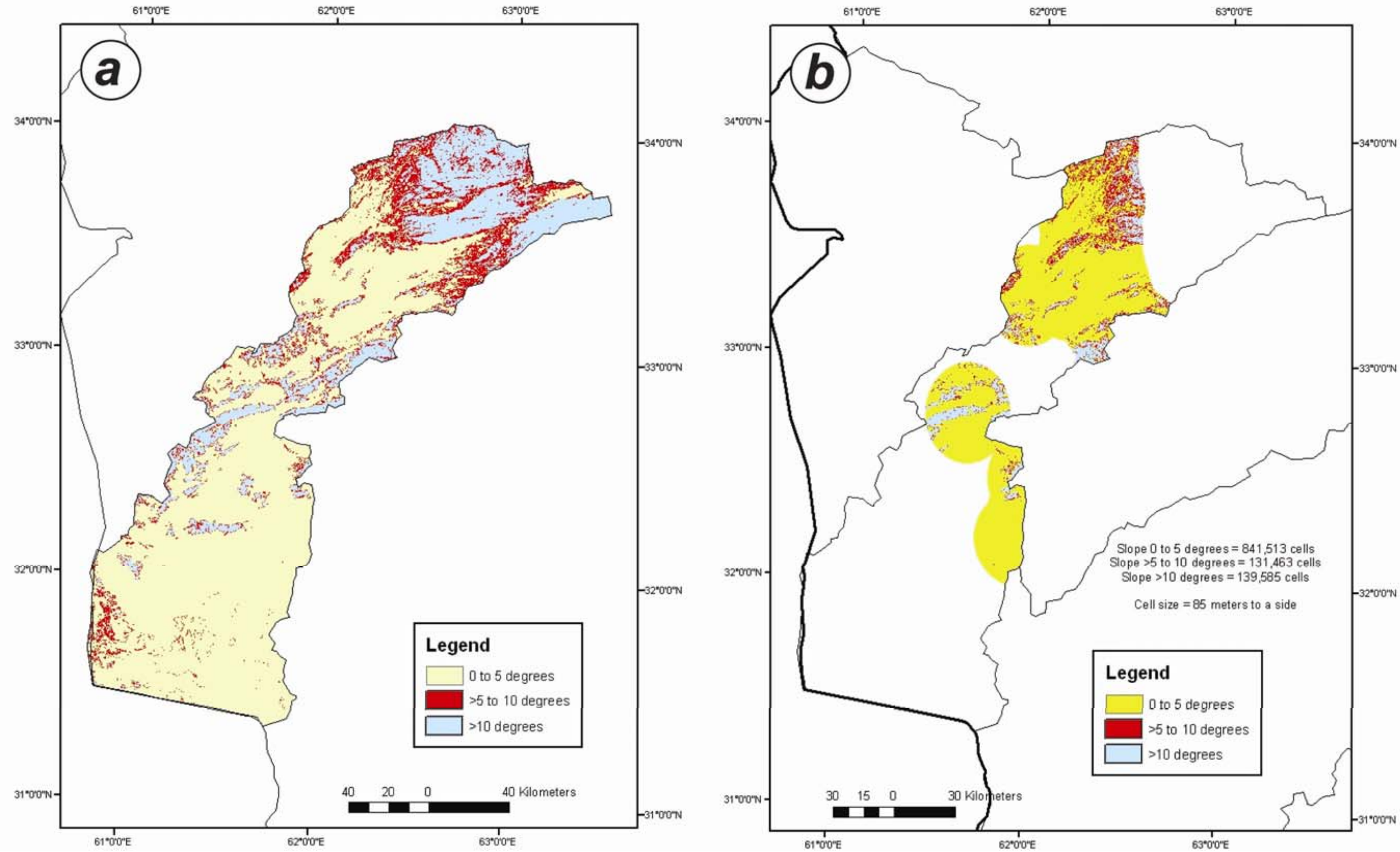

Figure 10.3-21. Outline of Basin 6 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits. Areas with slopes greater than 10 degrees (blue) are non-permissive. (*a*) entire basin. (*b*) areas within 25 kilometer buffer zone around towns and along roads. Slopes between 0-5 degrees (yellow), and 5-10 degrees (red) are permissive for fluvial sand and gravel deposits and those greater than 10 degrees (blue) are not permissive.

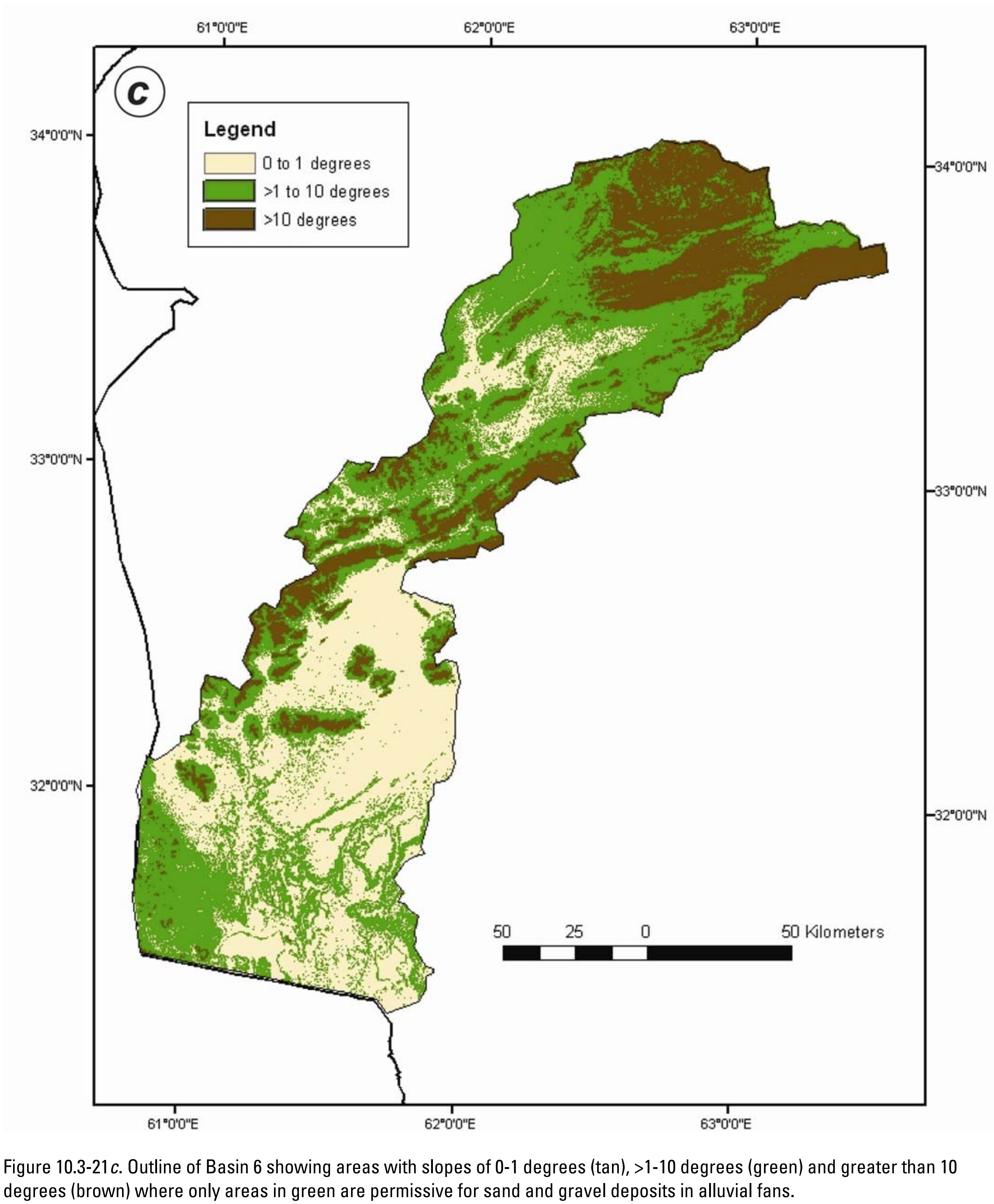

Figure 10.3-21*c*. Outline of Basin 6 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

***Needs to improve assessment*—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

***Optimistic factors*—**Of the Quaternary sediments in tracts in this basin, 39 percent are defined as an alluvium unit in which the gravel content is greater than that for silt or clay. This unit is highly likely to be the host of readily recognizable fluvial sand and gravel deposits. Alluvial fans and colluvium with gravel and sand greater than silt and clay along mountain fronts are in 32 percent of the tract areas with Quaternary sediments with slopes less than or equal to 10 degrees and can also be a source of fluvial sand and gravel deposits downstream from these features. However, alluvial fan sand and gravel deposits are separately assessed (see below).

***Pessimistic factors*—**Application of the uniform tract boundary criteria based on topographic slope to this basin resulted in 51 percent of the cells being on non-Quaternary rocks. This indicates that we may have produced a cumulative permissive tract area that is too large. Quaternary sediments in this tract include units that are 1) highly unlikely sources of sand and gravel or 2) overburden that obscure sand and gravel deposits at depth. These units include those dominated by loess (15 percent of the tract areas), and those with mud, silt and clay greater than sand (8.2 percent) and playa deposits (6.2 percent).

***Estimated number of undiscovered deposits*—**For the assessment of the slope-defined tracts in Basin 6 (fig. 10.3-21), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-16) All tracts, which have a total cumulative area of 20,000 km^2 within the basin, are evaluated simultaneously. Because information about discovered deposits is limited, the estimated number of deposits and their associated probability given in the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-16. Estimated number of fluvial sand and gravel deposits in Basin 6, both discovered and undiscovered, calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	7
80 % chance of at least	9
70 % chance of at least	13
60 % chance of at least	16
50 % chance of at least	55
40 % chance of at least	78
30 % chance of at least	106
20 % chance of at least	173
10 % chance of at least	239

***Monte Carlo Simulation results*—**There are three chances in four that the sand and gravel resources in Basin 6 in fluvial sand and gravel deposits will be equal to or greater than 200 million m^3, and there is an even chance that there will be equal to or greater than 1,000 million m^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 2,700 million m^3 (fig. 10.3-22).

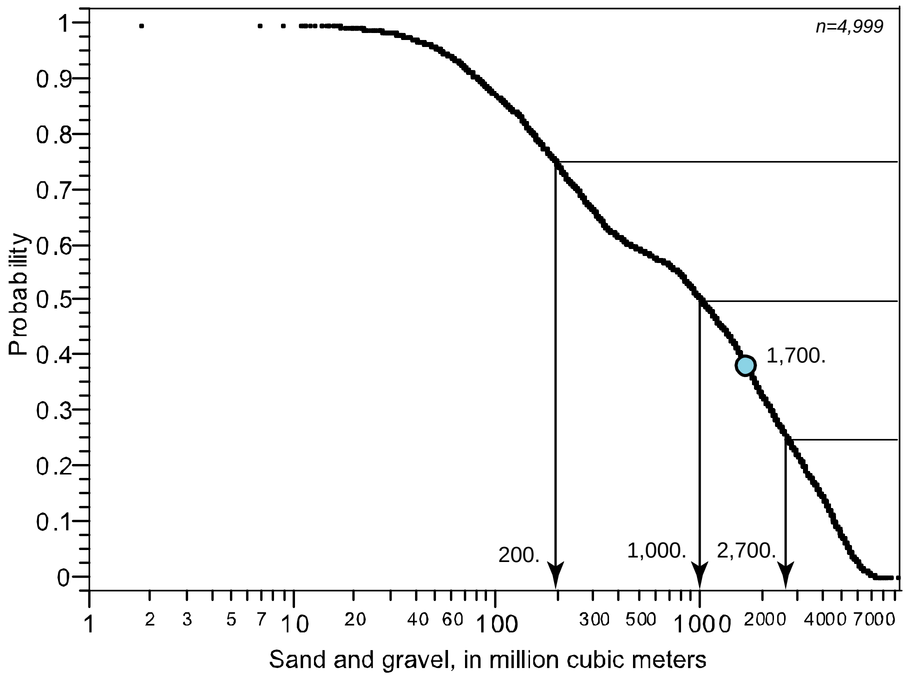

Figure 10.3-22. Distribution of sand and gravel resources in fluvial sand and gravel deposits in tracts in Basin 6. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Estimated number of undiscovered deposits in buffer zones—For the assessment of the slope-defined buffer zones in Basin 6 tracts (fig. 10.3-21*b*), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-17) from the permissive area of 7,000 km^2. All buffer zones in the basin are evaluated simultaneously. The estimated number of deposits and their associated probability given by the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees. Note that the same limitation related to Quaternary geology is also applicable to tracts within buffer zones.

Table 10.3-17. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zone tracts calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	2
80 % chance of at least	3
70 % chance of at least	5
60 % chance of at least	6
50 % chance of at least	19
40 % chance of at least	27
30 % chance of at least	37
20 % chance of at least	61
10 % chance of at least	84

Monte Carlo Simulation result for undiscovered deposits in buffer zones—There are three chances in four that the sand and gravel resources in Basin 6 in fluvial sand and gravel deposits will be equal to or greater than 51 million m^3. There is an even chance that there will be equal to or greater than 300 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 940 million m^3 (fig. 10.3-23). Proximity to towns and major roads suggests a portion of the estimated sand and gravel resources may have already been consumed.

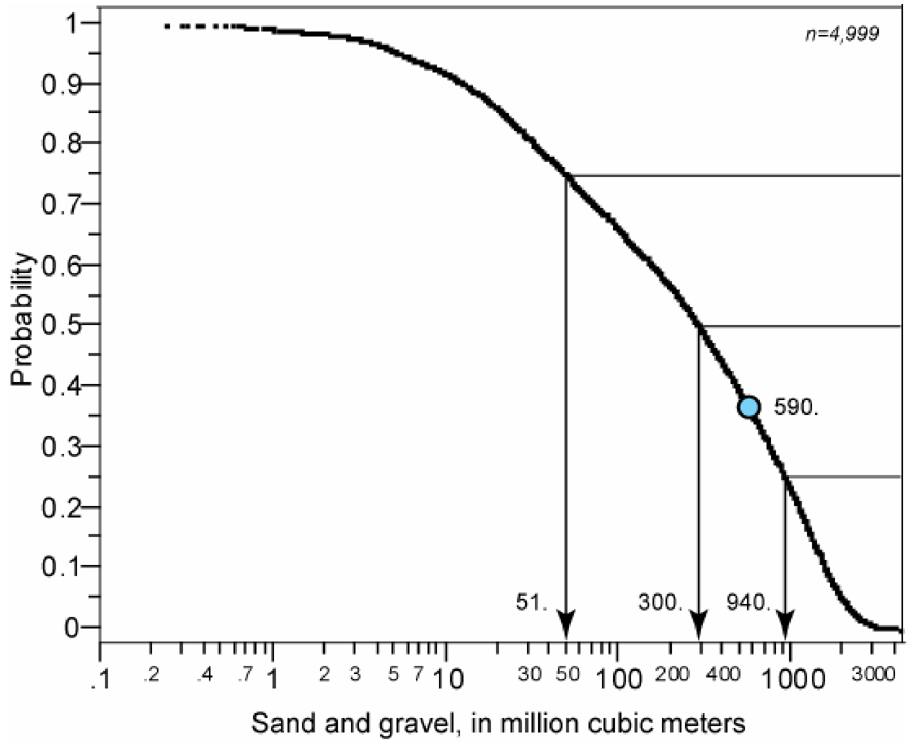

Figure 10.3-23. Distribution of sand and gravel resources in fluvial sand and gravel deposits in buffer zones in Basin 6 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of alluvial fan sand and gravel resources in Basin 6

***Deposit type*—**Alluvial fan sand and gravel

***Age of mineralization*—**Quaternary, better quality material is in younger alluvial fan sand and gravel deposits.

***Example deposits types*—**There are no reported examples of alluvial fan sand and gravel deposits in tracts in this basin. Most alluvial fan sand and gravel deposits are worked without record in many part of the world, and this is true in Afghanistan.

***Exploration history*—**The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified and produced in the tracts in this basin. Alluvial fan sand and gravel deposits may not be near towns unless a roadway passes up the fan slope into the stream basin in the adjacent mountains. Neither the intensity nor the extent of sand and gravel exploration is known. However, exploitation of deposits near major roads is expected given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. However, some of these alluvial sand and gravel deposits are near roads and other points of consumption. These deposits may have been exploited, but most of the resource is likely untouched. Deposits of this type are likely rare within buffer zones (as defined below) found near towns and roads and are not considered in this assessment.

***Tract boundary criteria*—**Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-21*c*).

***Needs to improve assessment*—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, former USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

***Optimistic factors*—**The steeper terrain and mountain fronts usually associated with alluvial fans are found widely in this basin. Also, 4,200 km^2 of the basin is map as fan alluvium and colluvium with gravel, sand and clay (Doebrich and Wahl, 2006). This unit comprises 47 percent of the Quaternary units on slopes less than 10 degrees in Basin 6. Also, alluvial fans are clearly recognized on topographic sheets (scale 1: 200,000).

***Pessimistic factors*—**Alluvial fans are often problematic as they are commonly poorly sorted with large amounts of unsuitable clay and silt interbedded or directly mixed with the sand and gravel. A number of the mountain ranges seen in this basin have alluvial aprons but lack adequate-sized mountain basins needed for development of alluvial fans downstream. While a number of fans may be present, only a small portion of them are likely to contain sand and gravel deposits suitable for development.

***Estimated number of undiscovered deposits*—**The number of alluvial fans was subjectively estimated. Because information about discovered deposits is not available, the estimated number of deposits and their associated probability for MCS are for both discovered and undiscovered deposits and are given together with an associated probability (table 10.3-18).

Table 10.3-18. Estimated number of sand and gravel deposits both discovered and undiscovered, in alluvial fans in Basin 6.

Probability level	Number of deposits
90 % chance of at least	0
70 % chance of at least	0
50 % chance of at least	0
30 % chance of at least	1
10 % chance of at least	2

***Monte Carlo Simulation results for alluvial fan deposits*—**There is one chance in four that the amount of sand and gravel resources will equal or be greater than 94 million m^3. (fig. 10.3-24).

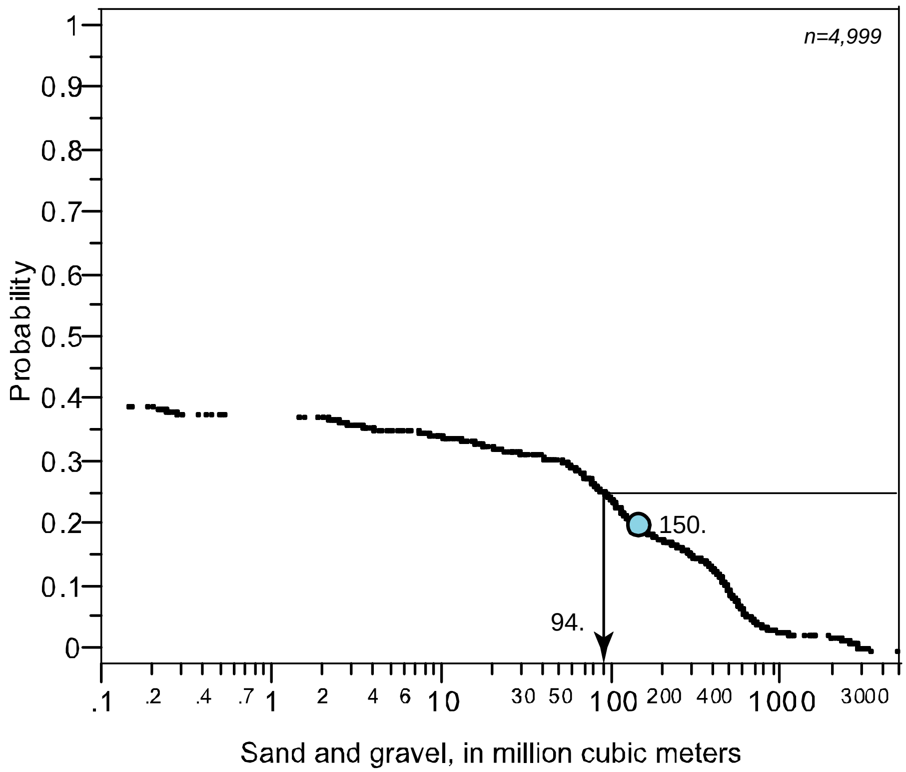

Figure 10.3-24. Distribution of sand and gravel resources in sand and gravel deposits in alluvial fans in Basin 6. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of fluvial sand and gravel resources in Basin 7

Introduction—Basin 7 runs east west across northwest Afghanistan (fig. 10.3-1) bounded by the Iranian border on the west. The basin includes the Harirut River and the towns of Herat in the west and Chaghcharan in the east. The areas permissive for sand and gravel are primarily in the western part of the basin.

Deposit type—Fluvial sand and gravel

Age of mineralization—Quaternary, as a rule, better quality material is in younger fluvial sand and gravel deposits.

Example deposits types—There are no examples of sand and gravel deposits in tracts in Basin 7. No official records of work in sand and gravel deposits are kept in many parts of the world, and this is true in Afghanistan. Basin 7 contains the Harirut River and its tributaries and fluvial sand and gravel deposits can be expected to be present along those waterways.

Exploration history—No sites have been reported as a sources of sand and gravel in Basin 7. The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified in the basin and that production likely has been wide spread. A major highway (A1) runs north across the basin at Herat and some nearby deposits are highly likely to have been worked for sand and gravel during its construction and ongoing maintenance. However, neither the intensity nor the extent of sand and gravel exploration is known. Exploitation of deposits near major roads is likely given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. Sand and gravel is produced near the point of consumption so locations in regions at some distance from existing roads and towns are likely untouched. Deposits within buffer zones (as defined below), which are near towns and roads are more likely to have been explored.

Tract boundary criteria in basins**—**See uniform tract boundary criteria based on topographic slope used for both basins and buffer zones as noted in the introductory discussion above. Sixty percent of Basin 7, or 22,000 km^2, is permissive for fluvial sand and gravel (fig. 10.3-25)

Buffer zone criteria**—**Buffer zones are defined as extending 25 km around towns and along both sides of major roads. Buffered areas (fig. 10.3-25*b*) with slopes less than 10 degrees have a cumulative area of 12,000 km^2.

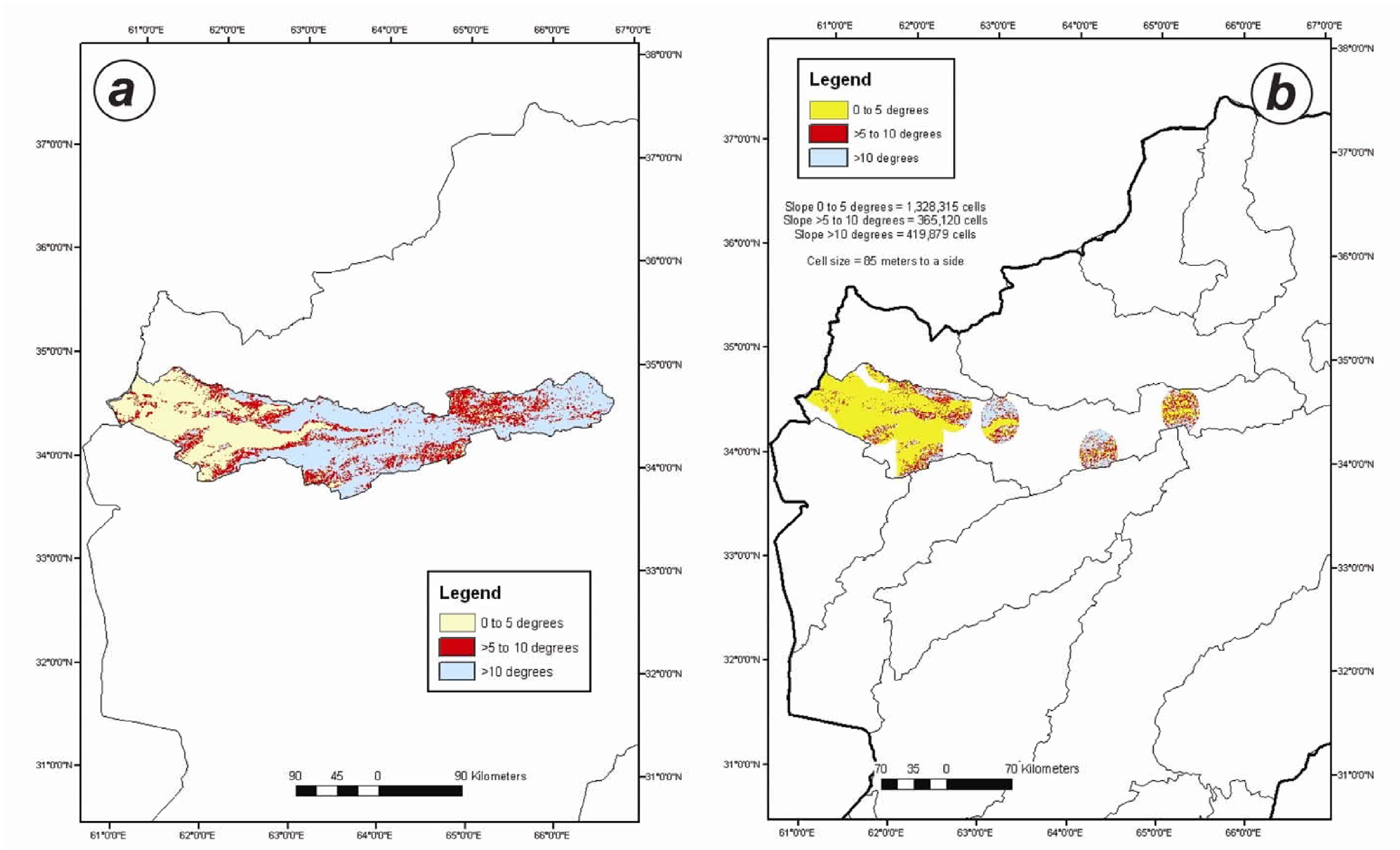

Figure 10.3-25. Outline of Basin 7 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits. Areas with slopes greater than 10 degrees (blue) are non-permissive. (*a*) entire basin. (*b*) areas within 25 kilometer buffer zone around towns and along roads. Slopes between 0-5 degrees (yellow), and 5-10 degrees (red) are permissive for fluvial sand and gravel deposits and those greater than 10 degrees (blue) are not permissive.

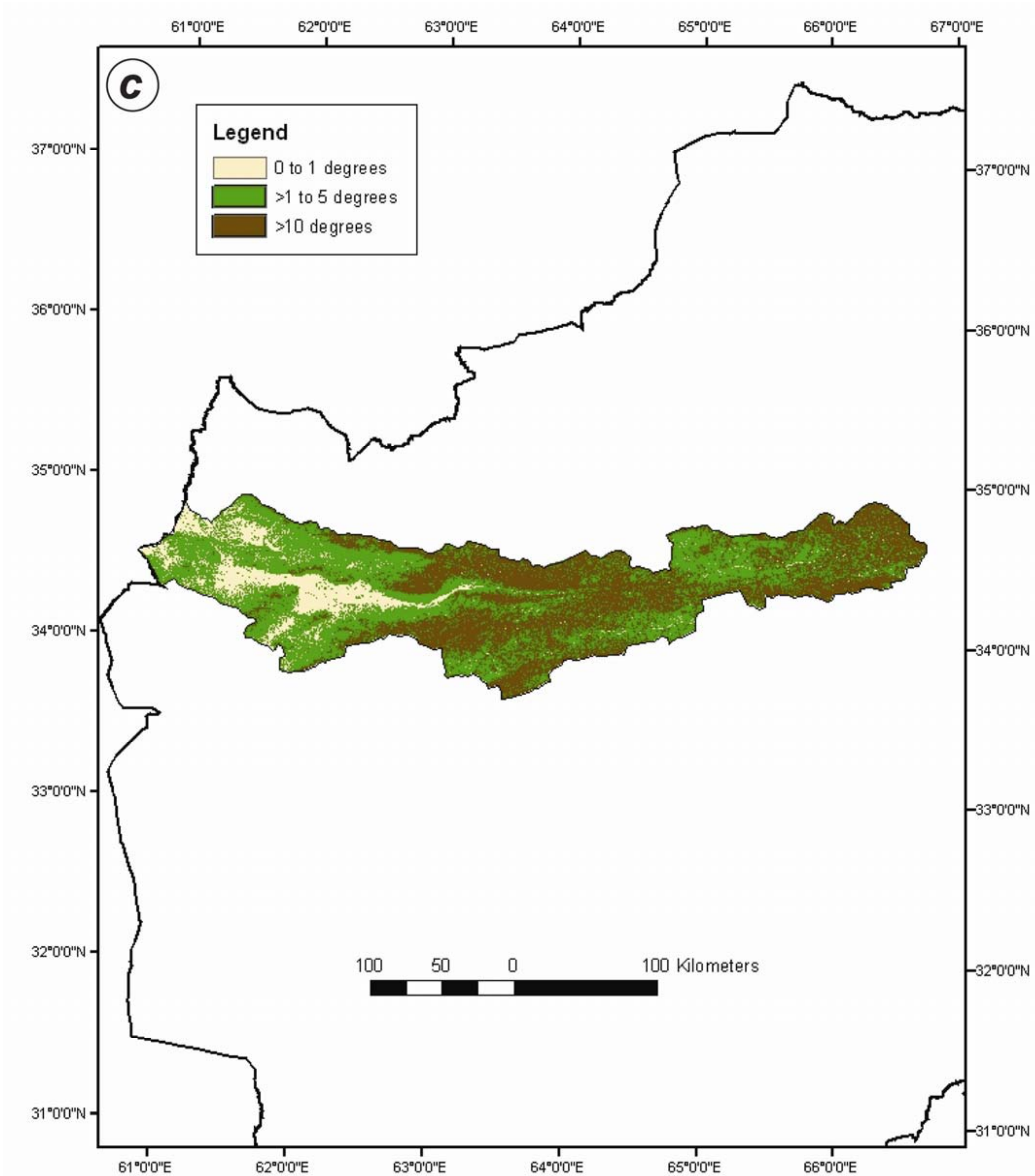

Figure 10.3-25*c*. Outline of Basin 7 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

***Needs to improve assessment*—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

***Optimistic factors*—**Of the Quaternary sediments in tracts in this basin, 55 percent are defined as an alluvium unit in which the gravel content is greater than that of silt or clay. This unit is highly likely to host readily recognizable fluvial sand and gravel deposits. Alluvial fans and colluvium with gravel and sand greater than silt and clay along mountain fronts are in 27 percent of the tract areas with Quaternary sediments and can also be a source of fluvial sand and gravel deposits downstream from these features. However, alluvial fan sand and gravel deposits are separately assessed (see below).

***Pessimistic factors*—**Application of the uniform tract boundary criteria based on topographic slope to this basin resulted in 53 percent of the cells being on non-Quaternary rocks. This indicates that we may have produced a cumulative permissive tract area that is too large. Other Quaternary sediments in this tract include a loess-dominated unit that is 1) a highly unlikely source of sand and gravel as well as 2) an overburden that may obscure sand and gravel deposits at depth. The unit dominated with loess includes 18 percent of the Quaternary sediments in permissive tracts.

***Estimated number of undiscovered deposits*—**For the assessment of the slope-defined tracts in Basin 7 (fig. 10.3-25), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-19) All tracts, which have a total cumulative area of 22,000 km^2 within the basin, are evaluated simultaneously. Because information about discovered deposits is limited, the estimated number of deposits and their associated probability given in the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-19. Estimated number of fluvial sand and gravel deposits in Basin 7, both discovered and undiscovered, calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	7
80 % chance of at least	9
70 % chance of at least	14
60 % chance of at least	17
50 % chance of at least	59
40 % chance of at least	84
30 % chance of at least	114
20 % chance of at least	186
10 % chance of at least	256

***Monte Carlo Simulation results*—**There are three chances in four that the sand and gravel resources in Basin 7 in fluvial sand and gravel deposits will be equal to or greater than 210 million m^3, and there is an even chance that there will be equal to or greater than 1,100 million m^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 2,800 million m^3 (fig. 10.3-26).

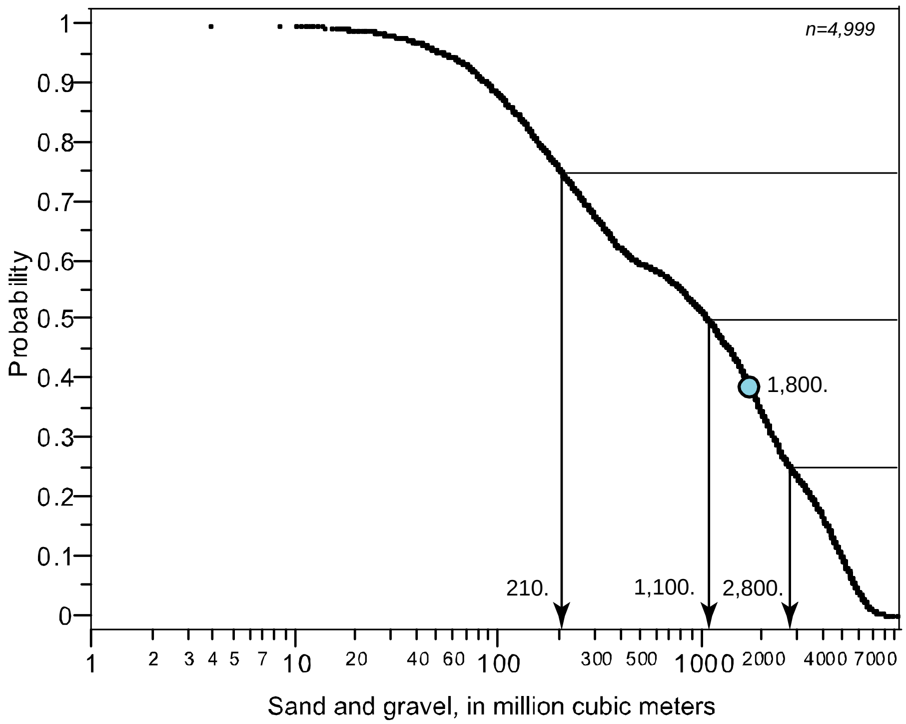

Figure 10.3-26. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 7 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Estimated number of undiscovered deposit buffer zones—For the assessment of the slope-defined tracts in buffer zones in Basin 7 (fig. 10.3-25*b*), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-20) from the permissive area of 12,000 km^2. All buffer zones in the basin are evaluated simultaneously. The estimated number of deposits and their associated probability given by the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees. The Quaternary geology in buffer zones contains considerable areas of fan alluvium and colluvium and lesser areas of the more promising alluvium units that are more likely to contain fluvial sand and gravel deposits. Loess, that will obscure undiscovered deposits, is found in parts of the buffer zones.

Table 10.3-20. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zone tracts calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	4
80 % chance of at least	5
70 % chance of at least	8
60 % chance of at least	10
50 % chance of at least	34
40 % chance of at least	48
30 % chance of at least	65
20 % chance of at least	105
10 % chance of at least	146

Monte Carlo Simulation result for undiscovered deposits in buffer zones—There are three chances in four that the sand and gravel resources in Basin 7 in fluvial sand and gravel deposits will be equal to or greater than 71 million m^3. There is an even chance that there is equal to or greater than 390 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 1,100 million m^3 (fig. 10.3-27). Proximity to towns and major roads suggests a portion of the estimated sand and gravel resources may have already been consumed.

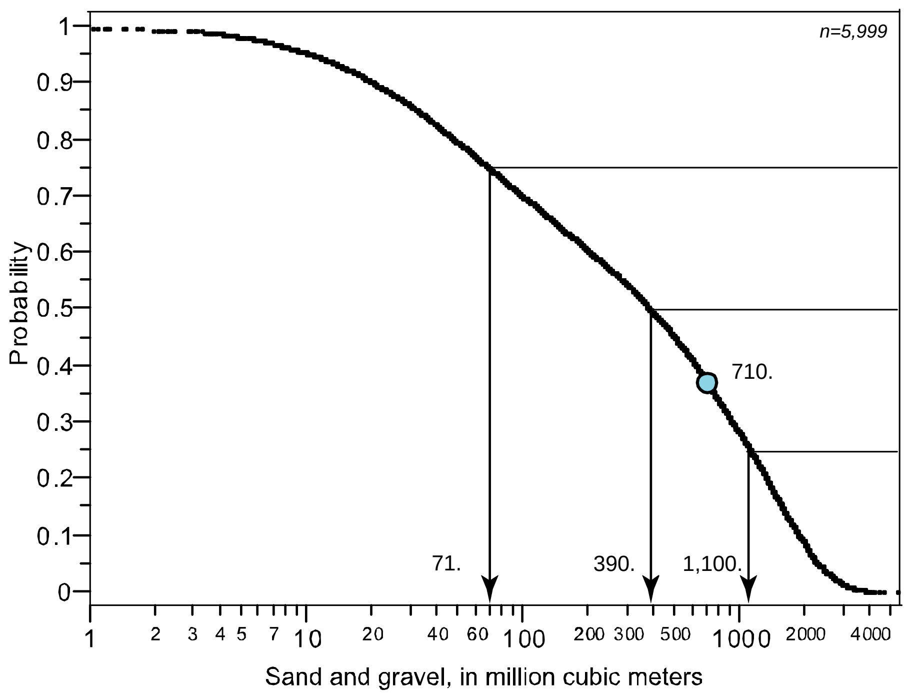

Figure 10.3-27. Distribution of sand and gravel resources in fluvial sand and gravel deposits in tracts in Basin 7 buffer zones. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of alluvial fan sand and gravel resources in Basin 7

***Deposit type*—**Alluvial fan sand and gravel

***Age of mineralization*—**Quaternary, better quality material is in younger alluvial fan sand and gravel deposits.

***Example deposits types*—**There are no reported examples of alluvial fan sand and gravel deposits in tracts in this basin. Most alluvial fan sand and gravel deposits are worked without record in many part of the world, and this is true in Afghanistan.

***Exploration history*—**The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified and produced in the tracts in this basin. Alluvial fan sand and gravel deposits are usually not found near towns unless a roadway passes up the fan slope into the stream basin in the adjacent mountains. Neither the intensity nor the extent of sand and gravel exploration is known. However, exploitation of deposits near major roads is likely given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. However, some of these alluvial sand and gravel deposits are near roads and other points of consumption. Therefore, some of these deposits may have been exploited, but most of the resource is likely untouched. Deposits of this type are infrequently found within buffer zones (as defined below) that are near towns and roads, and alluvial fan deposits are not considered in this part of the assessment.

Tract boundary criteria—Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-25*c*).

Needs to improve assessment—Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, former USSR engineers, and construction contractors who have built roads in Afghanistan would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors—The steeper terrain and mountain fronts usually associated with alluvial fans are found widely in this basin. Also, 2,800 km^2 of the basin is map as fan alluvium and colluvium with gravel, sand, and clay making up 27 percent of the Quaternary units within the permissive tracts for alluvial fan sand and gravel in which slopes are 10 degrees or less. A considerable number of the mountain ranges seen in this basin have adequate-sized mountain basins necessary for the development of alluvial fans downstream. Alluvial fans are clearly recognized on topographic sheets (scale 1: 200,000).

Pessimistic factors—Alluvial fans are often problematic as they are commonly poorly sorted with large amounts of unsuitable clay and silt interbedded or directly mixed with the sand and gravel. While a number of fans may be present, only a small portion of them is likely to contain sand and gravel deposits suitable for development.

Estimated number of undiscovered deposits—The number of alluvial fans was subjectively estimated. Because information about discovered deposits is not available, the estimated number of deposits and their associated probability for MCS are for both discovered and undiscovered deposits and are given together with an associated probability (table 10.3-21).

Table 10.3-21. Estimated number of fluvial sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 7.

Probability level	Number of deposits
90 % chance of at least	1
70 % chance of at least	2
50 % chance of at least	3
30 % chance of at least	4
10 % chance of at least	5

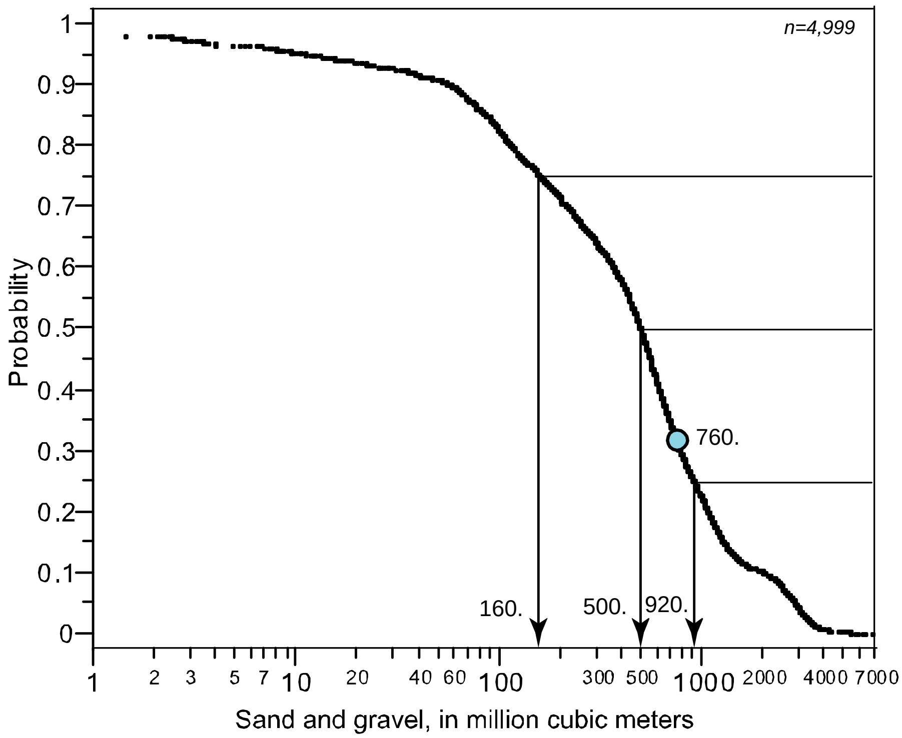

Figure 10.3-28. Distribution of sand and gravel resources in sand and gravel deposits in alluvial fans in Basin 7. Blue point on curve is the average of the 4,999 values generated by the MCS.

Monte Carlo Simulation results for alluvial fan deposits**—**There are three chances in four that the sand and gravel resources in Basin 7 in alluvial fan sand and gravel deposits will be equal to or greater than 160 million m^3. There is also an even chance that there will be equal to or greater than 500 million m^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 920 million m^3 (fig. 10.3-28).

Permissive tracts for fluvial sand and gravel resources in Basin 8

Introduction**—**Basin 8, with an estimated area of 31,000 km^2, is in northwestern Afghanistan and is bounded by Turkmenistan on the northwest (fig. 10.3-1) It includes the catchments of the Hilmand (also spelled Helmand or Helmund) River of which the Morghab River is an important tributary. The basin is partially bounded by the Torkestan Mountains on the north and the Safid Range in the south.

Deposit type**—**Fluvial sand and gravel

Age of mineralization**—**Quaternary; as a rule, better quality material is in younger fluvial sand and gravel deposits.

Example deposits types**—**There are no examples of sand and gravel deposits in tracts in Basin 8. No official records of work in sand and gravel deposits are kept in many parts of the world, and this is true in Afghanistan.

Exploration history**—**No sites have been reported as a sources of sand and gravel in Basin 8. The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified in the basin and that production likely has been wide spread. No major roads are recognized albeit a number of roads are present. It is highly likely that some sand and gravel may have extracted for their construction and ongoing maintenance. However, neither the intensity nor the extent of sand and gravel exploration is known. Exploitation of deposits near major roads is likely given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. Sand and gravel is produced near the point of consumption, so locations in regions at some distance from existing roads and towns are likely untouched. Deposits within buffer zones (as defined below), which are near towns in this basin are more likely to have been explored.

***Tract boundary criteria in basins*—**See uniform tract boundary criteria based on topographic slope used for both basins and buffer zones as noted in the introductory discussion above. Forty-five percent of Basin 8, or 14,000 km^2, is permissive for fluvial sand and gravel (fig. 10.3-29.)

***Buffer zone criteria*—**Buffer zones in tracts are defined as extending 25 km around towns and along both sides of major roads. Buffered areas (fig. 10.3-29*b*) with slopes less than 10 degrees have cumulative areas of 2,100 km^2.

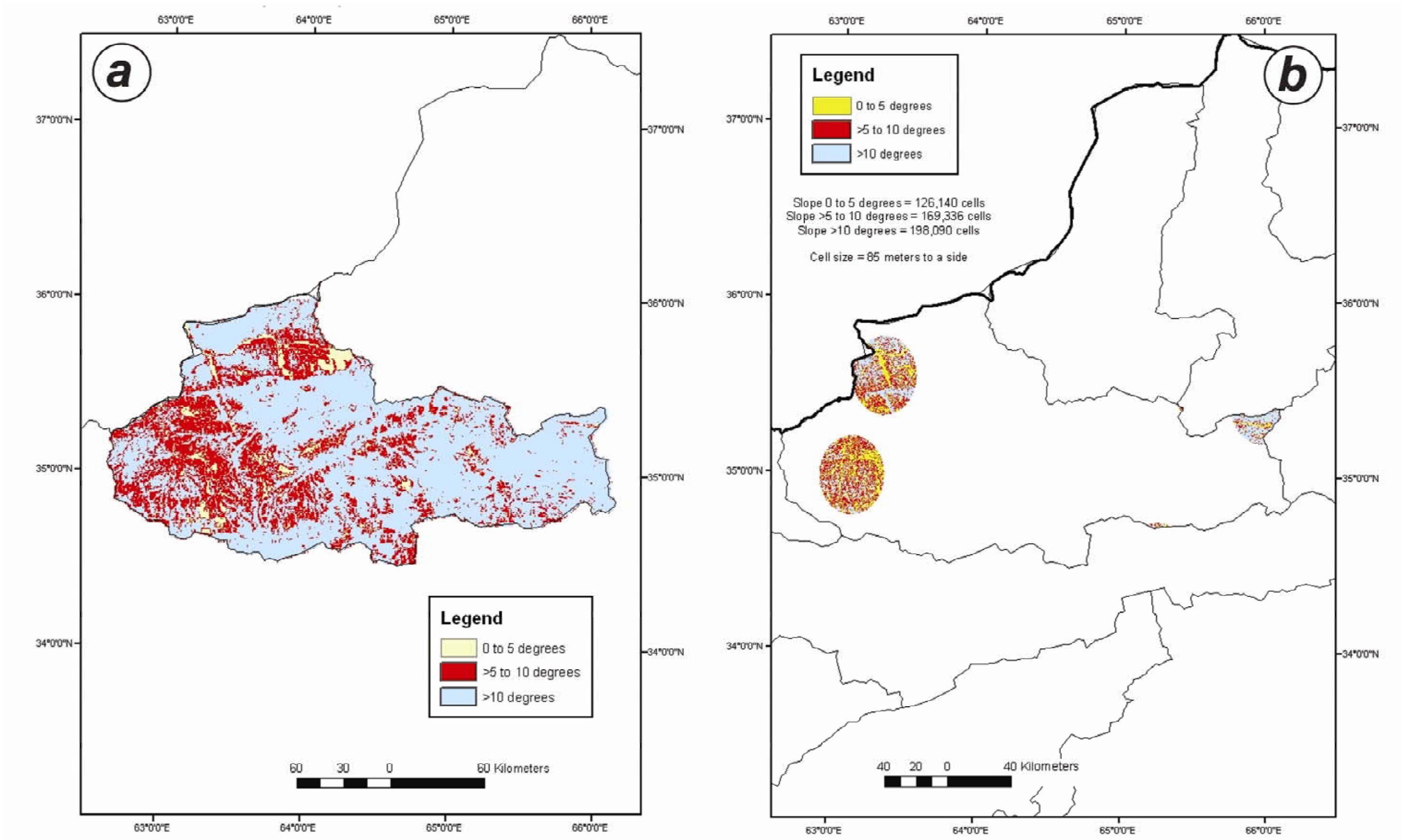

Figure 10.3-29. Outline of Basin 8 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits. Areas with slopes greater than 10 degrees (blue) are non-permissive (*a*) entire basin. (*b*) areas within 25 kilometer buffer zone around towns and along roads. Slopes between 0-5 degrees (yellow), and 5-10 degrees (red) are permissive for fluvial sand and gravel deposits and those greater than 10 degrees (blue) are not permissive.

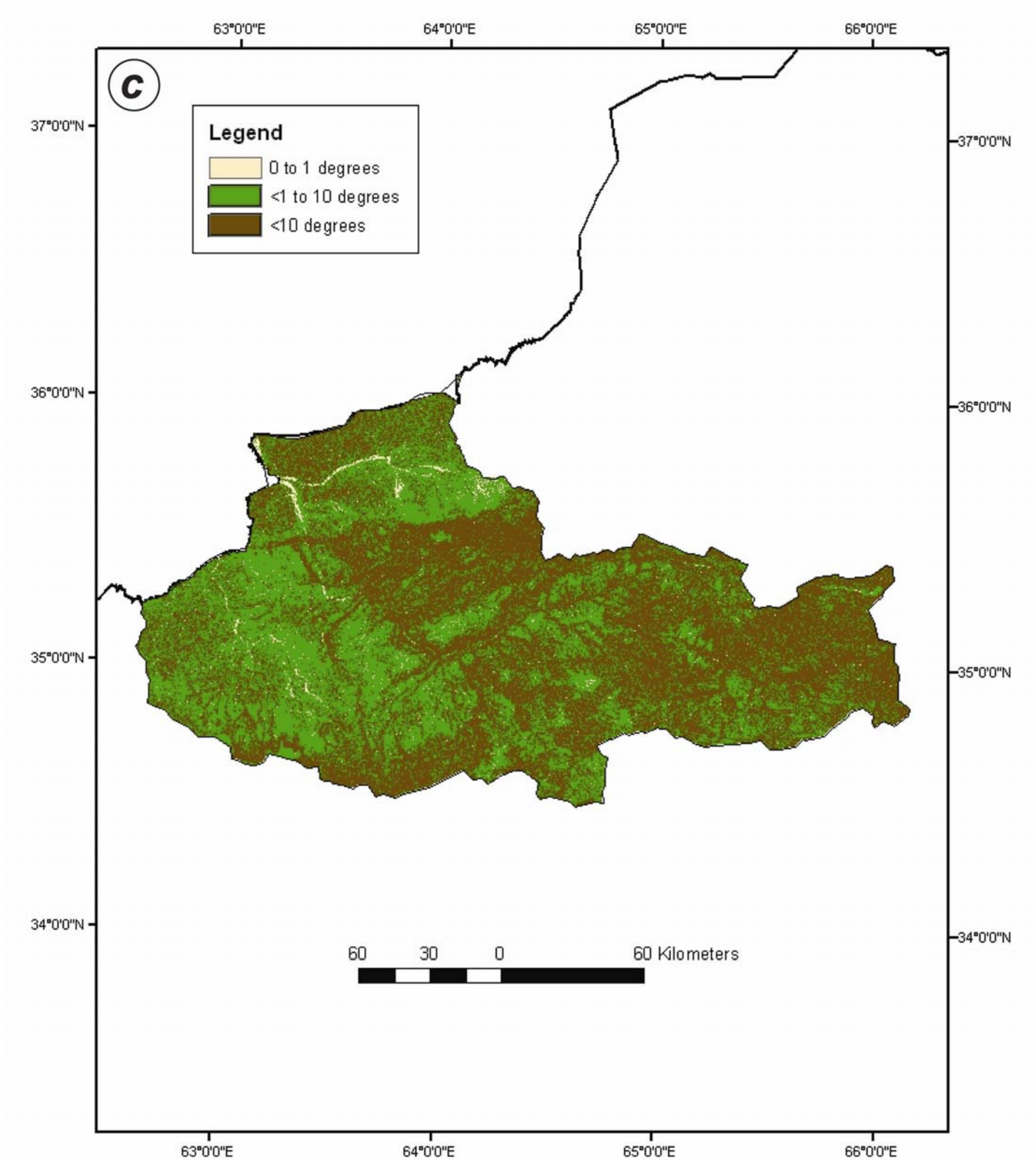

Figure 10.3-29*c*. Outline of Basin 8 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

***Needs to improve assessment*—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

***Optimistic factors*—**Of the Quaternary sediments in tracts in this basin, 49 percent are defined as an alluvium unit in which the gravel content is greater than that of silt or clay. This unit is highly likely to be the host of readily recognizable fluvial sand and gravel deposits. Alluvial fans and colluvium with gravel and sand greater than silt and clay along mountain fronts have been grouped with this unit. However, alluvial fan sand and gravel deposits are separately assessed (see below.)

***Pessimistic factors*—**Application of the uniform tract boundary criteria based on topographic slope to this basin resulted in 74 percent of the cells being on non-Quaternary rocks. This is among the largest values found in this study and indicates that we have likely produced a cumulative permissive tract area that is too large. Alluvial fan and colluvium have been also group with alluvium and will have inflated the size of this area as well. Other Quaternary sediments in this tract include loess dominated units that are 1) highly unlikely sources of sand and gravel or 2) overburden that obscure sand and gravel deposits at depth. The unit dominated by loess includes 51 percent of the Quaternary sediments in the permissive tracts.

***Estimated number of undiscovered deposits*—**For the assessment of the slope-defined tracts in Basin 8 (fig. 10.3-29*b*), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-22) All tracts, which have a total cumulative area of 14,000 km^2 within the basin, are evaluated simultaneously. Because information about discovered deposits is limited, the estimated number of deposits and their associated probability given in the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-22. Estimated number of fluvial sand and gravel deposits in Basin 8, both discovered and undiscovered, calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	5
80 % chance of at least	6
70 % chance of at least	10
60 % chance of at least	12
50 % chance of at least	40
40 % chance of at least	56
30 % chance of at least	77
20 % chance of at least	125
10 % chance of at least	172

***Monte Carlo Simulation results*—**There are three chances in four that the sand and gravel resources in Basin 8 in fluvial sand and gravel deposits will be equal to or greater than 130 million m^3, and there is an even chance that there will be equal to or greater than 760 million m^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 2,000 million m^3 (fig. 10.3-30).

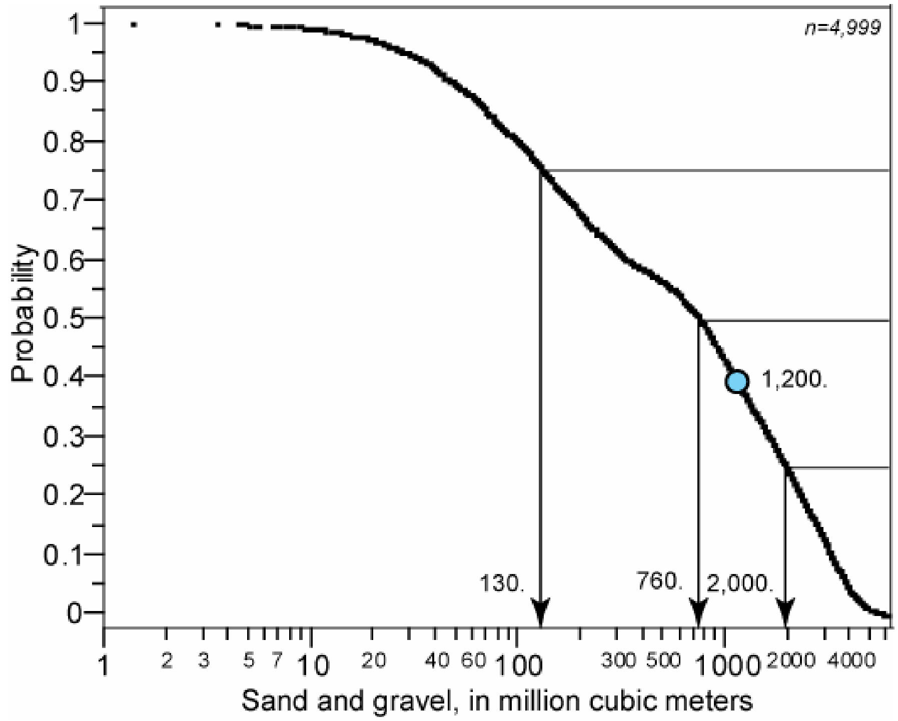

Figure 10.3-30. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 8 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

***Estimated number of undiscovered deposits in buffer zones*—**For the assessment of buffer zones in tracts in Basin 8 buffer zones (fig. 10.3-29*b*), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-23) from the permissive area of 2,100 km^2. All buffer zones in the basin are evaluated simultaneously. The estimated number of deposits and their associated probability given by the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees. The Quaternary geology in buffer zones contains possible areas of fan alluvium and colluvium together with areas of the more promising alluvium units that are more likely to contain fluvial sand and gravel deposits. Loess also found in the buffer zones and will obscure undiscovered deposits.

Table 10.3-23. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zone tracts calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	1
80 % chance of at least	1
70 % chance of at least	1
60 % chance of at least	2
50 % chance of at least	6
40 % chance of at least	8
30 % chance of at least	11
20 % chance of at least	18
10 % chance of at least	25

***Monte Carlo Simulation results for undiscovered deposits in buffer zones*—**There are three chances in four that the sand and gravel resources in Basin 8 in fluvial sand and gravel deposits will be equal to or greater than 7 million m^3. There is also an even chance that there will be equal to or greater than 70 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 250 million m^3 (fig. 10.3-31). Proximity to towns and major roads suggests a portion of the estimated sand and gravel resources may have already been consumed.

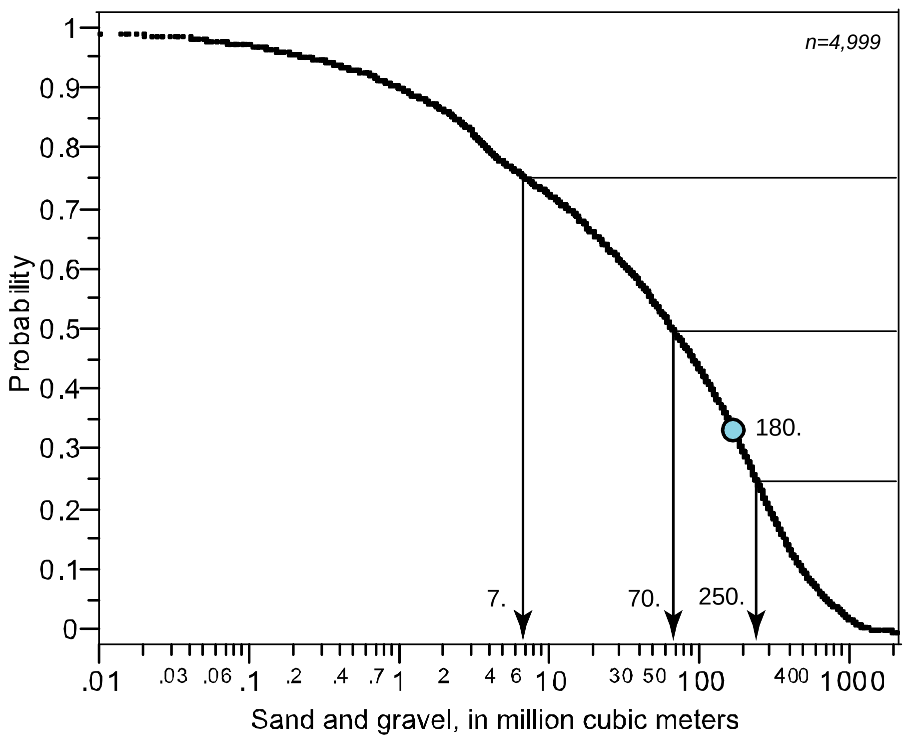

Figure 10.3-31. Distribution of sand and gravel resources in fluvial sand and gravel deposits in buffer zones in Basin 8 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Permissive tracts for alluvial fan sand and gravel resources in Basin 8.

Deposit type**—**Alluvial fan sand and gravel

Age of mineralization**—**Quaternary, better quality material is in younger alluvial fan sand and gravel deposits.

Example deposits types**—**There are no reported examples of alluvial fan sand and gravel deposits in tracts in this basin. No official records of work in sand and gravel deposits are kept in many part of the world, and this is also true in Afghanistan.

Exploration history**—**The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified and produced in the tracts in this basin. Alluvial fan sand and gravel deposits are usually not found near towns unless a roadway passes up the fan slope into the stream basin in the adjacent mountains. Neither the intensity nor the extent of sand and gravel exploration is known. However, exploitation of deposits near major roads is likely given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. However, few alluvial sand and gravel deposits are likely near roads and other points of consumption, so some of these deposits are likely untouched. Deposits of this type are likely rare within buffer zones (as defined below) found near towns and roads and these deposits are not considered in this assessment.

***Tract boundary criteria*—**Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-29*c*).

***Needs to improve assessment*—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, the former USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use. Distinguishing fan alluvium and colluvium would be helpful.

***Optimistic factors*—**The steeper terrain and mountain fronts usually associated with alluvial fans are found widely in this basin. Alluvial fans are clearly recognized on topographic sheets (scale 1: 200,000).

***Pessimistic factors*—**Alluvial fans are often problematic as they are commonly poorly sorted with large amounts of unsuitable clay and silt interbedded or directly mixed with the sand and gravel. Only a few fans are recognized on topographic sheets and only a small portion of them are likely to contain sand and gravel deposits suitable for development.

***Estimated number of undiscovered deposits*—**The number of alluvial fans was subjectively estimated. Because information about discovered deposits is not available, the estimated number of deposits and their associated probability for MCS are for both discovered and undiscovered deposits and are given together with an associated probability (table 10.3-24).

Table 10.3-24. Estimated number of sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 8.

Probability level	Number of deposits
90 % chance of at least	0
70 % chance of at least	0
50 % chance of at least	0
30 % chance of at least	0
10 % chance of at least	1

***Monte Carlo Simulation results for alluvial fan deposits*—**There is one chance in ten that the amount of sand and gravel resources will equal or be greater than 78 million m^3 (fig. 10.3-32).

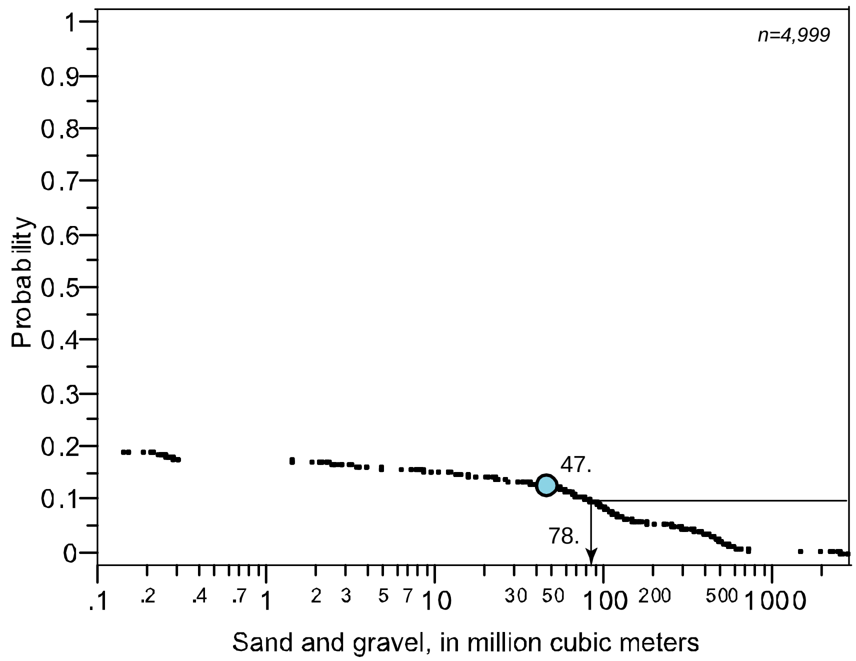

Figure 10.3-32. Distribution of sand and gravel resources in sand and gravel deposits in alluvial fans in Basin 8. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of fluvial sand and gravel resources in Basin 9

Introduction—Basin 9, with an estimated area of 17,000 km^2, is in north central Afghanistan and is bounded by Turkmenistan on the north and west (fig. 10.3-1) The basin includes the catchments of the Shirin Tagah (Shirin Tagab) River. The basin is partially bounded by the Torkestan Mountains on the south.

Deposit type—Fluvial sand and gravel

Age of mineralization—Quaternary; as a rule, better quality material is in younger fluvial sand and gravel deposits.

Example deposits types—There are no examples of sand and gravel deposits in tracts in Basin 9. No official records of work in sand and gravel deposits are kept in many parts of the world, and this is also true in Afghanistan. Fluvial sand and gravel deposits may be present along the waterways of the Shirin Tagah River and its tributaries.

Exploration history—No sites have been reported as a sources of sand and gravel in Basin 9. The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified in the basin and that production likely has been wide spread. One major road is recognized as well as a number of lesser roads. Therefore, it is highly likely that some sand and gravel may have been extracted for their construction and ongoing maintenance. However, neither the intensity nor the extent of sand and gravel exploration is known. Exploitation of deposits near major and other roads is likely given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. Sand and gravel is produced near the point of consumption, so locations in regions at some distance from existing roads and towns are likely untouched. Deposits within buffer zones (as defined below), which are near towns in this basin are more likely to have been explored.

***Tract boundary criteria in basins*—**See uniform tract boundary criteria based on topographic slope used for both basins and buffer zones as noted in the introductory discussion above. Sixty seven percent of Basin 9 , or 11,000 km^2, is permissive for fluvial sand and gravel deposits (fig. 10.3-33)

***Buffer zone criteria*—**Buffer zones are defined as extending 25 km around towns and along both sides of major roads. Buffered areas (fig. 10.3-33*b*) with slopes less than 10 degrees have a cumulative area of 7,100 km^2.

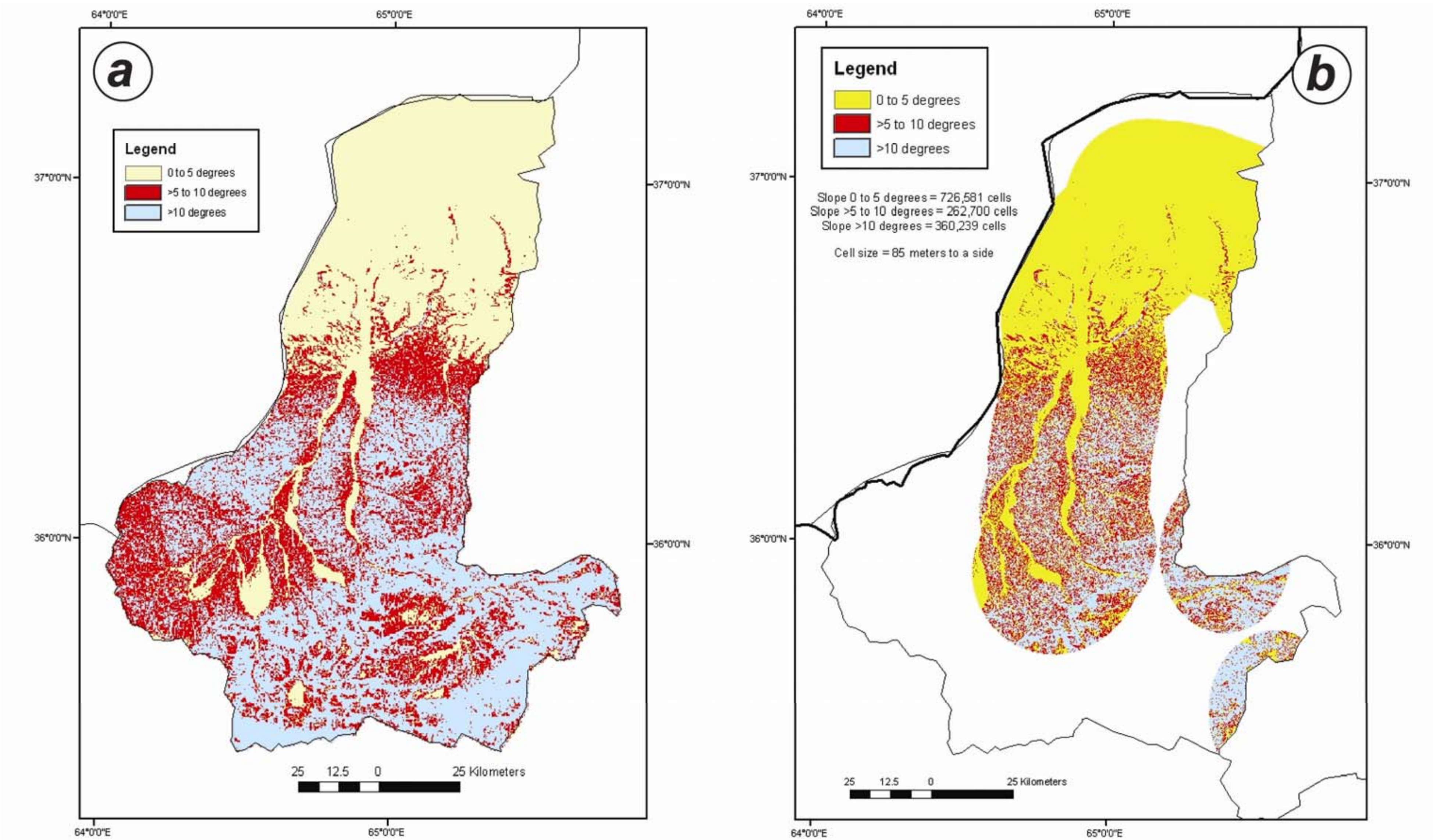

Figure 10.3-33. Outline of Basin 9 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits. Areas with slopes greater than 10 degrees (blue) are non-permissive. (*a*) entire basin. (*b*) areas within 25 kilometer buffer zone around towns and along roads. Slopes between 0-5 degrees (yellow), and 5-10 degrees (red) are permissive for fluvial sand and gravel deposits and those greater than 10 degrees (blue) are not permissive.

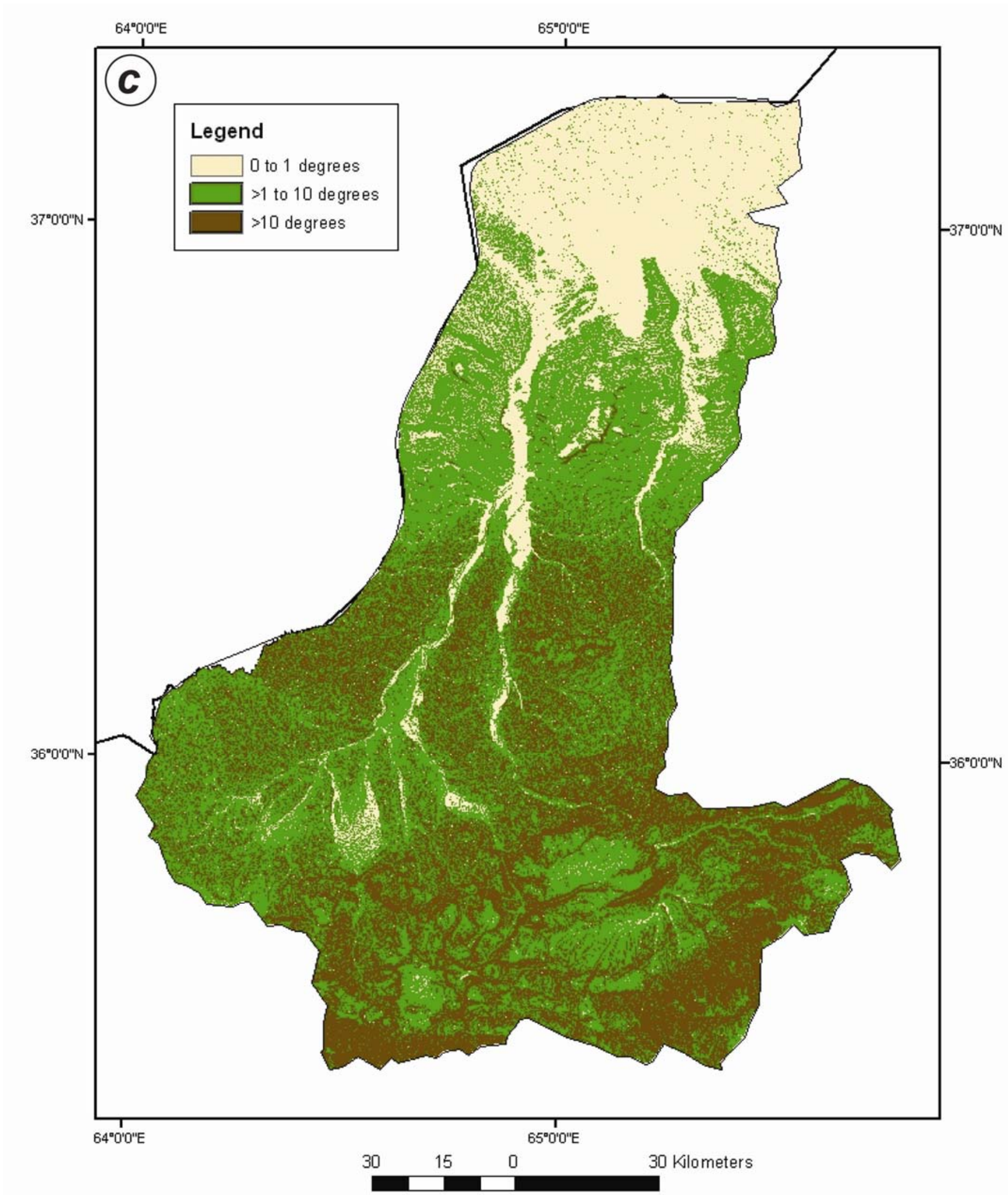

Figure 10.3-33*c*. Outline of Basin 9 showing areas with slopes of 0-5 degrees (tan), 1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

Needs to improve assessment**—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use. Separation of fan alluvium and colluvium from the rest of the alluvium unit would be particularly useful.

Optimistic factors**—**Of the Quaternary sediments in tracts in this basin, 70 percent are defined as an alluvium unit in which the gravel content is greater than that of silt or clay. This unit is highly likely to host readily recognizable fluvial sand and gravel deposits. Alluvial fans and colluvium with gravel and sand greater than silt and clay along mountain fronts have been grouped with this unit. However, alluvial fan sand and gravel deposits are separately assessed (see below).

Pessimistic factors**—**Application of the uniform tract boundary criteria based on topographic slope to this basin resulted in 28 percent of the cells being on non-Quaternary rocks. This is among the smallest values that we have produced, and it is likely the cumulative permissive tract area is nearly representative of the area that is a likely source of sand and gravel. One problem is that the alluvial fan and colluvium unit has been grouped with alluvium, and this will have inflated the size of area. Other Quaternary sediments in permissive tracts include units that are 1) highly unlikely sources of sand and gravel or 2) overburden that may obscure sand and gravel deposits at depth. These units include those dominated by sand (11 percent), loess (19 percent) and mud (0.5 percent) and cumulatively include 30 percent of all of the Quaternary sediments recognized in the permissive tract.

Estimated number of undiscovered deposits**—**For the assessment of the slope-defined tracts in Basin 9 (fig. 10.3-33*b*), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-25) All tracts, which have a total cumulative area of 11,000 km^2 within the basin, are evaluated simultaneously. Because information about discovered deposits is limited, the estimated number of deposits and their associated probability given in the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-25. Estimated number of fluvial sand and gravel deposits in Basin 9, both discovered and undiscovered, calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	4
80 % chance of at least	5
70 % chance of at least	7
60 % chance of at least	9
50 % chance of at least	31
40 % chance of at least	44
30 % chance of at least	60
20 % chance of at least	98
10 % chance of at least	135

Monte Carlo Simulation results**—**There are three chances in four that the sand and gravel resources in Basin 9 in fluvial sand and gravel deposits will be equal to or greater than 99 million m^3, and there is an even chance that there will be equal to or greater than 540 million m^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 1,500 million m^3 (fig. 10.3-34).

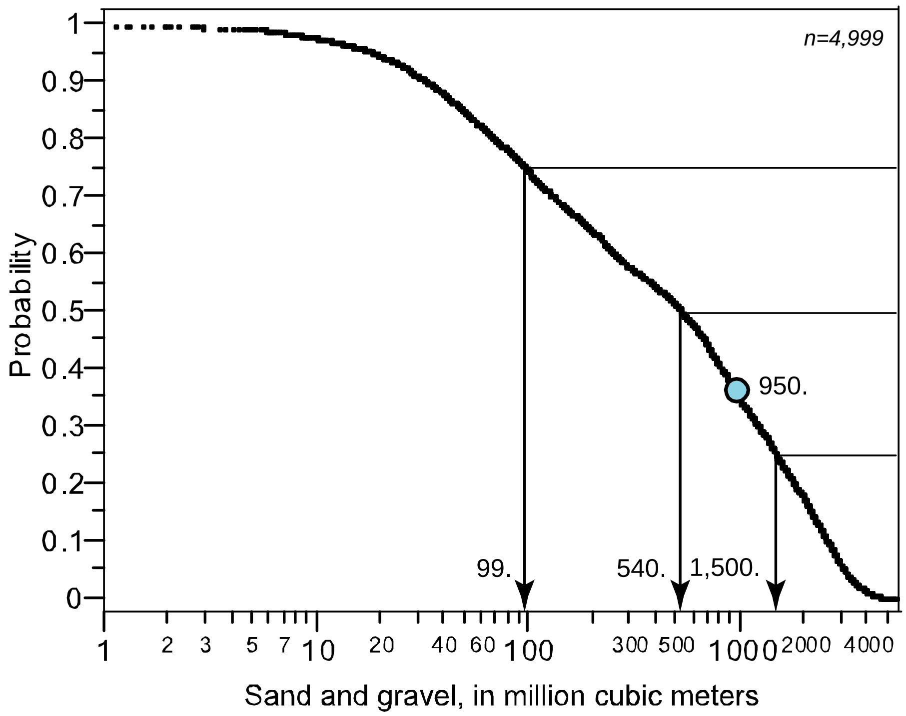

Figure 10.3-34. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 9 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Estimated number of undiscovered deposits in buffer zones—For the assessment of Basin 9 buffer zones (fig. 10.3-33b), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-26) from the permissive area of 7,100 km^2. All buffer zones in tracts in the basin are evaluated simultaneously. The estimated number of deposits and their associated probability given by the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees. The Quaternary geology in buffer zones contains possible areas of fan alluvium and colluvium together with areas of the more promising alluvium units that are more likely to contain fluvial sand and gravel deposits. Loess, sand and mud dominated units are in parts of the permissive tracts within buffer zones and those units might obscure undiscovered deposits.

Table 10.3-26. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zone tracts calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	2
80 % chance of at least	3
70 % chance of at least	5
60 % chance of at least	6
50 % chance of at least	20
40 % chance of at least	28
30 % chance of at least	38
20 % chance of at least	62
10 % chance of at least	85

***Monte Carlo Simulation results for undiscovered deposits in buffer zones*—**There are three chances in four that the sand and gravel resources in Basin 9 in fluvial sand and gravel deposits will be equal to or greater than 55 million m^3. There is also an even chance that there will be equal to or greater than 360 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 1,000 million m^3 (fig. 10.3-35). Proximity to towns and major roads suggests a portion of the estimated sand and gravel resources may have already been consumed.

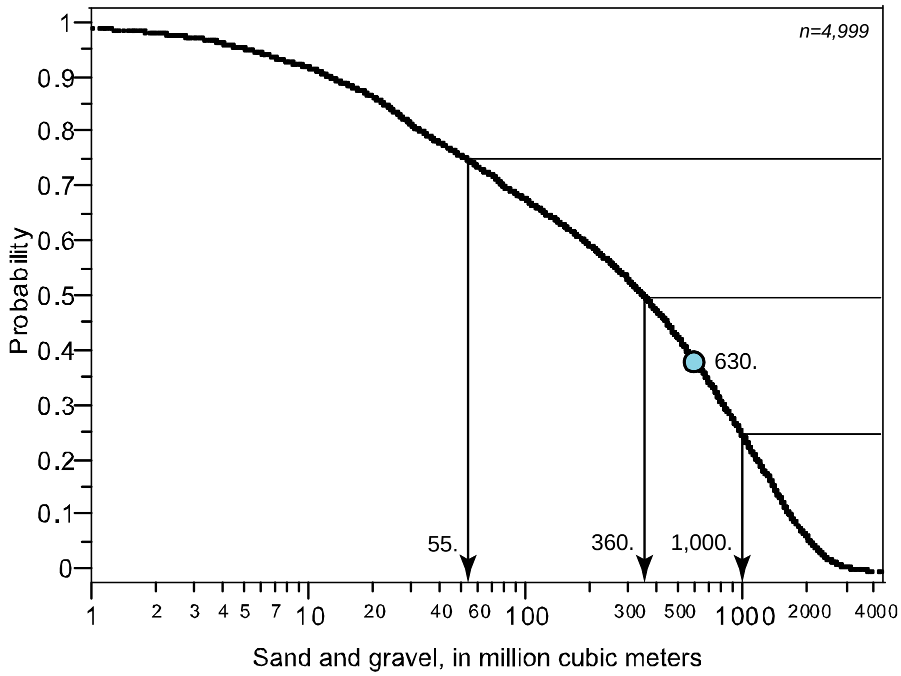

Figure 10.3-35. Distribution of sand and gravel resources in fluvial sand and gravel deposits in buffer zones in Basin 9 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of alluvial fan sand and gravel resources in Basin 9

Deposit type—Alluvial fan sand and gravel

***Age of mineralization*—**Quaternary, better quality material is in younger alluvial fan sand and gravel deposits.

***Example deposits types*—**There are no reported examples of alluvial fan sand and gravel deposits in tracts in this basin. No official records of work in sand and gravel deposits are kept in many part of the world, and this is also true in Afghanistan.

***Exploration history*—**The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified and produced in the tracts in this basin. Alluvial fan sand and gravel deposits are usually not found near towns unless a roadway passes up the fan slope into the stream basin in the adjacent mountains, which may be true in this basin. Neither the intensity nor the extent of sand and gravel exploration is known. However, exploitation of deposits near major roads is likely given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. However, some of these alluvial sand and gravel deposits are near roads and other points of consumption, so some of these deposits may have been exploited.

Therefore, most of the resource is likely untouched. Deposits of this type are likely rare within buffer zones (as defined below) that are near towns and roads and are not considered in this assessment.

***Tract boundary criteria*—**Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-33*c*).

***Needs to improve assessment*—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, the former USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

***Optimistic factors*—**The steeper terrain and mountain fronts usually associated with alluvial fans are found widely in this basin. Alluvial fans are clearly recognized on topographic sheets (scale 1:200,000).

***Pessimistic factors*—**Alluvial fans are often problematic as they are commonly poorly sorted with large amounts of unsuitable clay and silt interbedded or directly mixed with the sand and gravel. Only a few of fans are recognized on topographic sheets and only a small portion of them are likely to contain sand and gravel deposits suitable for development.

***Estimated number of undiscovered deposits*—**The number of alluvial fans was subjectively estimated. Because information about discovered deposits is not available, the estimated number of deposits and their associated probability for MCS are for both discovered and undiscovered deposits and are given together with an associated probability (table 10.3-27).

Table 10.3-27. Estimated number of sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 9.

Probability level	Number of deposits
90 % chance of at least	0
70 % chance of at least	0
50 % chance of at least	1
30 % chance of at least	1
10 % chance of at least	2

***Monte Carlo Simulation results for alluvial fan deposits*—**There is a even chance that the amount of sand and gravel resources will equal or be greater than 13 million m^3 and one chance in four that it will be equal or greater than 180 million m^3.(fig. 10.3-36).

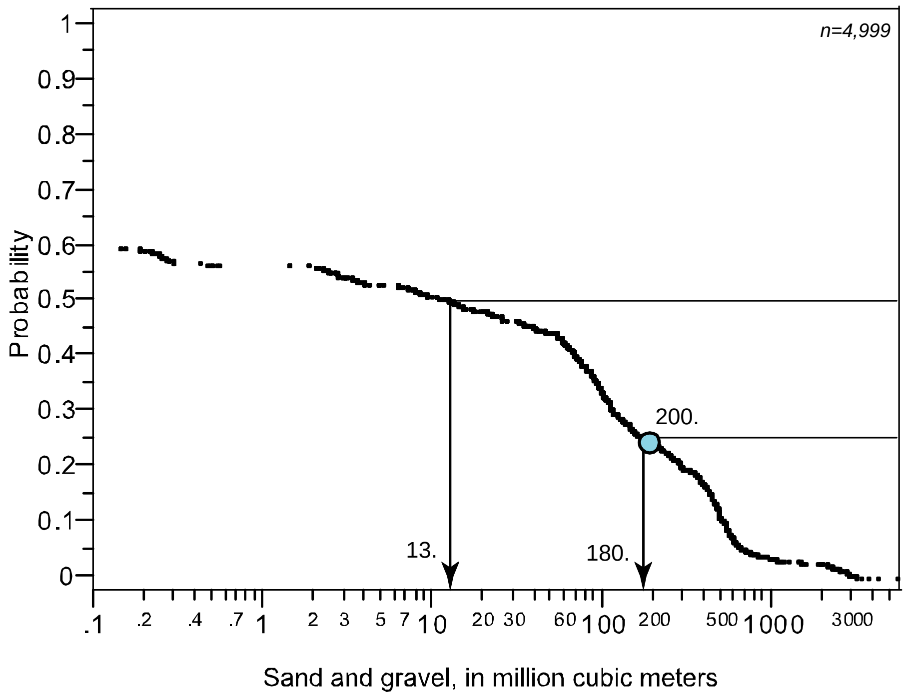

Figure 10.3-36. Distribution of sand and gravel resources in sand and gravel deposits in alluvial fans in Basin 9. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of fluvial sand and gravel resources in Basin 10

Introduction—Basin 10, with an estimated area of 17,000 km^2, is in north central Afghanistan and is bounded by Turkmenistan on the north and west (fig. 10.3-1) It includes the catchments of the Sare Pol and Safid Rivers. The basin is partially bounded by the Torkestan Mountains on the south.

Deposit type—Fluvial sand and gravel

Age of mineralization—Quaternary, as a rule, better quality material is in younger fluvial sand and gravel deposits.

Example deposits types—No examples of sand and gravel deposits in tracts in Basin 10. Most sand and gravel deposits are worked without record in many part of the world, and this is also true in Afghanistan. No official records of work in sand and gravel deposits are kept in many parts of the world, and this is also true in Afghanistan. Basin 10 contains the upper part of the Sare Pol and Safid Rivers and their tributaries and fluvial sand and gravel deposits can be expected to be present along those waterways.

Exploration history—No sites have been reported as a sources of sand and gravel in Basin 10. The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified in the basin and that production likely has been wide spread. One major road crosses the basin from east to west and there are also a number of lesser roads present. It is highly likely that some sand and gravel may have been extracted for their construction and ongoing maintenance. However, neither the intensity nor the extent of sand and gravel exploration is known. Exploitation of deposits near major and other roads is likely given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. Sand and gravel is produced near the points of consumption so locations in regions at some distance from existing road and towns are likely untouched. Deposits within buffer zones (as defined below), which are near towns in this basin are more likely to have been explored.

Tract boundary criteria in basins—See uniform tract boundary criteria based on topographic slope used for both basins and buffer zones as noted in the introductory discussion above. Sixty seven percent of Basin 10, 12,000 km^2, is permissive for fluvial sand and gravel deposits (fig. 10.3-37)

Buffer zone criteria—Buffer zones are defined as extending 25 km around towns and along both sides of major roads. Buffered areas (fig. 10.3-37*b*) with slopes less than 10 degrees have a cumulative area of 8,200 km^2.

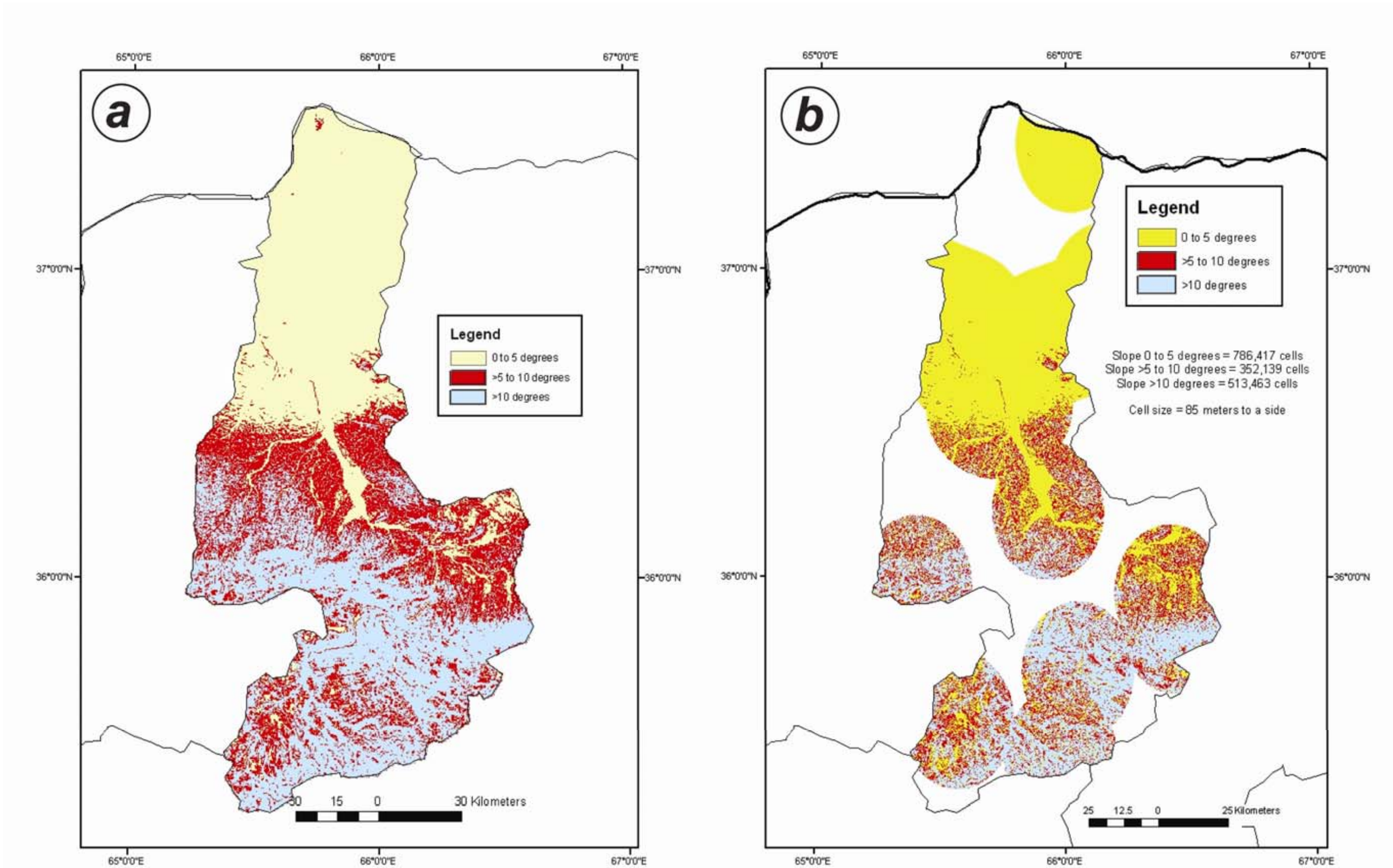

Figure 10.3-37. Outline of Basin 10 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits. Areas with slopes greater than 10 degrees (blue) are non-permissive. (*a*) entire basin. (*b*) areas within 25 kilometer buffer zone around towns and along roads. Slopes between 0-5 degrees (yellow), and 5-10 degrees (red) are permissive for fluvial sand and gravel deposits and those greater than 10 degrees (blue) are not permissive.

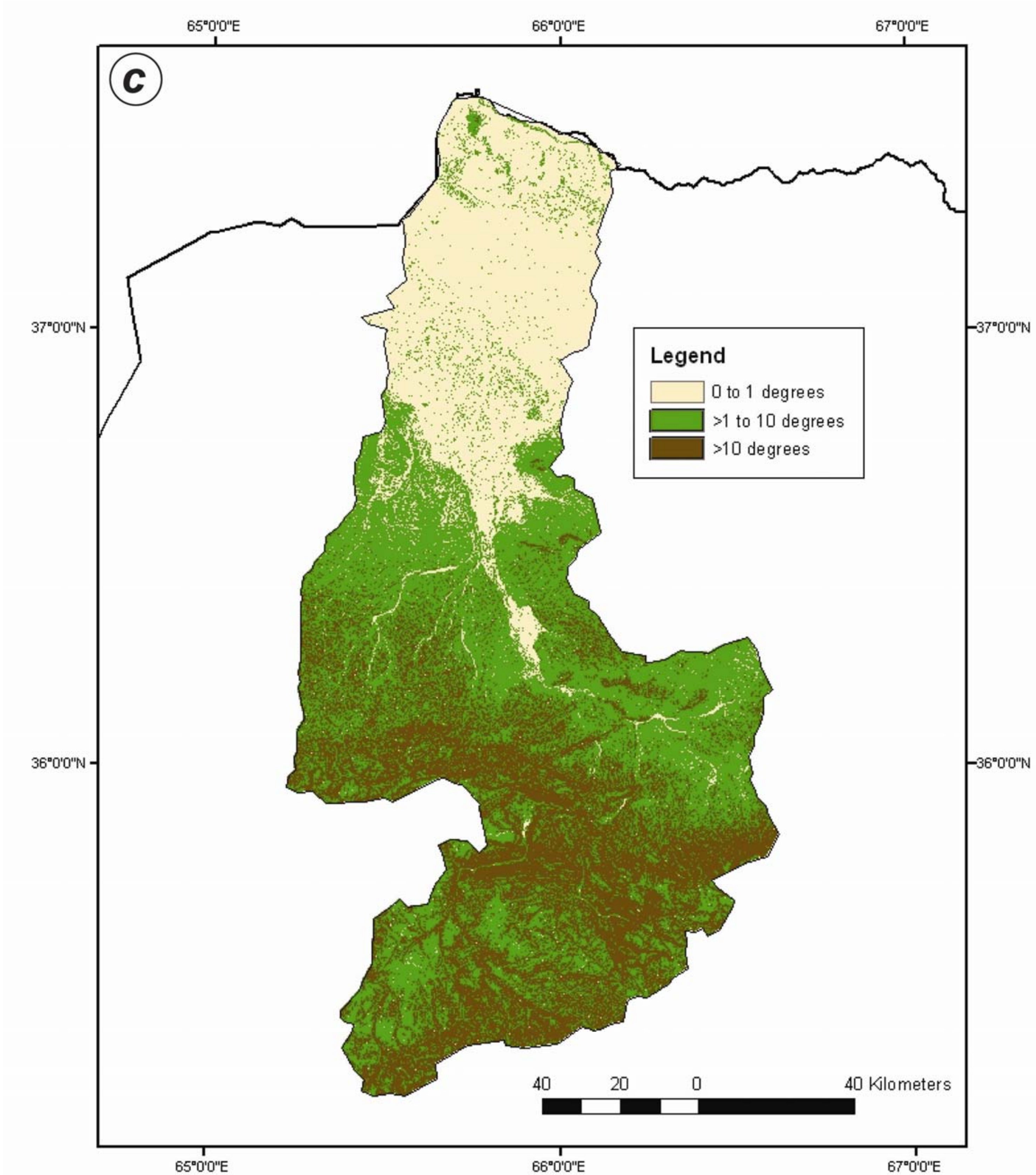

Figure 10.3-37*c*. Outline of Basin 10 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

Needs to improve assessment**—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors**—**Application of the uniform tract boundary criteria based on topographic slope to this basin resulted in no cells being on non-Quaternary rocks. The tracts so defined are likely representative of all areas that are possible sources of sand and gravel deposits. Of the Quaternary sediments in tracts in this basin, 37 percent are defined as an alluvium unit in which the gravel content is greater than silt or clay. This unit is highly likely the host of the readily recognizable fluvial sand and gravel deposits. Alluvial fans and colluvium with gravel and sand greater than silt and clay along mountain fronts have been grouped with this unit. However, alluvial fan sand and gravel deposits are separately assessed (see below.)

Pessimistic factors**—**Alluvial fan and colluvium have been also group with alluvium and this will have inflated the area size. Other Quaternary sediments in permissive tracts include units that are 1) highly unlikely sources of sand and gravel or 2) overburden that may obscure sand and gravel deposits at depth. These units include those dominated by sand (8.4 percent), loess (18 percent) and mud (2 percent) include 28 percent of the Quaternary sediments in the permissive tract.

Estimated number of undiscovered deposits**—**For the assessment of the slope-defined tracts in Basin 10 (fig. 10.3-37), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-28) All tracts within the basin are evaluated simultaneously. Because information about discovered deposits is limited, the estimated number of deposits and their associated probability given in the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-28. Estimated number of fluvial sand and gravel deposits in Basin 10, both discovered and undiscovered, calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	4
80 % chance of at least	5
70 % chance of at least	8
60 % chance of at least	9
50 % chance of at least	32
40 % chance of at least	45
30 % chance of at least	62
20 % chance of at least	100
10 % chance of at least	138

Monte Carlo Simulation results**—**There are three chances in four that the sand and gravel resources in Basin 10 in fluvial sand and gravel deposits will be equal to or greater than 100 million m^3, and there is an even chance that there will be equal to or greater than 600 million m^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 1,600 million m^3 (fig. 10.3-38).

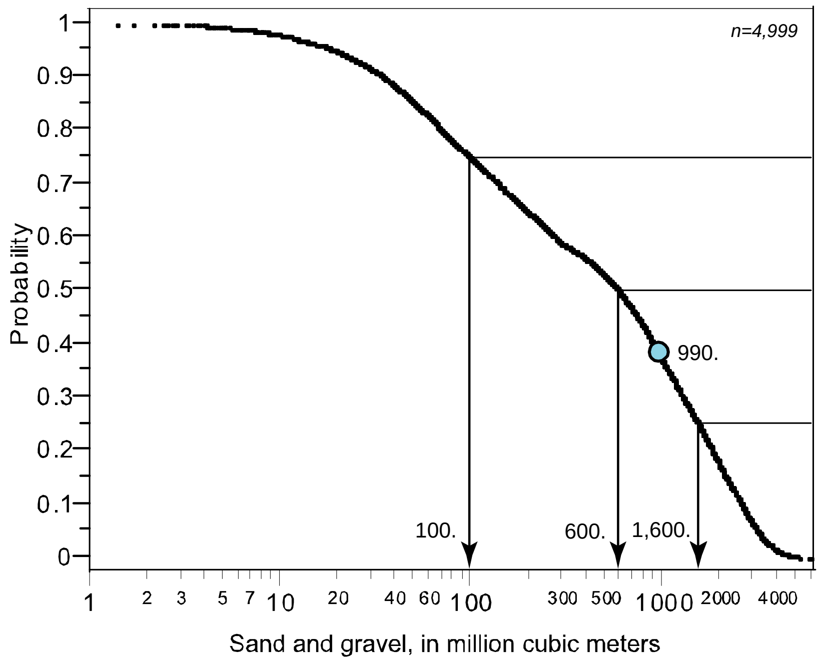

Figure 10.3-38. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 10 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Estimated number of undiscovered deposits in buffer zones—For the assessment of Basin 10 buffer zones (fig. 10.3-37*b*), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-29) from the permissive area of 8,200 km^2. All buffer zones in the basin are evaluated simultaneously. The estimated number of deposits and their associated probability given by the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees. The Quaternary geology in buffer zones contains possible areas of fan alluvium and colluvium together with areas of the more promising alluvium units that are more likely to contain fluvial sand and gravel deposits. Loess, sand and mud dominated units are found in parts of the permissive tracts within buffer zones that they will obscure or prohibit the presences of undiscovered deposits in those areas.

Table 10.3-29. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zone tracts calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	3
80 % chance of at least	4
70 % chance of at least	5
60 % chance of at least	7
50 % chance of at least	23
40 % chance of at least	32
30 % chance of at least	44
20 % chance of at least	71
10 % chance of at least	98

Monte Carlo Simulation results for undiscovered deposits in buffer zones—There are three chances in four that the sand and gravel resources in Basin 10 in fluvial sand and gravel deposits will be equal to or greater than 81 million m^3. There is also an even chance that there will be equal to or greater than 400 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 1,100 million m^3 (fig. 10.3-39). Proximity to towns and major roads suggests a portion of the estimated sand and gravel resources may have already been consumed.

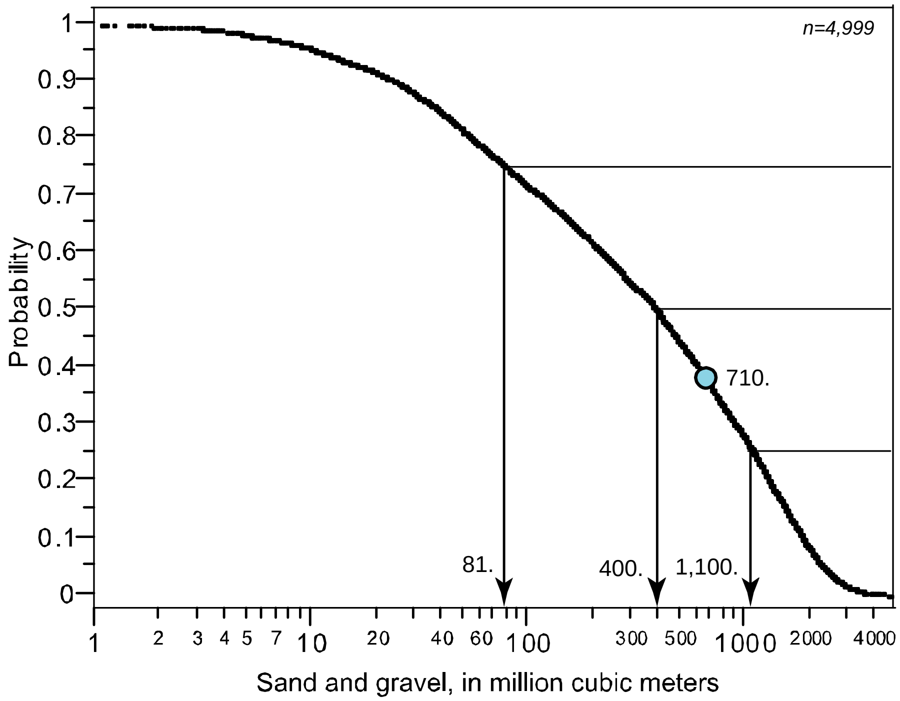

Figure 10.3-39. Distribution of sand and gravel resources in fluvial sand and gravel deposits in buffer zones in Basin 10 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of alluvial fan sand and gravel resources in Basin 10

***Deposit type*—**Alluvial fan sand and gravel

***Age of mineralization*—**Quaternary, better quality material is in younger alluvial fan sand and gravel deposits.

Example deposits types—There are no reported examples of alluvial fan sand and gravel deposits in tracts in this basin. No official records of work in sand and gravel deposits are kept in many part of the world, and this is also true in Afghanistan.

***Exploration history*—**The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified and produced in the tracts in this basin. Alluvial fan sand and gravel deposits are usually not found near towns unless a roadway passes up the fan slope into the stream basin in the adjacent mountains, which may be true in this basin. Neither the intensity nor the extent of sand and gravel exploration is known. However, exploitation of deposits near major roads is likely given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. However, some of these alluvial sand and gravel deposits are near roads and other points of consumption, so some of these deposits may have been exploited. Therefore, most of the resource is likely untouched. Alluvial fan sand and gravel deposits are likely rare within buffer zones (as defined below), which are located found near towns and roads and these deposits are not considered in this assessment.

***Tract boundary criteria*—**Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-37*c*).

***Needs to improve assessment*—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, the former USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use. A map of Quaternary geology showing fan alluvium would be a valuable addition.

***Optimistic factors*—**The steeper terrain and mountain fronts usually associated with alluvial fans are found widely in this basin. Alluvial fans are clearly recognized on topographic sheets (scale 1: 200,000).

***Pessimistic factors*—**Alluvial fans are often problematic as they are commonly poorly sorted with large amounts of unsuitable clay and silt interbedded or directly mixed with the sand and gravel. Only a few of fans are recognized on topographic sheets and only a small portion of them are likely to contain sand and gravel deposits suitable for development.

***Estimated number of undiscovered deposits*—**The number of alluvial fans was subjectively estimated. Because information about discovered deposits is not available, the estimated number of deposits and their associated probability for MCS are for both discovered and undiscovered deposits and are given together with an associated probability (table 10.3-30).

Table 10.3-30. Estimated number of sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 10.

Probability level	Number of deposits
90 % chance of at least	1
70 % chance of at least	1
50 % chance of at least	2
30 % chance of at least	3
10 % chance of at least	5

***Monte Carlo Simulation results for alluvial fan deposits*—**There are three chances in four that the sand and gravel resources in alluvial fans in Basin 10 will be equal to or greater than 89 million m^3. There are even chances that sand and gravel volume will be equal to, or greater than 370 million m^3 (fig. 10.3-40), and one chance in four that the amount of sand and gravel resources will equal or be greater than 710 million m^3.

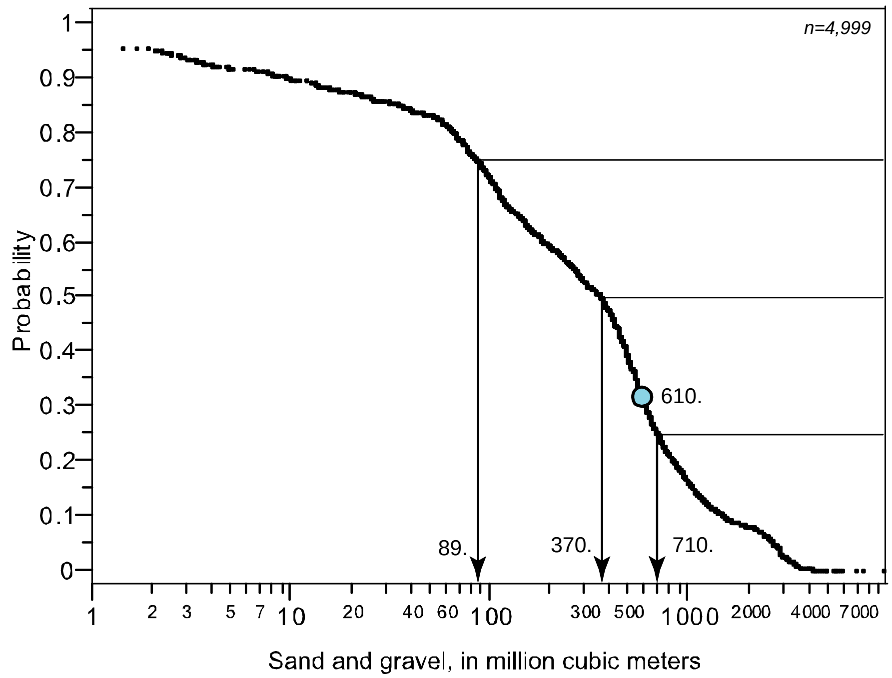

Figure 10.3-40. Distribution of sand and gravel resources in sand and gravel deposits in alluvial fans in Basin 10. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of fluvial sand and gravel resources in Basin 11

Introduction**—**Basin 11, with an estimated area of 29,000 km^2, is in north central Afghanistan and is bounded by Uzbekistan and Tajikistan on the north (fig. 10.3-1) It includes the catchments of the Balkhab River system.

Deposit type**—**Fluvial sand and gravel

Age of mineralization—Quaternary, as a rule, better quality material is in younger fluvial sand and gravel deposits.

Example deposits types**—**There are no examples of sand and gravel deposits in tracts in Basin 11. No official records of work in sand and gravel deposits are kept in many parts of the world, and this is also true in Afghanistan. Basin 11 contains the Balkhab River and its tributaries and fluvial sand and gravel deposits can be expected to be present along those waterways.

Exploration history**—**No sites have been reported as a sources of sand and gravel in Basin 11. The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified in the basin and that production likely has been wide spread. At least one major road is recognized as well as a number of lesser roads are present and it is highly likely that some sand and gravel may have been extracted for their construction and ongoing maintenance. However, neither the intensity nor the extent of sand and gravel exploration is known. Exploitation of deposits near major and other roads is likely given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. Sand and gravel is produced near the points of consumption so tracts in regions at some distance from existing road and towns are likely untouched. Deposits within buffer zones (as defined below), which are near towns in this basin are more likely to have been explored.

Tract boundary criteria in basins**—**see uniform tract boundary criteria based on topographic slope used for both basins and buffer zones as noted in the introductory discussion above. Fifty nine percent of Basin 11, or 10,000 km^2, is permissive for fluvial sand and gravel deposits (fig. 10.3-41)

Buffer zone criteria**—**Buffer zones in tracts are defined as extending 25 km around towns and along both sides of major roads. Buffered areas (fig. 10.3-41*b*) with slopes less than 10 degrees have a cumulative area of 10,000 km^2.

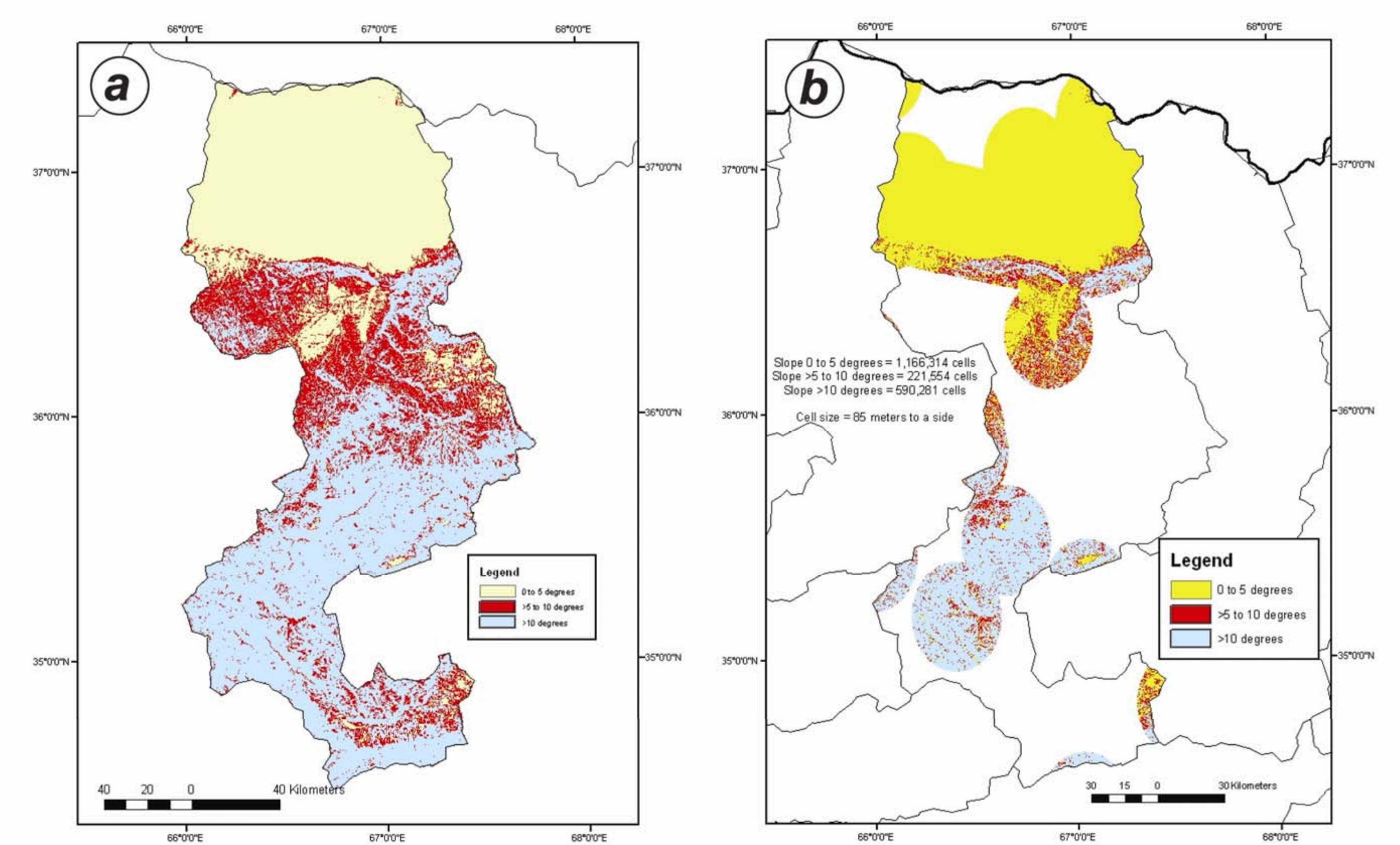

Figure 10.3-41. Outline of Basin 11 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits. Areas with slopes greater than 10 degrees (blue) are non-permissive, (*a*) entire basin. (*b*) areas within 25 km buffer zone around towns and along roads. Slopes between 0-5 degrees (yellow), and 5-10 degrees (red) are permissive for fluvial sand and gravel deposits and those greater than 10 degrees (blue) are not permissive.

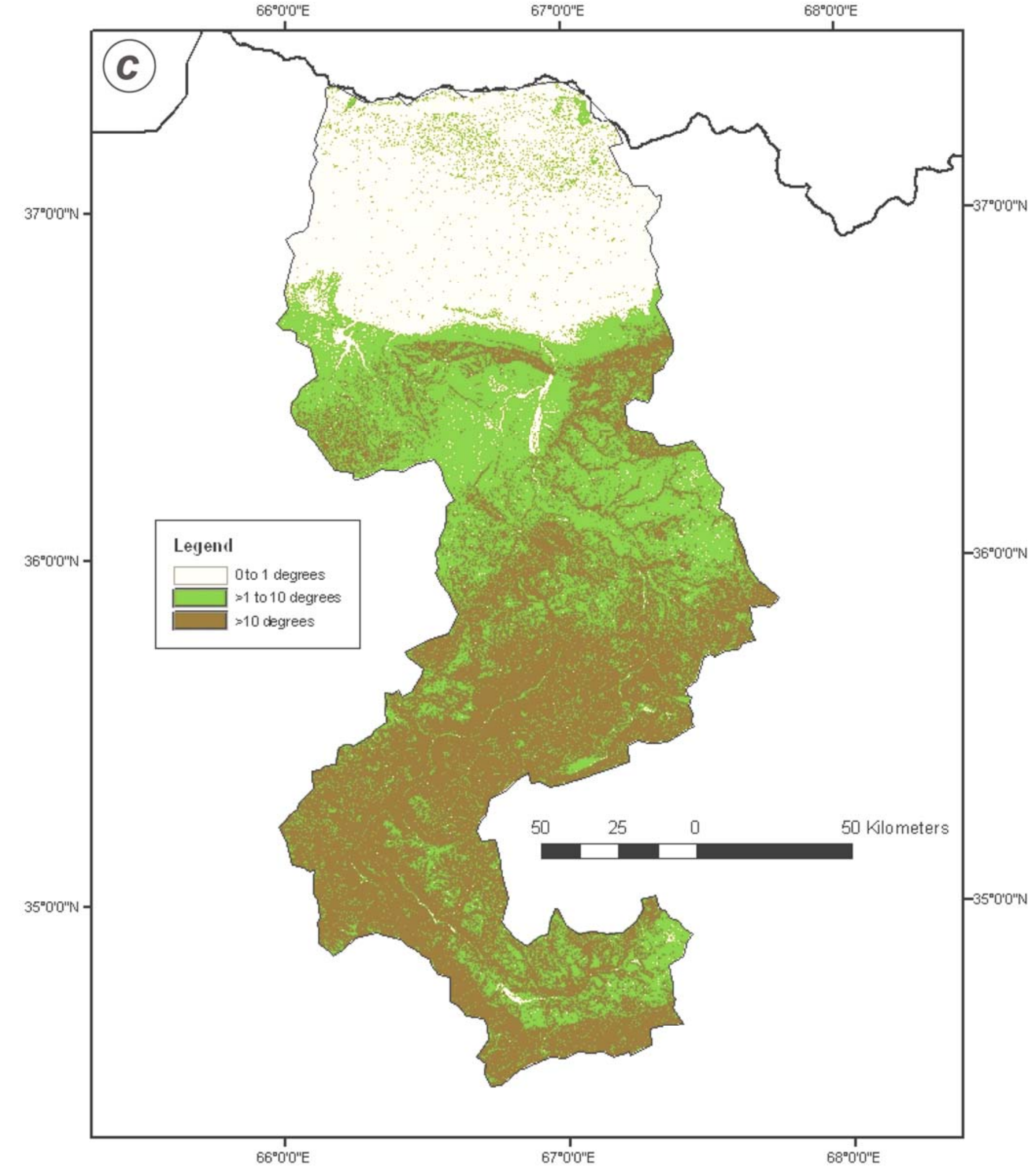

Figure 10.3-41*c*. Outline of Basin 11 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

Needs to improve assessment**—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors**—**Application of the uniform tract boundary criteria based on topographic slope to this basin resulted in 34 percent of the cells being on non-Quaternary rocks. The tracts so defined may slightly over-represent permissive areas that are possible sources of sand and gravel resources. Of the Quaternary sediments in tracts in this basin, 49 percent are defined as an alluvium unit in which the gravel content is greater than silt or clay. This unit is highly likely to be the host of readily recognizable fluvial sand and gravel deposits. Alluvial fans and colluvium with gravel and sand greater than silt and clay along mountain fronts have been grouped with this unit. However, alluvial fan sand and gravel deposits are separately assessed (see below).

Pessimistic factors**—**Alluvial fan and colluvium have been grouped with alluvium and this will have inflated the tract size. Other Quaternary sediments in permissive tracts include units that are 1) highly unlikely sources of sand and gravel or 2) overburden that may obscure sand and gravel deposits at depth. These units include those dominated by sand (17 percent), loess (15 percent) and mud (19 percent) that in their sum includes 32 percent of the Quaternary sediments in the permissive tract.

Estimated number of undiscovered deposits**—**For the assessment of the slope-defined tracts in Basin 11, a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-31). All tracts, which have a total cumulative area of 17,000 km^2 within the basin, are evaluated simultaneously. Because information about discovered deposits is limited, the estimated number of deposits and their associated probability given in the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-31. Estimated number of fluvial sand and gravel deposits in Basin 11, both discovered and undiscovered, calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	6
80 % chance of at least	7
70 % chance of at least	11
60 % chance of at least	14
50 % chance of at least	47
40 % chance of at least	67
30 % chance of at least	91
20 % chance of at least	147
10 % chance of at least	204

Monte Carlo Simulation results**—**There are three chances in four that the sand and gravel resources in Basin 11 in fluvial sand and gravel deposits will be equal to or greater than 600 million m^3, and there is an even chance that there will be equal to or greater than 900 million m^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 2,300 million m^3 (fig. 10.3-42).

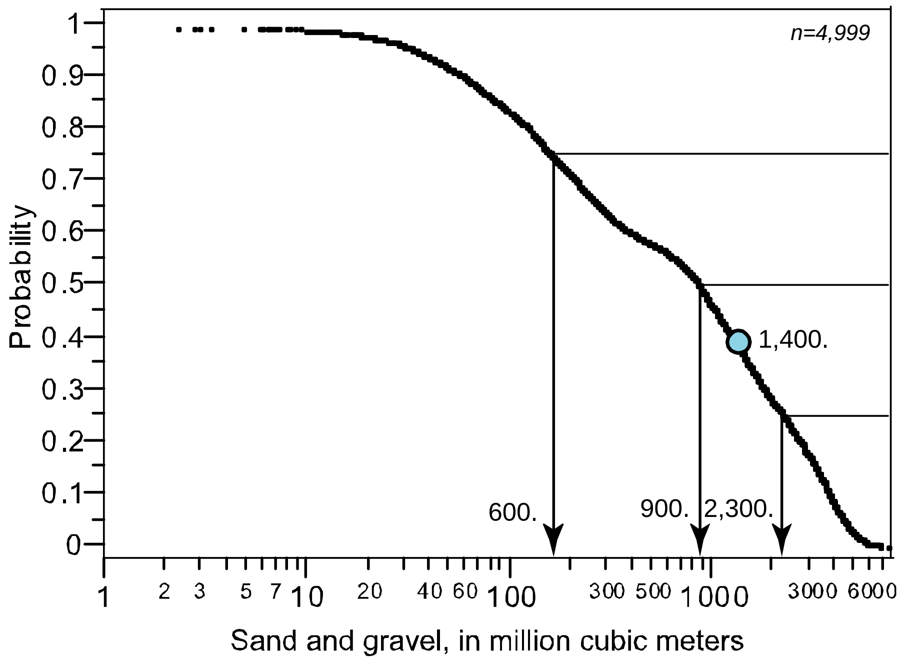

Figure 10.3-42. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 11 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Estimated number of undiscovered deposits in buffer zones—For the assessment of Basin 11 buffer zones (fig. 10.3-42), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-32) from the permissive area in buffers of 10,00 km^2. All buffer zones in the basin are evaluated simultaneously. The estimated number of deposits and their associated probability given by the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees. The Quaternary geology in buffer zones contains possible areas of fan alluvium and colluvium together with areas of the more promising alluvium units that are more likely to contain fluvial sand and gravel deposits. Loess, sand and mud dominated units are in parts of the permissive tracts within buffer zones that will obscure or prohibit the presences of undiscovered deposits.

Table 10.3-32. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zones in tracts calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	3
80 % chance of at least	4
70 % chance of at least	7
60 % chance of at least	8
50 % chance of at least	27
40 % chance of at least	39
30 % chance of at least	53
20 % chance of at least	86
10 % chance of at least	119

Monte Carlo Simulation results for undiscovered deposits in buffer zones—There are three chances in four that the sand and gravel resources in buffer zones of Basin 11 in fluvial sand and gravel deposits will be equal to or greater than 80 million m^3. There is also an even chance that there will be equal to or greater than 480 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 1,300 million m^3 (fig. 10.3-43). Proximity to towns and roads suggests a portion of the estimated sand and gravel resources may have already been consumed.

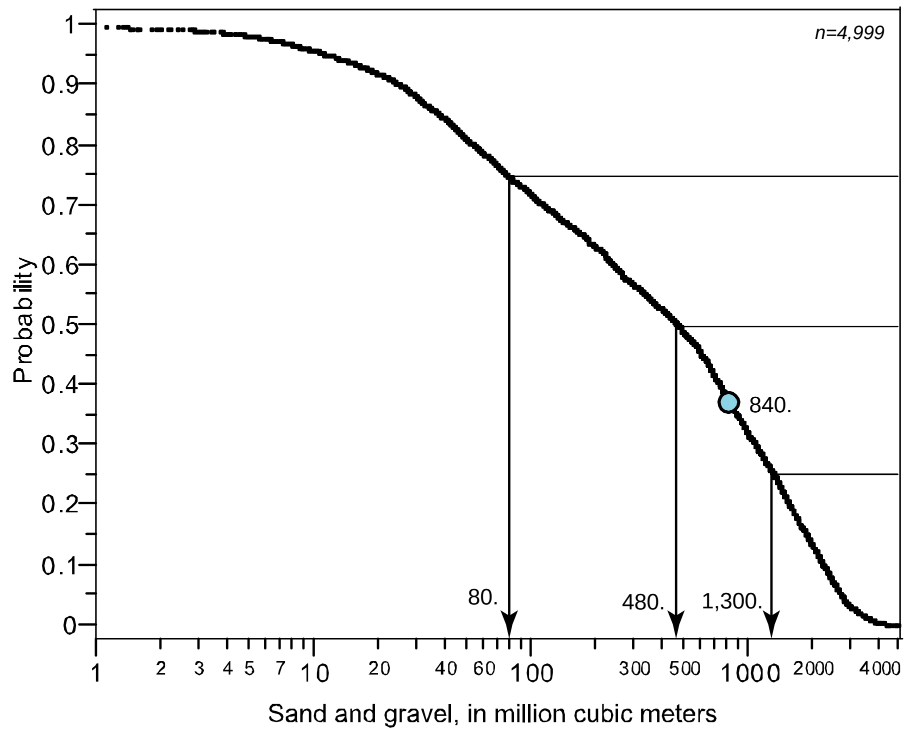

Figure 10.3-43. Distribution of sand and gravel resources in fluvial sand and gravel deposits in buffer zones in Basin 11 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS

Assessment of alluvial fan sand and gravel resources in Basin 11

***Deposit type*—**Alluvial fan sand and gravel

***Age of mineralization*—**Quaternary, better quality material is in younger alluvial fan sand and gravel deposits.

***Example deposits types*—**There are no reported examples of alluvial fan sand and gravel deposits in tracts in this basin. Most alluvial fan sand and gravel deposits are worked without record in many part of the world, and this is also true in Afghanistan.

***Exploration history*—**The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified and produced in the tracts in this basin. Alluvial fan sand and gravel deposits are usually not found near towns unless a roadway passes up the fan slope into the stream basin in the adjacent mountains, which may be true in this basin. Neither the intensity nor the extent of sand and gravel exploration is known. However, exploitation of deposits near major roads is likely given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. However, some of these alluvial sand and gravel deposits are near roads and other points of consumption, so some of these deposits may have been exploited, but most of the resource is likely untouched. Alluvial fan sand and gravel deposits are likely rare within buffer zones (as defined below) that are found near towns and roads and are not considered in this assessment.

Tract boundary criteria—Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-41*c*).

Needs to improve assessment—Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, the former USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use. A map of Quaternary geology with fan alluvium separately identified would be a valuable addition.

Optimistic factors—The steeper terrain and mountain fronts usually associated with alluvial fans are found widely in this basin. Alluvial fans are clearly recognized on topographic sheets (scale 1: 200,000).

Pessimistic factors—Alluvial fans are often problematic as they are commonly poorly sorted with large amounts of unsuitable clay and silt interbedded or directly mixed with the sand and gravel. Only a few fans are recognized on topographic sheets and only a small portion of them are likely to contain sand and gravel deposits suitable for development.

Estimated number of undiscovered deposits—The numbers of alluvial fan sand and gravel deposits were subjectively estimated. Because information about discovered deposits is not available, the estimated number of deposits and their associated probability for MCS are for both discovered and undiscovered deposits and are given together with an associated probability (table 10.3-33).

Table 10.3-33. Estimated number of sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 11.

Probability level	Number of deposits
90 % chance of at least	1
70 % chance of at least	1
50 % chance of at least	2
30 % chance of at least	2
10 % chance of at least	3

Monte Carlo Simulation results for alluvial fan deposits—there are three chances in four that the sand and gravel resources in alluvial fans in Basin 11 will be equal to or greater than 77 million m^3. There is also an even chance that there will be equal to or greater than 210 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 550 million m^3 (fig. 10.3-44).

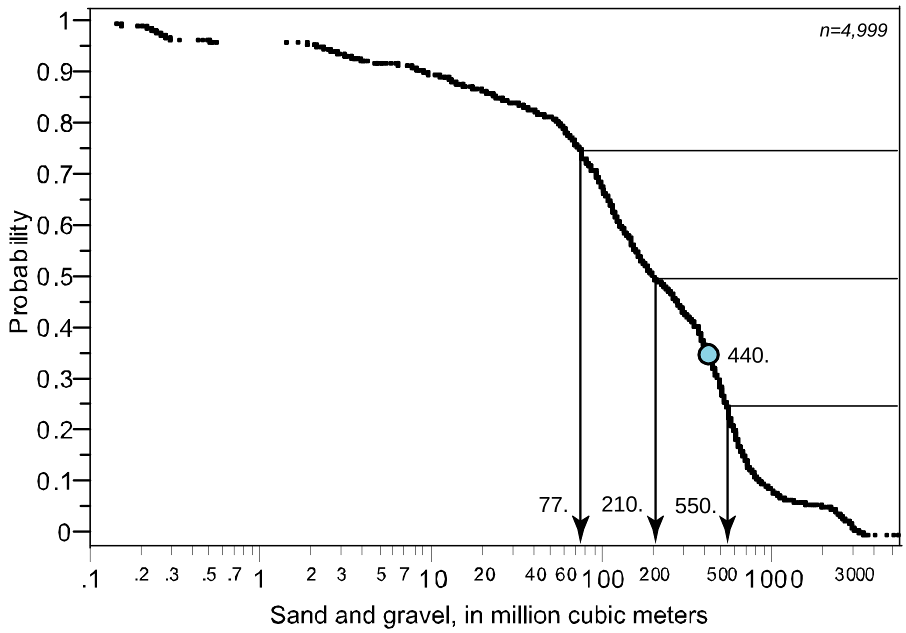

Figure 10.3-44. Distribution of sand and gravel resources in sand and gravel deposits in Basin 11 alluvial fans. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of fluvial sand and gravel resources in Basin 12

Introduction—Basin 12, with an estimated area of 12,000 km^2, is in northeastern Afghanistan (fig. 10.3-1) It includes the catchments of the Samangan River system.

Deposit type—Fluvial sand and gravel

Age of mineralization—Quaternary; as a rule, better quality material is in younger fluvial sand and gravel deposits.

Example deposits types—Thee are no examples of sand and gravel deposits in tracts in Basin 12. No official records of work in sand and gravel deposits are kept in many parts of the world, and this is also true in Afghanistan. Basin 12 contains the Samangan River and its tributaries and fluvial sand and gravel deposits can be expected to be present along those waterways.

Exploration history—No sites have been reported as a sources of sand and gravel in Basin 12. The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified in the basin and that production likely has been wide spread. Two major roads are recognized in the basin as well as a number of lesser roads and it is highly likely that some sand and gravel may have been extracted for their construction and ongoing maintenance. However, neither the intensity nor the extent of sand and gravel exploration is known. Exploitation of deposits near major and other roads is likely given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. Sand and gravel is produced near the points of consumption so locations in regions at some distance from existing roads and towns are likely untouched. Deposits within buffer zones (as defined below), which are near towns in this basin are more likely to have been explored.

Tract boundary criteria in basins—See uniform tract boundary criteria based on topographic slope used for both basins and buffer zones as noted in the introductory discussion above. Sixty six percent of Basin 12, or 8,200 km^2, is permissive for fluvial sand and gravel deposits (fig. 10.3-45)

Buffer zone criteria—Buffer zones are defined as extending 25 km around towns and along both sides of major roads. Buffered areas (fig. 10.3-45*b*) with slopes less than 10 degrees have cumulative areas of 5,200 km^2.

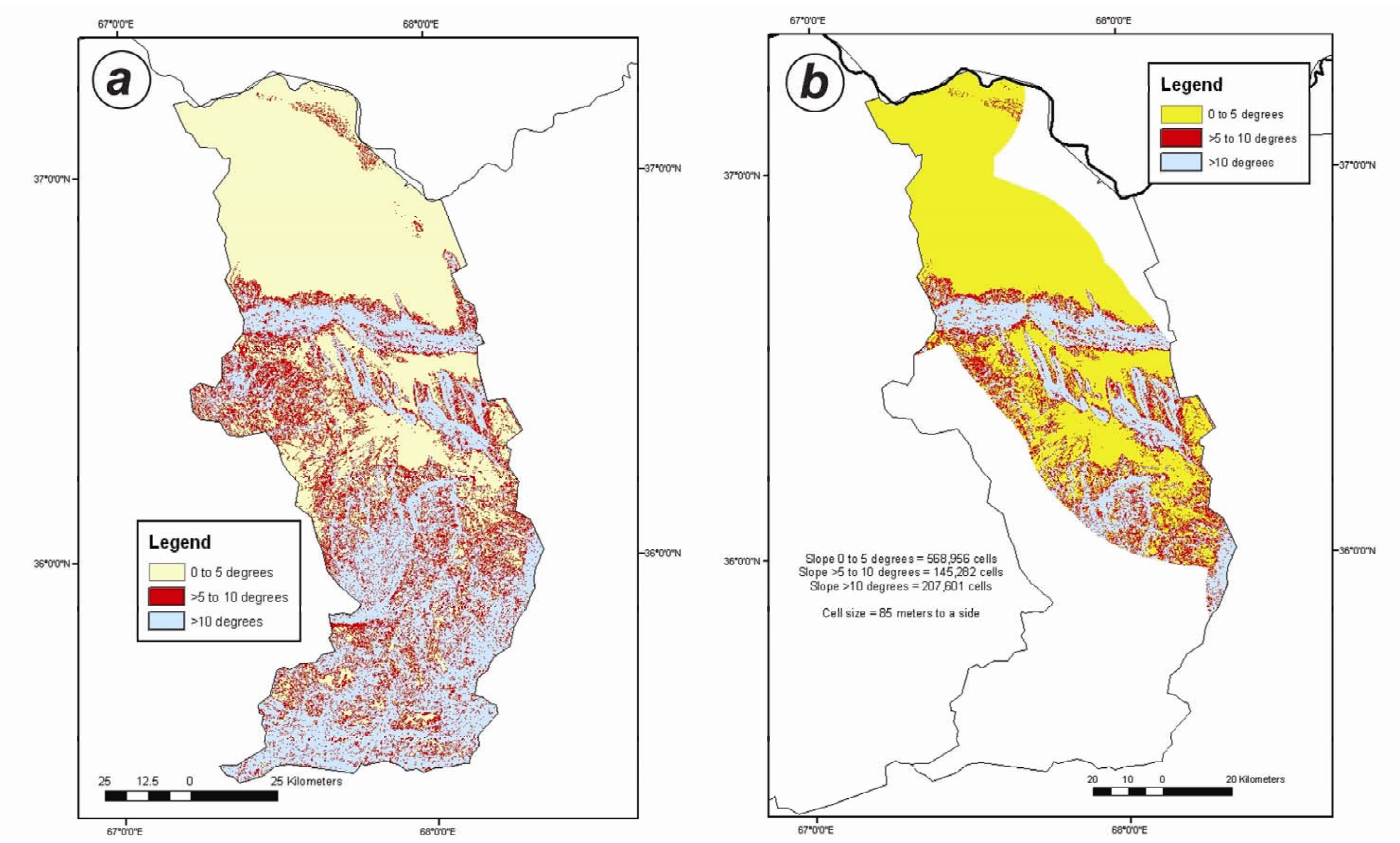

Figure 10.3-45. Outline of Basin 12 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits. Areas with slopes greater than 10 degrees (blue) are non permissive. (*a*) entire basin. (*b*) areas within 25 kilometer buffer zone around towns and along roads. Slopes between 0-5 degrees (yellow), and 5-10 degrees (red) are permissive for fluvial sand and gravel deposits and those greater than 10 degrees (blue) are not permissive.

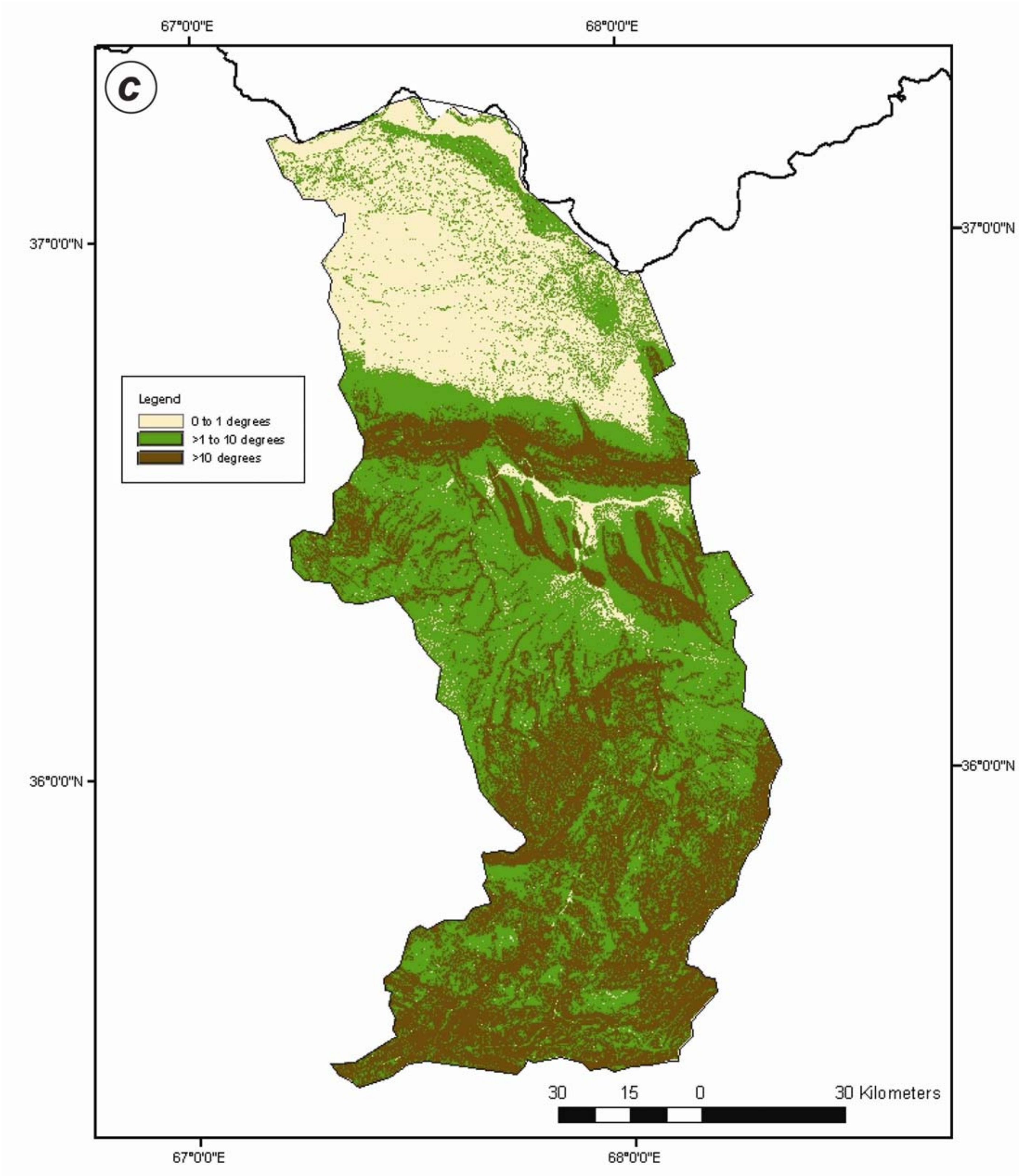

Figure 10.3-45*c*. Outline of Basin 12 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

Needs to improve assessment**—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors**—**Application of the uniform tract boundary criteria based on topographic slope to this basin resulted in 45 percent of the permissive tracts being on non-Quaternary rocks. This indicates that we may have produced a cumulative permissive tract area that is too large. Of the Quaternary sediments in tracts in this basin, 36 percent are defined as an alluvium unit in which the gravel content is greater than silt or clay. This unit is highly likely to be the host of readily recognizable fluvial sand and gravel deposits. Alluvial fans and colluvium with gravel and sand greater than silt and clay along mountain fronts have been grouped with this unit. However, alluvial fan sand and gravel deposits are separately assessed (see below.)

Pessimistic factors**—**Alluvial fan and colluvium have been also group with alluvium and this will have inflated the area size. Other Quaternary sediments in permissive tracts include units that are 1) highly unlikely sources of sand and gravel or 2) overburden that may obscure sand and gravel deposits at depth. These units include those dominated by sand (36 percent), loess (11 percent) and mud (1 percent) and, in total, include 51 percent of the Quaternary sediments in permissive tracts.

Estimated number of undiscovered deposits**—**For the assessment of the slope-defined tracts in Basin 12 (fig. 10.3-45), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-34) All tracts, which have a total cumulative area of 8,200 km^2 within the basin, are evaluated simultaneously. Because information about discovered deposits is limited, the estimated number of deposits and their associated probability given in the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-34. Estimated number of fluvial sand and gravel deposits in Basin 12, both discovered and undiscovered, calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	3
80 % chance of at least	4
70 % chance of at least	5
60 % chance of at least	7
50 % chance of at least	22
40 % chance of at least	32
30 % chance of at least	43
20 % chance of at least	70
10 % chance of at least	97

Monte Carlo Simulation results**—**There are three chances in four that the sand and gravel resources in Basin 12 in fluvial sand and gravel deposits will be equal to or greater than 68 million m^3, and there is an even chance that there will be equal to or greater than 390 million m^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 1,100 million m^3 (fig. 10.3-46).

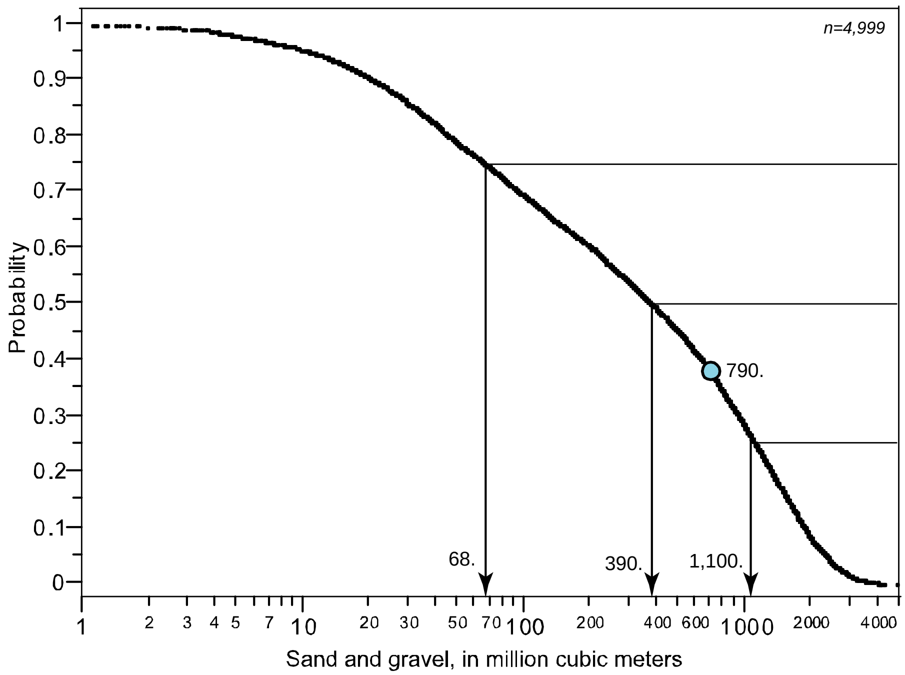

Figure 10.3-46. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 12 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Estimated number of undiscovered deposits in buffer zones—For the assessment of Basin 12 buffer zones (fig. 10.3-45*b*), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-35) from the permissive area of 5,200 km^2. All buffer zones in the basin are evaluated simultaneously. The estimated number of deposits and their associated probability given by the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees. The Quaternary geology in buffer zones contains possible areas of fan alluvium and colluvium together with areas of the more promising alluvium units that are more likely to contain fluvial sand and gravel deposits. Loess, sand and mud dominated units are found in parts of the permissive tracts within buffer zones that will obscure or prohibit the presences of undiscovered deposits.

Table 10.3-35. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zones in tracts calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	2
80 % chance of at least	2
70 % chance of at least	3
60 % chance of at least	4
50 % chance of at least	14
40 % chance of at least	20
30 % chance of at least	27
20 % chance of at least	44
10 % chance of at least	61

Monte Carlo Simulation result for undiscovered deposits in buffer zones—There are three chances in four that the sand and gravel resources in Basin 12 in fluvial sand and gravel deposits will be equal to or greater than 30 million m^3. There is also an even chance that there will be equal to or greater than 220 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 680 million m^3 (fig. 10.3-47). Proximity to towns and major roads suggests a portion of the estimate sand and gravel resources may have already been consumed.

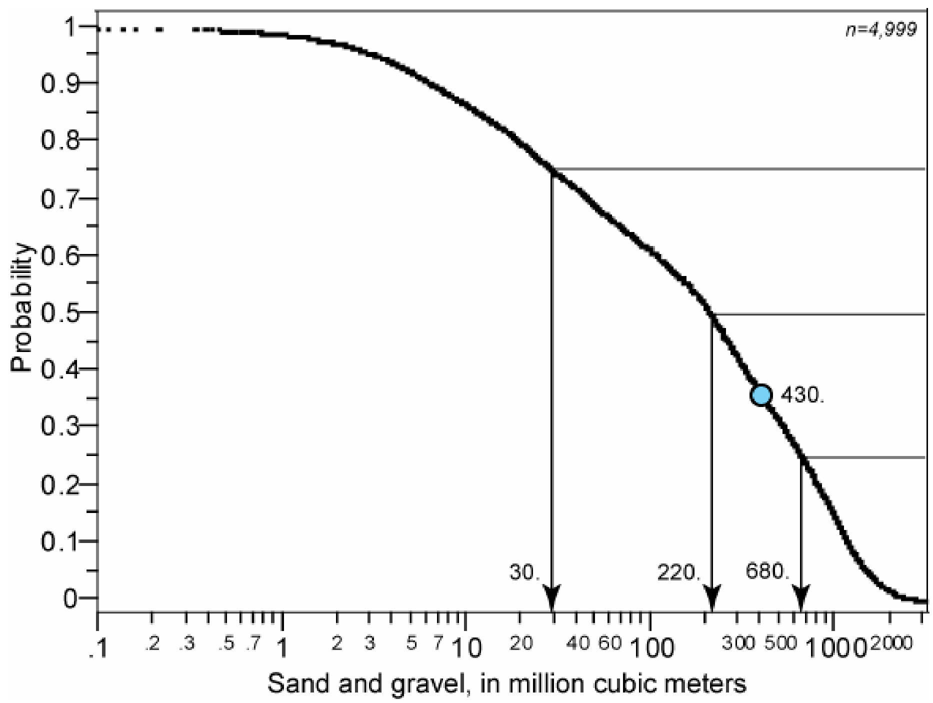

Figure 10.3-47. Distribution of sand and gravel resources in fluvial sand and gravel deposits in buffer zones in Basin 12 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of alluvial fan sand and gravel resources in Basin 12

Deposit type—Alluvial fan sand and gravel

Age of mineralization—Quaternary, better quality material is in younger fluvial fan sand and gravel deposits.

Example deposits types—There are no reported examples of fluvial fan sand and gravel deposits in tracts in this basin. No official records of work in sand and gravel deposits are kept in many part of the world, and this is also true in Afghanistan.

Exploration history—The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified and produced in the tracts in this basin. Alluvial fan sand and gravel deposits are usually not found near towns unless a roadway passes up the fan slope into the stream basin in the adjacent mountains, which may be true in this basin. Neither the intensity nor the extent of sand and gravel exploration is known. However, exploitation of deposits near major roads is likely given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. However, some of these alluvial sand and gravel deposits are near roads and other points of consumption, so some of these deposits may have been exploited, but most of the resource is likely untouched. Alluvial fan sand and gravel deposits are likely rare within buffer zones (as defined below) that are near towns and roads, and they are not considered in this assessment.

Tract boundary criteria—Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-45*c*).

Needs to improve assessment—Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, the former USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use. A Quaternary geology map separately depicting an alluvial fan alluvium unit would be a valuable addition.

Optimistic factors—The steeper terrain and mountain fronts usually associated with alluvial fans are found widely in this basin. Alluvial fans are clearly recognized on topographic sheets (scale 1: 200,000).

Pessimistic factors—Alluvial fans are often problematic as they are commonly poorly sorted with large amounts of unsuitable clay and silt interbedded or directly mixed with the sand and gravel. Only a few fans are recognized on topographic sheets, and only a small portion of them is likely to contain sand and gravel deposits suitable for development.

Estimated number of undiscovered deposits—The number of alluvial fans was subjectively estimated. Because information about discovered deposits is not available, the estimated number of deposits and their associated probability for MCS are for both discovered and undiscovered deposits and are given together with an associated probability (table 10.3-36).

Table 10.3-36. Estimated number of sand and gravel deposits, both discovered and undiscovered, in alluvial fans in Basin 12.

Probability level	Number of deposits
90 % chance of at least	1
70 % chance of at least	1
50 % chance of at least	2
30 % chance of at least	3
10 % chance of at least	5

Monte Carlo Simulation results for alluvial fan deposits—There are three chances in four that the sand and gravel resources in alluvial fans in Basin 12 will be equal to or greater than 120 million m^3. There is also an even chance that there will be equal to or greater than 410 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 770 million m^3 (fig. 10.3-48).

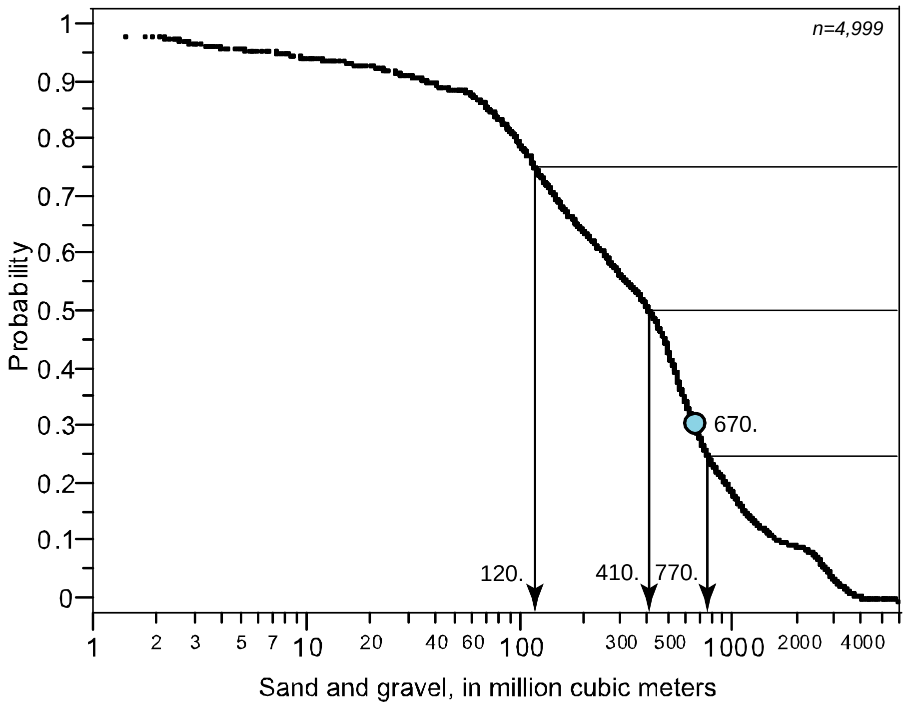

Figure 10.3-48. Distribution of sand and gravel resources in sand and gravel deposits in Basin 12 alluvial fans. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of fluvial sand and gravel resources in Basin 13

Introduction**—**Basin 13, with an estimated area of 41,000 km^2, is in northeastern Afghanistan (fig. 10.3-1) It includes the catchments of the Surkhab River system.

Deposit type**—**Fluvial sand and gravel

Age of mineralization**—**Quaternary; as a rule, better quality material is in younger fluvial sand and gravel deposits.

Example deposits types**—**There are no examples of sand and gravel deposits in tracts in Basin 13. No official records of work in sand and gravel deposits are kept in many parts of the world, and this is also true in Afghanistan. Basin 13 contains the Surkhab River and its tributaries and fluvial sand and gravel deposits can be expected to be present along those waterways.

Exploration history**—**No sites have been reported as a sources of sand and gravel in Basin 13. The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified in the basin and that production likely has been wide spread. At least two major roads are recognized in this basin and their presences suggest that it is highly likely that some sand and gravel may have been extracted for their construction and ongoing maintenance. However, neither the intensity nor the extent of sand and gravel exploration is known. Exploitation of deposits near major and other roads is likely given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. Sand and gravel is produced near the points of consumption so locations in regions at some distance from existing roads and towns are likely untouched. Deposits within buffer zones (as defined below), which are near towns in this basin are more likely to have been explored.

Tract boundary criteria in basins—See uniform tract boundary criteria based on topographic slope used for both basins and buffer zones as noted in the introductory discussion above. Thirty six percent of Basin 13, or 14,000 km^2, is permissive for fluvial sand and gravel deposits (fig. 10.3-49)

Buffer zone criteria—Buffer zones in tracts are defined as extending 25 km around towns and along both sides of major roads. Buffered areas (fig. 10.3-49*b*) with slopes less than 10 degrees have a cumulative area of 11,000 km^2.

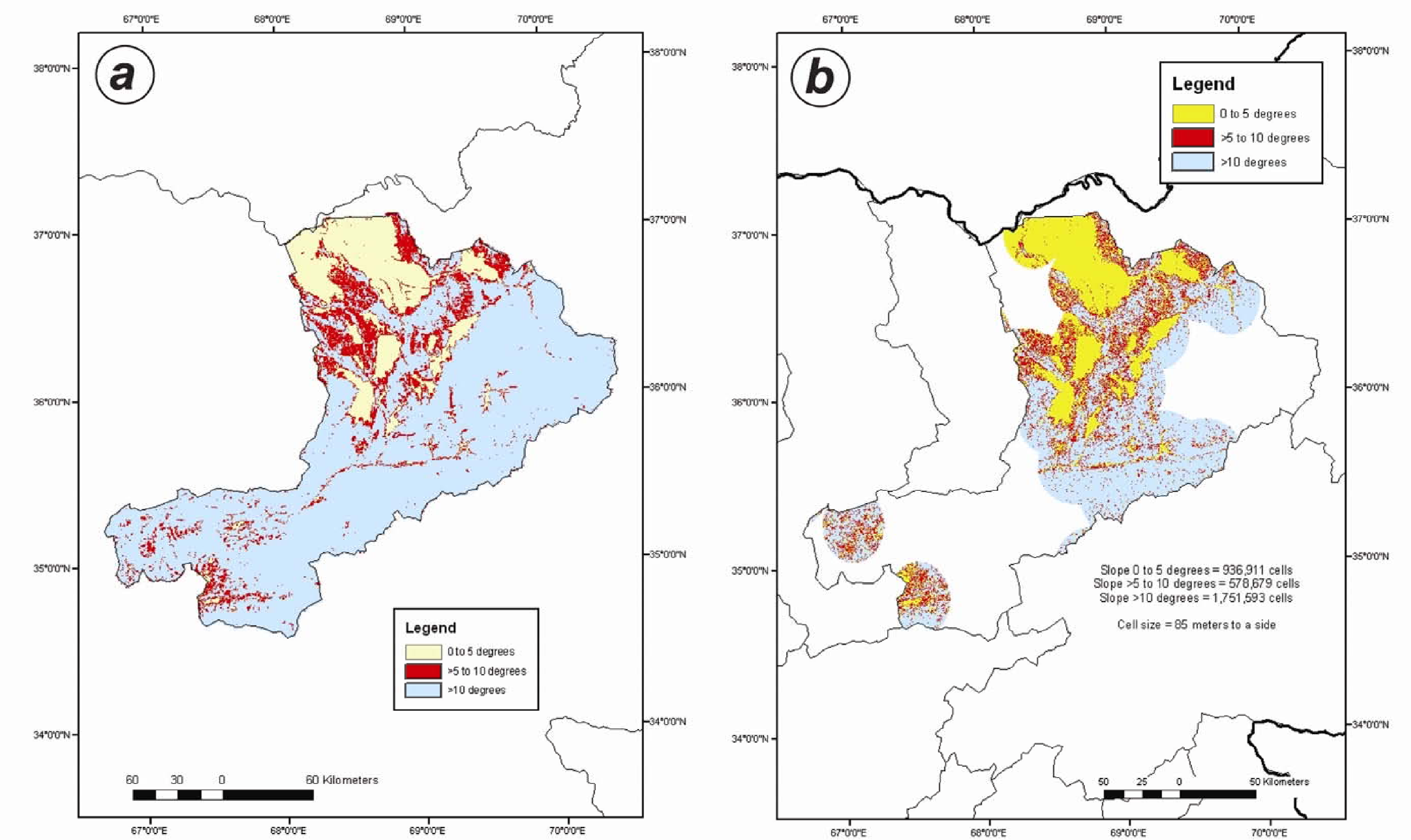

Figure 10.3-49. Outline of Basin 13 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits. Areas with slopes greater than 10 degrees (blue) are non-permissive. (*a*) entire basin. (*b*) areas within 25 kilometer buffer zones around towns and along roads. Slopes between 0-5 degrees (yellow), and 5-10 degrees (red) are permissive for fluvial sand and gravel deposits and those greater than 10 degrees (blue) are not permissive.

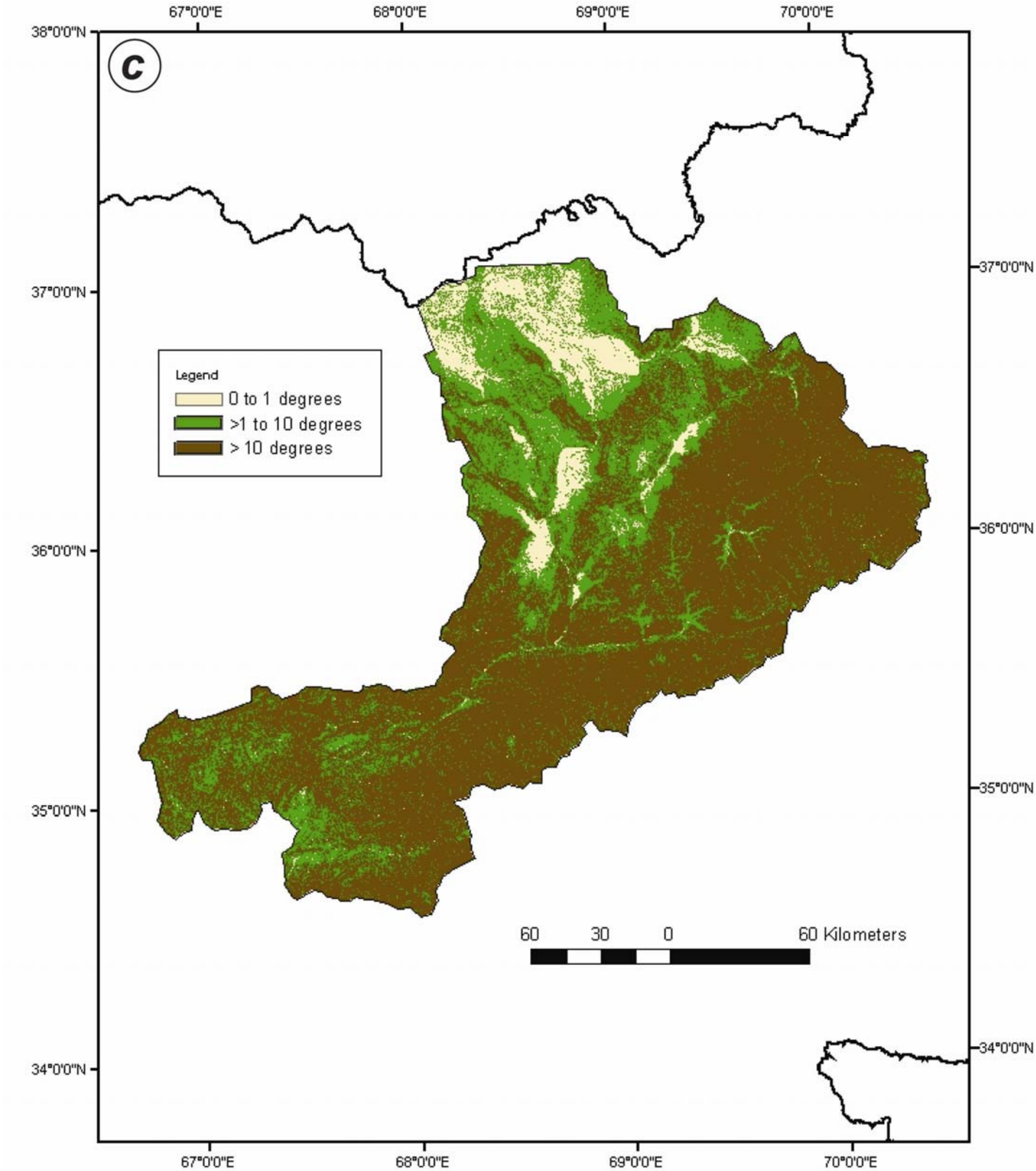

Figure 10.3-49*c*. Outline of Basin 13 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

***Needs to improve assessment*—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

***Optimistic factors*—**Of the Quaternary sediments in tracts in this basin, 65 percent are defined as an alluvium unit in which the gravel content is greater than silt or clay. This unit is highly likely to host readily recognizable fluvial sand and gravel deposits. A small amount of alluvial fans and colluvium with gravel and sand greater than silt is mapped and is located along mountain fronts. Erosion of these sediments may contribute sand and gravel downstream. Sand and gravel resources expected to be present in alluvial fan sand and gravel deposits are separately assessed (see below).

***Pessimistic factors*—**Application of the uniform tract boundary criteria based on topographic slope to this basin resulted in 36 percent of the cells being on surface described as non-Quaternary rocks. This indicates that we may have produced a cumulative permissive tract area that is too large. Alluvial fan and colluvium have been grouped with alluvium, but the area is very small (2 percent of Quaternary units shown). This may suggest that some of the alluvium (and other units) may be fan deposits. Other Quaternary sediments in permissive tracts include units that are 1) highly unlikely sources of sand and gravel or 2) overburden may obscure sand and gravel deposits at depth. These units include outcrops dominated by sand (11 percent), loess (21 percent) and glacial till (0.17 percent) where these units cumulatively include 32 percent of the Quaternary sediments in permissive tracts.

***Estimated number of undiscovered deposits*—**For the assessment of the slope-defined tracts in Basin 13 (fig. 10.3-49b), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-37) All tracts, which have a total cumulative area of 14,000 km^2 within the basin, are evaluated simultaneously. Because information about discovered deposits is limited, the estimated number of deposits and their associated probability given in the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-37. Estimated number of fluvial sand and gravel deposits in Basin 13, both discovered and undiscovered, calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	5
80 % chance of at least	10
70 % chance of at least	5
60 % chance of at least	12
50 % chance of at least	40
40 % chance of at least	57
30 % chance of at least	77
20 % chance of at least	125
10 % chance of at least	173

***Monte Carlo Simulation results*—**There are three chances in four that the sand and gravel resources in Basin 13 in fluvial sand and gravel deposits will be equal to or greater than 150 million m^3, and there is an even chance that there will be equal to or greater than 790 million m^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 2,000 million m^3 (fig. 10.3-50).

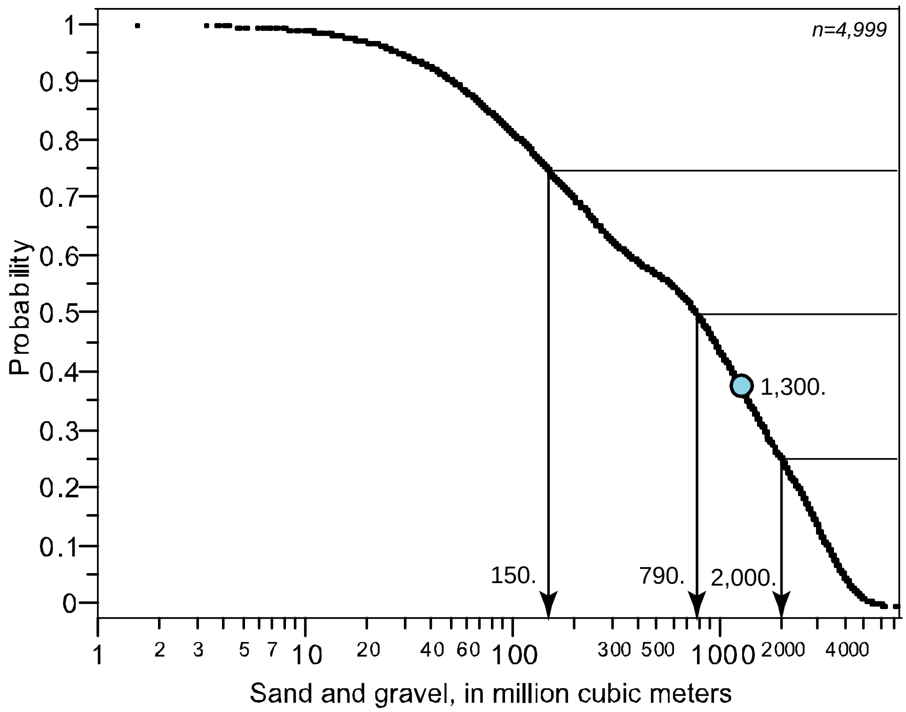

Figure 10.3-50. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 13 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Estimated number of undiscovered deposits in buffer zones—For the assessment of Basin 13 buffer zones (fig. 10.3-49b), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-38) from the permissive area of 11,000 km^2. All buffer zones in the basin are evaluated simultaneously. The estimated number of deposits and their associated probability given by the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees. The Quaternary geology in buffer zones contains possible areas of fan alluvium and colluvium together with areas of the more promising alluvium units that are more likely to contain fluvial sand and gravel deposits. Loess, sand and mud dominated units are found in parts of the permissive tracts within buffer zones, and they can obscure or prohibit the presences of undiscovered deposits.

Table 10.3-38. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zones calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	4
80 % chance of at least	5
70 % chance of at least	7
60 % chance of at least	9
50 % chance of at least	30
40 % chance of at least	43
30 % chance of at least	58
20 % chance of at least	94
10 % chance of at least	130

Monte Carlo Simulation results for undiscovered deposits in buffer zones—There are three chances in four that the sand and gravel resources in Basin 13 found in fluvial sand and gravel deposits will be equal to or greater than 98 million m^3. There is also an even chance that there will be equal to or greater than 560 million m^3 (fig. 10.3-51) and one chance in four that the amount of sand and gravel resources will equal or be greater than 1,500 million m^3. Proximity to towns and major roads suggests a portion of the estimated sand and gravel resources may have already been consumed.

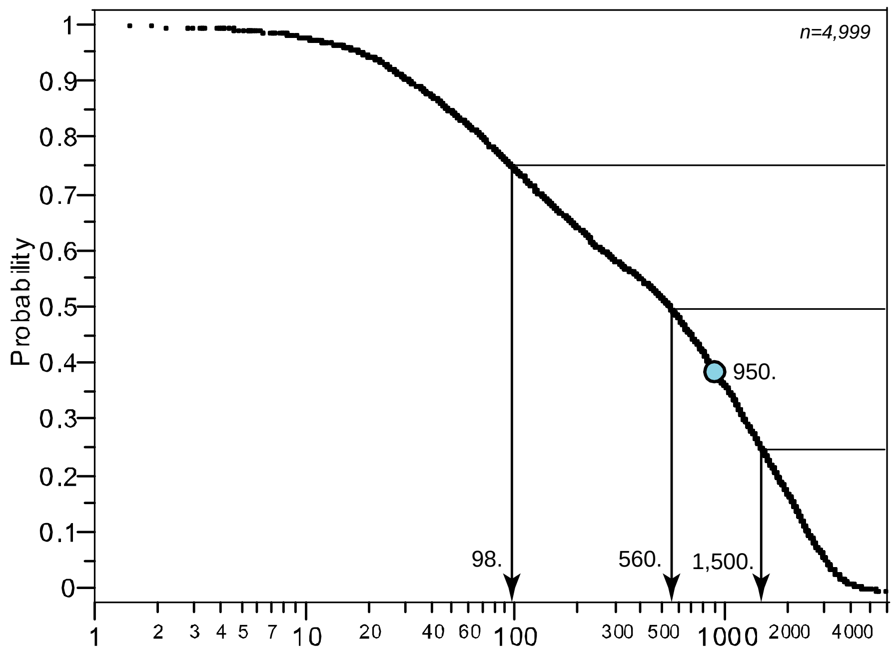

Figure 10.3-51. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 13 buffer zones. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of alluvial fan sand and gravel resources in Basin 13

***Deposit type*—**Alluvial fan sand and gravel

***Age of mineralization*—**Quaternary, better quality material is found in younger alluvial fan sand and gravel deposits.

***Example deposits types*—**There are no reported examples of alluvial fan sand and gravel deposits in tracts in this basin. No official records of work in sand and gravel deposits are kept in many part of the world, and this is also true in Afghanistan.

***Exploration history*—**The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified and produced in the tracts in this basin. Alluvial fan sand and gravel deposits are usually not found near towns unless a roadway passes up the fan slope into the stream basin in the adjacent mountains, which may be true in this basin. Neither the intensity nor the extent of sand and gravel exploration is known. However, exploitation of deposits near major roads is likely given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. Some of these alluvial sand and gravel deposits are near roads and other points of consumption, so some of these deposits may have been exploited. Most of the resource, however, is likely untouched. Alluvial fan sand and gravel deposits are recognized within buffer zones (as defined below) near towns and roads but are not considered separately in this assessment.

***Tract boundary criteria*—**Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-49*c*).

***Needs to improve assessment*—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, the former USSR engineers, and construction contractors who have built roads in Afghanistan would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

***Optimistic factors*—**The steeper terrain and mountain fronts usually associated with alluvial fans are found widely in this basin. Alluvial fans are clearly recognized on topographic sheets. The alluvial fan and colluvium unit (Doebrich and Wahl, 2006) has a mapped outcrop area of 180 km^2.

***Pessimistic factors*—**Alluvial fans are often problematic as they are commonly poorly sorted with large amounts of unsuitable clay and silt interbedded or directly mixed with the sand and gravel. Only a few of fans are recognized on topographic sheets and only a small portion of them are likely to contain sand and gravel deposits suitable for development.

***Estimated number of undiscovered deposits*—**The number of alluvial fans was subjectively estimated. Because information about discovered deposits is not available, the estimated number of deposits and their associated probability for MCS are for both discovered and undiscovered deposits and are given together with an associated probability (table 10.3-39).

Table 10.3-39. Estimated number of sand and gravel deposits, both discovered and undiscovered, in alluvial fans in Basin 13.

Probability level	**Number of deposits**
90 % chance of at least	1
70 % chance of at least	1
50 % chance of at least	1
30 % chance of at least	2
10 % chance of at least	2

***Monte Carlo Simulation results for alluvial fan deposits*—**There are three chances in four that the sand and gravel resources in alluvial fans in Basin 13 will be equal to or greater than 43 million m^3. There are also an even chance that there will be equal to or greater than 130 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 460 million m^3 (fig. 10.3-52).

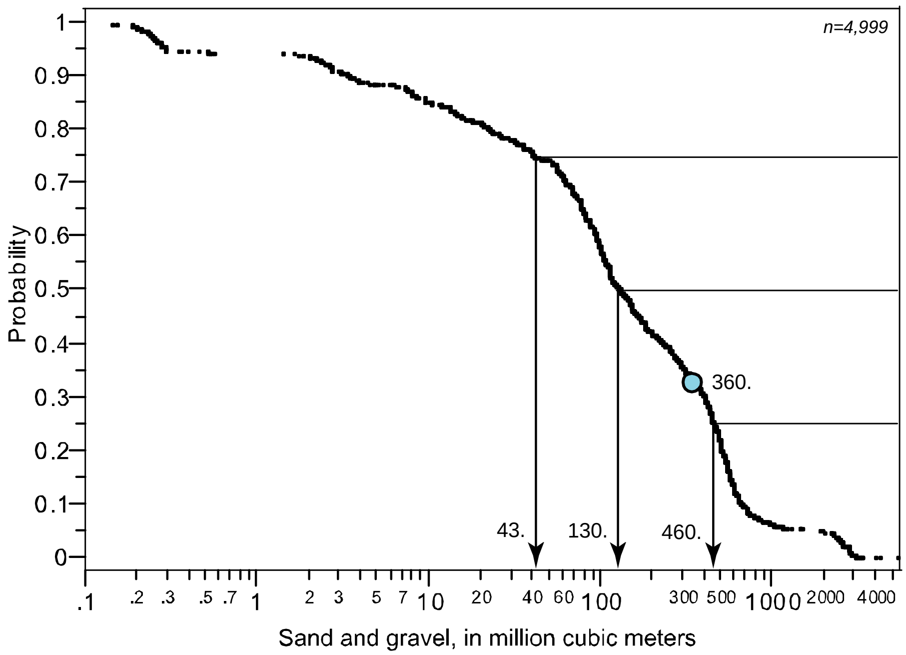

Figure 10.3-52. Distribution of sand and gravel resources in sand and gravel deposits in Basin 13 alluvial fans. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of fluvial sand and gravel resources in Basin 14

Introduction—Basin 14, with an estimated area of 26,000 km^2, is in northeastern Afghanistan (fig. 10.3-1) It extends from Tajikistan on the northwest to Pakistan on the southeast. It includes the catchments of the Kokcha (Kowcheh, Kowkcheh) River and its tributaries.

Deposit type—Fluvial sand and gravel

Age of mineralization—Quaternary; as a rule, better quality material is in younger fluvial sand and gravel deposits.

Example deposits types—There are no examples of sand and gravel deposits in tracts in Basin 14. No official records of work in sand and gravel deposits are kept in many parts of the world, and this is also true in Afghanistan. Basin 14 contains the Kokcha River and its tributaries and fluvial sand and gravel deposits can be expected to be present along those waterways.

Exploration history—No sites have been reported as a sources of sand and gravel in Basin 14. The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified in the basin and that production likely has been wide spread. At least two major roads are recognized in this basin and their presences suggest that it is highly likely that some sand and gravel may have been extracted for their construction and ongoing maintenance. However, neither the intensity nor the extent of sand and gravel exploration is known. Exploitation of deposits near major and other roads is expected given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. Sand and gravel is produced near the points of consumption so locations in regions at some distance from existing roads and towns are likely untouched. Deposits within buffer zones (as defined below), which are near towns in this basin are more likely to have been explored.

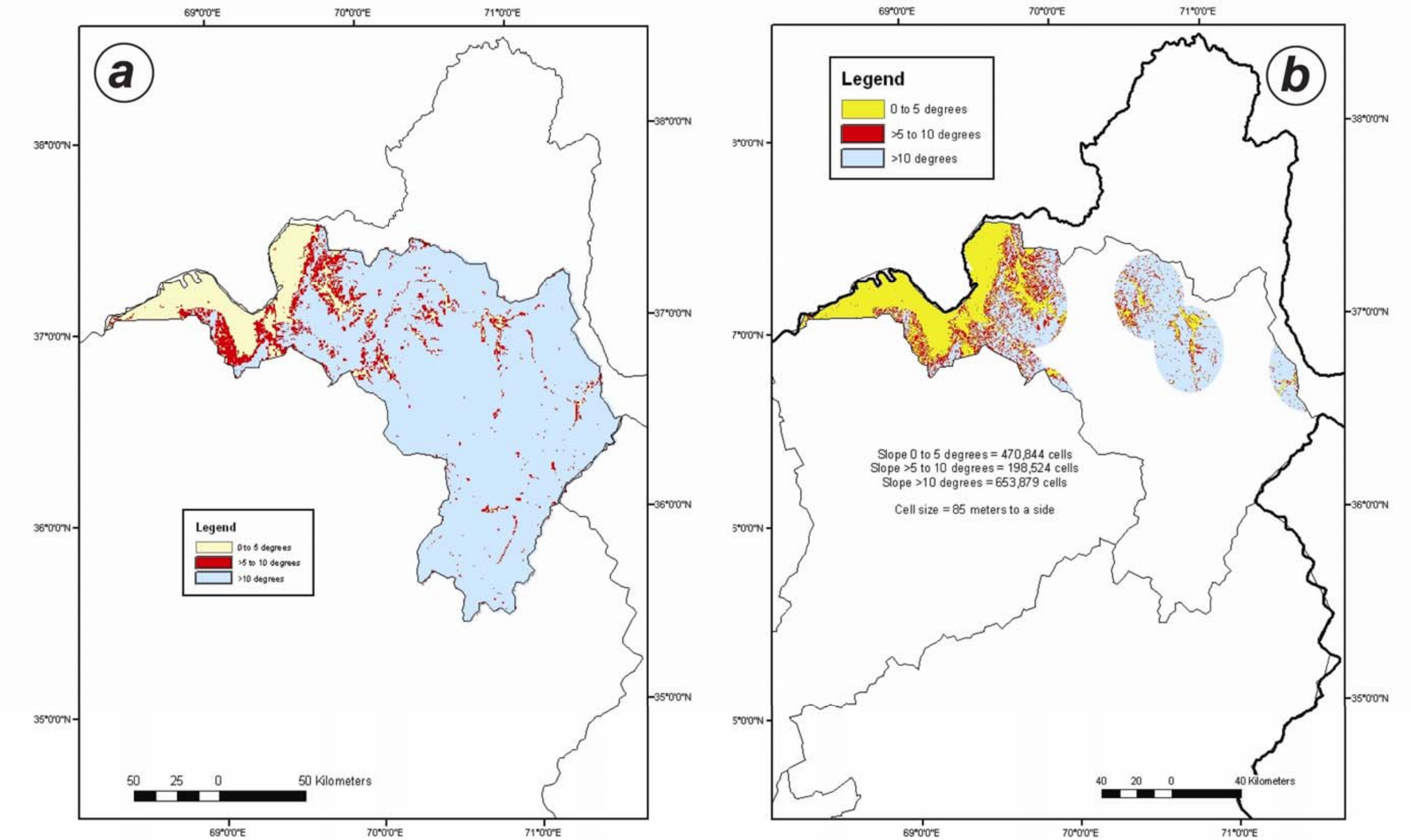

Figure 10.3-53. Outline of Basin 14 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits. Areas with slopes greater than 10 degrees (blue) are non-permissive. (*a*) entire basin. (*b*) areas within 25 km buffer zone around towns and along roads. Slopes between 0-5 degrees (yellow), and 5-10 degrees (red) are permissive for fluvial sand and gravel deposits and those greater than 10 degrees (blue) are not permissive.

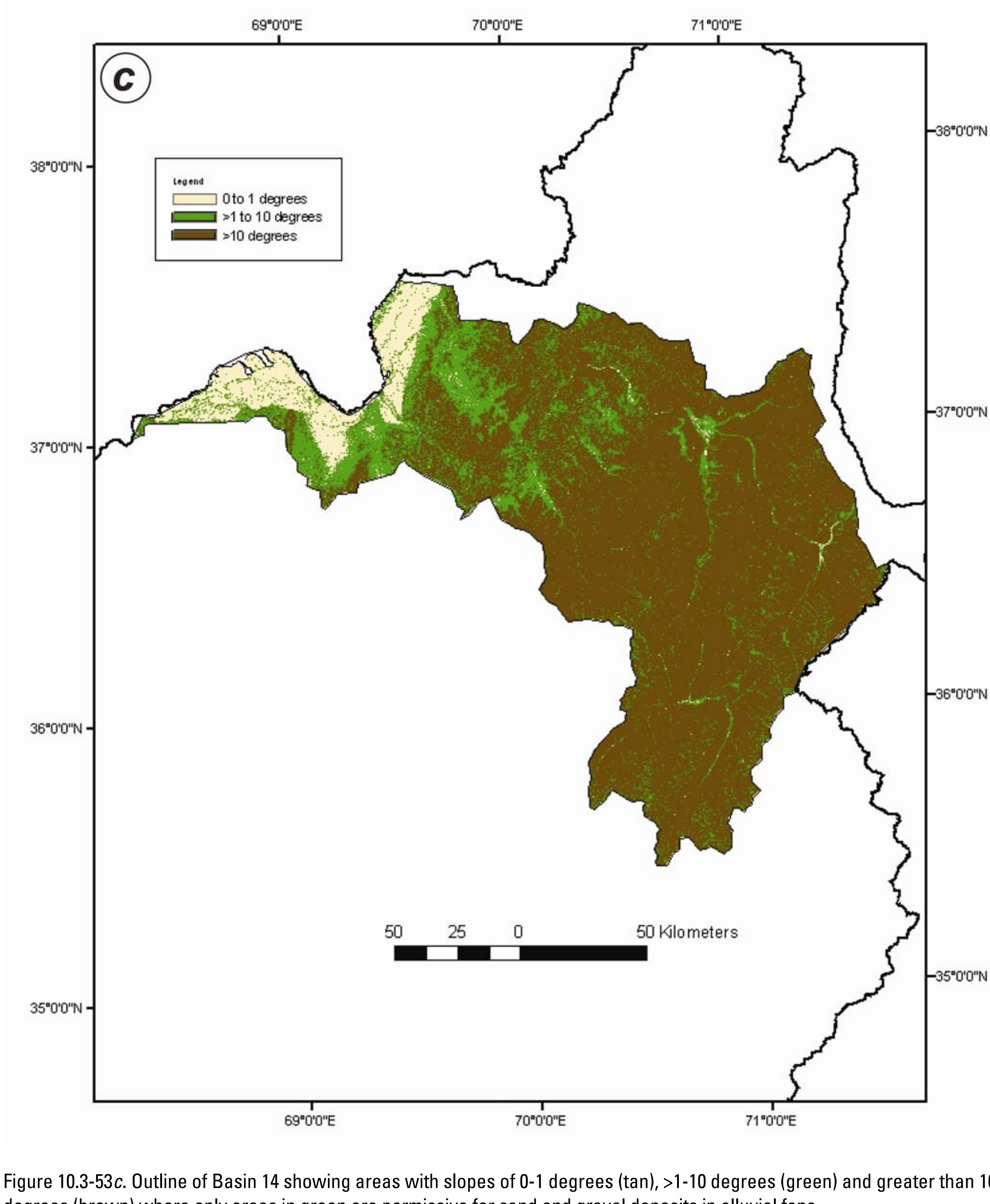

Figure 10.3-53*c*. Outline of Basin 14 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

Tract boundary criteria in basins—See uniform tract boundary criteria based on topographic slope used for both basins and buffer zones as noted in the introductory discussion above. Thirty five percent of Basin 14 or 6,600 km^2 is permissive for fluvial sand and gravel deposits (fig. 10.3-53)

Buffer zone criteria—Buffer zones in tracts are defined as extending 25 km around towns and along both sides of major roads. Buffered areas (fig. 10.3-53b) with slopes less than 10 degrees have a cumulative area of 4,800 km^2.

Needs to improve assessment—Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors—Of the Quaternary sediments in tracts in this basin, 84 percent are defined as an alluvium unit in which the gravel content is greater than silt or clay. This unit is highly likely to be the host of readily recognizable fluvial sand and gravel deposits. This unit also includes an unknown amount of alluvial fans and colluvium with gravel and sand greater than silt that are located along mountain fronts. Erosion of these sediments may contribute sand and gravel downstream. Sand and gravel resources expected to be present in alluvial fan sand and gravel deposits are separately assessed (see below).

Pessimistic factors—Application of the uniform tract boundary criteria based on topographic slope to this basin resulted in 45 percent of the cells being on surface described as non-Quaternary rocks. This indicates that we may have produced a cumulative permissive tract area that is too large. Alluvial fan and colluvium have been not group with alluvium and this may suggest that some of the alluvium (and other units) may be fan deposits and not fluvial deposits as defined in this study. Other Quaternary sediments in permissive tracts include units that are 1) highly unlikely sources of sand and gravel or 2) overburden that may obscure sand and gravel deposits at depth. These units include those dominated by sand (4 percent), loess (12 percent) and glacial till (0.25 percent) where these units cumulatively include 16 percent of the Quaternary sediments in permissive tracts.

Estimated number of undiscovered deposits—For the assessment of the slope-defined tracts in Basin 14 (fig. 10.3-53*b*), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-40) All tracts, which have a total cumulative area of 6,600 km^2 within the basin, are evaluated simultaneously. Because information about discovered deposits is limited, the estimated number of deposits and their associated probability given in the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-40. Estimated number of fluvial sand and gravel deposits in Basin 14, both discovered and undiscovered, calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	2
80 % chance of at least	3
70 % chance of at least	4
60 % chance of at least	5
50 % chance of at least	18
40 % chance of at least	26
30 % chance of at least	35
20 % chance of at least	57
10 % chance of at least	78

Monte Carlo Simulation results**—**There are three chances in four that the sand and gravel resources in Basin 14 in fluvial sand and gravel deposits will be equal to or greater than 42 million m^3, and there is an even chance that there will be equal to or greater than 290 million m^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 900 million m^3 (fig. 10.3-54).

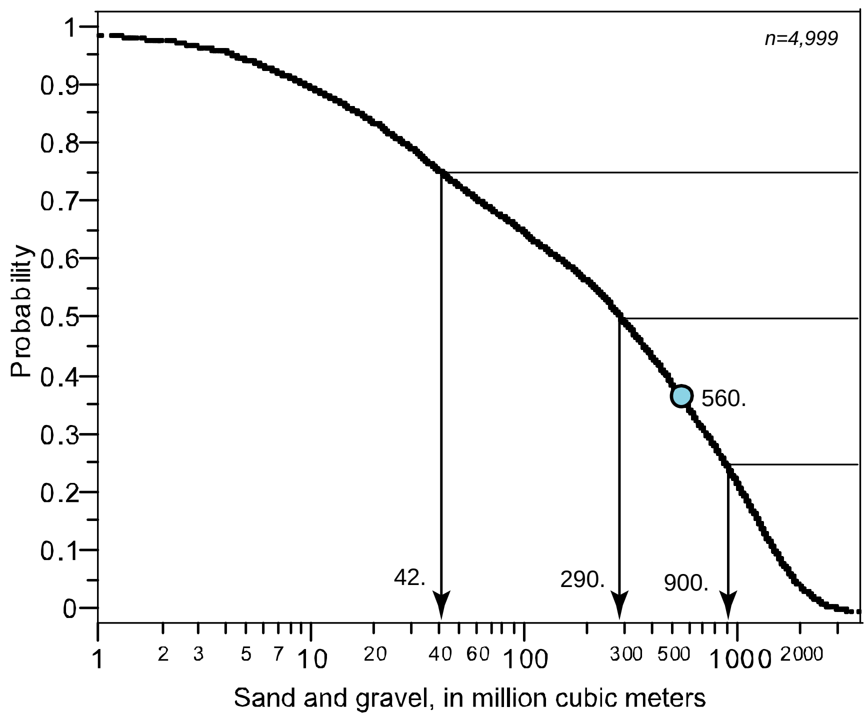

Figure 10.3-54. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 14 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Estimated number of undiscovered deposits in buffer zones**—**For the assessment of Basin 14 buffer zones (fig. 10.3-53*b*), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-41) from the permissive area of 4,800 km^2. All buffer zones in the basin are evaluated simultaneously. The estimated number of deposits and their associated probability given by the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees. The Quaternary geology in buffer zones contains possible areas of fan alluvium and colluvium together with areas of the more promising alluvium units that are more likely to contain fluvial sand and gravel deposits. Loess, sand and mud dominated units are found in parts of the permissive tracts within buffer zones that will obscure or prohibit the presences of undiscovered deposits.

Table 10.3-41. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zones calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	2
80 % chance of at least	2
70 % chance of at least	3
60 % chance of at least	4
50 % chance of at least	13
40 % chance of at least	19
30 % chance of at least	26
20 % chance of at least	42
10 % chance of at least	58

***Monte Carlo Simulation results for undiscovered deposits in buffer zones*—**There are three chances in four that the sand and gravel resources in Basin 14 in fluvial sand and gravel deposits will be equal to or greater than 32 million m^3. There is also an even chance that there will be equal to or greater than 210 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 640 million m^3 (fig. 10.3-55). Proximity to towns and major roads suggests a portion of the estimate sand and gravel resources may have already been consumed.

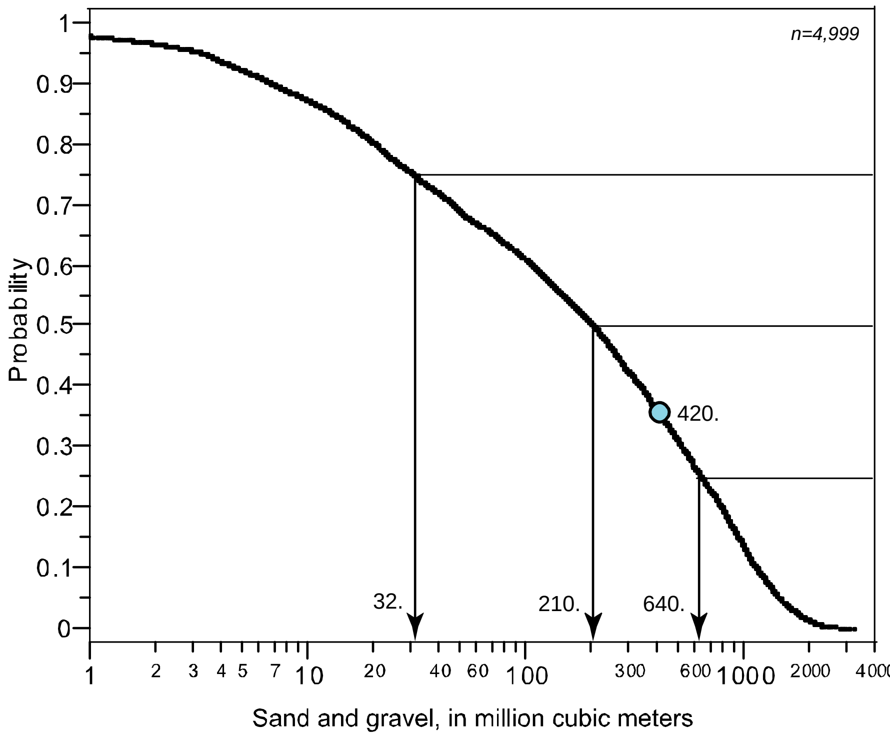

Figure 10.3-55. Distribution of sand and gravel resources in fluvial sand and gravel deposits in tracts in Basin 14 buffer zones. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of alluvial fan sand and gravel resources in Basin 14

Deposit type—Alluvial fan sand and gravel

Age of mineralization—Quaternary, better quality material is in younger alluvial fan sand and gravel deposits.

Example deposits types—There are no reported examples of alluvial fan sand and gravel deposits in tracts in this basin. Most alluvial fan sand and gravel deposits are worked without record in many part of the world, and this is also true in Afghanistan.

Exploration history—The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified and produced in the tracts in this basin. Alluvial fan sand and gravel deposits are usually not found near towns unless a roadway passes up the fan slope into the stream basin in the adjacent mountains, which may be true in this basin. Neither the intensity nor the extent of sand and gravel exploration is known. However, exploitation of deposits near major roads is expected given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. However, some of these alluvial sand and gravel deposits are near roads and other points of consumption, so some of these deposits may have been exploited. However, most of the resource is likely untouched. Deposits of this type are likely rare within buffer zones (as defined below) that are found near towns and roads and these deposits are not considered in this assessment.

Tract boundary criteria—Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-53c).

***Needs to improve assessment*—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, the former USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use. A map of Quaternary geology with fan alluvium depicted would be a valuable addition.

***Optimistic factors*—**The steeper terrain and mountain fronts usually associated with alluvial fans are found widely in this basin. Alluvial fans are clearly recognized on topographic sheets (scale 1: 200,000).

***Pessimistic factors*—**Alluvial fans are often problematic as they are commonly poorly sorted with large amounts of unsuitable clay and silt interbedded or directly mixed with the sand and gravel. Only a few of fans are recognized on topographic sheets and only a small portion of them are likely to contain sand and gravel deposits suitable for development.

***Estimated number of undiscovered deposits*—**The number of alluvial fans was subjectively estimated. Because information about discovered deposits is not available, the estimated number of deposits and their associated probability for MCS are for both discovered and undiscovered deposits and are given together with an associated probability (table 10.3-42).

Table 10.3-42. Estimated number of sand and gravel deposits, both discovered and undiscovered, in alluvial fans in Basin 14.

Probability level	Number of deposits
90 % chance of at least	0
70 % chance of at least	1
50 % chance of at least	2
30 % chance of at least	2
10 % chance of at least	3

***Monte Carlo Simulation results for alluvial fan deposits*—**There are three chances in four that the sand and gravel resources in alluvial fans in Basin 14 will be equal to or greater than 8 million m^3. There are also an even chance that there will be equal to or greater than 160 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 550 million m^3 (fig. 10.3-56).

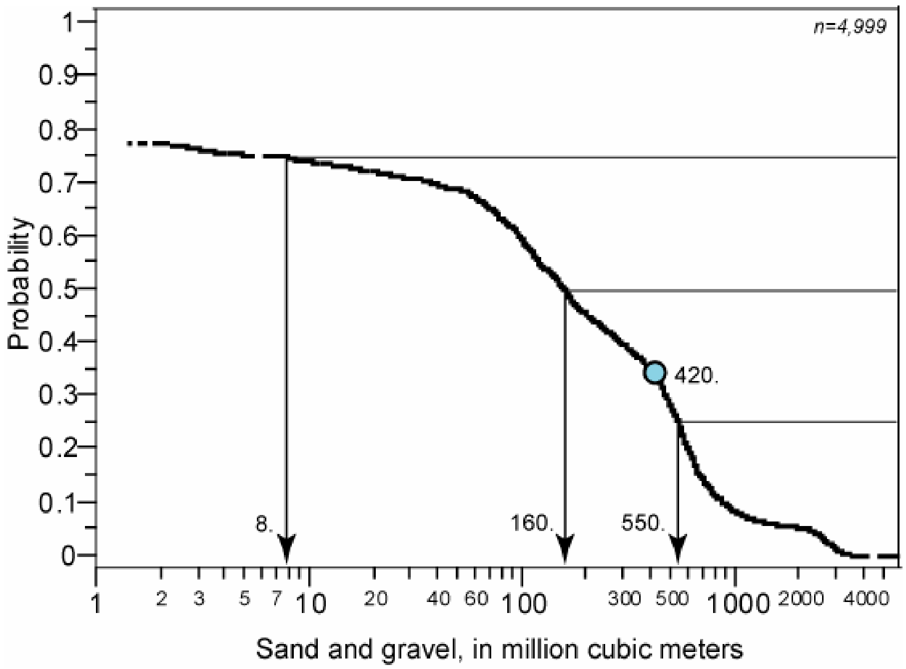

Figure 10.3-56. Distribution of sand and gravel resources in sand and gravel deposits in Basin 14alluvial fans. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of fluvial sand and gravel resources in Basin 15

***Introduction*—**Basin 15, with an estimated area of 53,000 km^2, is located in eastern Afghanistan and is bounded by Pakistan on the east (fig. 10.3-1) It includes the catchments of the Kabul River and its tributaries as well as the city of Kabul and Jalabad.

***Deposit type*—**Fluvial sand and gravel

***Age of mineralization*—**Quaternary; as a rule, better quality material is in younger fluvial sand and gravel deposits.

***Example deposits types*—**There are no examples of sand and gravel deposits in tracts in Basin 15. No official records of work in sand and gravel deposits are kept in many parts of the world, and this is also true in Afghanistan. Fluvial sand and gravel deposits can be expected to be present in and near the Kabul River and its tributaries and fluvial sand and gravel deposits can be expected to be present along those waterways.

***Exploration history*—**No sites have been reported as a sources of sand and gravel in Basin 15. The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified in the basin and that production likely has been wide spread. At least two major roads are recognized in this basin and their presences suggest that it is highly likely that some sand and gravel may have been extracted for their construction and ongoing maintenance. However, neither the intensity nor the extent of sand and gravel exploration is known. Exploitation of deposits near major and other roads is expected given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. Sand and gravel is produced near the points of consumption so locations in regions at some distance from existing road and towns are likely untouched. Deposits within buffer zones (as defined below), which are near towns in this basin are more likely to have been explored.

Tract boundary criteria in basins—See uniform tract boundary criteria based on topographic slope used for both basins and buffer zones as noted in the introductory discussion above. Thirty five percent of Basin 15 or 16,000 km^2 is permissive for fluvial sand and gravel deposits (fig. 10.3-57)

Buffer zone criteria—Buffer zones are defined as extending 25 km around towns and along both sides of major roads. Buffered areas (fig. 10.3-57*b*) with slopes less than 10 degrees have a cumulative area of 13,000 km^2.

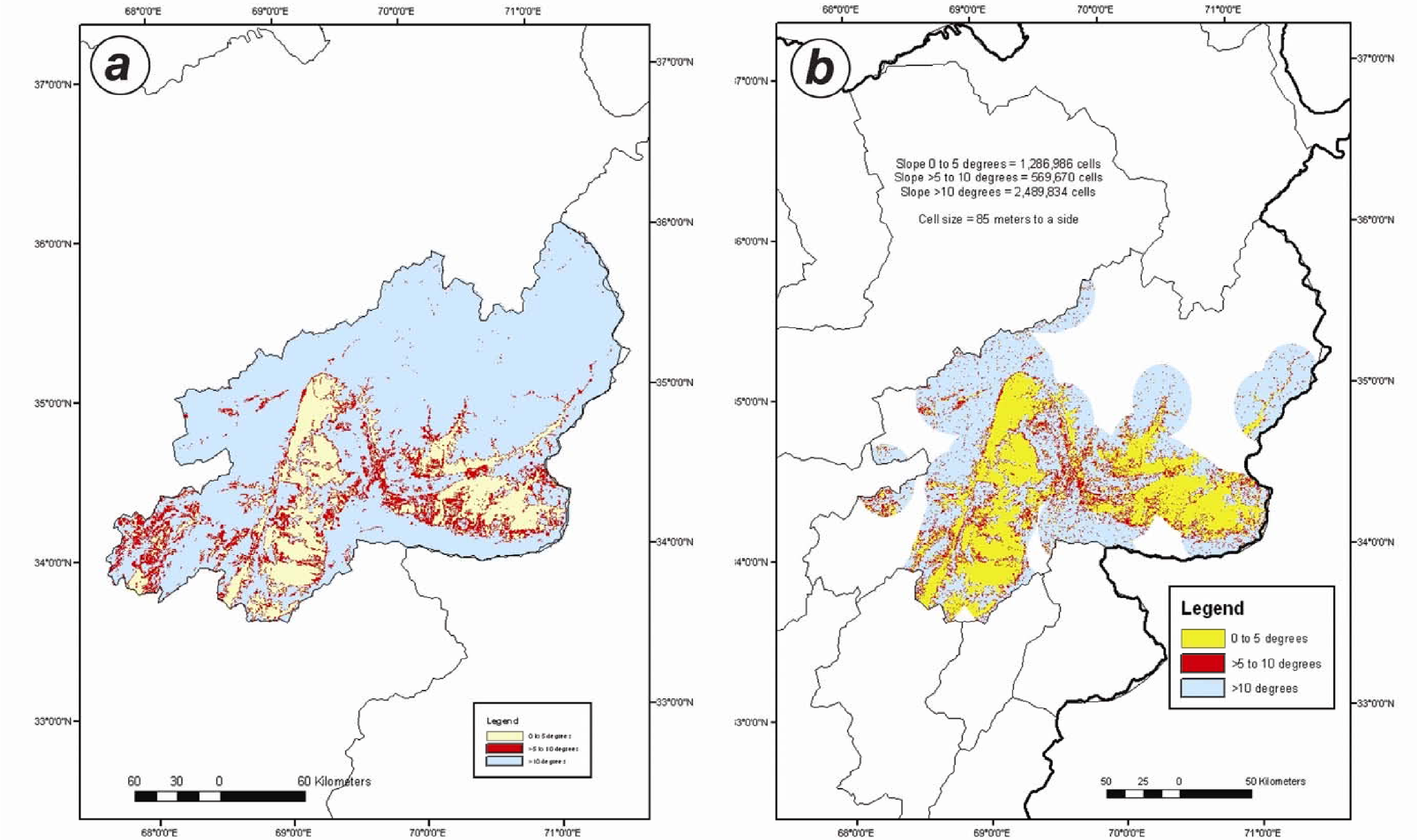

Figure 10.3-57. Outline of Basin 15 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits. Areas with slopes greater than 10 degrees (blue) are non-permissive. (*a*) entire basin. (*b*) areas within 25 kilometer buffer zone around towns and along roads. Slopes between 0-5 degrees (yellow), and 5-10 degrees (red) are permissive for fluvial sand and gravel deposits and those greater than 10 degrees (blue) are not permissive.

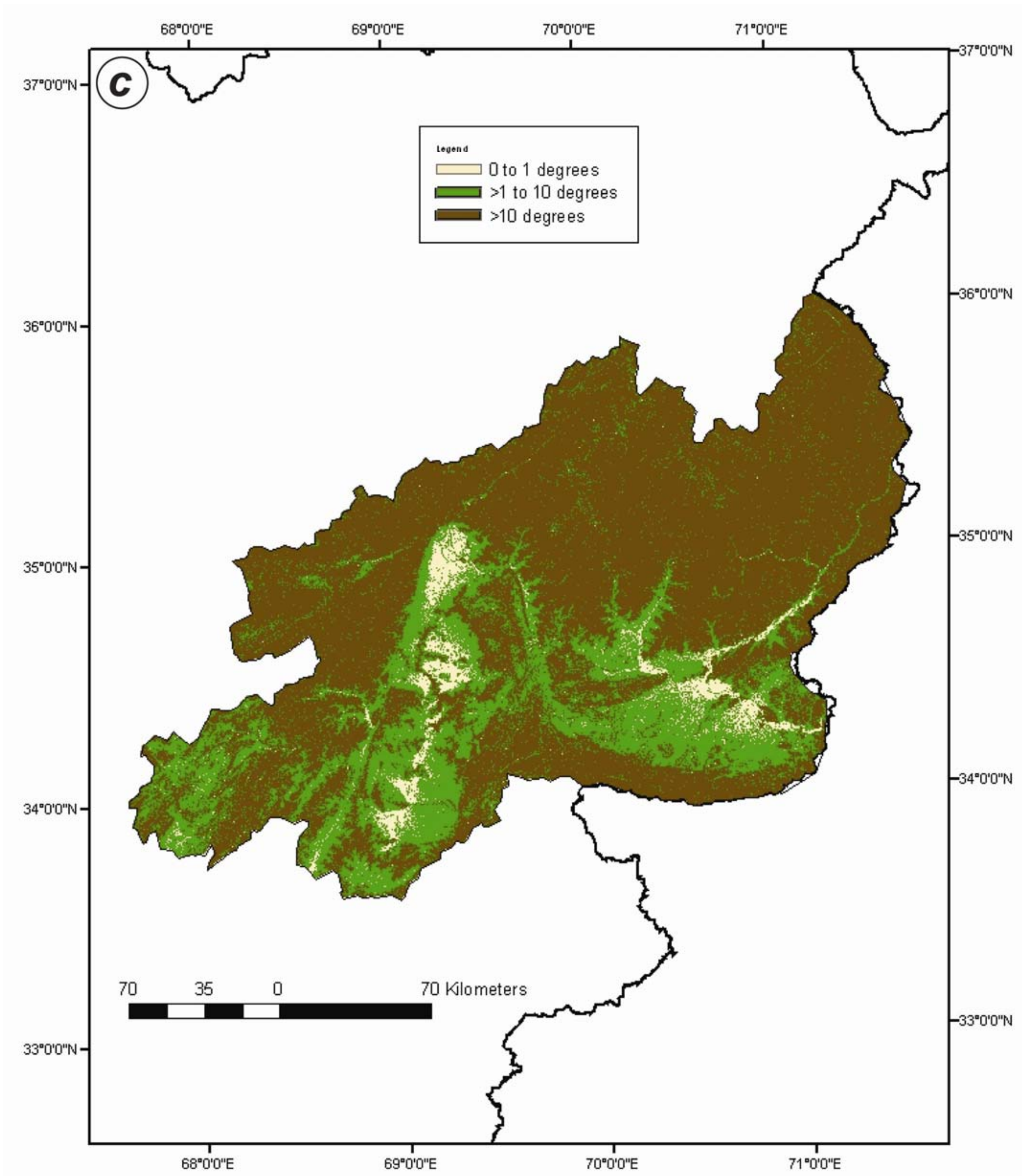

Figure 10.3-57*c*. Outline of Basin 15 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

Needs to improve assessment**—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors**—**Of the Quaternary sediments in tracts in this basin, 43 percent are defined as an alluvium unit in which the gravel content is greater than silt or clay content. This unit is highly likely to be the host of readily recognizable fluvial sand and gravel deposits. A unit depicting alluvial fans and colluvium with gravel and sand greater than silt is located along mountain front and may contribute sand and gravel downstream. Sand and gravel resources expected to be present in alluvial fan sand and gravel deposits are separately assessed (see below).

Pessimistic factors**—**Application of the uniform tract boundary criteria based on topographic slope to this basin resulted in 49 percent of the cells being on surface described as non-Quaternary rocks. This indicates that we may have produced a cumulative permissive tract area that is too large. Alluvial fans and colluvium have not been grouped with alluvium, and this may suggest that some of the alluvium (and other units) may be fan deposits and not fluvial deposits as defined in this study. Other Quaternary sediments in permissive tracts include units that are 1) highly unlikely sources of sand and gravel or 2) overburden may obscure sand and gravel deposits at depth. These units include outcrops dominated by loess (29 percent), travertine deposits (3.6 percent) and glacial till (0.13 percent) where these units cumulatively include 33 percent of the Quaternary sediments in permissive tracts.

Estimated number of undiscovered deposits**—**For the assessment of the slope-defined tracts in Basin 15 (fig. 10.3-57*b*), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-43) All tracts, which have a total cumulative area of 16,000 km^2 within the basin, are evaluated simultaneously. Because information about discovered deposits is limited, the estimated number of deposits and their associated probability given in the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-43. Estimated number of fluvial sand and gravel deposits in Basin 15, both discovered and undiscovered, calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	6
80 % chance of at least	7
70 % chance of at least	11
60 % chance of at least	13
50 % chance of at least	45
40 % chance of at least	65
30 % chance of at least	88
20 % chance of at least	143
10 % chance of at least	197

Monte Carlo Simulation results**—**There are three chances in four that the sand and gravel resources in Basin 15 in fluvial sand and gravel deposits will be equal to or greater than 160 million m^3, and there is an even chance that there will be equal to or greater than 850 million m^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 2,200 million m^3 (fig. 10.3-58).

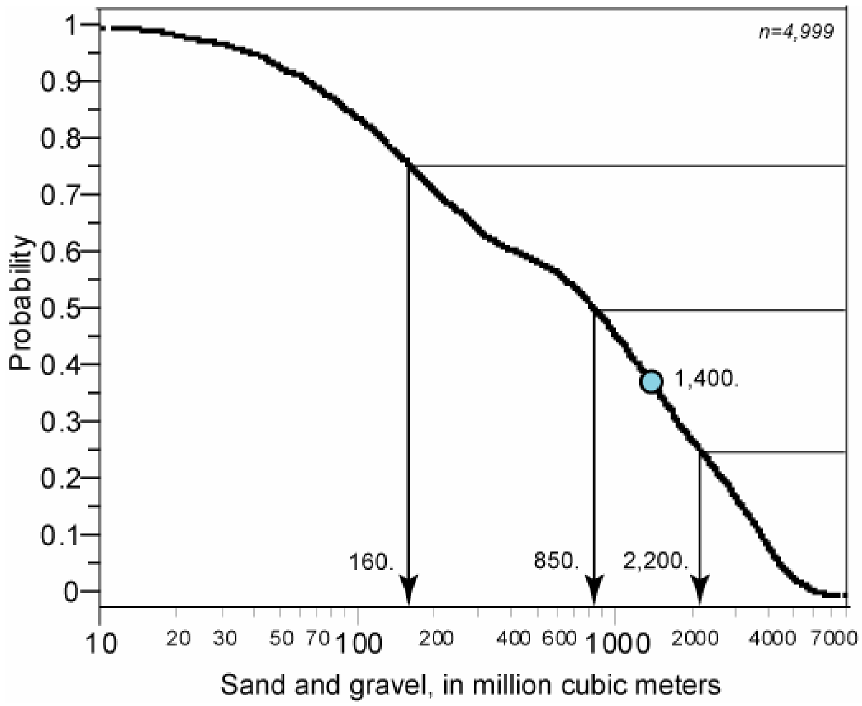

Figure 10.3-58. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 15 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Estimated number of undiscovered deposits in buffer zones—For the assessment of Basin 15 buffer zones (fig. 10.3-57b), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-44) from the permissive area of 13,000 km^2. All buffer zones in the basin are evaluated simultaneously. The estimated number of deposits and their associated probability given by the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees. The Quaternary geology in buffer zones contains possible areas of fan alluvium and colluvium together with areas of the more promising alluvium units that are more likely to contain fluvial sand and gravel deposits. Loess, sand and mud dominated units are found in parts of the permissive tracts within buffer zones that will obscure or prohibit the presences of undiscovered deposits.

Table 10.3-44. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zones calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	5
80 % chance of at least	6
70 % chance of at least	9
60 % chance of at least	11
50 % chance of at least	37
40 % chance of at least	52
30 % chance of at least	71
20 % chance of at least	116
10 % chance of at least	160

Monte Carlo Simulation results for undiscovered deposits in buffer zones—There are three chances in four that the sand and gravel resources in Basin 15 in fluvial sand and gravel deposits will be equal to or greater than 140 million m^3. There is also an even chance that there will be equal to or greater than 760 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 1,800 million m^3 (fig. 10.3-59). Proximity to towns and major roads suggests a portion of the estimated sand and gravel resources may have already been consumed.

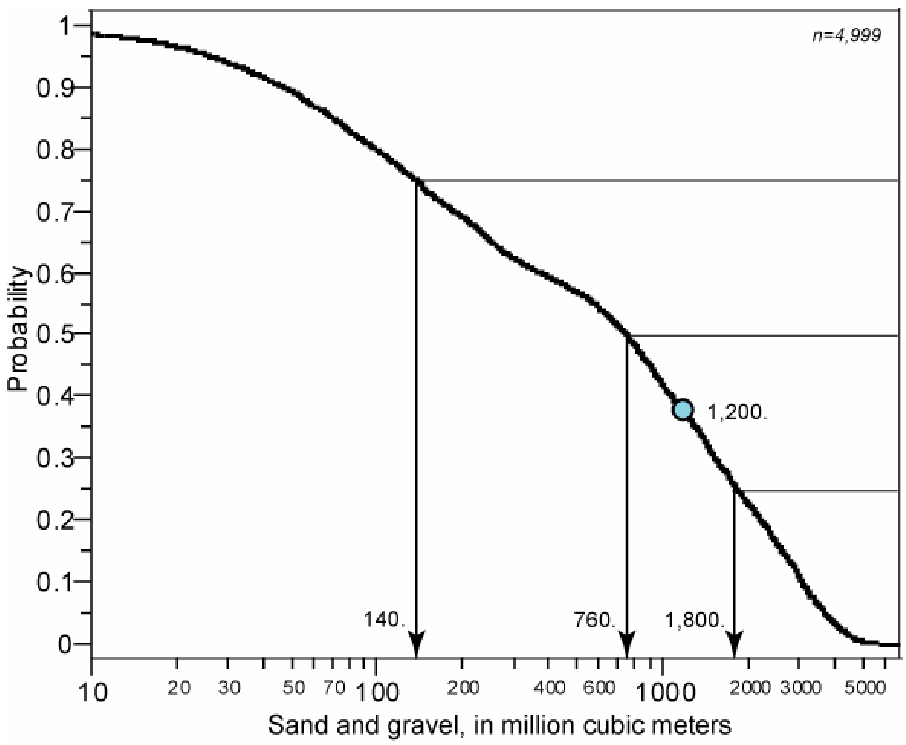

Figure 10.3-59. Distribution of sand and gravel resources in fluvial sand and gravel deposits in buffer zones in Basin 15 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of alluvial fan sand and gravel resources in Basin 15

Deposit type—Alluvial fan sand and gravel

Age of mineralization—Quaternary, better quality material is in younger fluvial fan sand and gravel deposits.

Example deposits types—There are no reported examples of fluvial fan sand and gravel deposits in tracts in this basin. No official records of work in sand and gravel deposits are kept in many part of the world, and this is also true in Afghanistan.

Exploration history—The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified and produced in the tracts in this basin. Alluvial fan sand and gravel deposits are usually not found near towns unless a roadway passes up the fan slope into the stream basin in the adjacent mountains, which may be true in this basin. Neither the intensity nor the extent of sand and gravel exploration is known. However, exploitation of deposits near major roads is expected given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. However, some of these alluvial sand and gravel deposits are near roads and other points of consumption, so some of these deposits may have been exploited. However, most of the resource is likely untouched. Deposits of this type are likely rare within buffer zones (as defined below) that are found near towns and roads, and those deposits are not considered in this assessment.

***Tract boundary criteria*—**Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-57*c*).

***Needs to improve assessment*—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, the former 111 and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

***Optimistic factors*—**The steeper terrain and mountain fronts usually associated with alluvial fans are found widely in this basin. Quaternary units, described as alluvial fans and colluvium, are identified as having an area of 2,000 km^2 on the geologic map (Doebrich and Wahl, 2006). Alluvial fans are clearly recognized on topographic sheets (scale 1: 200,000).

***Pessimistic factors*—**Alluvial fans are often problematic as they are commonly poorly sorted with large amounts of unsuitable clay and silt interbedded or directly mixed with the sand and gravel. Only a few fans are recognized on topographic sheets and only a small portion of them are expected to contain sand and gravel deposits suitable for development.

***Estimated number of undiscovered deposits*—**The number of alluvial fans was subjectively estimated. Because information about discovered deposits is not available, the estimated number of deposits and their associated probability for MCS are for both discovered and undiscovered deposits and are given together with an associated probability (table 10.3-45).

Table 10.3-45. Estimated number of sand and gravel deposits, both discovered and undiscovered, in alluvial fans in Basin 15.

Probability level	Number of deposits
90 % chance of at least	2
70 % chance of at least	3
50 % chance of at least	5
30 % chance of at least	6
10 % chance of at least	7

***Monte Carlo Simulation results for alluvial fan deposits*—**there are three chances in four that the sand and gravel resources in alluvial fans in Basin 15 will be equal to or greater than 420 million m^3. There are also an even chance that there will be equal to or greater than 810 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 1,500 million m^3 (fig. 10.3-60).

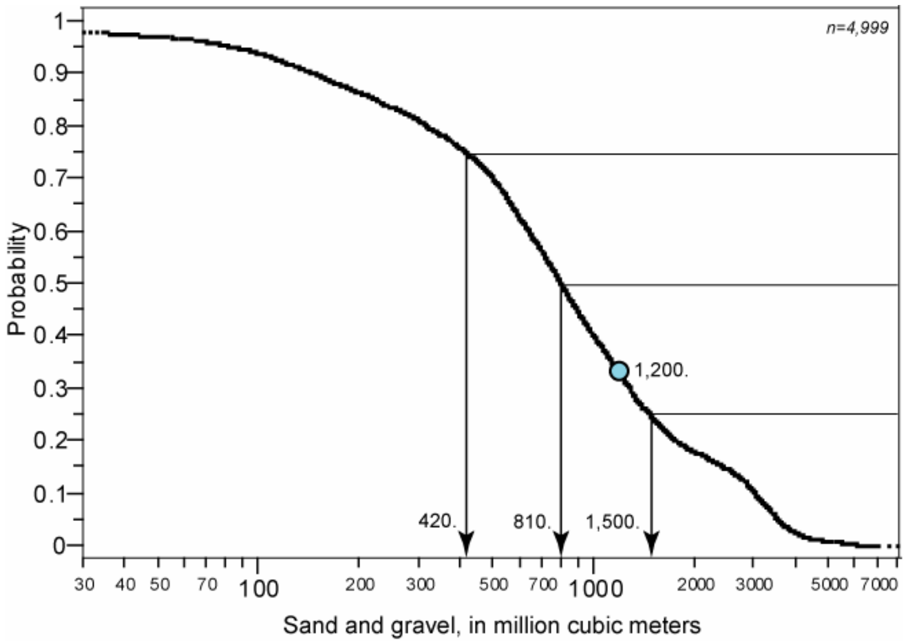

Figure 10.3-60. Distribution of sand and gravel resources in sand and gravel deposits in Basin 15 alluvial fans. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of fluvial sand and gravel resources in Basin 16

Introduction—Basin 16, with an estimated area of 4,700 km^2, is in eastern Afghanistan (fig. 10.3-1) It includes the catchments of the Gardez (Jilga) River as well as the towns of Gardeyz (Gardez) and Zareh Sharan. (fig. 10.3-1)

Deposit type—Fluvial sand and gravel

Age of mineralization—Quaternary; as a rule, better quality material is in younger fluvial sand and gravel deposits.

Example deposits types—There are no examples of sand and gravel deposits in tracts in Basin 16. No official records of work in sand and gravel deposits are kept in many parts of the world, and this is also true in Afghanistan. Basin 16 contains the Gardez River and its tributaries, and fluvial sand and gravel deposits can be expected to be present along those waterways.

Exploration history—No sites have been reported as a sources of sand and gravel in Basin 16. The presence of roads and other infrastructure that require sand and gravel suggest that sand and gravel has been previously identified in the basin and that production likely has been wide spread. At least on major road is recognized in this basin and its presences suggest that it is highly likely that some sand and gravel may have been extracted for its construction and ongoing maintenance. However, neither the intensity nor the extent of sand and gravel exploration is known. Exploitation of deposits near major and other roads is expected given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. Sand and gravel is produced near the points of consumption so locations in regions at some distance from existing roads and towns are likely untouched. Deposits within buffer zones (as defined below), which are near towns in this basin are more likely to have been explored.

Tract boundary criteria in basins—See uniform tract boundary criteria based on topographic slope used for both basins and buffer zones as noted in the introductory discussion above. Seventy eight percent of Basin 16 or 3,700 km^2 is permissive for fluvial sand and gravel deposits (fig. 10.3-61)

***Buffer zone criteria*—**Buffer zones in tracts are defined as extending 25 km around towns and along both sides of major roads. Buffered areas (fig. 10.3-61*b*) with slopes less than 10 degrees have a cumulative area of 2,800 km^2.

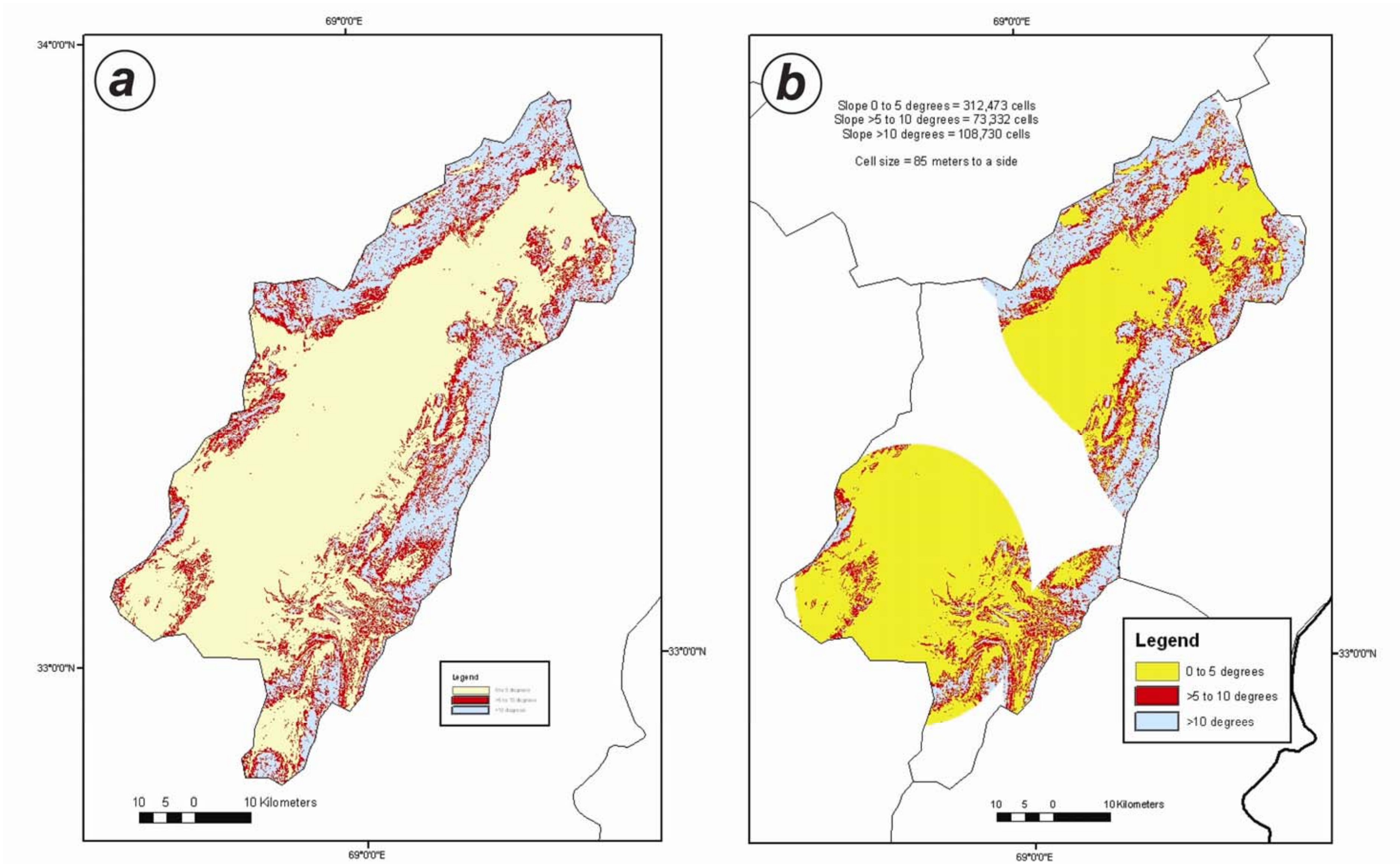

Figure 10.3-61. Outline of Basin 16 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits. Areas with slopes greater than 10 degrees (blue). (*a*) entire basin. (*b*) areas within 25 kilometer buffer zone around towns and along roads. Slopes between 0-5 degrees (yellow), and 5-10 degrees (red) are permissive for fluvial sand and gravel deposits and those greater than 10 degrees (blue) are not permissive.

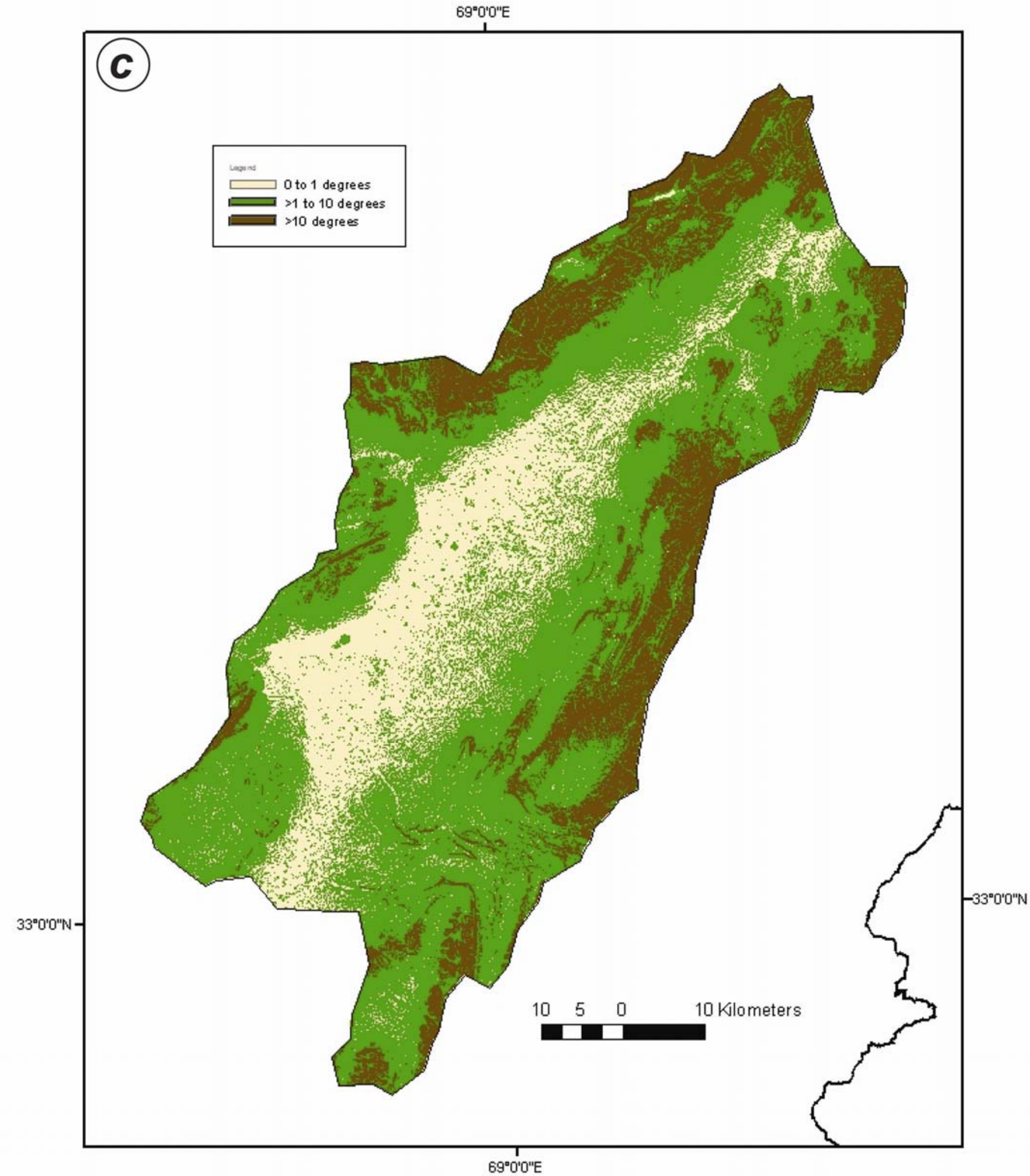

Figure 10.3-61*c*. Outline of Basin 16 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

Needs to improve assessment**—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors**—**Of the Quaternary sediments in tracts in this basin, 26 percent are defined as an alluvium unit in which the gravel content is greater than silt or clay. This unit is highly likely to be the host of readily recognizable fluvial sand and gravel deposits. Alluvial fans and colluvium with gravel and sand greater than silt and is located along mountain front and may contribute sand and gravel downstream. Sand and gravel resources expected to be present in alluvial fan sand and gravel deposits are separately assessed (see below.)

Pessimistic factors**—**Application of the uniform tract boundary criteria based on topographic slope to this basin resulted in 43 percent of the cells being on surface described as non-Quaternary rocks. This indicates that we may have produced a cumulative permissive tract area that is too large. Quaternary sediments in permissive tracts includes loess (43 percent) that is 1) a highly unlikely sources of sand and gravel or 2) overburden that may obscure sand and gravel deposits at depth. Alluvial fan and colluvium make up 31 percent of the tracts and may be a source of sand and gravel downstream but are separately assessed (see below.)

Estimated number of undiscovered deposits**—**For the assessment of the slope-defined tracts in Basin 16 (fig. 10.3-61*b*), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-46) All tracts, which have a total cumulative area of 3,700 km^2 within the basin, are evaluated simultaneously. Because information about discovered deposits is unavailable, the estimated number of deposits and their associated probability given in the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-46. Estimated number of fluvial sand and gravel deposits in Basin 16, both discovered and undiscovered, calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	1
80 % chance of at least	2
70 % chance of at least	2
60 % chance of at least	3
50 % chance of at least	10
40 % chance of at least	14
30 % chance of at least	20
20 % chance of at least	32
10 % chance of at least	44

Monte Carlo Simulation results**—**There are three chances in four that the sand and gravel resources in Basin 16 in fluvial sand and gravel deposits will be equal to or greater than 17 million m^3, and there is an even chance that there will be equal to or greater than 140 million m^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 470 million m^3 (fig. 10.3-62).

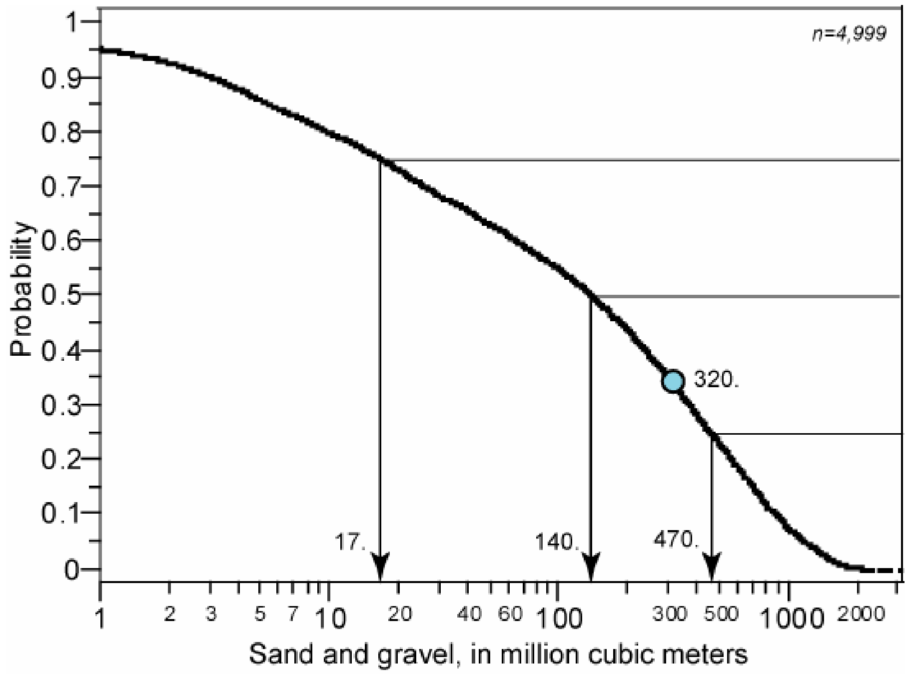

Figure 10.3-62. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 16 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Estimated number of undiscovered deposits in buffer zones—For the assessment of Basin 16 buffer zones (fig. 10.3-61b), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-47) from the permissive area of 2,800 km^2. All buffer zones in the basin are evaluated simultaneously. The estimated number of deposits and their associated probability given by the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees. The Quaternary geology in buffer zones contains possible areas of fan alluvium and colluvium together with areas of the more promising alluvium units that are more likely to contain fluvial sand and gravel deposits. Loess, sand, and mud dominated units are found in parts of the permissive tracts within buffer zones that will obscure or prohibit the presences of undiscovered deposits.

Table 10.3-47. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zones calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	1
80 % chance of at least	1
70 % chance of at least	2
60 % chance of at least	2
50 % chance of at least	8
40 % chance of at least	11
30 % chance of at least	15
20 % chance of at least	24
10 % chance of at least	33

Monte Carlo Simulation results for undiscovered deposits in buffer zones**—**There are three chances in four that the sand and gravel resources in Basin 16 found in buffer zone fluvial sand and gravel deposits will be equal to or greater than 11 million m^3. There is also an even chance that there will be equal to or greater than 110 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 330 million m^3 (fig. 10.3-63). Proximity to towns and major roads suggests a portion of the estimated sand and gravel resources may have already been consumed.

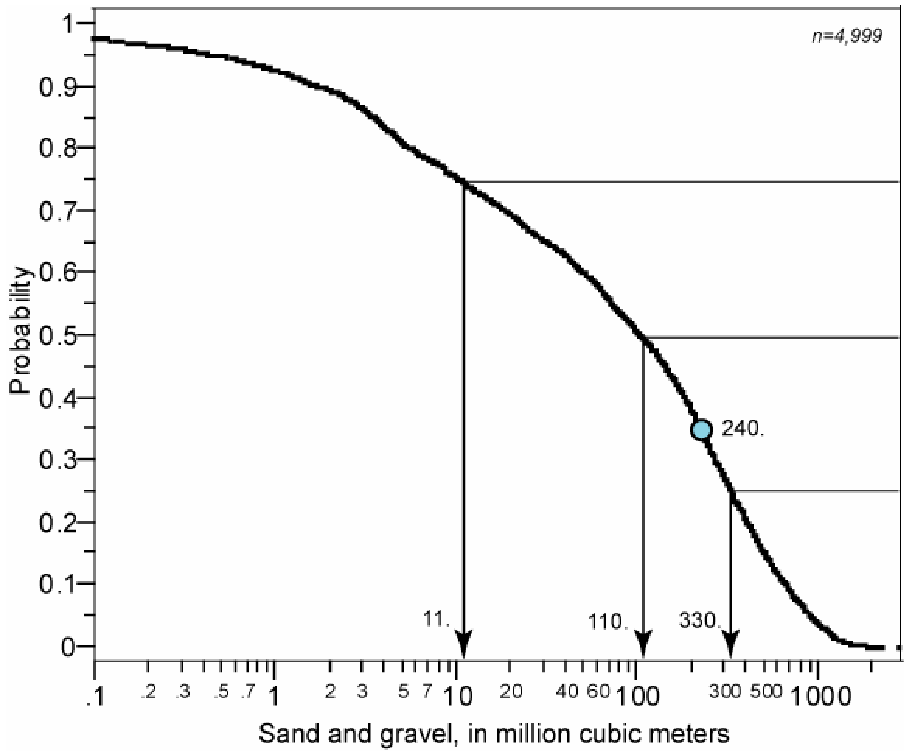

Figure 10.3-63. Distribution of sand and gravel resources in fluvial sand and gravel deposits in buffer zones in Basin 16 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of alluvial fan sand and gravel resources in Basin 16

Deposit type—Alluvial fan sand and gravel

Age of mineralization**—**Quaternary, better quality material is in younger fluvial fan sand and gravel deposits.

Example deposits types**—**There are no reported examples of fluvial fan sand and gravel deposits in tracts in this basin. Most fluvial fan sand and gravel deposits are worked without record in many part of the world, and this is also true in Afghanistan.

Exploration history**—**The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified and produced in the tracts in this basin. Alluvial fan sand and gravel deposits are usually not found near towns unless a roadway passes up the fan slope into the stream basin in the adjacent mountains, which may be true in this basin. Neither the intensity nor the extent of sand and gravel exploration is known. However, exploitation of deposits near major roads is expected given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. However, some of these alluvial sand and gravel deposits are near roads and other points of consumption, so some of these deposits may have been exploited but most of the resource is likely untouched. Deposits of this type are likely rare within buffer zones (as defined above) found near towns and roads and are not considered in this assessment.

Tract boundary criteria—Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-61c).

Needs to improve assessment—Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, the former USSR engineers, and construction contractors who have built roads in Afghanistan would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors—The steeper terrain and mountain fronts usually associated with alluvial fans are found widely in this basin. Quaternary units defined as alluvial fans and colluvium (at all slopes) is identified as being 700 km^2 on the geologic map (Doebrich and Wahl, 2006) in this basin. Alluvial fans are clearly recognized on topographic sheets (scale 1: 200,000).

Pessimistic factors—Alluvial fans are often problematic as they are commonly poorly sorted with large amounts of unsuitable clay and silt interbedded or directly mixed with the sand and gravel. Only a few of fans are recognized on topographic sheets and only a small portion of them are expected to contain sand and gravel deposits suitable for development.

Estimated number of undiscovered deposits—The number of alluvial fans was subjectively estimated. Because information about discovered deposits is not available, the estimated number of deposits and their associated probability for MCS are for both discovered and undiscovered deposits and are given together with an associated probability (table 10.3-48).

Table 10.3-48. Estimate number of fluvial sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 16.

Probability level	Number of deposits
90 % chance of at least	1
70 % chance of at least	1
50 % chance of at least	2
30 % chance of at least	2
10 % chance of at least	2

Monte Carlo Simulation results for alluvial fan deposits—There are three chances in four that the sand and gravel resources in alluvial fans in Basin 16 will be equal to or greater than 69 million m^3. There is also an even chance that there will be equal to or greater than 170 million m^3 (fig. 10.3-64) and one chance in four that the amount of sand and gravel resources will equal or be greater than 500 million m^3.

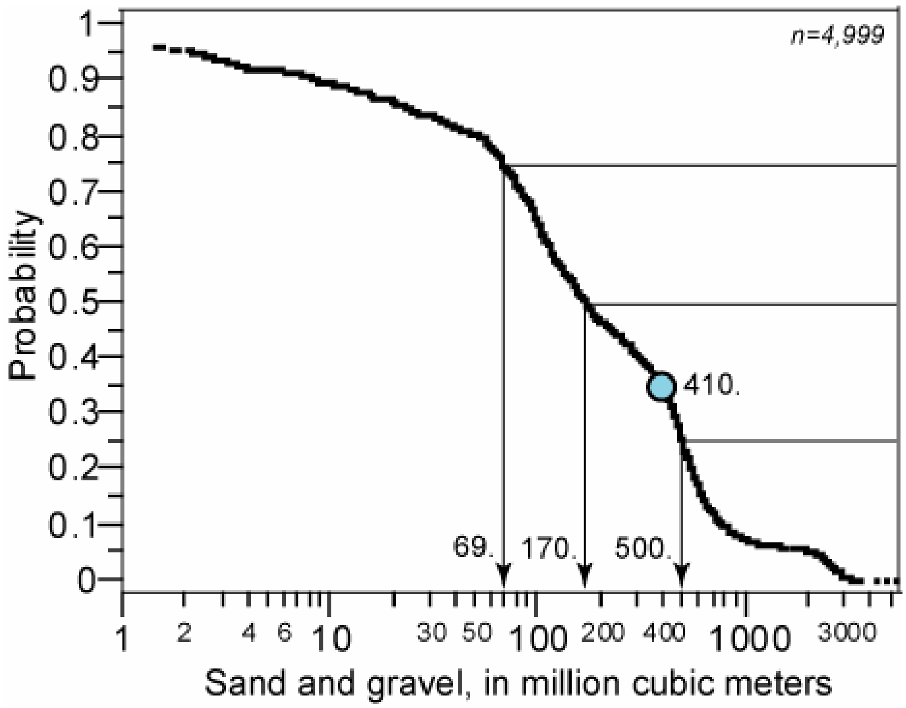

Figure 10.3-64. Distribution of sand and gravel resources in sand and gravel deposits in alluvial fans in Basin 16. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of fluvial sand and gravel resources in Basin 17

Introduction—Basin 17, with an estimated area of 7,400 km^2, is in eastern Afghanistan on the border with Pakistan (fig. 10.3-1) It includes the catchments of the Putay Shelah River and its tributaries (fig. 10.3-1)

Deposit type—Fluvial sand and gravel

Age of mineralization—Quaternary; as a rule, better quality material is in younger fluvial sand and gravel deposits.

Example deposits types—There are no examples of sand and gravel deposits in tracts in Basin 17. No official records of work in sand and gravel deposits are kept in many parts of the world, and this is also true in Afghanistan. Basin 1 contains the Putay Shelah River and its tributaries, and fluvial sand and gravel deposits can be expected to be present along those waterways.

Exploration history—No sites have been reported as a sources of sand and gravel in Basin 17. The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified in the basin and that production likely has been wide spread. At least two major roads are recognized in this basin and their presences suggest that it is highly likely that some sand and gravel may have been extracted for their construction and ongoing maintenance. However, neither the intensity nor the extent of sand and gravel exploration is known. Exploitation of deposits near major and other roads is expected given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. Sand and gravel is produced near the point of consumption, so tracts in regions at some distance from existing roads and towns are likely untouched. Deposits within buffer zones (as defined below), which are near towns in this basin are more likely to have been explored.

Tract boundary criteria in basins—See uniform tract boundary criteria based on topographic slope used for both basins and buffer zones as noted in the introductory discussion above. Thirty five percent of Basin 17 or 2,900 km^2 is permissive for fluvial sand and gravel deposits (fig. 10.3-65).

***Buffer zone criteria*—**Buffer zones in tracts are defined as extending 25 km around towns and along both sides of major roads. Buffered areas (fig. 10.3-65*b*) with slopes less than 10 degrees have a cumulative area of 2,100 km^2.

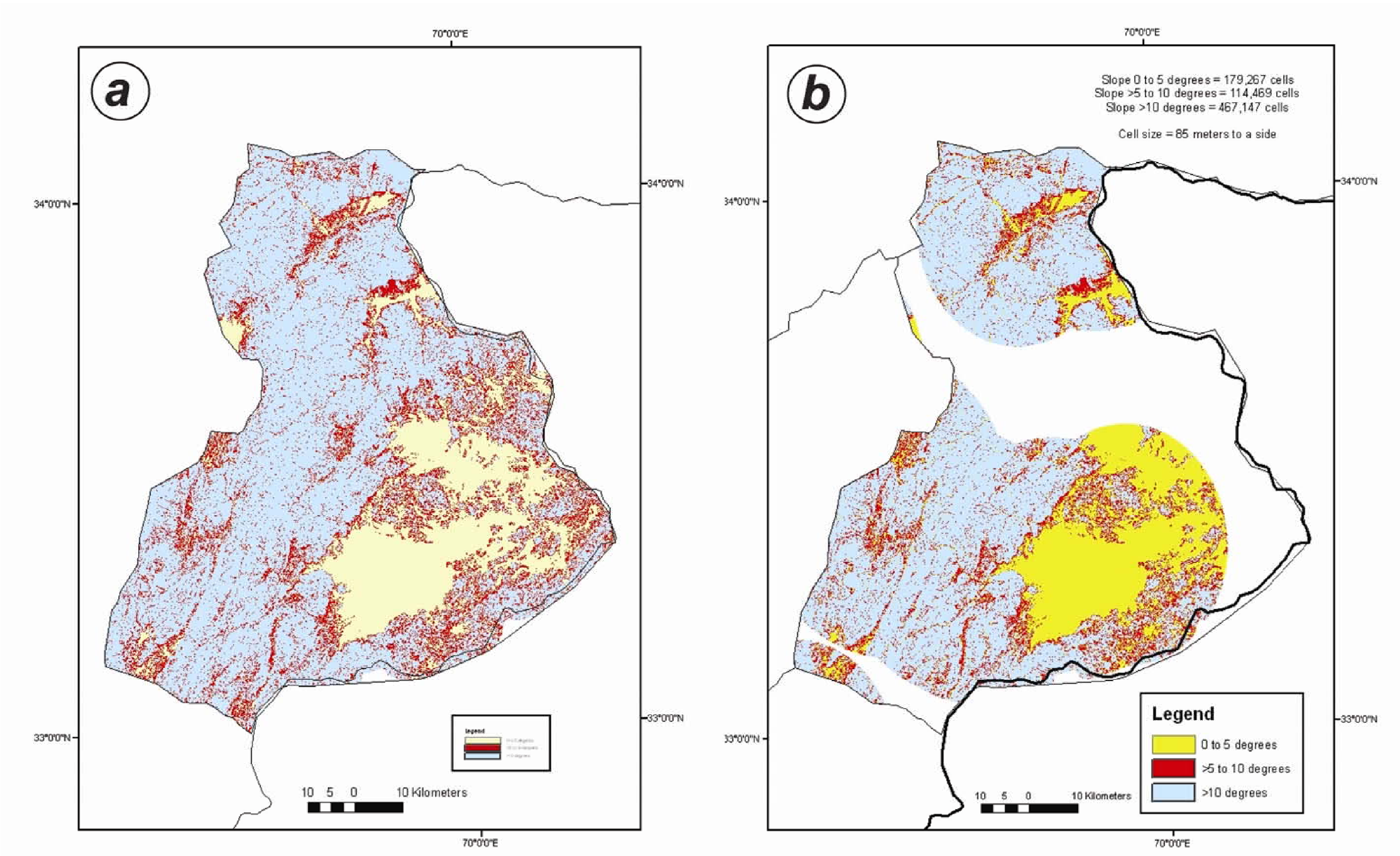

Figure 10.3-65. Outline of Basin 17 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits. Areas with slopes greater than 10 degrees (blue) are non-permissive. (*a*) entire basin. (*b*) areas within 25 kilometer buffer zone around towns and along roads. Slopes between 0-5 degrees (yellow), and 5-10 degrees (red) are permissive for fluvial sand and gravel deposits and those greater than 10 degrees (blue) are not permissive.

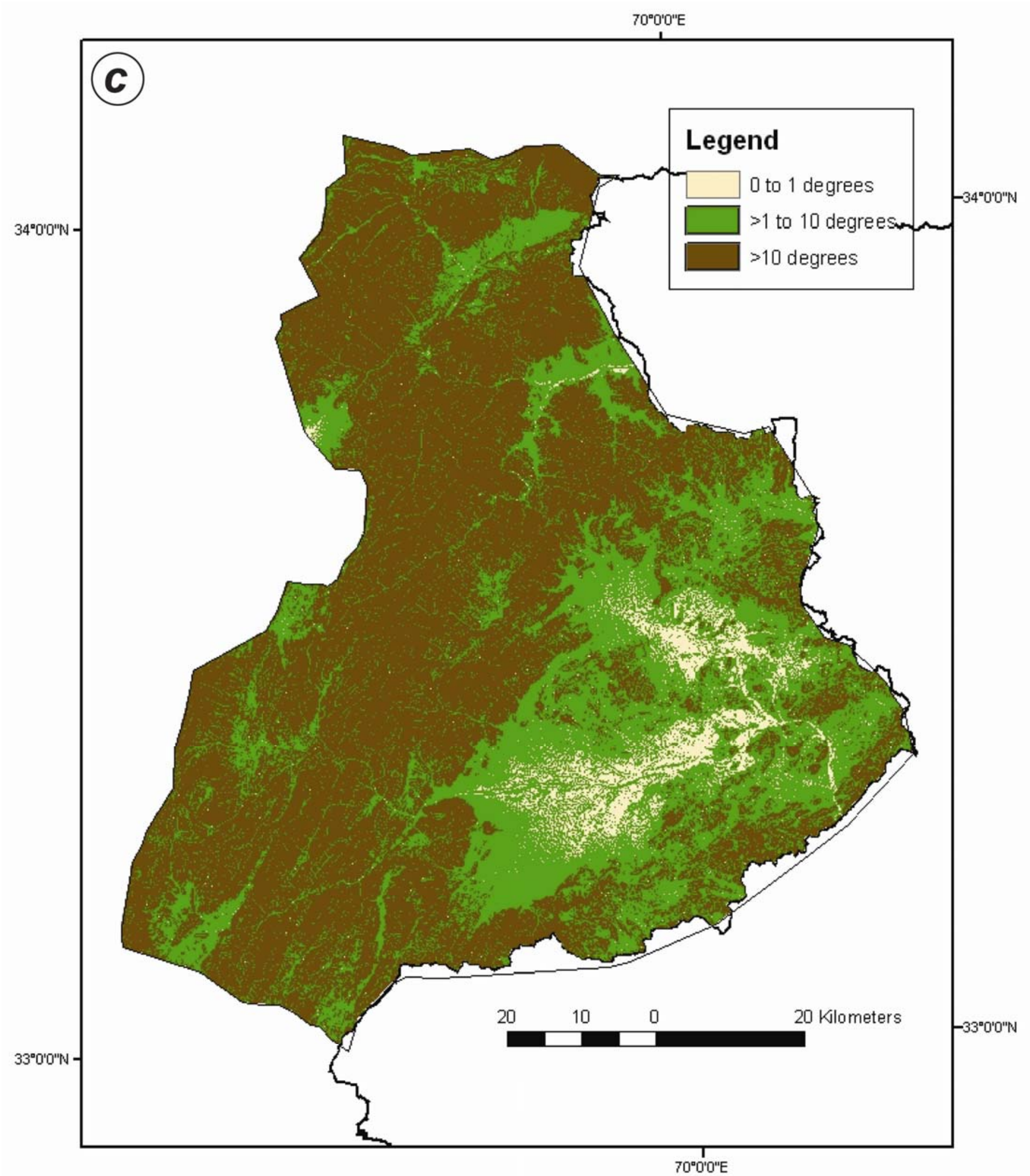

Figure 10.3-65*c*. Outline of Basin 17 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

Needs to improve assessment**—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors**—**Of the Quaternary sediments in tracts in this basin, 81 percent are defined as an alluvium unit in which the gravel content is greater than silt or clay. This unit is highly likely to host the readily recognizable fluvial sand and gravel deposits. The alluvial fans and colluvium with gravel and sand greater than silt and clay unit is located along mountain front and may contribute sand and gravel downstream. Sand and gravel resources expected to be present in alluvial fan sand and gravel deposits are separately assessed (see below).

Pessimistic factors**—**Application of the uniform tract boundary criteria based on topographic slope to this basin resulted in 63 percent of the cells being on surface described as non-Quaternary rocks. The tracts so defined may have over represented possible sources of sand and gravel deposits in the basin. Alluvial fan and colluvium along mountains fronts have been separately shown on the geologic map and account for 17 percent of the permissive area. Other Quaternary sediments in permissive tracts includes loess (1.4 percent) that is 1) a highly unlikely source of sand and gravel or 2) overburden that may obscure sand and gravel deposits at depth.

Estimated number of undiscovered deposits**—**For the assessment of the slope-defined tracts in Basin 17 (fig. 10.3-65), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-49) All tracts, which have a total cumulative area of 2,900 km^2 within the basin, are evaluated simultaneously. Because information about discovered deposits is unavailable, the estimated number of deposits and their associated probability given in the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-49. Estimated number of fluvial sand and gravel deposits in Basin 17, both discovered and undiscovered, calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	1
80 % chance of at least	1
70 % chance of at least	2
60 % chance of at least	2
50 % chance of at least	8
40 % chance of at least	11
30 % chance of at least	15
20 % chance of at least	25
10 % chance of at least	34

Monte Carlo Simulation results**—**There are three chances in four that the sand and gravel resources in Basin 17 in fluvial sand and gravel deposits will be equal to or greater than 11 million m^3, and there is an even chance that there will be equal to or greater than 100 million m^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 350 million m^3 (fig. 10.3-66).

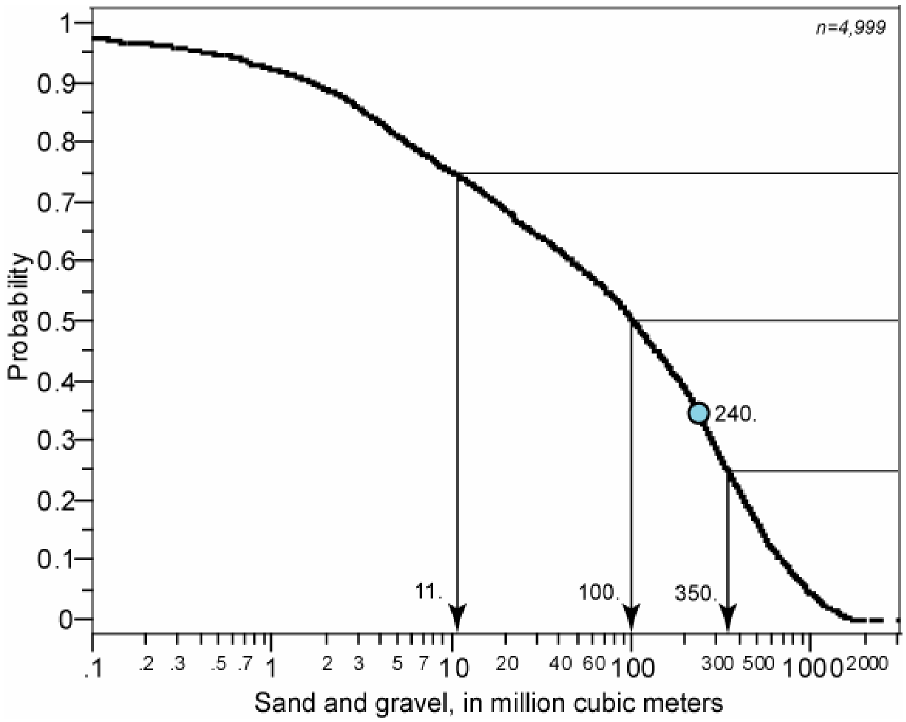

Figure 10.3-66. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 17 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Estimated number of undiscovered deposits in buffer zones—For the assessment of Basin 17 buffer zones (fig. 10.3-65*b*), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-50) from the permissive area of 2,100 km^2. All buffer zones in the basin are evaluated simultaneously. The estimated number of deposits and their associated probability given by the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees. The Quaternary geology in buffer zones contains possible areas of fan alluvium and colluvium together with areas of the more promising alluvium units that are more likely to contain fluvial sand and gravel deposits. Loess, sand, and mud dominated units are found in parts of the permissive tracts within buffer zones that will obscure or prohibit the presences of undiscovered deposits.

Table 10.3-50. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zones calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	1
80 % chance of at least	1
70 % chance of at least	1
60 % chance of at least	2
50 % chance of at least	6
40 % chance of at least	8
30 % chance of at least	11
20 % chance of at least	18
10 % chance of at least	25

***Monte Carlo Simulation results for undiscovered deposits in buffer zone tracts*—**There are three chances in four that the sand and gravel resources in Basin 17 in fluvial sand and gravel deposits will be equal to or greater than 7 million m^3. There is also an even chance that there will be equal to or greater than 70 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 240 million m^3 (fig. 10.3-67). Proximity to towns and major roads suggests a portion of the estimate sand and gravel resources may have already been consumed.

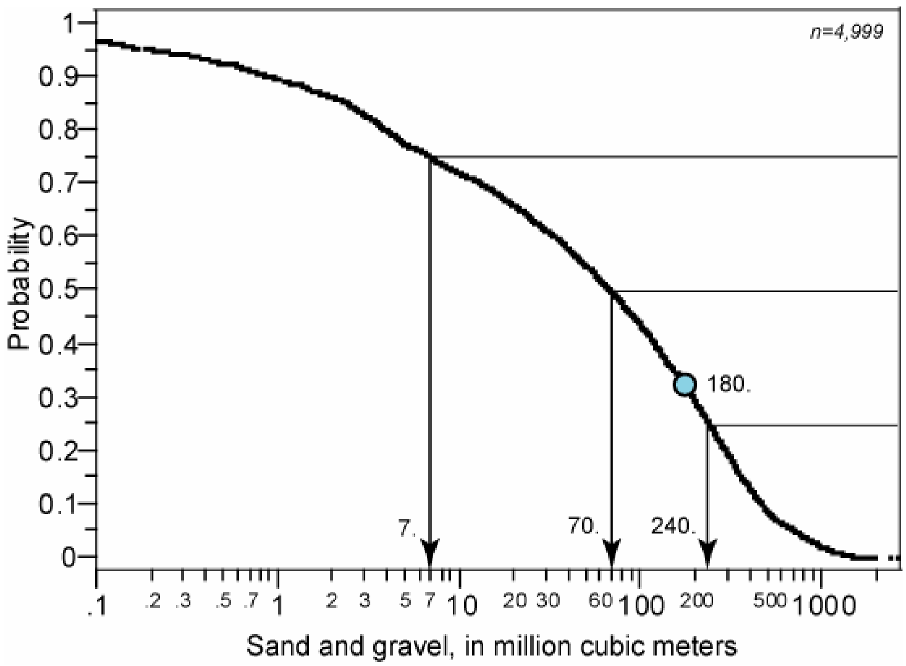

Figure 10.3-67. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 17 buffer zones. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Assessment of alluvial fan sand and gravel resources in Basin 17

***Deposit type*—**Alluvial fan sand and gravel

***Age of mineralization*—**Quaternary, better quality material is in younger alluvial fan sand and gravel deposits.

***Example deposits types*—**There are not reported examples of alluvial fan sand and gravel deposits in tracts in this basin. No official records of work in sand and gravel deposits are kept in many part of the world, and this is also true in Afghanistan.

***Exploration history*—**The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified and produced in the tracts in this basin. Alluvial fan sand and gravel deposits are usually not found near towns unless a roadway passes up the fan slope into the stream basin in the adjacent mountains, which may be true in this basin. Neither the intensity nor the extent of sand and gravel exploration is known. However, exploitation of deposits near major roads is expected given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. However, some of these alluvial sand and gravel deposits are near roads and other points of consumption, so some of these deposits may have been exploited. However, most of the resource is likely untouched. Alluvial fan sand and gravel deposits, which are found near towns and roads, are not considered in the assessment of buffer areas.

Tract boundary criteria—Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-65*c*).

Needs to improve assessment—Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, the former USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors—The steeper terrain and mountain fronts usually associated with alluvial fans are found widely in this basin. Quaternary units described as alluvial fan and colluvium are identified as being 190 km^2 on the geologic map (Doebrich and Wahl, 2006) in this basin. Alluvial fans are clearly recognized on topographic sheets (scale 1: 200,000).

Pessimistic factors—Alluvial fans are often problematic as they are commonly poorly sorted with large amounts of unsuitable clay and silt interbedded or directly mixed with the sand and gravel. Only a few fans are recognized on topographic sheets and only a small portion of them are expected to contain sand and gravel deposits suitable for development.

Estimated number of undiscovered deposits—The number of alluvial fans was subjectively estimated. Because information about discovered deposits is not available, the estimated number of deposits and their associated probability for MCS are for both discovered and undiscovered deposits and are given together with an associated probability (table 10.3-51).

Table 10.3-51. Estimated number of sand and gravel deposits both discovered and undiscovered in alluvial fans in Basin 17.

Probability level	Number of deposits
90 % chance of at least	0
70 % chance of at least	1
50 % chance of at least	1
30 % chance of at least	1
10 % chance of at least	1

Monte Carlo Simulation results for alluvial fan deposits—There are three chances in four that the sand and gravel resources in alluvial fans in Basin 17 will be equal to or greater than 0.3 million m^3. There is also an even chance that there will be equal to or greater than 60 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 180 million m^3 (fig. 10.3-68).

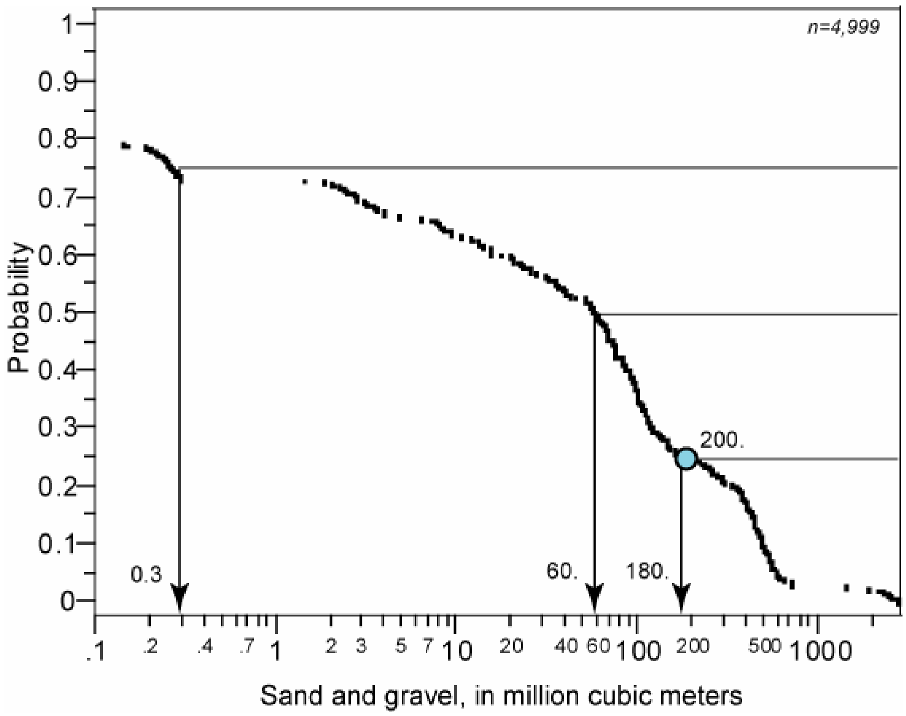

Figure 10.3-68. Distribution of sand and gravel resources in sand and gravel deposits in Basin 17 alluvial fans. Blue point on curve is the average of the 4,999 values generated by the MCS.

Permissive tracts for fluvial sand and gravel resources in Basin 18

Introduction—Basin 18, with an estimated area of 11,000 km^2, is in eastern Afghanistan (fig. 10.3-1) It includes the catchments of the Ghazni (Gazni) River and its tributaries as well as the town of Ghazni.

Deposit type—Fluvial sand and gravel

Age of mineralization—Quaternary; as a rule, better quality material is in younger fluvial sand and gravel deposits.

Example deposits types—There are no examples of sand and gravel deposits in tracts in Basin 18. No official records of work in sand and gravel deposits are kept in many parts of the world, and this is also true in Afghanistan. Basin 1 contains the Ghazni River and its tributaries, and fluvial sand and gravel deposits can be expected to be present along those waterways.

Exploration history—No sites have been reported as a sources of sand and gravel in Basin 18. The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified in the basin and that production likely has been wide spread. At least on major road (A1) is recognized in this basin and its presences suggest that it is highly likely that some sand and gravel may have been extracted for its construction and ongoing maintenance. However, neither the intensity nor the extent of sand and gravel exploration is known. Exploitation of deposits near major and other roads is expected given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. Sand and gravel is produced near the points of consumption so locations in regions at some distance from existing roads and towns are likely untouched. Deposits within buffer zones (as defined below), which are near towns in this basin are more likely to have been explored.

Tract boundary criteria in basins—See uniform tract boundary criteria based on topographic slope used for both basins and buffer zones as noted in the introductory discussion above. Eighty four percent of Basin 18 or 9,500 km^2 is permissive for fluvial sand and gravel deposits (fig. 10.3-69)

Buffer zone criteria—Buffer zones in tracts are defined as extending 25 km around towns and along both sides of major roads. Buffered areas (fig. 10.3-69*b*) with slopes less than 10 degrees have a cumulative area of 6,500 km^2.

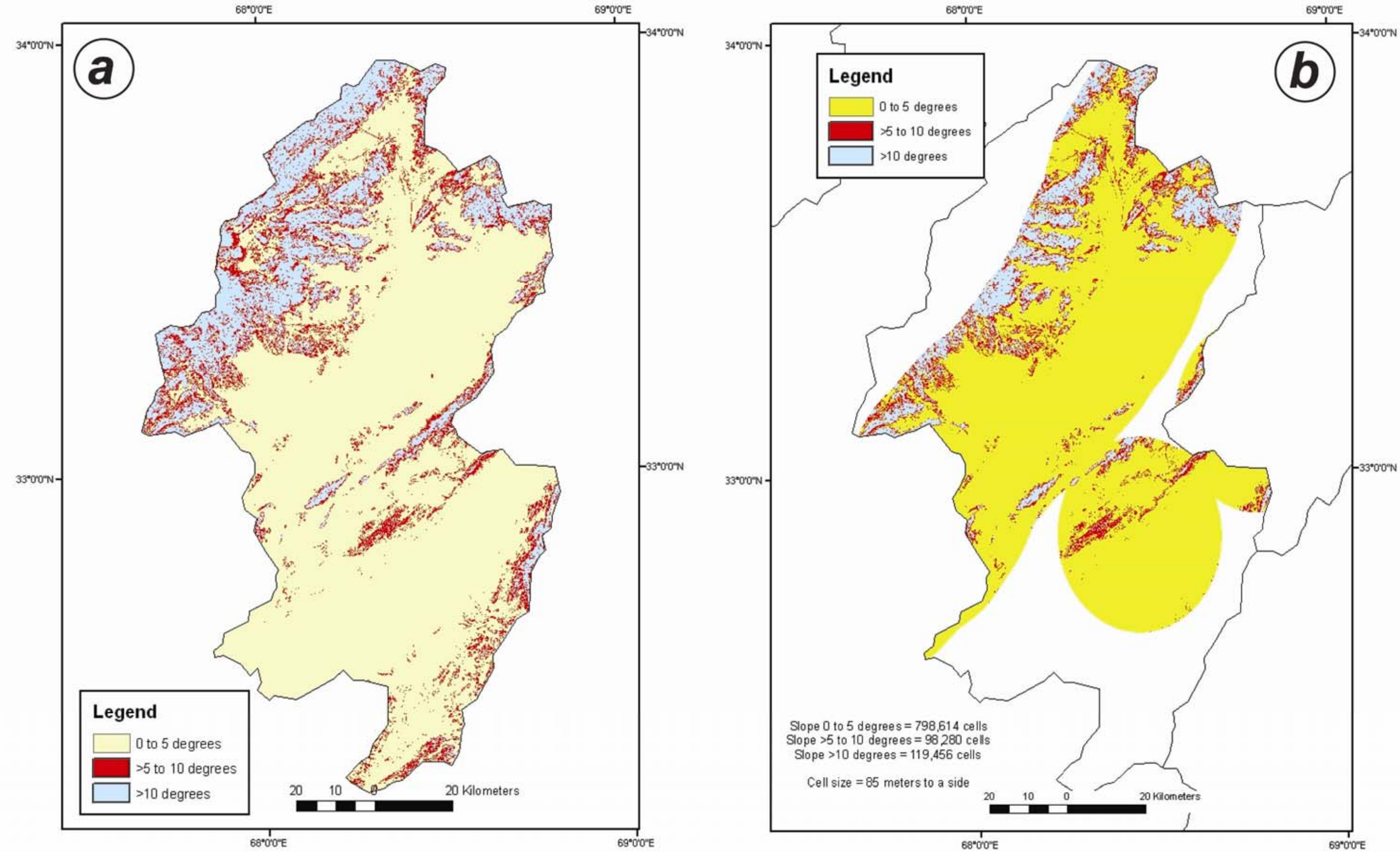

Figure 10.3-69. Outline of Basin 18 showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits. Areas with slopes greater than 10 degrees (blue) are non permissive. (*a*) entire basin. (*b*) areas within 25 kilometer buffer zone around towns and along roads. Slopes between 0-5 degrees (yellow), and 5-10 degrees (red) are permissive for fluvial sand and gravel deposits and those greater than 10 degrees (blue) are not permissive.

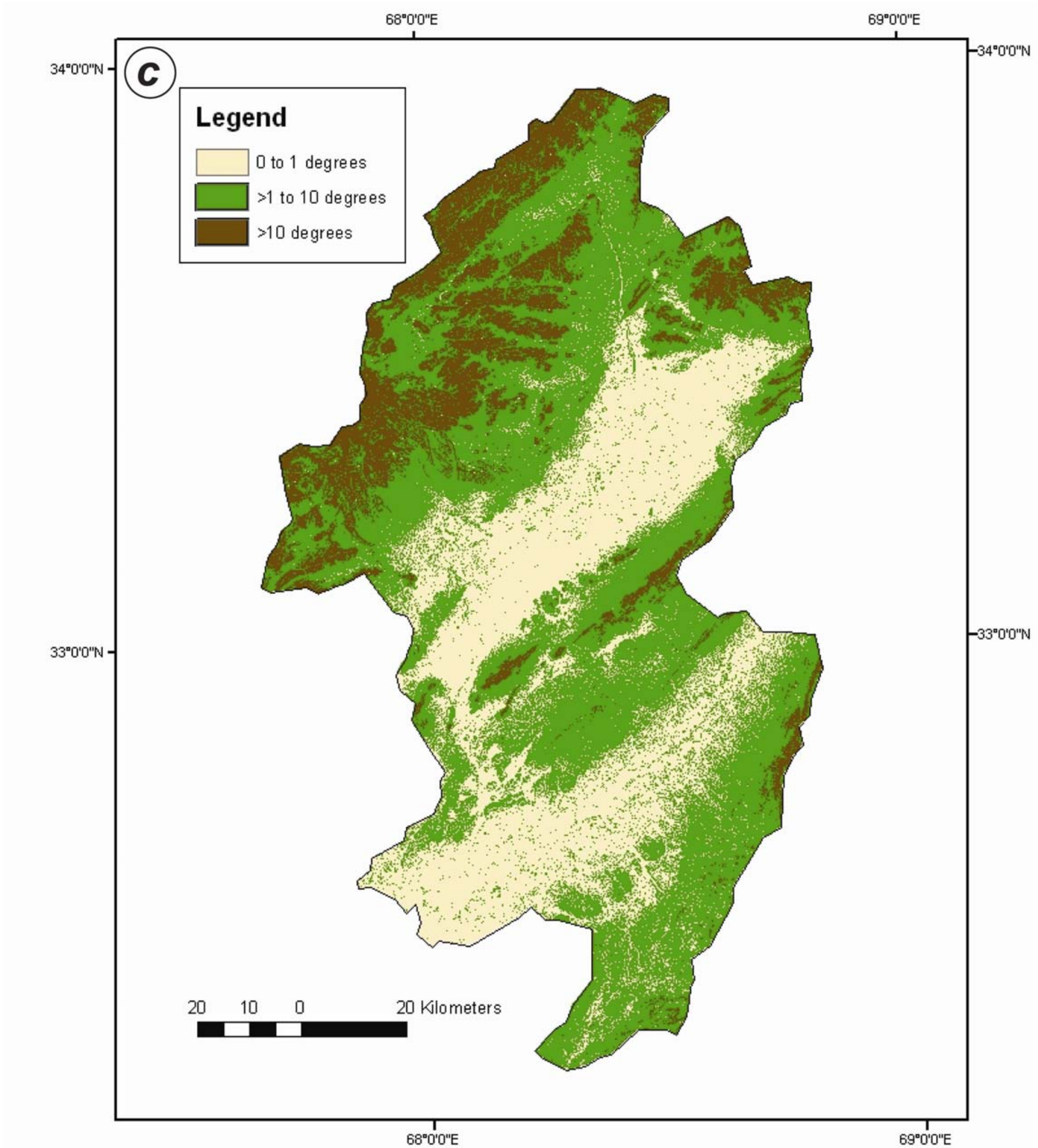

Figure 10.3-69*c*. Outline of Basin 18 showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

Needs to improve assessment—Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors—Of the Quaternary sediments in tracts in Basin 18, 31 percent are defined as an alluvium unit in which the gravel content is greater than silt or clay. This unit is highly likely to be the host of readily recognizable fluvial sand and gravel deposits. Alluvial fans and colluvium with gravel and sand greater than silt and is located along mountain front and may contribute sand and gravel downstream. Sand and gravel resources expected to be present in alluvial fan sand and gravel deposits are separately assessed (see below).

Pessimistic factors—Application of the uniform tract boundary criteria based on topographic slope to this basin resulted in 30 percent of the cells being on surface described as non-Quaternary rocks. This indicates that we may have produced a cumulative permissive tract area may slightly over representative possible sources of sand and gravel deposits in the basin. Other Quaternary sediments in permissive tracts include units that are 1) highly unlikely sources of sand and gravel or 2) overburden that may obscure sand and gravel deposits at depth. This includes units dominated with mud, silt and clay (7.6 percent), and loess (28 percent).

Estimated number of undiscovered deposits—For the assessment of the slope-defined tracts in Basin 18 (fig. 10.3-69), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-52) All tracts, which have a total cumulative area of 9,500 km^2 within the basin, are evaluated simultaneously. Because information about discovered deposits is unavailable, the estimated number of deposits and their associated probability given in the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-52. Estimated number of fluvial sand and gravel deposits in Basin 18, both discovered and undiscovered, calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	3
80 % chance of at least	4
70 % chance of at least	6
60 % chance of at least	8
50 % chance of at least	26
40 % chance of at least	37
30 % chance of at least	51
20 % chance of at least	82
10 % chance of at least	114

Monte Carlo Simulation results—There are three chances in four that the sand and gravel resources in Basin 18 in fluvial sand and gravel deposits will be equal to or greater than 78 million m^3, and there is an even chance that there will be equal to or greater than 450 million m^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 1,300 million m^3 (fig. 10.3-70).

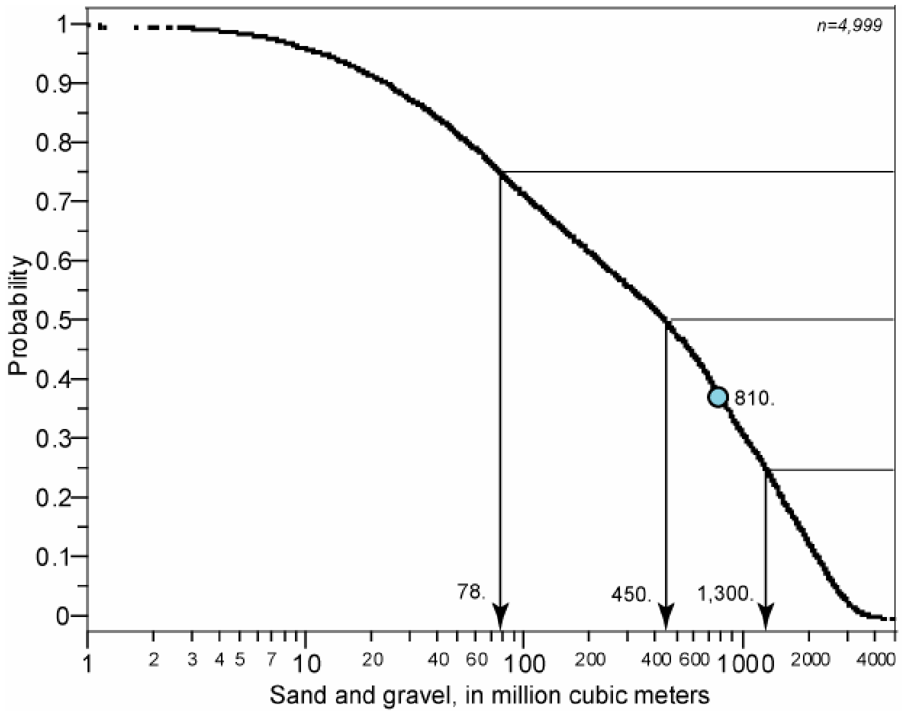

Figure 10.3-70. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Basin 18 tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Estimated number of undiscovered deposits in buffer zones—For the assessment of Basin 18 buffer zones (fig. 10.3-69b), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-53) from the permissive area of 6,500 km^2. All buffer zones in the basin are evaluated simultaneously. The estimated number of deposits and their associated probability given by the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees. The Quaternary geology in buffer zones contains possible areas of fan alluvium and colluvium together with areas of the more promising alluvium units that are expected to contain fluvial sand and gravel deposits. Loess, sand and mud dominated units are found in parts of the permissive tracts within buffer zones that will obscure or prohibit the presences of undiscovered deposits.

Table 10.3-53. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zones in Basin 18 calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	2
80 % chance of at least	3
70 % chance of at least	4
60 % chance of at least	5
50 % chance of at least	18
40 % chance of at least	25
30 % chance of at least	34
20 % chance of at least	56
10 % chance of at least	77

Monte Carlo Simulation results for undiscovered deposits in buffer zones**—**There are three chances in four that the sand and gravel resources in Basin 18 in fluvial sand and gravel deposits will be equal to or greater than 42 million m^3. There are also an even chance that there will be equal to or greater than 270 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 850 million m^3 (fig. 10.3-71). Proximity to towns and major roads suggests a portion of the estimated sand and gravel resources may have already been consumed.

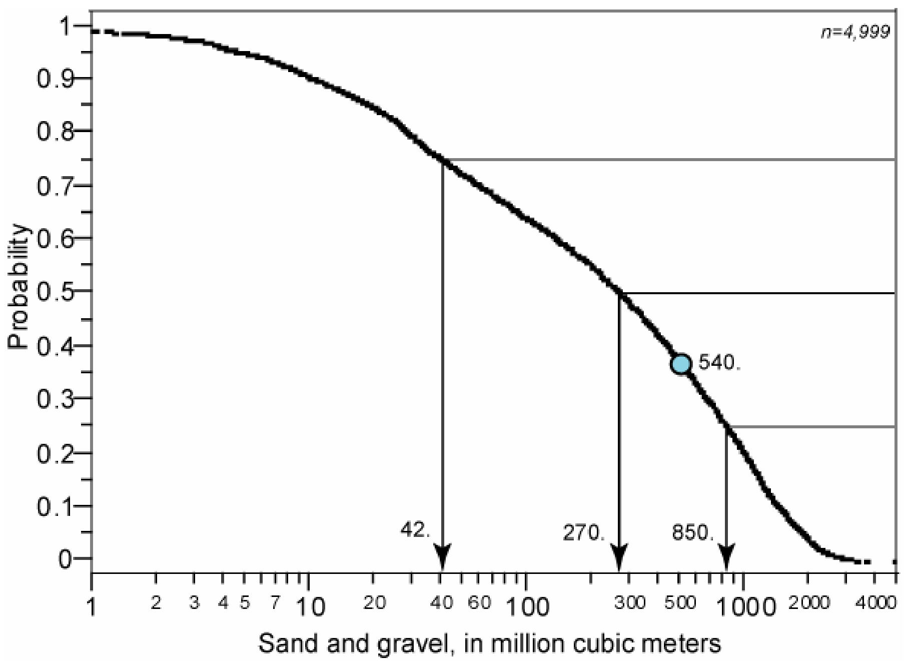

Figure 10.3-71. Distribution of sand and gravel resources in fluvial sand and gravel deposits in buffer zones in Basin 18. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Permissive tracts for alluvial fan sand and gravel resources in Basin 18

Deposit type**—**Alluvial fan sand and gravel

Age of mineralization**—**Quaternary, better quality material is in younger alluvial fan sand and gravel deposits.

Example deposits types**—**There are no reported examples of alluvial fan sand and gravel deposits in tracts in this basin. Most alluvial fan sand and gravel deposits are worked without record in many part of the world, and this is also true in Afghanistan.

Exploration history**—**The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified and produced in the tracts in this basin. Alluvial fan sand and gravel deposits are usually not found near towns unless a roadway passes up the fan slope into the stream basin in the adjacent mountains, which may be true in this basin. Neither the intensity nor the extent of sand and gravel exploration is known. However, exploitation of deposits near major roads is likely given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. Deposits of this type are likely rare within buffer zones (as defined below) that are found near towns and roads and these deposits are not considered in this assessment.

Tract boundary criteria—Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-69*c*).

Needs to improve assessment—Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, the former USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors—The steeper terrain and mountain fronts usually associated with alluvial fans are found widely in this basin. Quaternary units described as alluvial fan and colluvium are identified as being 2,300 km2 on the geologic map (Doebrich and Wahl, 2006) in this basin. Alluvial fans are recognized on topographic sheets (scale 1:200,000)

Pessimistic factors—Alluvial fans are often problematic as they are commonly poorly sorted with large amounts of unsuitable clay and silt interbedded or directly mixed with the sand and gravel. While a number of fans are recognized on topographic sheets, only a small portion of them are expected to contain sand and gravel deposits suitable for development.

Estimated number of undiscovered deposits—The number of alluvial fans was subjectively estimated. Because information about discovered deposits is not available, the estimated number of deposits and their associated probability for MCS are for both discovered and undiscovered deposits and are given together with an associated probability (table 10.3-54).

Table 10.3-54. Estimated number of sand and gravel deposits, both discovered and undiscovered, in alluvial fans in Basin 18.

Probability level	Number of deposits
90 % chance of at least	1
70 % chance of at least	1
50 % chance of at least	2
30 % chance of at least	3
10 % chance of at least	3

Monte Carlo Simulation results for alluvial fan deposits—There are three chances in four that the sand and gravel resources in alluvial fans in Basin 18 will be equal to or greater than 83 million m^3. There are also an even chance that there will be equal to or greater than 280 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 600 million m^3 (fig. 10.3-72).

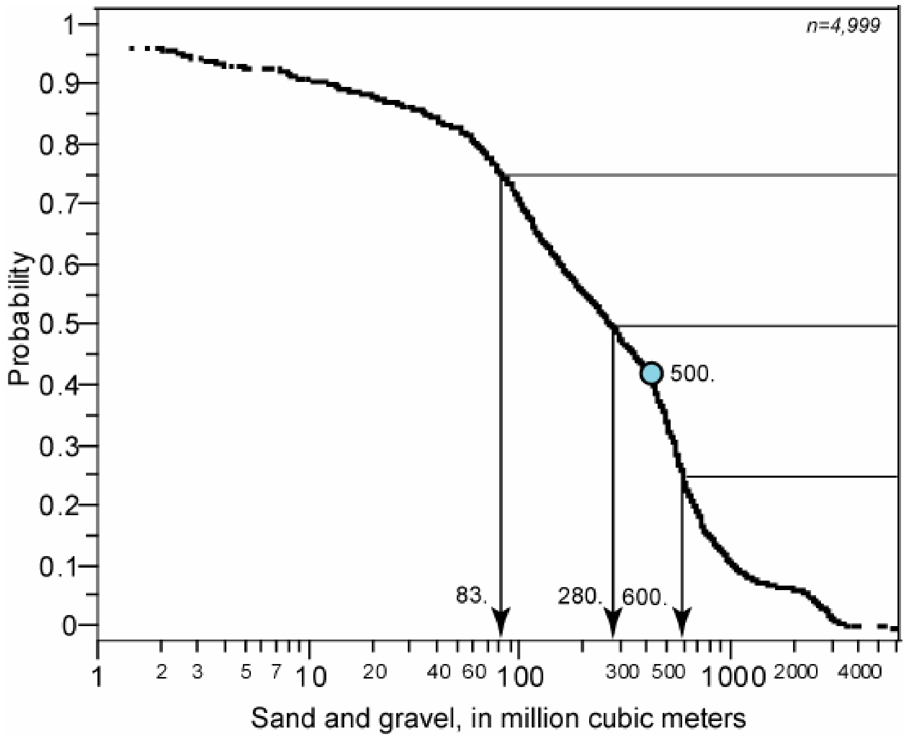

Figure 10.3-72. Distribution of sand and gravel resources in sand and gravel deposits in Basin 18 alluvial fans. Blue point on curve is the average of the 4,999 values generated by the MCS.

Permissive tracts for fluvial sand and gravel resources in Area A.

Introduction**—**Area A has an estimated area of 25,000 km^2 and is in eastern Afghanistan, a region that includes the panhandle (Vakhan Corridor) and that is bounded by China on east, Tajakistan on the north, and Kashmir on the south (fig. 10.3-1) The area also includes the northern parts of Badakhshan and Takhar provinces of Afghanistan. The northern boundary of Area A is defined by the Amu Darya River (fig. 10.3-73)

Deposit type**—**Fluvial sand and gravel

Age of mineralization**—**Quaternary; as a rule, better quality material is in younger fluvial sand and gravel deposits.

Example deposits types**—**There are about 13 examples of sand and gravel sites in tracts in Area A, all along or in the Amu Darya River along the northern Afghanistan boarder (fig. 10.3-73). None of the examples are located in permissive tracts as defined in this study. Fluvial sand and gravel deposits can be expected to be present in and near rivers.

Exploration history**—**There are about 13 examples of sand and gravel sites that have been identified as sources of sand and gravel in Area A (fig. 10.3-73*b*). The presence of a few roads and other infrastructure that require sand and gravel suggests that a small amount of sand and gravel has been produced and likely has been wide spread. Neither the intensity nor the extent of sand and gravel exploration is known. Exploitation of deposits near major and other roads is expected given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. Sand and gravel is produced near the point of consumption so tracts in regions at some distance from existing roads and towns are likely untouched. Deposits within buffer zones (as defined below) which are near towns in this area are more likely to have been explored.

Tract boundary criteria in areas—See uniform tract boundary criteria based on topographic slope used for both areas and buffer zones as noted in the introductory discussion above. Sixteen percent of Area A or 4,000 km^2 is permissive for fluvial sand and gravel deposits (fig. 10.3-73)

Buffer zone criteria—Buffer zones in tracts are defined as extending 25 km around towns and along both sides of major roads. Buffered areas (fig. 10.3-73*b*) with slopes, less than 10 degrees have a cumulative area of 590 km^2.

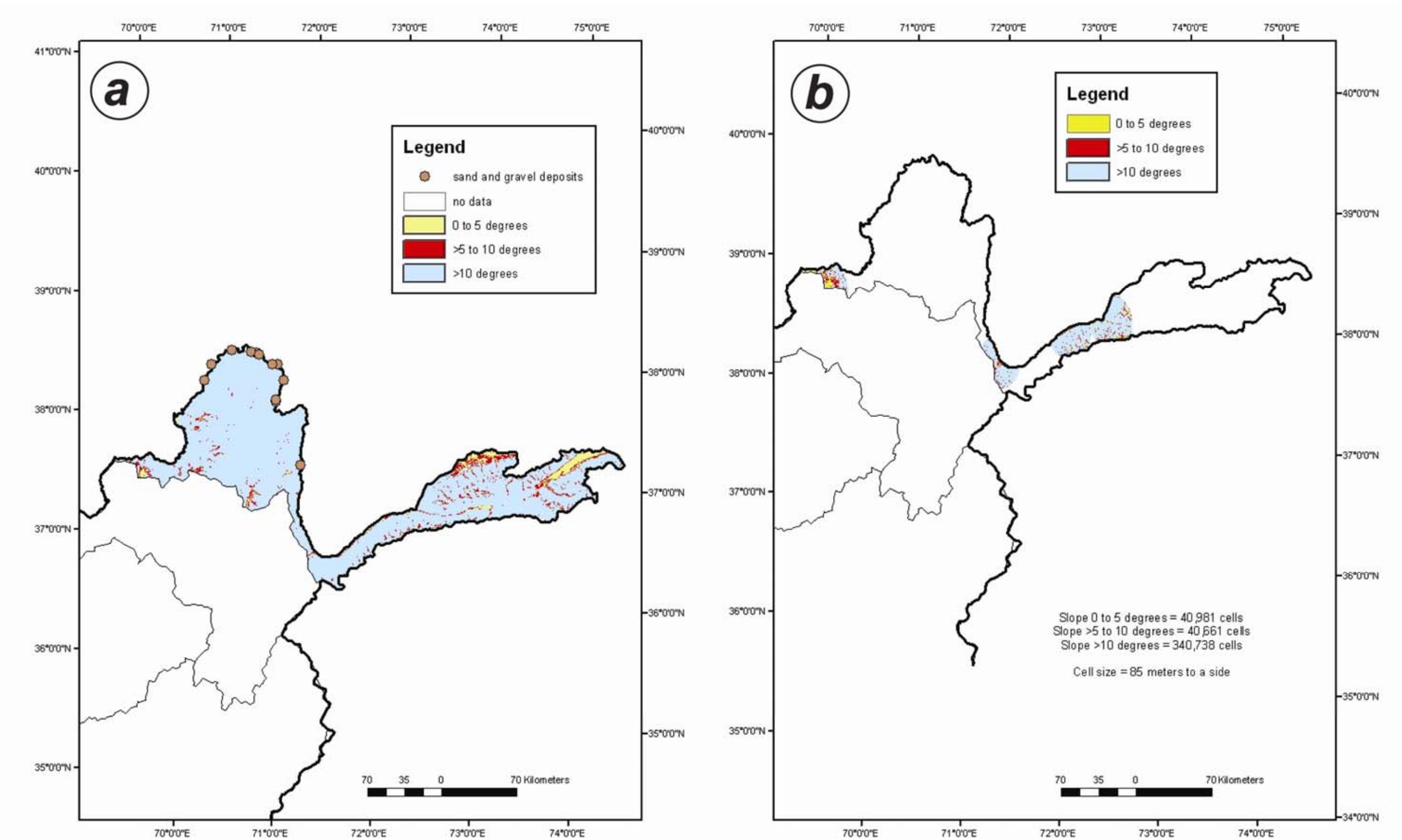

Figure 10.3-73. Outline of Area A showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits. Areas with slopes greater than 10 degrees (blue) are non-permissive. (*a*) entire area. (*b*) areas within 25 kilometer buffer zone around towns and along roads. Slopes between 0-5 degrees (yellow), and 5-10 degrees (red) are permissive for fluvial sand and gravel deposits and those greater than 10 degrees (blue) are not permissive.

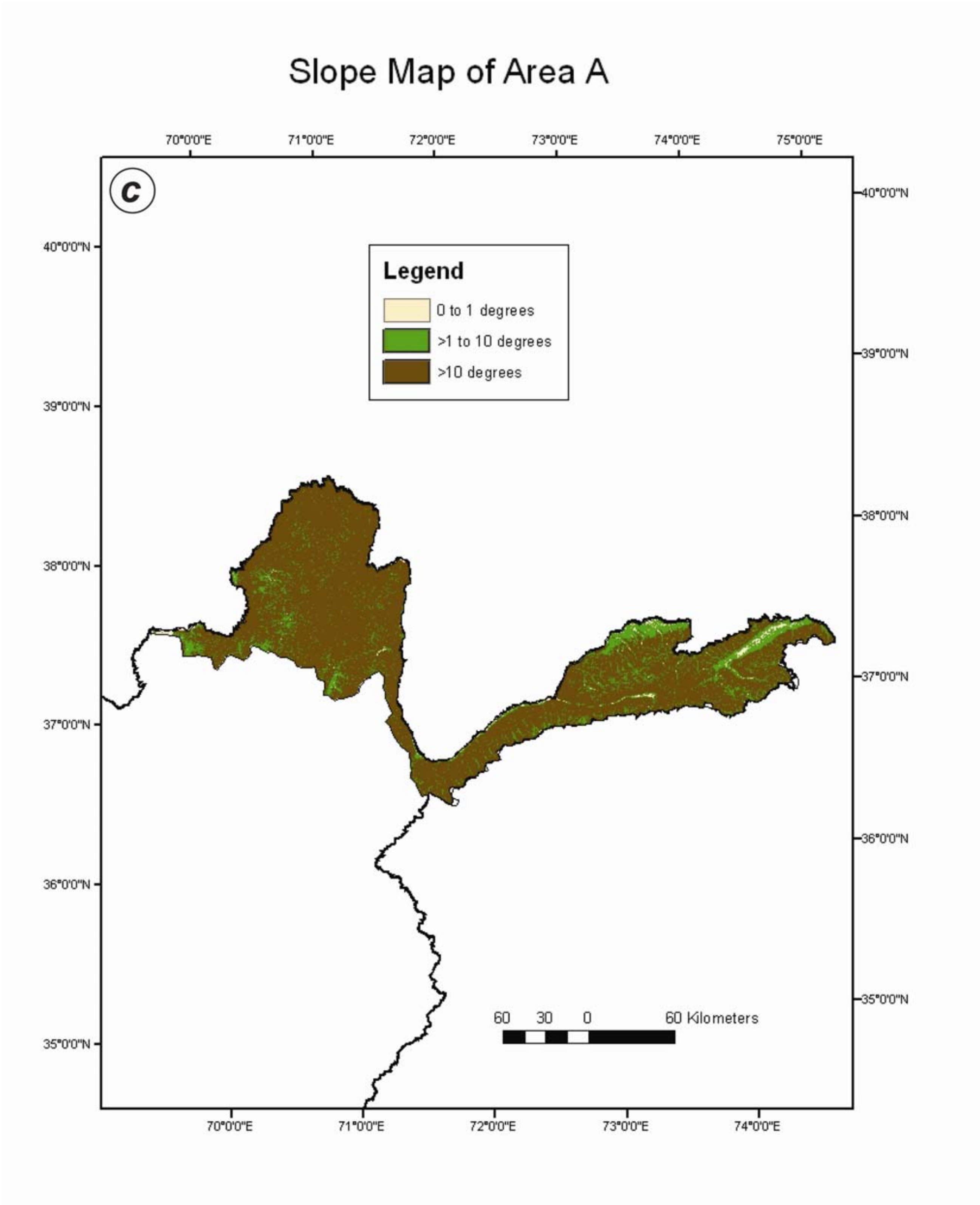

Figure 10.3-73*c*. Outline of Area A showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

Needs to improve assessment**—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors**—**Of the Quaternary sediments in tracts in this area, 60 percent are defined as an alluvium unit in which the gravel content is greater than silt or clay content. This unit is highly likely to be the host of readily recognizable fluvial sand and gravel deposits. Alluvial fans and colluvium with gravel and sand greater than silt and clay is located along mountain fronts and may contribute sand and gravel downstream. Sand and gravel resources expected to be present in alluvial fan sand and gravel deposits are separately assessed (see below.)

Pessimistic factors**—**Application of the uniform tract boundary criteria based on topographic slope to this area resulted in 54 percent of the cells being on surface described as non-Quaternary outcrops. The tracts so defined may over represent possible sources of sand and gravel deposits in the area. Some areas in and along the Amu Darya River are not in tracts but would be permissive for deposits. Alluvial fan and colluvium along mountains fronts are not mapped and likely have been included with alluvium unit are described above. Other Quaternary sediments in permissive tracts include units that are 1) highly unlikely sources of sand and gravel or 2) overburden may obscure sand and gravel deposits at depth. These units include those dominated by glacial till (37 percent) and areas covered with lakes (2.7 percent).

Estimated number of undiscovered deposits**—**For the assessment of the slope-defined tracts in Area A (fig. 10.3-73*b*), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-55) All tracts, which have a total cumulative area of 4,000 km^2 within the area, are evaluated simultaneously. Because information about discovered deposits is unavailable, the estimated number of deposits and their associated probability given in the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-55. Estimated number of fluvial sand and gravel deposits in Area A, both discovered and undiscovered, calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	1
80 % chance of at least	2
70 % chance of at least	3
60 % chance of at least	3
50 % chance of at least	11
40 % chance of at least	15
30 % chance of at least	21
20 % chance of at least	34
10 % chance of at least	47

Monte Carlo Simulation results—There are three chances in four that the sand and gravel resources in Area A in fluvial sand and gravel deposits will be equal to or greater than 20 million m^3, and there is an even chance that there will be equal to or greater than 150 million m^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 510 million m^3 (fig. 10.3-74).

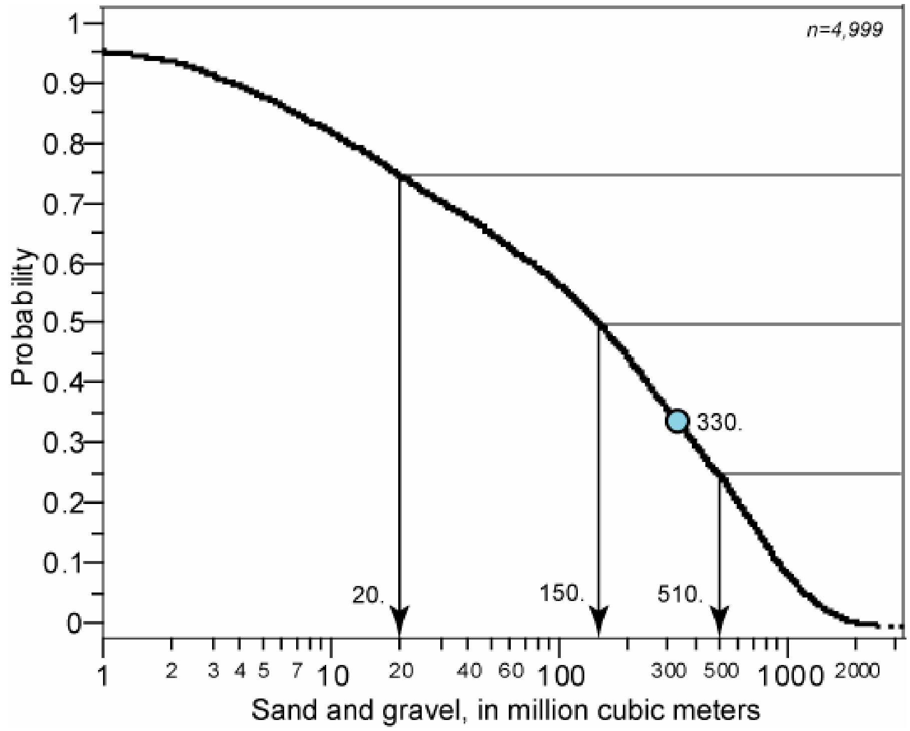

Figure 10.3-74. Distribution of sand and gravel resources in fluvial sand and gravel deposits in tracts in Area A. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Estimated number of undiscovered deposits in buffer zones—For the assessment of Area A buffer zones (fig. 10.3-73*b*), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-56) from the permissive area of 590 km^2. All buffer zones in the area are evaluated simultaneously. The estimated number of deposits and their associated probability given by the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees. The Quaternary geology in buffer zones contains possible areas of fan alluvium and colluvium together with areas of the more promising alluvium units that are more likely to contain fluvial sand and gravel deposits. Loess, sand and mud dominated units are found in parts of the permissive tracts within buffer zones that will obscure or prohibit the presences of undiscovered deposits.

Table 10.3-56. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zones calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	0
80 % chance of at least	0
70 % chance of at least	0
60 % chance of at least	0
50 % chance of at least	2
40 % chance of at least	2
30 % chance of at least	3
20 % chance of at least	5
10 % chance of at least	7

Monte Carlo Simulation results for buffer zones**—**There is also an even chance that there will be equal to or greater than 3.5 million m^3 in Area A. In addition, there is one chance in four that the amount of sand and gravel resources will equal or be greater than 41 million m^3 (fig. 10.3-75). Few towns and major roads in this basin may suggest that little or none of the estimated sand and gravel resources have been consumed.

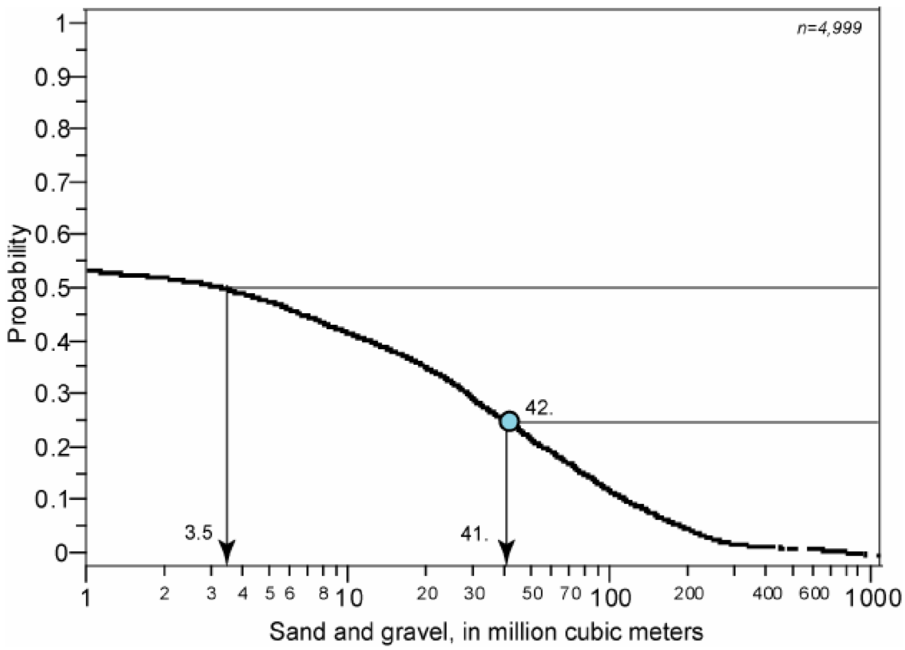

Figure 10.3-75. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Area A buffer zones. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Permissive tracts for alluvial fan sand and gravel resources in Area A.

Deposit type—Alluvial fan sand and gravel

Age of mineralization—Quaternary, better quality material is found in younger alluvial fan sand and gravel deposits.

Example deposits types**—**There are no reported examples of alluvial fan sand and gravel deposits in tracts in this area. No official records of work in sand and gravel deposits are kept in many part of the world, and this is also true in Afghanistan.

Exploration history**—**The presence of only a few roads and other infrastructure that require sand and gravel suggests that little sand and gravel has been previously identified and produced in the tracts in this area. Alluvial fan sand and gravel deposits are usually not found near towns unless a roadway passes up the fan slope into the stream area in the adjacent mountains, which may be true in this area. Neither the intensity nor the extent of sand and gravel exploration is known but likely has been small. However, exploitation of deposits in this basin, if any, may be possible since the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan.

Tract boundary criteria**—**Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-73c).

Needs to improve assessment—Quaternary mapping with a focus on alluvial fans is needed. Also useful is information about sources of sand and gravel used by the U.S. Corp of Engineers, the former USSR engineers, and construction contractors who have built roads in Afghanistan would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors—The steeper terrain and mountain fronts usually associated with alluvial fans are present in Area A.

Pessimistic factors—Alluvial fans are not recognized on topographic sheets (scale 1:200,000) in this study but may have been missed.

Estimated number of undiscovered deposits—None.

Monte Carlo Simulation results for alluvial fan deposits—None.

Permissive tracts for fluvial sand and gravel resources in Area B.

Introduction—Area B, with an estimated area of 11,000 km^2, is in eastern Afghanistan along the border with Pakistan (fig. 10.3-1). The area includes most of Paktika and Paktia provinces. Ephemeral streams are common as well as several local closed basins with lake beds.

Deposit type—Fluvial sand and gravel

Age of mineralization—Quaternary; as a rule, better quality material is in younger fluvial sand and gravel deposits.

Example deposits types—There are no records of sand and gravel deposits in tracts in Area B. Usually no official records of work in sand and gravel deposits is kept, and this is also true in Afghanistan. Fluvial sand and gravel deposits can be expected to be present in and near rivers.

Exploration history—There are no examples of sand and gravel sites that have been identified as sources of sand and gravel in Area B (fig. 10.3-76). The presence of a few roads and other infrastructure that require sand and gravel suggests that a small amount of sand and gravel has been produced and that production likely has been wide spread. Neither the intensity nor the extent of sand and gravel exploration is known. Exploitation of deposits near major and other roads is likely given that both the U.S. Corp of Engineers and the former Soviet Union has historically been involved in developing roads in Afghanistan. Sand and gravel is produced near the points of consumption so tracts in regions at some distance from existing roads and towns are likely untouched. Deposits within buffer zones (as defined below) which are near towns in this area are more likely to have been explored.

Tract boundary criteria in areas—See uniform tract boundary criteria based on topographic slope used for both areas and buffer zones as noted in the introductory discussion above. Seventy percent of Area B or 7,700 km^2 is permissive for fluvial sand and gravel deposits (fig. 10.3-76)

Buffer zone criteria—Buffer zones in tracts are defined as extending 25 km around towns and along both sides of major roads. Buffered areas (fig. 10.3-76*b*) with slopes, less than 10 degrees have a cumulative area of 800 km^2.

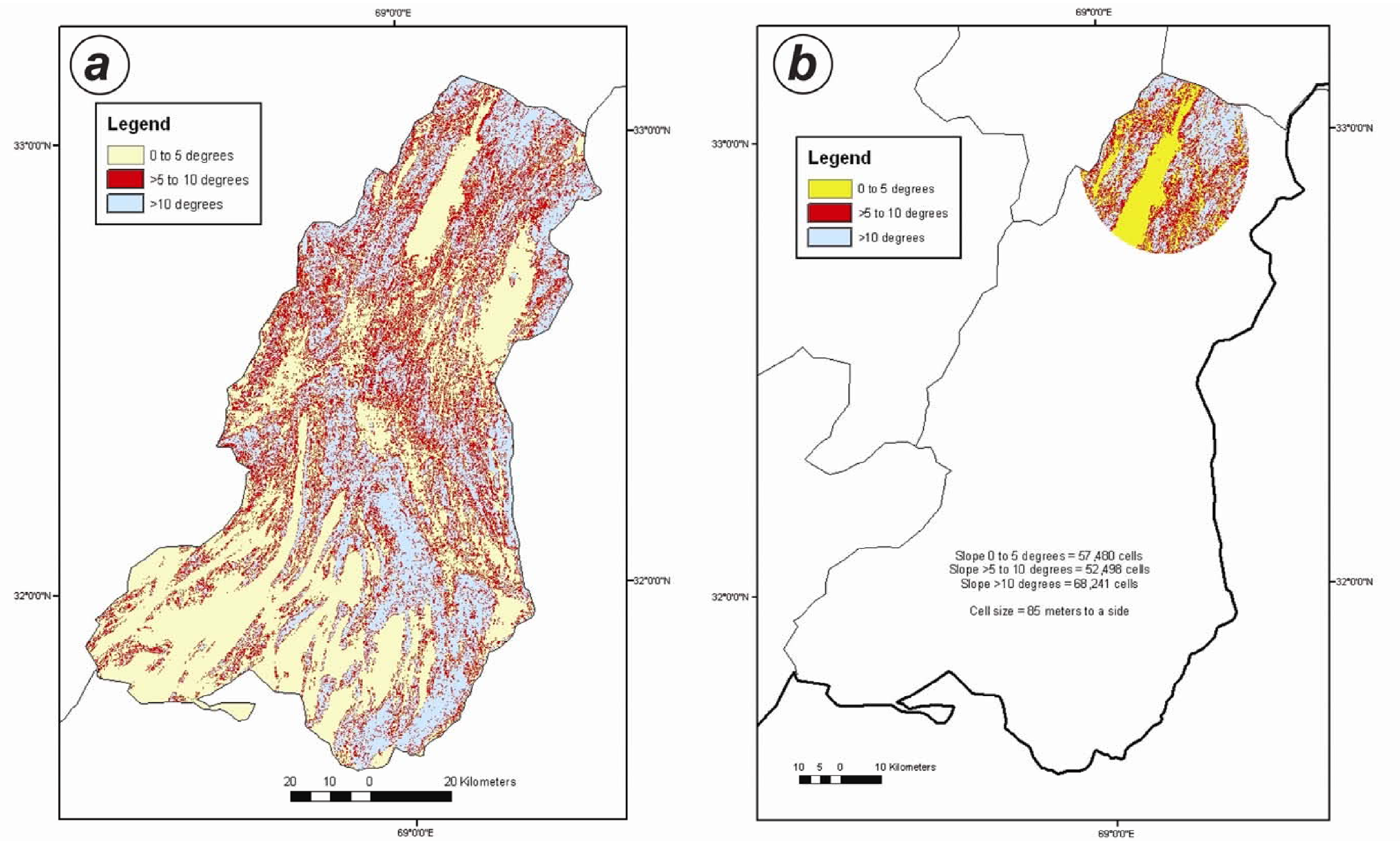

Figure 10.3-76. Outline of Area B showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits. Areas with slopes greater than 10 degrees (blue) are non-permissive. (*a*) entire area. (*b*) areas within 25 kilometer buffer zone around towns and along roads. Slopes between 0-5 degrees (yellow), and 5-10 degrees (red) are permissive for fluvial sand and gravel deposits and those greater than 10 degrees (blue) are not permissive.

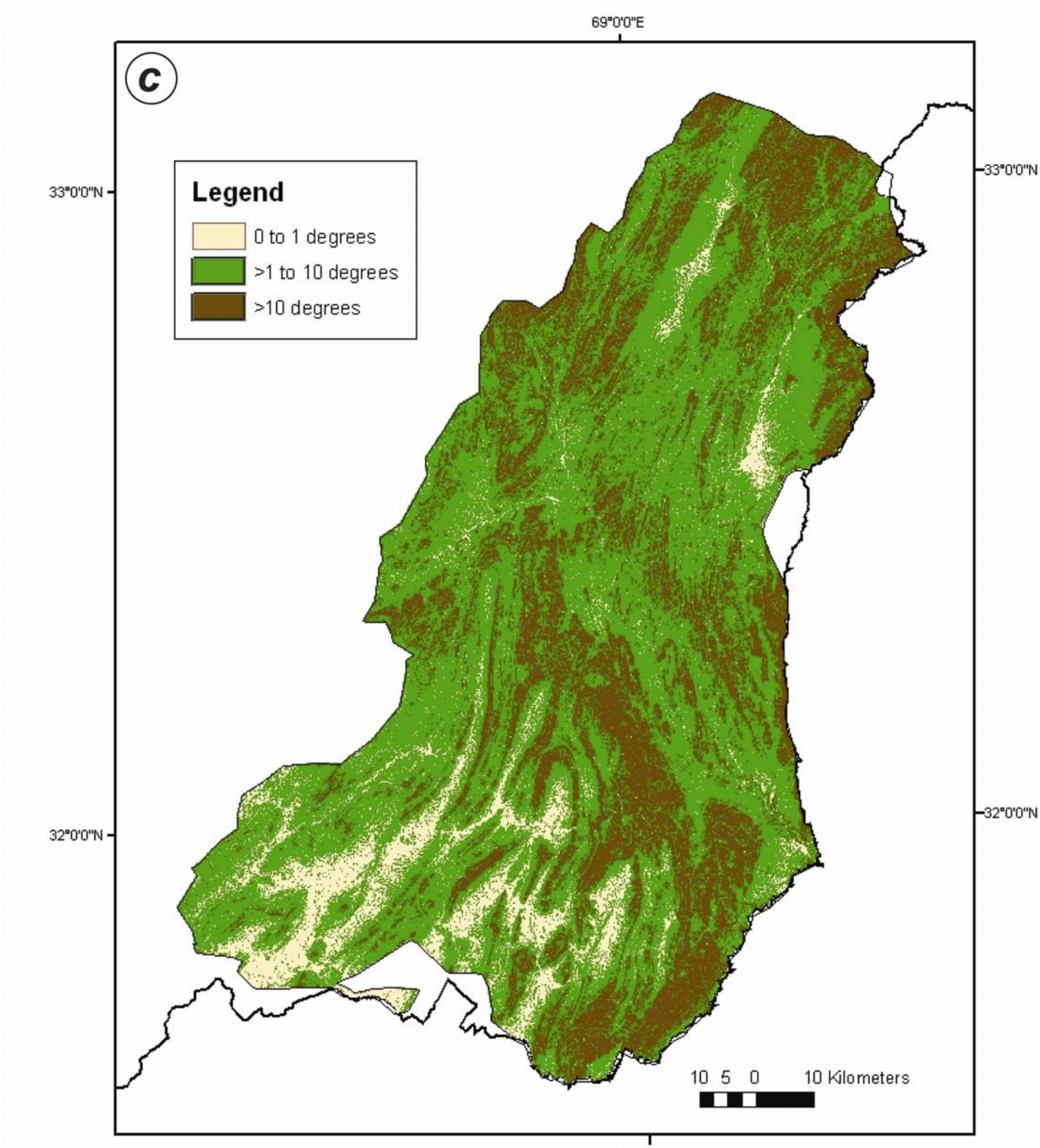

Figure 10.3-76*c*. Outline of Area B showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

***Needs to improve assessment*—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

***Optimistic factors*—**Of the Quaternary sediments in tracts in this area, 22 percent are defined as an alluvium unit in which the gravel content is greater than silt or clay content. This unit is highly likely to be the host of readily recognizable fluvial sand and gravel deposits. The unit reported as alluvial fans and colluvium with gravel and sand that includes the balance of Quaternary sediments, as mapped in the area, is located along mountain front and may contribute sand and gravel downstream. Sand and gravel resources expected to be present in alluvial fan sand and gravel deposits are separately assessed (see below.)

***Pessimistic factors*—**Application of the uniform tract boundary criteria based on topographic slope to this area resulted in 76 percent of the cells being on surface described as non-Quaternary rocks. The tracts so defined may over representative possible sources of sand and gravel deposits in the area. No other Quaternary unit is reported in permissive tracts and the unit for alluvial fans and colluvium that may be sources of sand and gravel down stream is separately assessed.

***Estimated number of undiscovered deposits*—**For the assessment of the slope-defined tracts in Area B (fig. 10.3-76b), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-57) All tracts, which have a total cumulative area of 7,700 km^2 within the area, are evaluated simultaneously. Because information about discovered deposits is unavailable, the estimated number of deposits and their associated probability given in the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-57. Estimated number of fluvial sand and gravel deposits in Area B, both discovered and undiscovered, calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	3
80 % chance of at least	3
70 % chance of at least	5
60 % chance of at least	6
50 % chance of at least	21
40 % chance of at least	30
30 % chance of at least	41
20 % chance of at least	67
10 % chance of at least	92

***Monte Carlo Simulation results*—**There are three chances in four that the sand and gravel resources in Area B found in fluvial sand and gravel deposits will be equal to or greater than 59 million m^3, and there is an even chance that there will be equal to or greater than 350 million m^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 1,100 million m^3 (fig. 10.3-77).

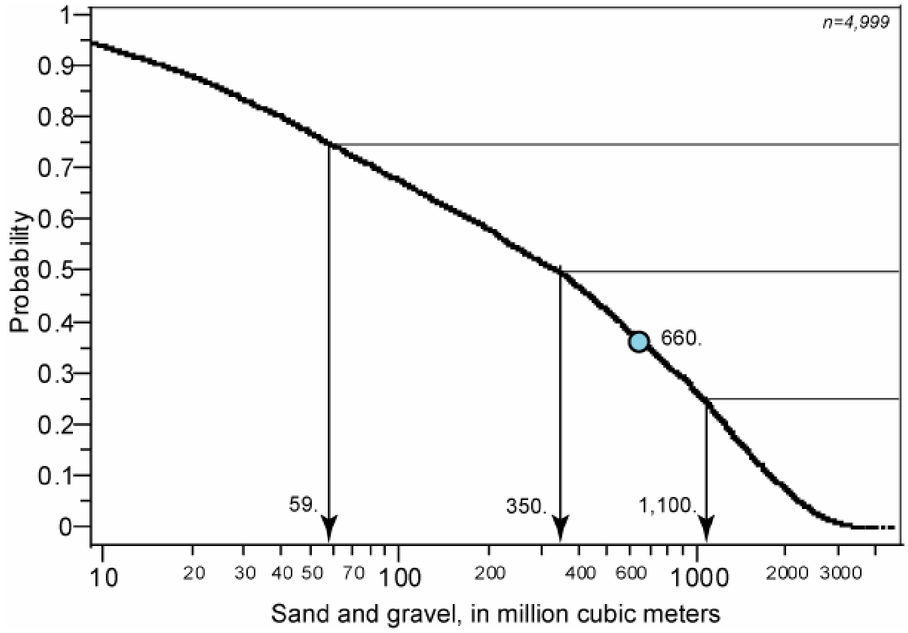

Figure 10.3-77. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Area B tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Estimated number of undiscovered deposits in buffer zones—For the assessment of Area B buffer zones (fig. 10.3-76*b*), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-58) from the permissive area of 800 km^2. All buffer zones in the area are evaluated simultaneously. The estimated number of deposits and their associated probability given by the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees. The Quaternary geology in buffer zones contains possible areas of fan alluvium and colluvium together with areas of the more promising alluvium units that are more likely to contain fluvial sand and gravel deposits.

Table 10.3-58. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in Area B buffer zones calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	0
80 % chance of at least	0
70 % chance of at least	1
60 % chance of at least	1
50 % chance of at least	2
40 % chance of at least	3
30 % chance of at least	4
20 % chance of at least	7
10 % chance of at least	9

Monte Carlo Simulation results for buffer zones—There is an even chance that there will be equal to, or greater than, 15 million m^3 in Area B (fig. 10.3-78). In addition, there is one chance in four that the amount of sand and gravel resources will equal or be greater than 76 million m^3. Proximity to notable towns may suggest that a portion of the estimated sand and gravel resources may have already been consumed.

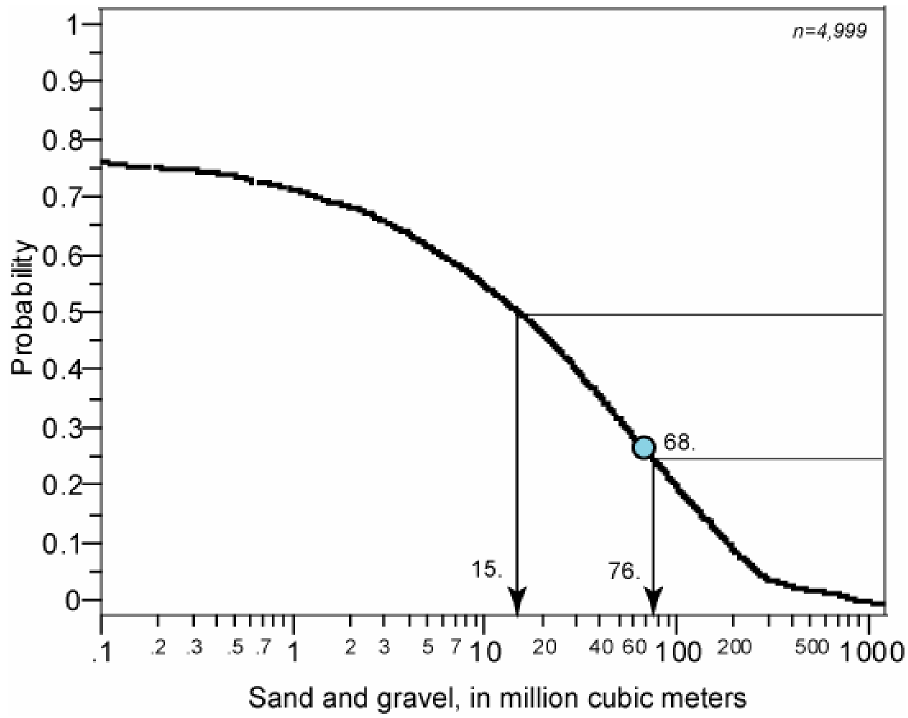

Figure 10.3-78. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Area B buffer zones. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Permissive tracts for alluvial fan sand and gravel resources in Area B.

Deposit type—Alluvial fan sand and gravel

Age of mineralization—Quaternary, better quality material is in younger alluvial fan sand and gravel deposits.

Example deposits types—There are no reported examples of alluvial fan sand and gravel deposits in tracts in this area. Most alluvial fan sand and gravel deposits are worked without record in many part of the world, and this is also true in Afghanistan.

Exploration history—The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified and produced in the tracts in this area. Alluvial fan sand and gravel deposits are usually not found near towns unless a roadway passes up the fan slope into the stream area in the adjacent mountains, which may be true in this area. Neither the intensity nor the extent of sand and gravel exploration is known. However, exploitation of deposits near notable towns in this basin is likely given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. However, some of these alluvial sand and gravel deposits are near roads and other points of consumption, so some of these deposits may have been exploited. However, most of the resource is likely untouched. Deposits of this type are likely rare within buffer zones (as defined below), which are found near towns and roads and are not considered in this assessment.

Tract boundary criteria—Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-76*c*).

Needs to improve assessment—Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, the former USSR engineers, and construction contractors who have built roads in Afghanistan would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors—The steeper terrain and mountain fronts usually associated with alluvial fans are found widely in this area. Quaternary units described as alluvial fan and colluvium are identified as being 1,400 km^2 on the geologic map (Doebrich and Wahl, 2006) in Area B. Alluvial fans are recognized on topographic sheets (scale 1:200,000)

Pessimistic factors—Alluvial fans are often problematic as they are commonly poorly sorted with large amounts of unsuitable clay and silt interbedded or directly mixed with the sand and gravel. While a number of fans are recognized on topographic sheets, only a small portion of them is likely to contain sand and gravel deposits suitable for development.

Estimated number of undiscovered deposits—The number of alluvial fans was subjectively estimated using information about subjective estimates made in adjoining area and the size of area mapped as fan alluvium and colluvium. Because information about discovered deposits is not available, the estimated number of deposits and their associated probability for MCS are for both discovered and undiscovered deposits and are given together with an associated probability (table 10.3-59).

Table 10.3-59. Estimated number of alluvial sand and gravel deposits, both discovered and undiscovered, in alluvial fans in Area B.

Probability level	Number of deposits
90 % chance of at least	1
70 % chance of at least	1
50 % chance of at least	2
30 % chance of at least	3
10 % chance of at least	3

Monte Carlo Simulation results for alluvial fan deposits—There are three chances in four that the sand and gravel resources in alluvial fans in Area B will be equal to or greater than 83 million m^3. There are also an even chance that there will be equal to or greater than 280 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 600 million m^3 (fig. 10.3-79).

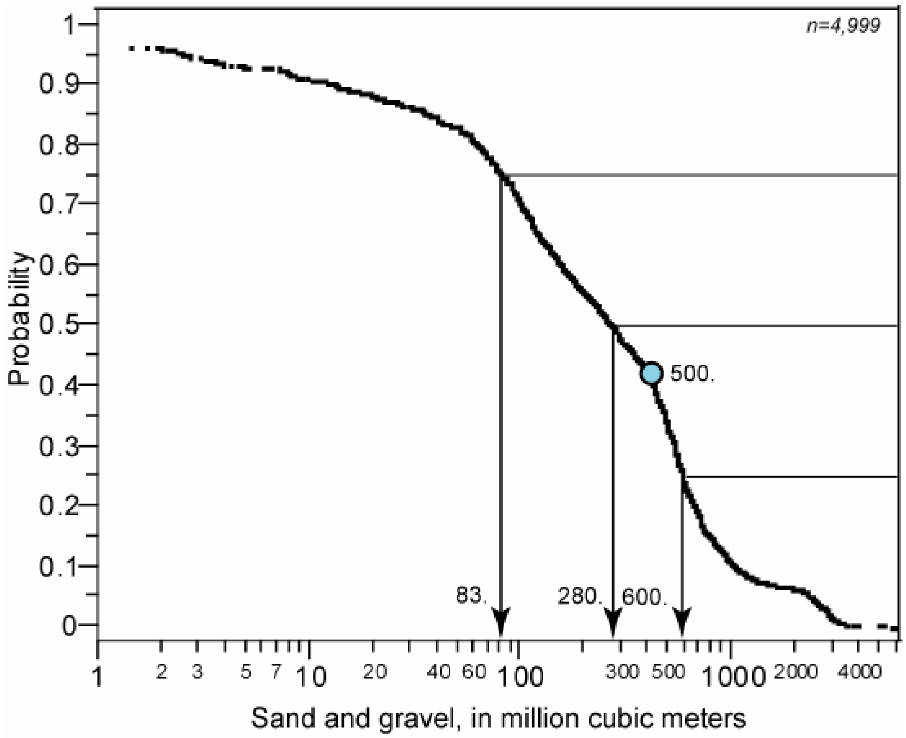

Figure 10.3-79. Distribution of sand and gravel resources in sand and gravel deposits in alluvial fans in Area B. Blue point on curve is the average of the 4,999 values generated by the MCS.

Permissive tracts for fluvial sand and gravel resources in Area C.

Introduction—Area C, with an estimated area of 25,000 km^2, is southern Afghanistan along the border with Pakistan (fig. 10.3-1) The area is in the Helmand Area and exhibits little evidence of the presence of sand and gravel.

Deposit type—Fluvial sand and gravel

Age of mineralization—Quaternary; as a rule, better quality material is in younger fluvial sand and gravel deposits.

Example deposits type—There are no records of sand and gravel deposits in tracts in Area C. Usually no official records of work in sand and gravel deposits are kept, and this is also true in Afghanistan. Fluvial sand and gravel deposits can be expected to be present in and near rivers.

Exploration history—There are no examples of sand and gravel sites that have been identified as sources of sand and gravel in Area C. The presences of a few primitive roads and other infrastructure that require sand and gravel suggest that very little sand and gravel has likely been production. Neither the intensity nor the extent of sand and gravel exploration is known. No buffer zones are present in Area C.

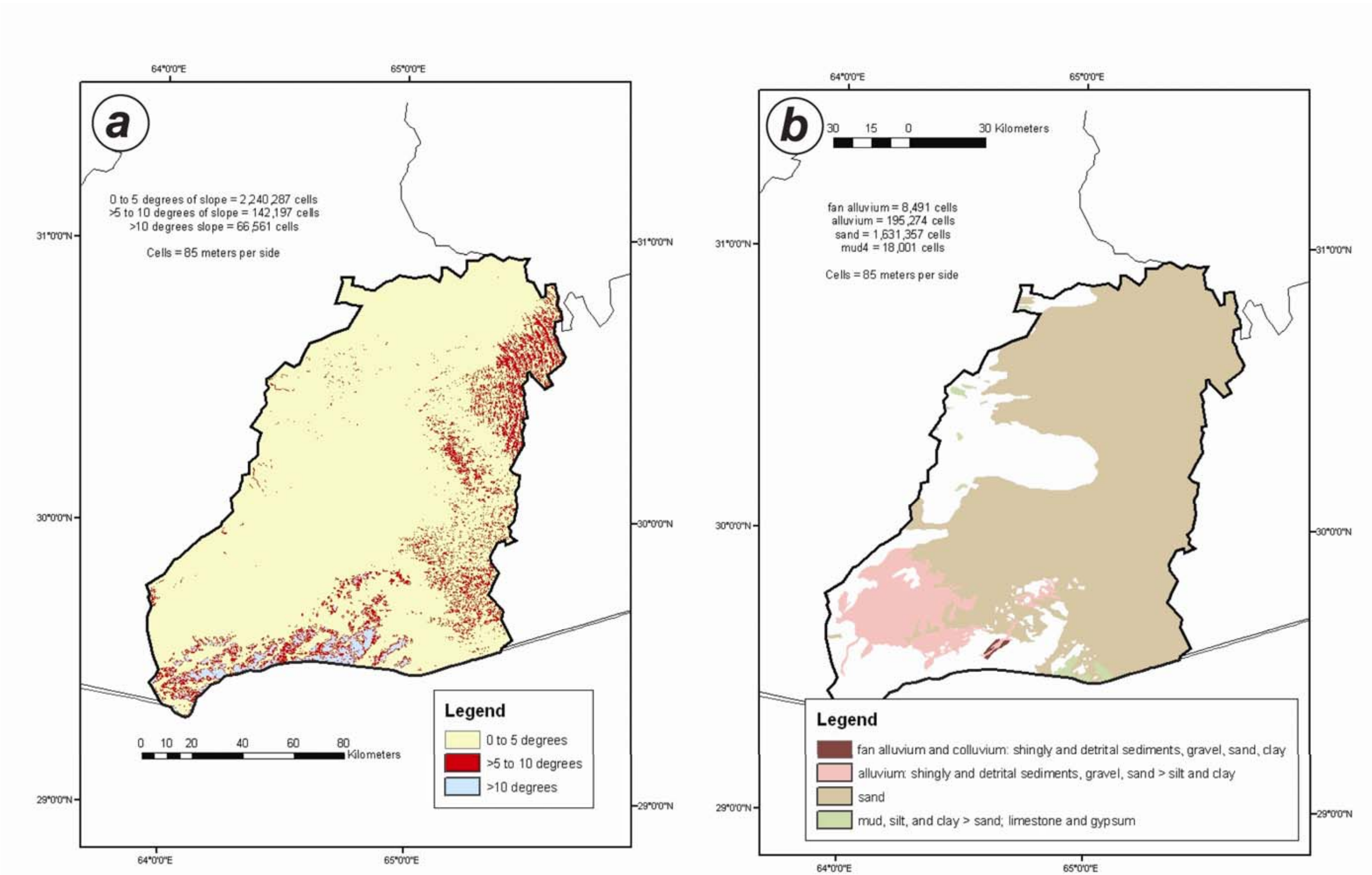

Figure 10.3-80. Outline of Area C showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits. Areas with slopes greater than 10 degrees (blue). (*a*) entire area. (*b*) showing Quaternary units.

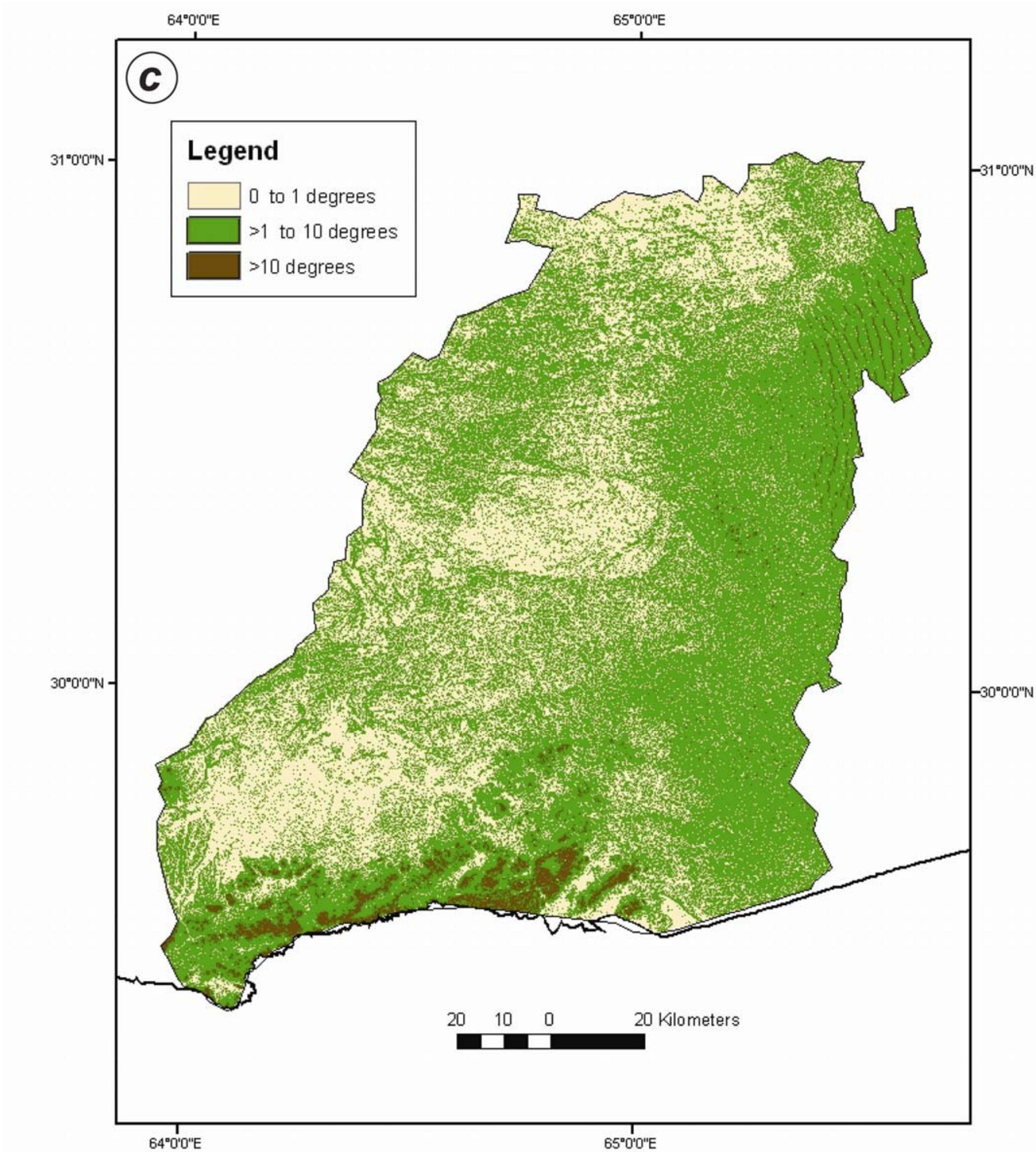

Figure 10.3-80*c*. Outline of Area C showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

***Tract boundary criteria*—**Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-80*c*).

***Buffer zone criteria*—**No buffer zones are present.

Needs to improve assessment—Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors—Of the Quaternary sediments in tracts in this area, ten percent are defined as an alluvium unit in which the gravel content is greater than silt or clay. This unit is highly likely to host readily recognizable fluvial sand and gravel deposits and for this area is the only portion evaluated. Sand and gravel resources expected to be present in alluvial fan sand and gravel deposits are separately assessed (see below.)

Pessimistic factors—Application of the uniform tract boundary criteria based on topographic slope to this area was not used. The tracts were only defined as those area including outcrops of the alluvium unit. Whitney (2006) does not suggest this area has any Neogene coarse gravel as found elsewhere in the Helmand Basin. In addition, it is possible that the alluvium, as reported, may be an area covered with desert pavement. This is the lag concentrate of gravel left behind with the removal of fine grain material, including sand by wind.

***Estimated number of undiscovered deposits*—**For the assessment of the tracts in Area C (fig. 10.3-80b), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-60). In this area only, alluvium is used to estimate the area of permissive tracts, which have a total cumulative size of 1,400 km^2 and are evaluated simultaneously. The alluvium appears to be in an area where there are some suggestions of ephemeral stream on topographic sheets extending north from a low mountain range in Pakistan. Because information about discovered deposits is unavailable, the estimated number of deposits and their associated probability given in the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with alluvium as its major component.

Table 10.3-60. Estimated number of fluvial sand and gravel deposits in Area C, both discovered and undiscovered, calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	0
80 % chance of at least	1
70 % chance of at least	1
60 % chance of at least	1
50 % chance of at least	4
40 % chance of at least	5
30 % chance of at least	7
20 % chance of at least	12
10 % chance of at least	17

***Monte Carlo Simulation results*—**There are three chances in four that the sand and gravel resources in Area C in fluvial sand and gravel deposits will be equal to or greater than 2.2 million m^3, and there is an even chance that there will be equal to or greater than 34 million m^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 140 million m^3 (fig. 10.3-81).

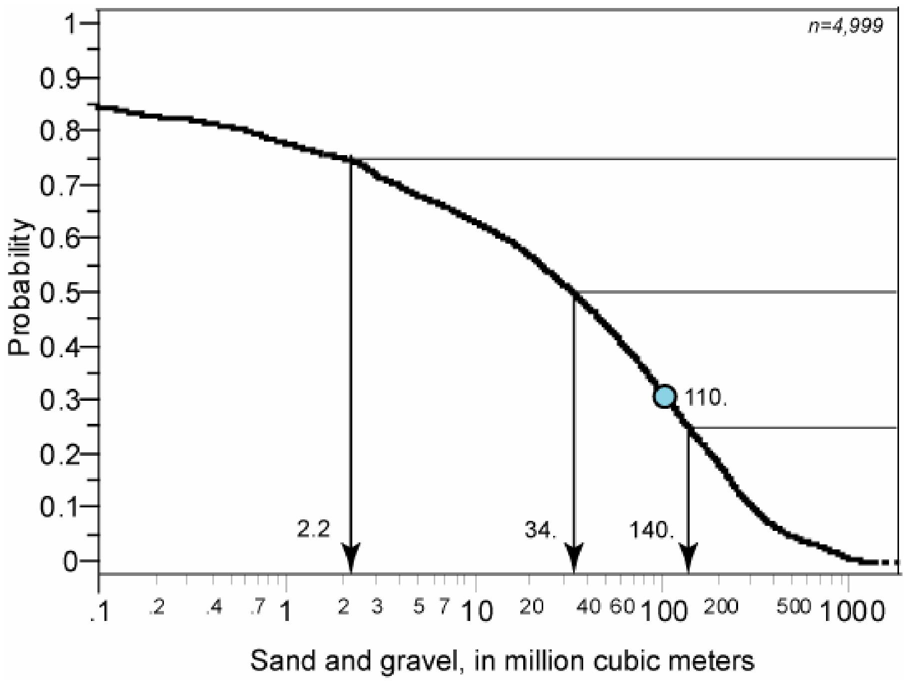

Figure 10.3-81. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Area C tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Permissive tracts for alluvial fan sand and gravel resources in Area C.

Deposit type—Alluvial fan sand and gravel

Age of mineralization—Quaternary, better quality material is in younger alluvial fan sand and gravel deposits.

Example deposits types—There are no reported examples of alluvial fan sand and gravel deposits in tracts in this area. Most alluvial fan sand and gravel deposits are worked without record in many part of the world, and this is also true in Afghanistan.

Exploration history—The presence of only a few primitive roads and other infrastructure that require sand and gravel suggests that little sand and gravel has been previously identified and produced in the tracts in this area. Alluvial fan sand and gravel deposits are usually not found near towns unless a roadway passes up the fan slope into the stream area in the adjacent mountains. Neither the intensity nor the extent of sand and gravel exploration is known. However, exploitation of deposits near major roads is expected given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan.

Tract boundary criteria—Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-80*c*).

Needs to improve assessment—Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, the former USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors—The steeper terrain and mountain fronts usually associated with alluvial fans are present along the southern edge of the area. Quaternary units described as alluvial fan and colluvium are identified as being 56 km^2 on the geologic map (Doebrich and Wahl, 2006) of Area C.

Pessimistic factors—The permissive area is small and alluvial fans are not recognized on topographic sheets (scale 1:200,000). Alluvial fans are often problematic as they are commonly poorly sorted with large amounts of unsuitable clay and silt interbedded or directly mixed with the sand and gravel.

Estimated number of undiscovered deposits—The number of alluvial fans was subjectively estimated using previous subjective estimates made in adjoining basins and the size of area mapped as fan alluvium and colluvium in this area. This review suggests that there is on the order of one chance out of hundred of one alluvial fan sand and gravel deposits in Area C. No MCS is run.

Permissive tracts for fluvial sand and gravel resources in Area D.

Introduction—Area D, with an estimated area of 18,000 km^2, is in the southwest corner of Afghanistan along the border with Pakistan and Iran (fig. 10.3-1) The area is in the Helmand Basin and includes the Zereh depression. There is very little evidence of the presence of sand and gravel deposits in this area. Perhaps one exception is the along the north edge of the tract near the current coarse of the Helmand River.

Deposit type—Fluvial sand and gravel

Age of mineralization—Quaternary; as a rule, better quality material is in younger fluvial sand and gravel deposits.

Example deposits types—There are no examples of sand and gravel sites in deposits in tracts in Area D. Usually no official records of work in sand and gravel deposits are kept, and this is also true in Afghanistan.

Exploration history—There are no examples of sand and gravel sites that have been identified as sources of sand and gravel in Area D (fig. 10.3-82). The presences of primitive roads and other infrastructure that require sand and gravel suggest that a little sand and gravel has been production.

Tract boundary criteria in areas—No tracts prepared as units are unsuitable for sand and gravel deposits, and alluvium is likely desert pavement as described below.

Buffer zone criteria—No buffer zones are present.

Needs to improve assessment—Better Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors—There is a small chance that some of the course gravel described by Whitney (2006) may be present all on the north edge of the area. Sand and gravel resources expected to be present in alluvial fan sand and gravel deposits are separately assessed (see below.)

Pessimistic factors—Application of the uniform tract boundary criteria based on topographic slope to this area was not used. Few fluvial sand and gravel deposits are expected given the considerable distance of the area from bedrock and other sources of sand and gravel. Alluvium is reported within an area of probable desert pavement, the lag concentrate of gravel left behind with the removal by wind of fine grain material including sand. Most of the area that would be considered if the uniform tract boundary criteria had been applied but is unlikely to host deposits found in areas of sand (34 percent), a small area of fan alluvium and colluvium (0.14 percent), mud (11 percent) and playas (7.9 percent).

Estimated number of undiscovered deposits—No estimate made.

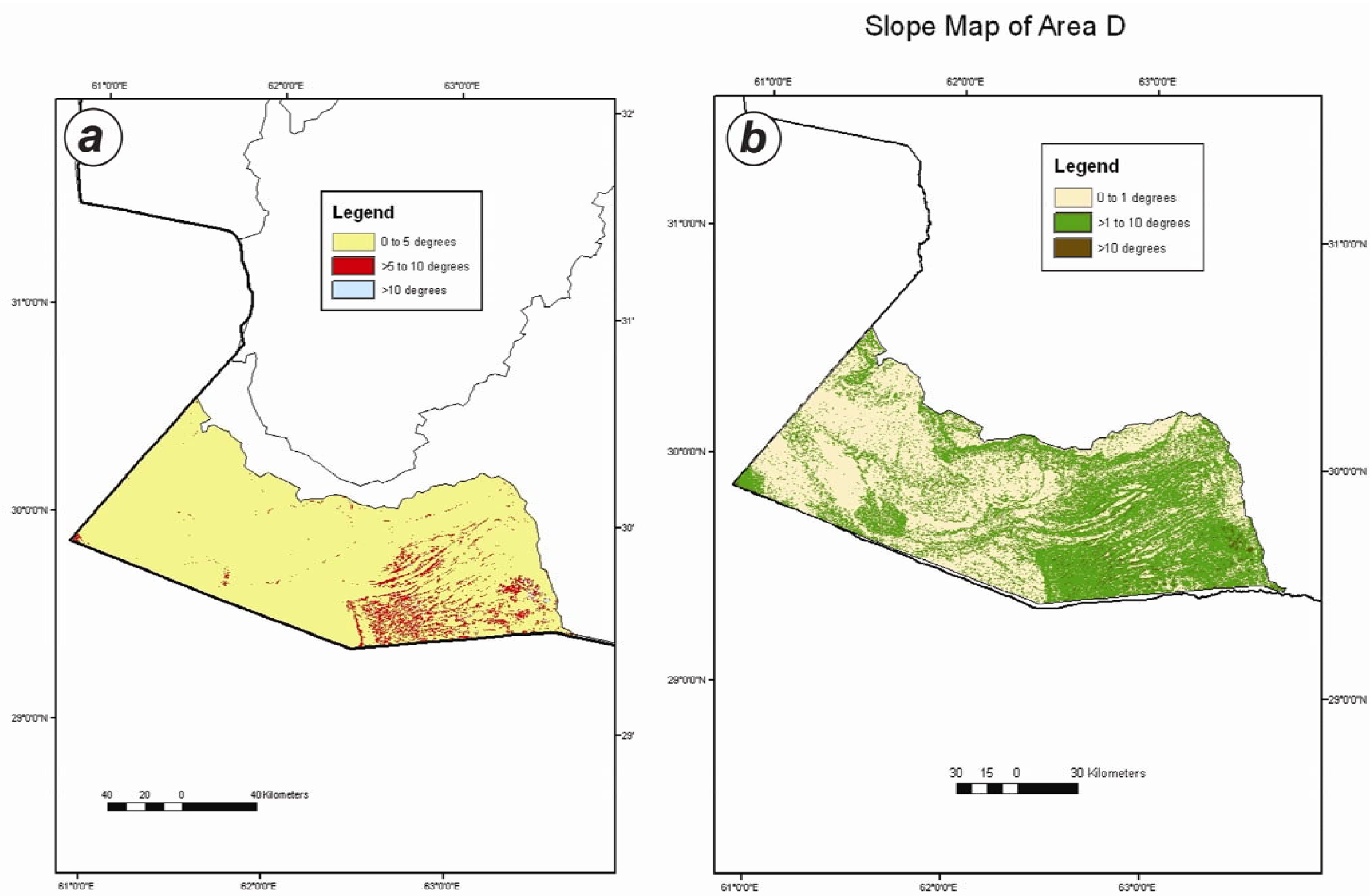

Figure 10.3-82. (*a*) Outline of Area D showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits and not permissive areas with slopes greater than 10 degrees (blue.) (*b*) Outline of Area D showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

Permissive tracts for alluvial fan sand and gravel resources in Area D.

Deposit type—Alluvial fan sand and gravel

Age of mineralization—Quaternary, better quality material is in younger alluvial fan sand and gravel deposits.

Example deposits types—There are no reported examples of alluvial fan sand and gravel deposits in tracts in this area. Most alluvial fan sand and gravel deposits are worked without record in many parts of the world, and this is also true in Afghanistan.

Exploration history—Unknown.

Tract boundary criteria—Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-82*b*).

Needs to improve assessment—Better Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, former USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors— Quaternary units defined as alluvial fan and colluvium are identified as being 24 km^2 on the geologic map (Doebrich and Wahl, 2006) in Area D.

Pessimistic factors—The permissive area is small and alluvial fans are not recognized on topographic sheets (1:200,000 scale).

Estimated number of undiscovered deposits—None, the permissive areas are too small to host the typical sized alluvial fan sand and gravel deposits.

Permissive tracts for fluvial sand and gravel resources in Area E.

Introduction—Area E, with an estimated area of 20,000 km^2, is on the west edge of Afghanistan on the border with and Iran (fig. 10.3-1) The area is dominated by the low lying Naomid Plain and contains numerous closed area playas. The area is dominated by indistinct drainage systems.

Deposit type—Fluvial sand and gravel

Age of mineralization—Quaternary; as a rule, better quality material is in younger fluvial sand and gravel deposits.

Example deposits types—No examples of sand and gravel deposits in tracts in Area E.

Exploration history—There are no records of sand and gravel deposits in tracts in Area E. No official records of work in sand and gravel deposits are kept in many parts of the world, and this is also true in Afghanistan. The presence of significant roads and other infrastructure that require sand and gravel suggest are not obvious.

Tract boundary criteria in areas—No tracts are prepared.

Buffer zone criteria—Buffer zones in tracts are defined as extending 25 km around towns and along both sides of major roads that extend into Area E from Basins 6 and 7. Buffered areas include 700 km^2.

Needs to improve assessment—Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors—Of the Quaternary sediments in tracts in this area, 47 percent are defined as an alluvium unit in which the gravel content is greater than silt or clay. This unit is highly likely to be the host of readily recognizable fluvial sand and gravel deposits. One complication is that a portion of the unit may actually be lag gravels (desert pavement) related to removal of sand and silt by wind common in many deserts. The alluvial fans and colluvium with gravel and sand greater than silt unit includes 49 percent of the Quaternary sediments and is located along mountain front and may contribute sand and gravel deposits downstream from these features. Sand and gravel resources expected to be present in alluvial fan sand and gravel deposits are separately assessed (see below.)

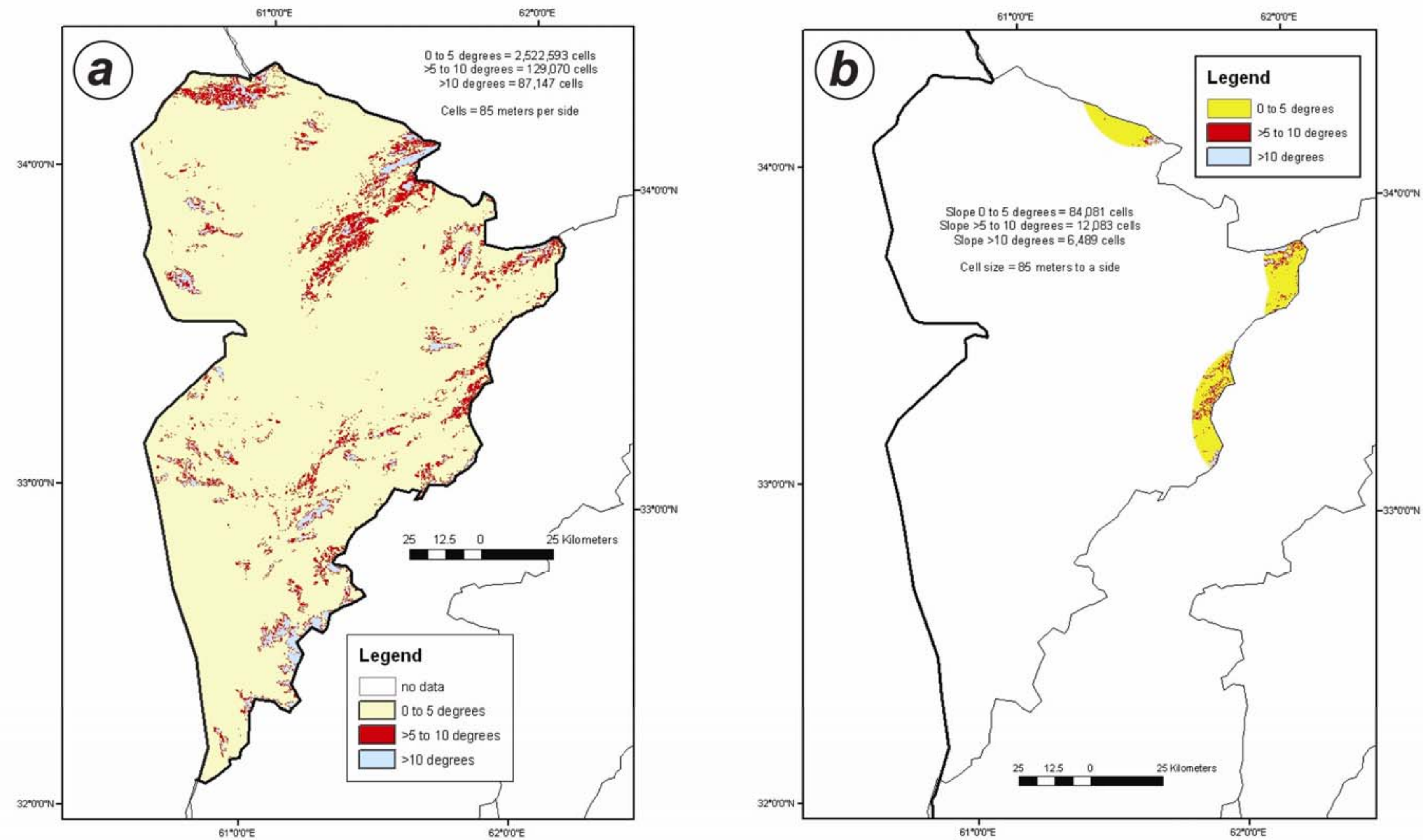

Figure 10.3-83. Outline of Area E showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits. Areas with slopes greater than 10 degrees (blue) are non-permissive. (*a*) entire area. (*b*) areas within 25 kilometer buffer zone around towns and along roads. Slopes between 0-5 degrees (yellow), and 5-10 degrees (red) are permissive for fluvial sand and gravel deposits and those greater than 10 degrees (blue) are not permissive.

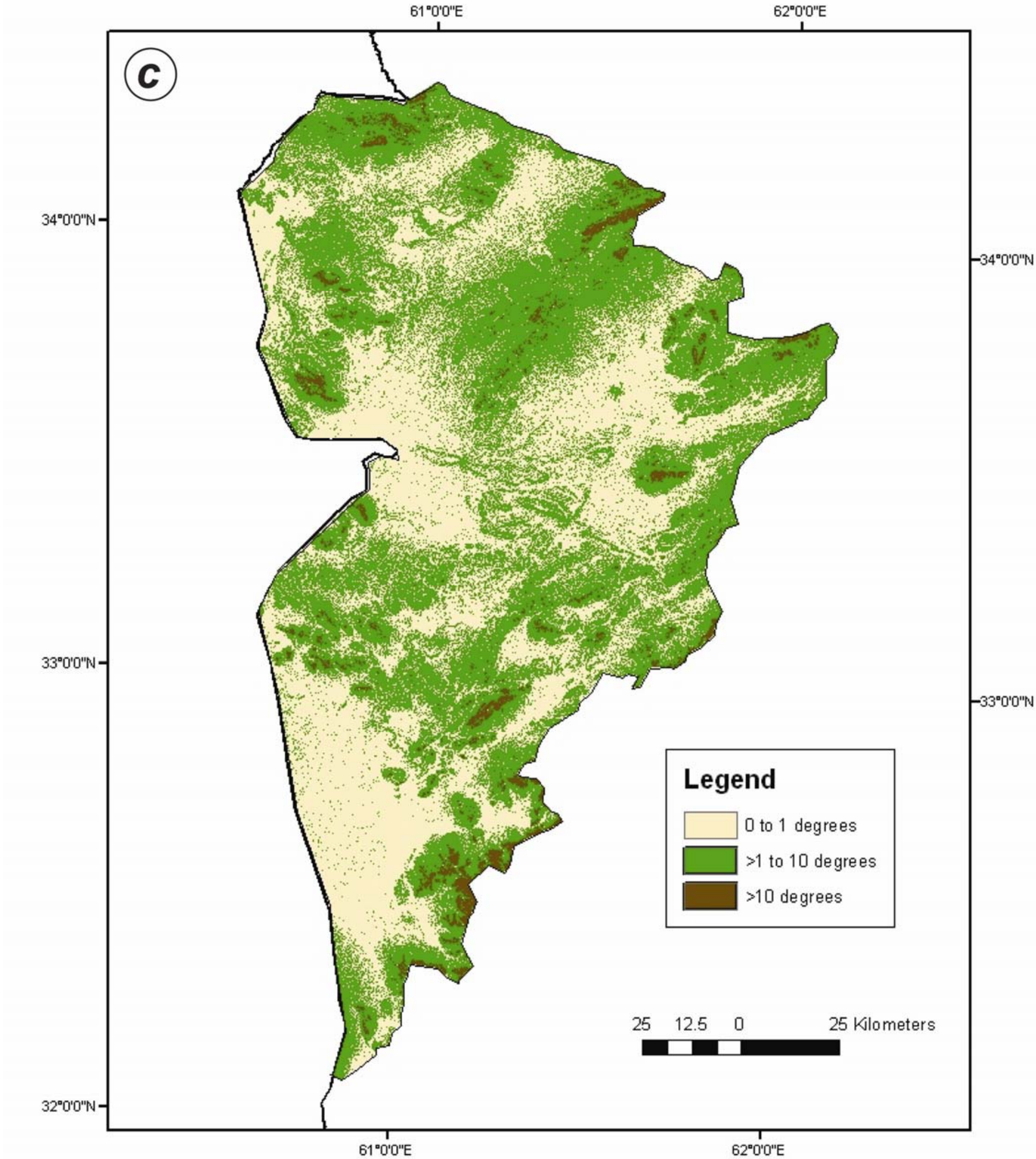

Figure 10.3-83*c*. Outline of Area E showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

Pessimistic factors**—**The dominance of a region of very low relief like Area E (92 percent with 5 degree slope or less) is not promising for the development of sand and gravel at or near the surface. Most of the area is removed for the type of steams and rivers that are needed for development of fluvial sand and gravel deposits. Other Quaternary sediments in permissive tracts includes muds (3.2 percent) that are 1) highly unlikely sources of sand and gravel or 2) overburden that obscure sand and gravel deposits at depth.

Estimated number of undiscovered deposits**—**For the assessment of the slope-defined tracts in Area E (fig. 10.3-83b), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-61) All tracts, based on the slope criteria would suggest that the total cumulative area of 19,000 km^2 within the area would be permissive. However, a review of topographic and hydrologic data suggest that most of this area is likely not permissive. The area determined as permissive is estimated to be 1,900 km^2. Because information about discovered deposits is unavailable, the estimated number of deposits and their associated probability given in the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-61. Estimated number of fluvial sand and gravel deposits in Area E, both discovered and undiscovered, calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	1
80 % chance of at least	1
70 % chance of at least	1
60 % chance of at least	2
50 % chance of at least	5
40 % chance of at least	7
30 % chance of at least	10
20 % chance of at least	16
10 % chance of at least	23

Monte Carlo Simulation results**—**There are three chances in four that the sand and gravel resources in Area E in fluvial sand and gravel deposits will be equal to or greater than 7.0 million m^3, and there is an even chance that there will be equal to or greater than 59 million m^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 220 million m^3 (fig. 10.3-84).

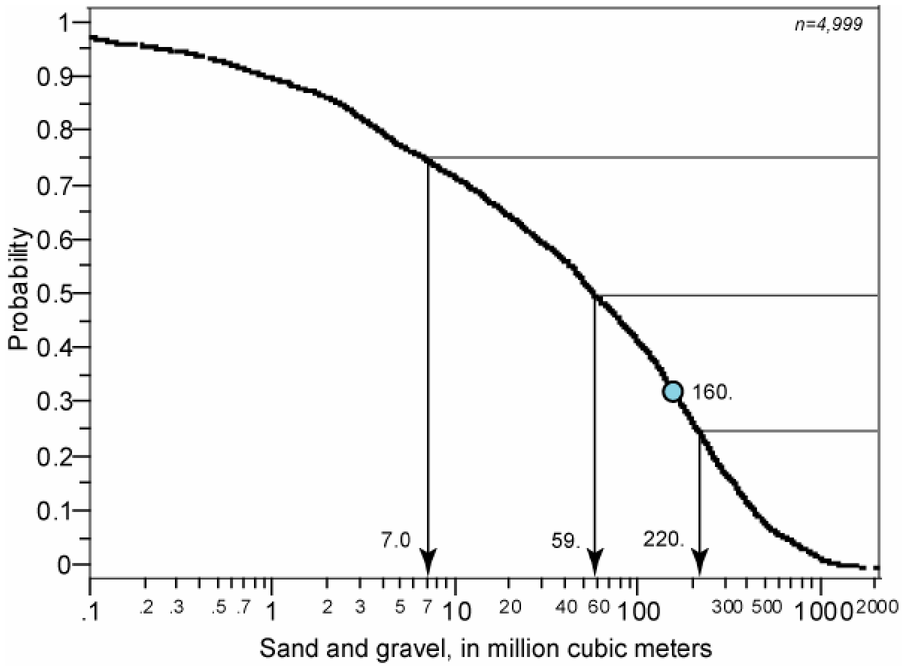

Figure 10.3-84. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Area E tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Estimated number of undiscovered deposits in buffer zones—For the assessment of Area E buffer zones (fig. 10.3-83b), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-62) from the permissive area of 690 km^2. All buffer zones in the tracts are evaluated simultaneously. The estimated number of deposits and their associated probability given by the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees as modified and discussed above.

Table 10.3-62. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zones calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	0
80 % chance of at least	0
70 % chance of at least	0
60 % chance of at least	1
50 % chance of at least	2
40 % chance of at least	3
30 % chance of at least	4
20 % chance of at least	6
10 % chance of at least	8

Monte Carlo Simulation results for buffer zones—There is also an even chance that there will be equal to or greater than 11 million m^3 in Area E (fig. 10.3-85). There is also one chance in four that the amount of sand and gravel resources will equal or be greater than 66 million m^3.in Area E buffer zones. Proximity to towns and major roads suggests a portion of the estimated sand and gravel resources may have already been consumed.

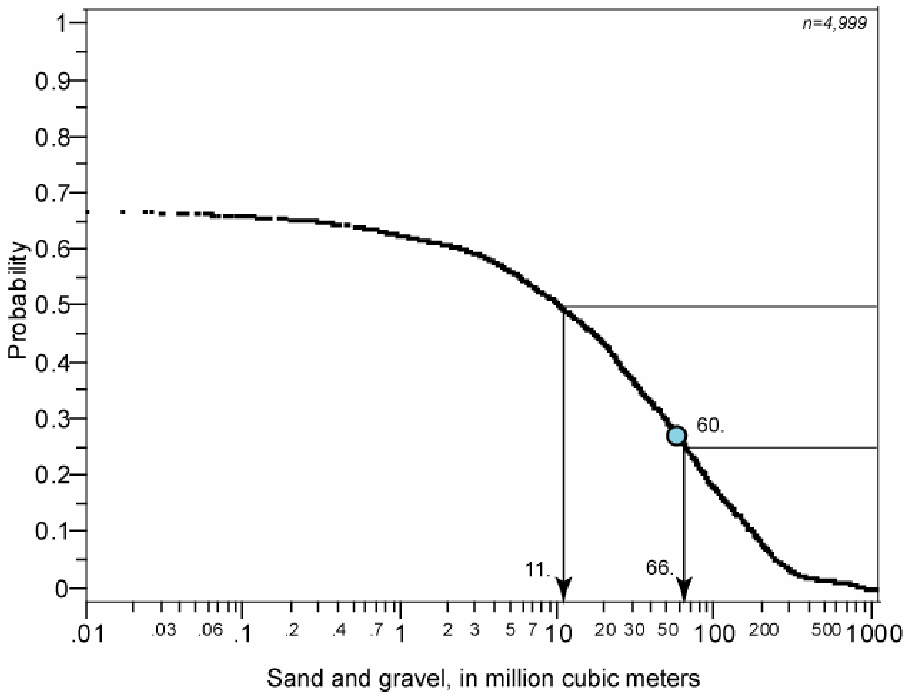

Figure 10.3-85. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Area E buffer zones. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Permissive tracts for alluvial fan sand and gravel resources in Area E.

Deposit type**—**Alluvial fan sand and gravel

Age of mineralization**—**Quaternary, better quality material is in younger fluvial fan sand and gravel deposits.

Example deposits types**—**There are no reported examples of fluvial fan sand and gravel deposits in tracts in this area. Most fluvial fan sand and gravel deposits are worked without record in many part of the world, and this is also true in Afghanistan.

Exploration history**—**Absence of significant roads and other infrastructure that require sand and gravel suggests that sand and gravel has been little exploited in this area.

Tract boundary criteria**—**Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-83*c*).

Needs to improve assessment**—**Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, former USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors**—**The steeper terrain and mountain fronts usually associated with alluvial fans are found widely in this area. Quaternary units defined as alluvial fan and colluvium are identified as being 4,700 km^2 from the geologic map (Doebrich and Wahl, 2006) in Area E. Alluvial fans are recognized on topographic sheets (scale 1:200,000)

Pessimistic factors**—**Areas with fan alluvium and colluvium are on the margins of largely erode mountain ridges that lack upstream basins and therefore lack the necessary hydrological setting for the development of sand and gravel at or near the surface in the alluvial fans found downstream. Alluvial fans are often problematic as they are commonly poorly sorted with large amounts of unsuitable clay and silt interbedded or directly mixed with the sand and gravel. Area E was not surveyed on topographic sheets.

Estimated number of undiscovered deposits**—**The number of alluvial fans was subjectively estimated. Because information about discovered deposits is not available, the estimated number of deposits and their associated probability for MCS are for both discovered and undiscovered deposits and are given together with an associated probability (table 10.3-63).

Table 10.3-63. Estimated number of fluvial sand and gravel deposits both discovered and undiscovered in alluvial fans in Area E.

Probability level	Number of deposits
90 % chance of at least	0
70 % chance of at least	0
50 % chance of at least	0
30 % chance of at least	0
10 % chance of at least	1

Monte Carlo Simulation results for alluvial fan deposits**—**There is one chance in ten that the sand and gravel resources in alluvial fans in Area E will be equal to or greater than 77 million m^3 (fig. 10.3-86).

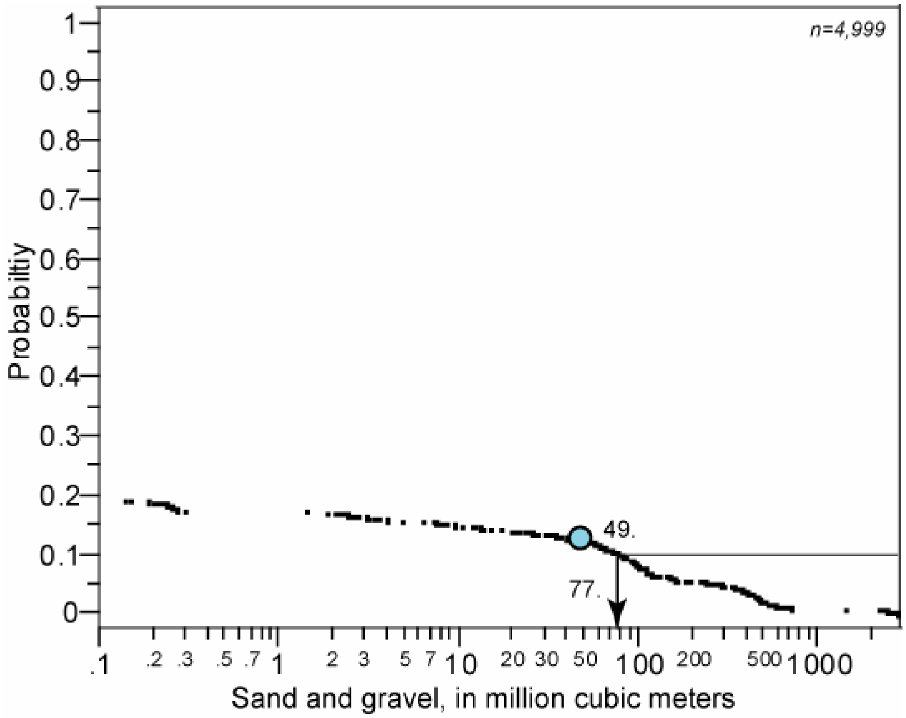

Figure 10.3-86. Distribution of sand and gravel resources in sand and gravel deposits in alluvial fans in Area E. Blue point on curve is the average of the 4,999 values generated by the MCS.

Permissive tracts for fluvial sand and gravel resources in Area F.

Introduction—Area F, with an estimated area of 10,000 km^2, is in the northwestern corner of Afghanistan along the border with Iran to the west where the boundary is defined partly by the Harirud River. Turkmenistan is to the north (fig. 10.3-1). The area also includes the west end of the Paropamisus Range that is notable for its aridity. Ephemeral streams are common and most drain to the north.

Deposit type—Fluvial sand and gravel

Age of mineralization—Quaternary; as a rule, better quality material is in younger fluvial sand and gravel deposits.

Example deposits types—There are records of sand and gravel deposits in tracts in Area F. No official records of work in sand and gravel deposits are kept in many parts of the world, and this is also true in Afghanistan. Fluvial sand and gravel deposits can be expected to be present in and near rivers.

Exploration history—No sites have been reported as a sources of sand and gravel in Area F. The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified in the area and that production likely has been wide spread. At least two major roads are recognized in (Herat to Gusgy) or adjacent to this area (A1 from Herat to Iran in Basin 7) and their presence suggest that it is highly likely that some sand and gravel may have been extracted for their construction and ongoing maintenance. However, neither the intensity nor the extent of sand and gravel exploration is known. Exploitation of deposits near major and other roads is likely given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. Sand and gravel is produced near the point of consumption, so locations in regions at some distance from existing road and towns are likely untouched. Deposits within buffer zones (as defined below) near towns in this area are more likely to have been explored.

Tract boundary criteria in areas—See uniform tract boundary criteria based on topographic slope used for both areas and buffer zones as noted in the introductory discussion above. Eight five percent of Area F or 8,900 km^2 is permissive for fluvial sand and gravel deposits (fig. 10.3-87).

Buffer zone criteria—Buffer zones in tracts are defined as extending 25 km around towns and along both sides of major roads. Buffered areas (fig. 10.3-87b) with slopes less than 10 degrees have a cumulative area of 4,300 km^2.

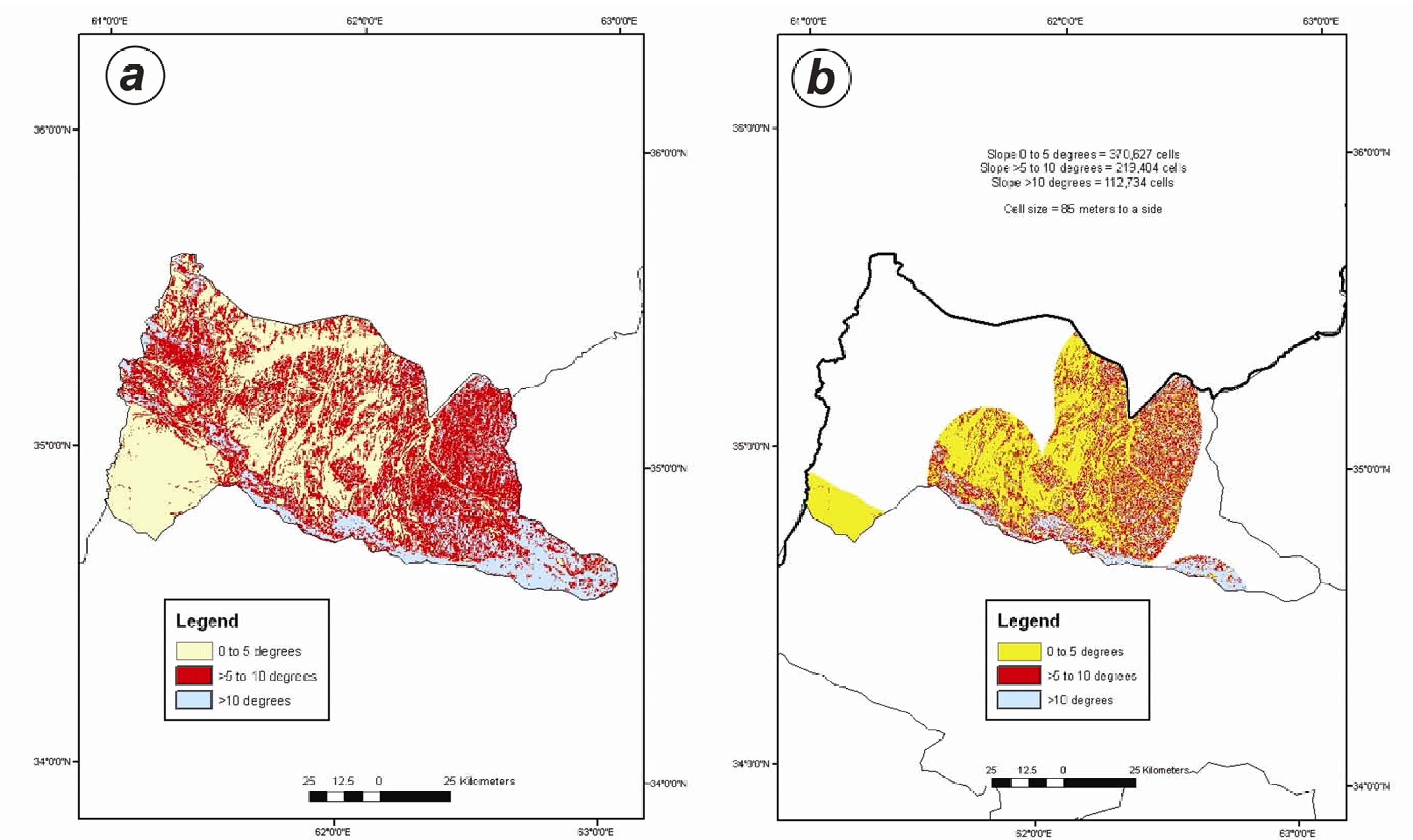

Figure 10.3-87. Outline of Area F showing areas with slopes of 0-5 degrees (yellow) and 5-10 degrees (red) that are both permissive for fluvial sand and gravel deposits. Areas with slopes greater than 10 degrees (blue) are non-permissive. (*a*) entire area. (*b*) areas within 25 kilometer buffer zone around towns and along roads. Slopes between 0-5 degrees (yellow), and 5-10 degrees (red) are permissive for fluvial sand and gravel deposits and those greater than 10 degrees (blue) are not permissive.

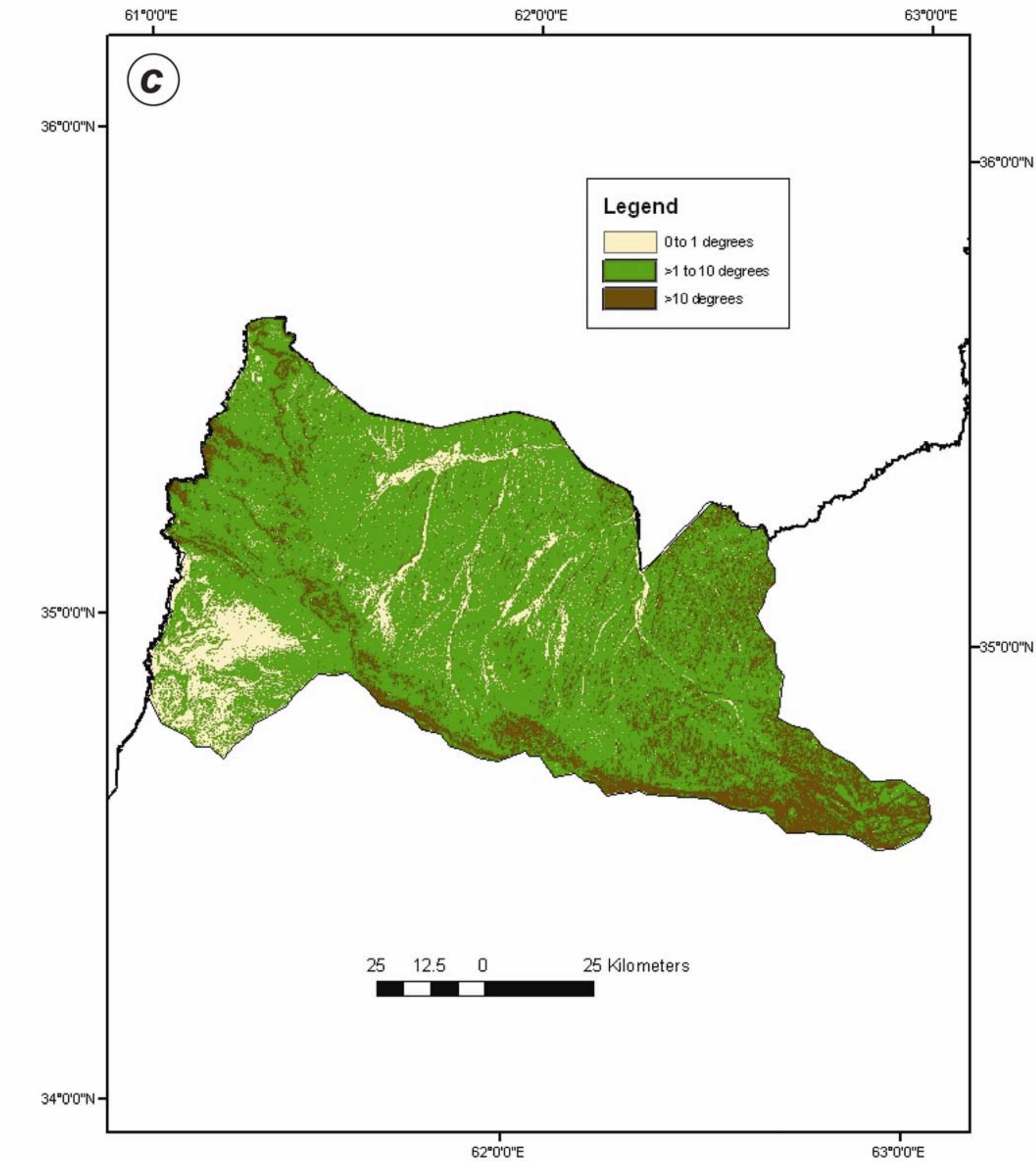

Figure 10.3-87*c*. Outline of Area F showing areas with slopes of 0-1 degrees (tan), >1-10 degrees (green) and greater than 10 degrees (brown) where only areas in green are permissive for sand and gravel deposits in alluvial fans.

Needs to improve assessment—Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use.

Optimistic factors—Of the Quaternary sediments in tracts in this area, 14 percent are defined as an alluvium unit in which the gravel content is greater than silt or clay content. This unit is highly likely to host readily recognizable fluvial sand and gravel deposits, and is likely located along mountain fronts and may contribute sand and gravel downstream. Sand and gravel resources expected to be present in alluvial fan sand and gravel deposits are separately assessed (see below.)

Pessimistic factors—Application of the uniform tract boundary criteria based on topographic slope to this area resulted in 80 percent of the cells being on surface described as non-Quaternary rocks. The tracts so defined may over representative possible sources of sand and gravel deposits in the area. Alluvial fan and colluvium along mountains fronts have not been separately shown on the geologic map and may account for some of the permissive area grouped with alluvium. Other Quaternary sediments in permissive tracts include units that are 1) highly unlikely sources of sand and gravel or 2) overburden that may obscure sand and gravel deposits at depth. This includes units dominated with sand (23 percent) and loess (63 percent).

Estimated number of undiscovered deposits—For the assessment of the slope-defined tracts in Area F (fig. 10.3-87b), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-64) All tracts, which have a total cumulative area of 8,900 km^2 within the area, are evaluated simultaneously. Because information about discovered deposits is unavailable, the estimated number of deposits and their associated probability given in the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees.

Table 10.3-64. Estimated number of fluvial sand and gravel deposits in Area F, both discovered and undiscovered, calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	3
80 % chance of at least	4
70 % chance of at least	6
60 % chance of at least	7
50 % chance of at least	24
40 % chance of at least	35
30 % chance of at least	47
20 % chance of at least	77
10 % chance of at least	106

Monte Carlo Simulation results—There are three chances in four that the sand and gravel resources in Area F in fluvial sand and gravel deposits will be equal to or greater than 73 million m^3, and there is an even chance that there will be equal to or greater than 420 million m^3. There is one chance in four that the amount of sand and gravel resources will equal or be greater than 1,200 million m^3 (fig. 10.3-88).

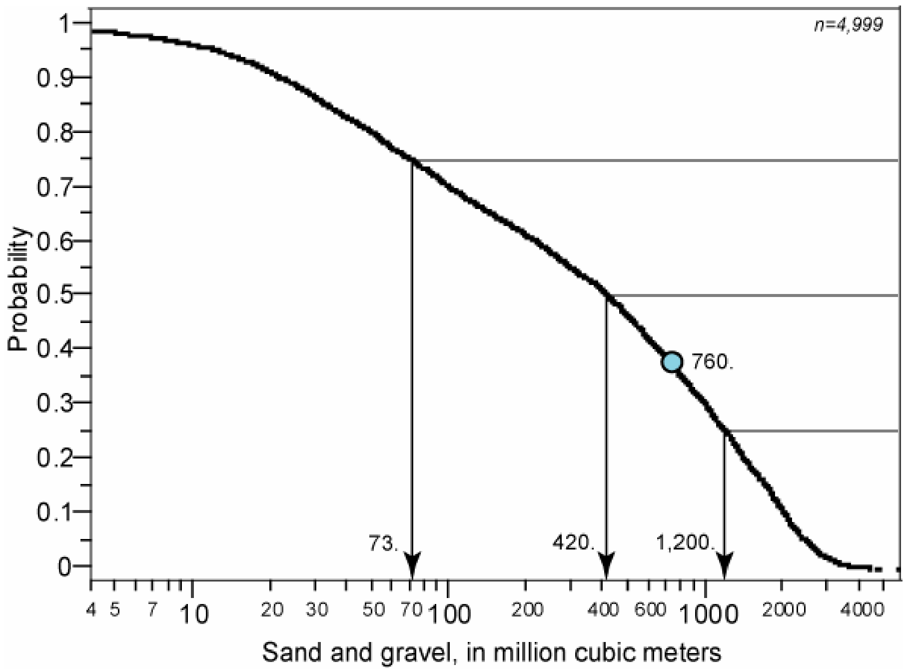

Figure 10.3-88. Distribution of sand and gravel resources in fluvial sand and gravel deposits in Area F tracts. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

***Estimated number of undiscovered deposits in buffer zones*—**For the assessment of Area F buffer zones (fig. 10.3-87b), a mineral deposit density model is used to provide an estimate of undiscovered deposits (table 10.3-65) from the permissive area of 4,300 km^2. All buffer zones in tracts are evaluated simultaneously. The estimated number of deposits and their associated probability given by the simulation are for both discovered and undiscovered deposits. Probabilities are keyed to the model, and the number of deposits is calculated using the size of the area with slopes less than 10 degrees. The Quaternary geology in buffer zones contains possible areas of fan alluvium and colluvium together with areas of the more promising alluvium units that are more likely to contain fluvial sand and gravel deposits. Loess, sand and mud dominated units are in parts of the permissive tracts within buffer zones that will obscure or prohibit the presences of undiscovered deposits.

Table 10.3-65. Estimated number of fluvial sand and gravel deposits, both discovered and undiscovered, in buffer zones calculated using the MDD model.

Probability level	Number of deposits
90 % chance of at least	1
80 % chance of at least	2
70 % chance of at least	3
60 % chance of at least	3
50 % chance of at least	12
40 % chance of at least	17
30 % chance of at least	23
20 % chance of at least	37
10 % chance of at least	51

***Monte Carlo Simulation results for buffer zones*—**There are three chances in four that the sand and gravel resources in Area F in fluvial sand and gravel deposits will be equal to or greater than 23 million

m^3. There is also an even chance that there will be equal to or greater than 180 million m^3 and one chance in four that the amount of sand and gravel resources will equal or be greater than 560 million m^3 (fig. 10.3-89). Proximity to towns and major roads suggests a portion of the estimated sand and gravel resources may have already been consumed.

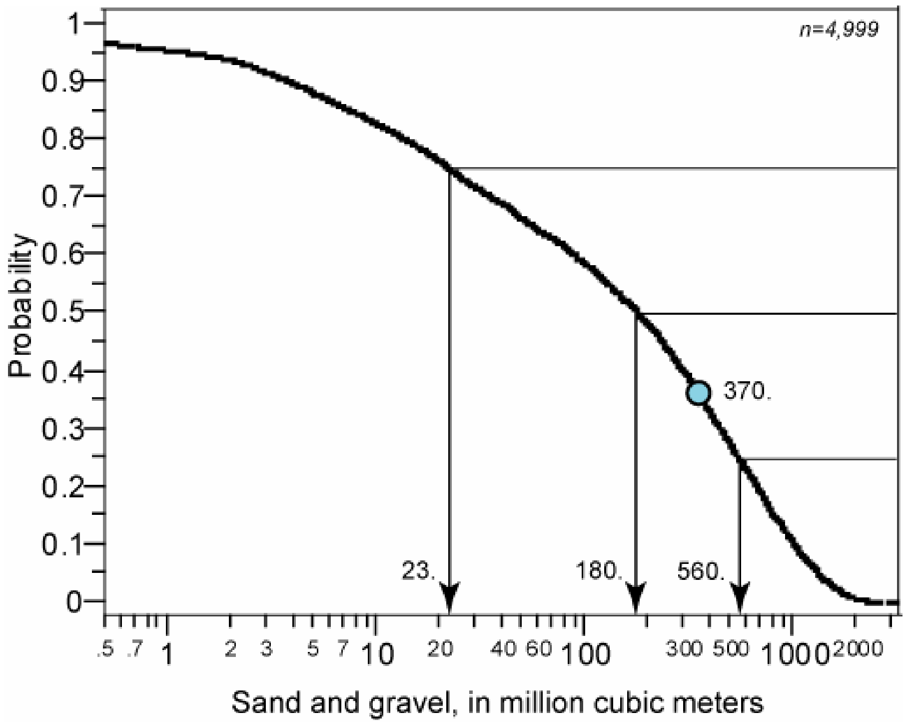

Figure 10.3-89. Distribution of sand and gravel resources in fluvial sand and gravel deposits in tracts in Area F buffer zones. Note that 1,000 million cubic meters is equal to one cubic kilometer. Blue point on curve is the average of the 4,999 values generated by the MCS.

Permissive tracts for alluvial fan sand and gravel resources in Area F.

Deposit type—Alluvial fan sand and gravel

Age of mineralization—Quaternary, better quality material is in younger alluvial fan sand and gravel deposits.

Example deposits types—There are no reported examples of alluvial fan sand and gravel deposits in tracts in this area. Most alluvial fan sand and gravel deposits are worked without record in many part of the world, and this is also true in Afghanistan.

Exploration history—The presence of roads and other infrastructure that require sand and gravel suggests that sand and gravel has been previously identified and produced in the tracts in this area. Alluvial fan sand and gravel deposits are usually not found near towns unless a roadway passes up the fan slope into the stream basin in the adjacent mountains, which may be true in this area. Neither the intensity nor the extent of sand and gravel exploration is known. However, exploitation of deposits near major roads is likely given that both the U.S. Corp of Engineers and the former Soviet Union have historically been involved in developing roads in Afghanistan. However, some of these alluvial sand and gravel deposits are near roads and other points of consumption, so some of these deposits may have been exploited. However, most of the resource is likely untouched. Deposits of this type are likely rare within buffer zones (as defined below) found near towns and roads and are not considered in this assessment.

Tract boundary criteria—Tracts are defined as areas with slopes between 1 and 10 degrees (fig. 10.3-87c).

Needs to improve assessment—Quaternary mapping, plus information about sources of sand and gravel used by the U.S. Corp of Engineers, the former USSR engineers, and construction contractors who have built roads in Afghanistan, would help identify sources of sand and gravel as well as help in the classification of aggregate quality and its suitability for use. A review of the topographic maps and evaluation of remote sensing data may improve the assessment.

Optimistic factors—The steep terrain and mountain fronts usually associated with alluvial fans are found widely in this area on topographic maps (scale 1: 200,000)

Pessimistic factors**—**Alluvial fans are often problematic as they are commonly poorly sorted with large amounts of unsuitable clay and silt interbedded or directly mixed with the sand and gravel.

Estimated number of undiscovered deposits**—**The number of alluvial fans was subjectively estimated. This particular subjectively assessment was guided by using a possible relationship observed elsewhere between sand and gravel deposits in fluvial systems and gravel deposits in alluvial fans in the same region when both deposit types are found together. Because information about discovered deposits is not available, the estimated number of deposits and their associated probability for MCS are for both discovered and undiscovered deposits and are given together with an associated probability (table 10.3-66).

Table 10.3-66. Estimated number of fluvial sand and gravel deposits both discovered and undiscovered in alluvial fans in Area F.

Probability level	Number of deposits
90 % chance of at least	0
70 % chance of at least	0
50 % chance of at least	0
30 % chance of at least	1
10 % chance of at least	1

Monte Carlo Simulation results for alluvial fan deposits**—**There is one chance in four that the amount of sand and gravel resources in alluvial fan deposits will be equal to, or greater than, 59 million m^3 in Area F (fig. 10.3-90)

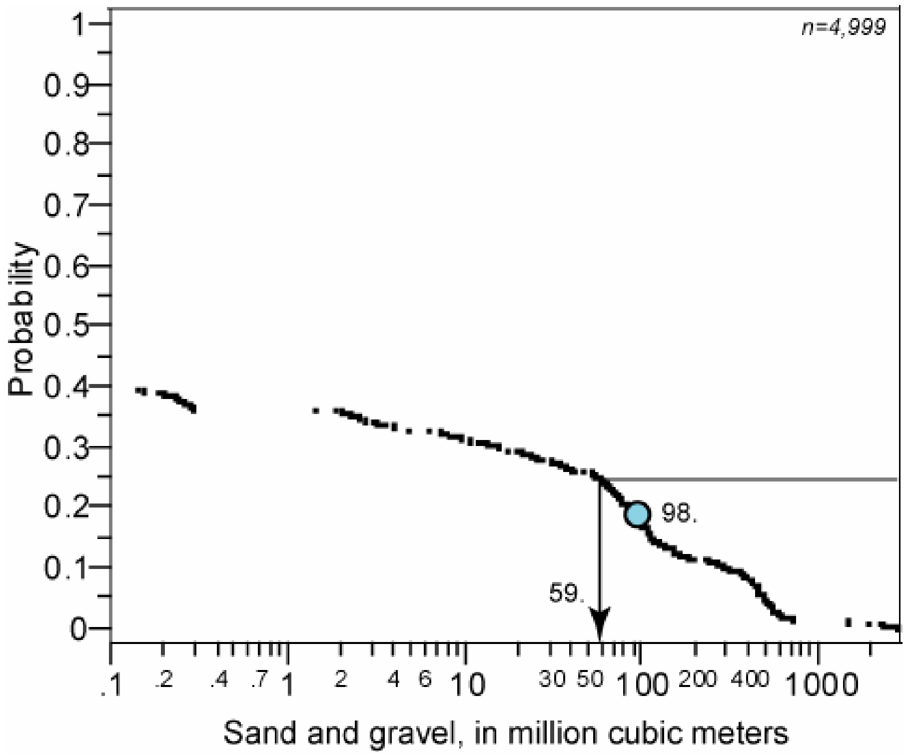

Figure 10.3-90. Distribution of sand and gravel resources in sand and gravel deposits in alluvial fans in Area F. Blue point on curve is the average of the 4,999 values generated by the MCS.

Closing Remarks

Estimating endowments of suspected and undiscovered sand and gravel resources is an important function of government that enables the inclusion of mineral resources in land use and planning. Aggregate in proximity to the end-user markets is more attractive because producers enjoy transportation cost advantages. However, proximity to consumer is more likely to result in conflict with other land uses. To help in resolving this, and other problems, assessment estimates may be useful. Assessment of sand and gravel is in its infancy, and it is expected that improved models and assessment methods will provide better estimates of sand and gravel resources in the future.

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