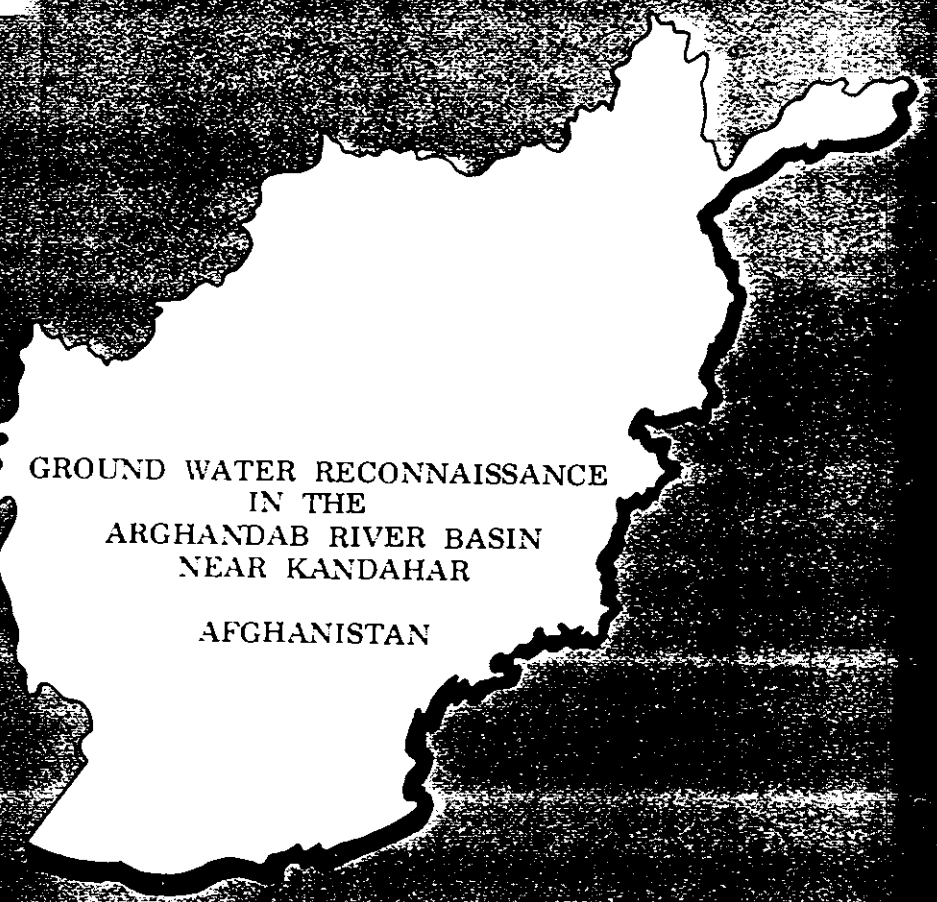
AF
333.9104
S189

PN-ACS-451
11953



GROUND WATER RECONNAISSANCE IN THE ARGHANDAB RIVER BASIN NEAR KANDAHAR

AFGHANISTAN

Prepared by
the United States Geological Survey in cooperation with the
Royal Government of Afghanistan
under the auspices of the
United States Agency for International Development

OFF-SITE WITHDRAWN

AF
333.9104 Geological Survey, Washington, D. C.
S189
Ground Water Reconnaissance in the Arghandab River Basin Near Kandahar, Afghanistan. Edward A. Sammel. Dec. 1971.
94 p.
Bibliography: p. 74-75.
map.
PASA.
1.Water, Underground - AF.2.Water resources development - AF.3.River basins - AF.I.Sammel, Edward A.II.Title.III. Arghandab River Basin, Afghanistan.

B

Ground Water Reconnaissance in the Arghandab River Basin near Kandahar, Afghanistan

by

Edward A. Sammel

U.S. Geological Survey

Open File Report

December 1971

C

Contents

	Page
Abstract	1
Introduction	3
Physiography and Geology	5
Climate	8
Surface Water Resources	10
Ground Water Resources	14
Ground Water Reservoir	14
Extent and Thickness	14
Lithology of Ground Water Reservoir	14
Water Levels	17
Potentiometric Heads	18
Fluctuation of Water Table	20
Hydraulic Conductivity, Transmissivity, and Specific Yield	21
Recharge to Ground Water Reservoir	25
Discharge from Ground Water Reservoir	27
Withdrawals from Wells and Karezes	27
Evapotranspiration	29
Discharge to Streams	31
Quality of Ground Water	33
Development of Ground Water	47
Current Status	47
Future Development	54
Shallow Aquifers	54

d

	Page
Deep Aquifers	57
Perennial Yield	60
Effects of Future Development	61
Further Studies	65
Summary and Conclusions	67
Background	67
Ground Water Resources	68
Development of Ground Water	71
References	74
Appendix A. Logs of Wells and Power Auger Holes in the Kandahar Area	76-87
Appendix B. Orthographic List of Geographic Names	88-94

Illustrations

Page

Figure 1.--Map of the Kandahar Area, Afghanistan showing Locations of Wells, Karezes and Canals---------- In pocket

2.--Graphs summarizing Climatic Data at Kandahar---------- 9

f

Tables

	Page
Table 1.--Annual Withdrawals of Ground Water in Kandahar Area, 1971	28
2.--Quality of Water in Wells, Drains, Karezes and Streams of Kandahar area	35-44
3.--Hydrologic Data on Drilled Wells in Kandahar Area	51-53

Abstract

During the summer of 1971 a U.S. Geological Survey team carried out a reconnaissance of ground-water conditions over an area of 1,500 square kilometers in southern Afghanistan near Kandahar. In this arid area of broad alluvial valleys separated by a few narrow bedrock ridges, waters of four intermittent streams, the Arghandab, Arghastan, Dori, and Tarnak are utilized for irrigation. The Arghandab River, its flow regulated by a dam upstream from Kandahar, provides an average flow of about 40 cubic meters (m^3) per second (1 million-acre-feet) annually, which is nearly two-thirds of the surface water available in the area. In addition karezes supply about 31 million m^3 (25,000 acre-feet) annually for irrigation. During the first 9 months of 1971 about 300 shallow irrigation wells were dug in the alluvial sediments in efforts to alleviate drought conditions resulting from a shortage of surface water. Although water levels over much of the area are generally high, 2 to 5 meters (m) below land surface, the low hydraulic conductivities typically found (1 to 3 m per day) preclude large-scale development of ground water from shallow wells. Information from 23 drilled wells in the area suggests, however, that a large potential for development of ground water exists in the deeper alluvium. Annual recharge to the ground-water reservoir is estimated to be of the order of 665 million m^3 (530,000 acre-feet). Although this estimate is approximate,

it is clear that annual withdrawals from wells could be greatly increased over the present 38 million m^3 (31,000 acre-feet).

Ground water in the area is dominantly of sodium chloride-sulfate type. Although measured concentrations of dissolved solids are as high as 10,000 milligrams per liter (mgl) most ground water contains less than 2,000 mgl dissolved solids and is suitable for irrigation, if good land-use practices are followed. Large-scale use of ground water from wells will be competitive in many places with use of water from streams, karezes, and neighboring wells. Further studies are needed to determine the hydrologic characteristics of potential aquifers so that development may be properly guided and unacceptable consequences avoided.

Introduction

This report summarizes information obtained during the summer of 1971 from a brief reconnaissance of the Kandahar area by members of a 3-man team from the U.S. Geological Survey (USGS). The team, on temporary duty with USAID/Afghanistan, worked closely with personnel from the U.S. Bureau of Reclamation (USBR) and their counterparts in the Helmand-Arghandab Valley Authority (HAVA).

The purpose of the study in the Kandahar area, one of several areas examined by the USGS team, was primarily to provide guidance in alleviating water shortage during a prolonged drought which had developed to critical proportions during the summer of 1971. It was hoped, however, that the study would also be useful in guiding decisions regarding the future development of ground water in the Kandahar area. The brevity of the study and an almost complete lack of adequate test-drilling information have limited the conclusions which can be drawn at this time. The data and conclusions presented here should serve primarily as a basis for project proposals and a starting point for future work.

In addition to the assistance of Mr. J. R. Jones, Party Chief, and Mr. N. E. McClymonds of the USGS team, significant help and advice were received during the field work from Messrs. Sanford Caudill and A. K. Long of the USBR team, USAID/HAVR. The assistance in the auger drilling program of Messrs. Sarwar Samadi,

Abdul Ahad Sarsam, and Obidullah Hotaki, HAVA, Lashkar Gah, is also gratefully acknowledged. Sher Ahmad Achaksai, a student at Kabul University, ably served as interpreter and field assistant during much of the investigation. Finally, appreciation and thanks are due to the many officials and supporting personnel of both USAID/HAVR and HAVA, who made this project possible and contributed so largely to making our stay in Afghanistan a pleasant one.

Physiography and Geology

The area investigated for this report includes, and is generally limited to, project areas referred to in previous engineering reports as the North Arghandab, the Central Arghandab, the North Tarnak, and the South Tarnak Units (fig. 1). The area is enclosed by latitudes 31°22' and 31°45'N. and by longitudes 65°08' and 65°53'E.; it comprises about 1,500 square kilometers (km^2).

As the surficial features of this region have been described in detail in several of the references cited beyond, and a brief description should suffice here. The region includes several broad alluvial valleys separated by narrow ridges of bedrock which trend northeast-southwest in conformity with the regional geologic structure. Altitudes range from less than 900 meters (m) at the confluence of the Arghandab and Dori Rivers to 1,782 m on a bedrock ridge northeast of Kandahar. About 90 percent of the area is relatively flat and featureless and lies at elevations of less than 1,000 m.

Four major intermittent streams, the Arghandab, Arghastan, Dori, and Tarnak, along with several smaller ephemeral water-courses, drain broad alluvium-filled valleys in channels which are incised to depths of 10 m or more in places. The surface of the valley-fill deposits slopes gently to the south and west, ending on the southern border of the area in an abrupt scarp along which the Dori River flows and which marks the edge of the Registan Desert.

Bedrock crops out in about 10 percent of the area in a series of nearly parallel ridges, the highest of which rises nearly 800 m above the adjacent valley floor. The rock in the dominant ridges is a generally massive but locally bedded gray to brown limestone which is cut by minor faults and intruded by numerous igneous dikes. The limestone is highly fractured, relatively unaltered by metamorphism, and fossiliferous. Fossils noted by the writer are probably pelecypods. Underlying the limestone at places are laminar siltstones, shales, and massive conglomerates. The age of these sediments is presumably Cretaceous. (See Geologic Map of Afghanistan, Afghan Geological Survey Department). No evidence was seen in the Kandahar area of the flysch sediments which have been described elsewhere in southern Afghanistan (FAO, 1965, v. 2, p. 10-14).

In close association with the limestone are rocks which appear in hand specimen to be largely of volcanic or igneous origin. These rocks range from light-colored fine-grained laminar clastics to massive dark-gray crystalline texture with minor mineralization of copper and iron. The composition of the rocks may be in the andesite-dacite range. These rocks underlie some of the major limestone ridges, appear to intrude other limestone masses, and form separate low rounded ridges parallel to the limestone. Contrary to statements appearing in earlier engineering reports on the area, the rocks are not basalts, and they constitute only a minor percentage of the exposed rocks.

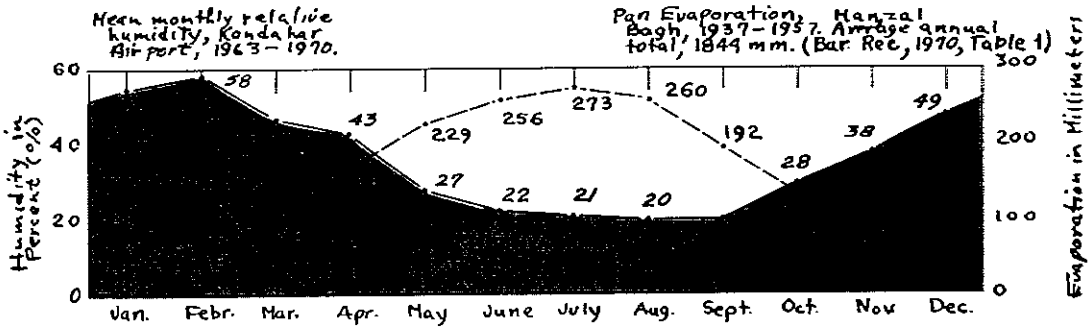
No attempt was made to map the bedrock geology during this investigation, and the field identifications of most rocks other than the limestone are tentative. However, two conclusions relevant to the occurrence of ground water have been reached:

1. Because all the exposed rocks are highly fractured, their capacity for transmitting water may be relatively high. The limestone is known to be cavernous at places. As a consequence, altitudes of ground-water pressure heads in the outcrops are probably only slightly higher than water levels in the surrounding alluvium. The low artesian heads applied over small areas of outcrop are probably relatively ineffective as sources of artesian pressure and flow to wells.

2. Although the structural and stratigraphic relationships of the bedrock masses could not be satisfactorily determined, there is the possibility that the depressions between the ridges are predominantly structural rather than erosional. At least some of the alluvial fills in the valleys may therefore be relatively deep. Even if the valleys are erosional, however, nothing is known to preclude the possibility that their depths are much greater than the ones reportedly reached by the deepest existing wells. Depths of 400 m or more would not be unexpected in the major basins.

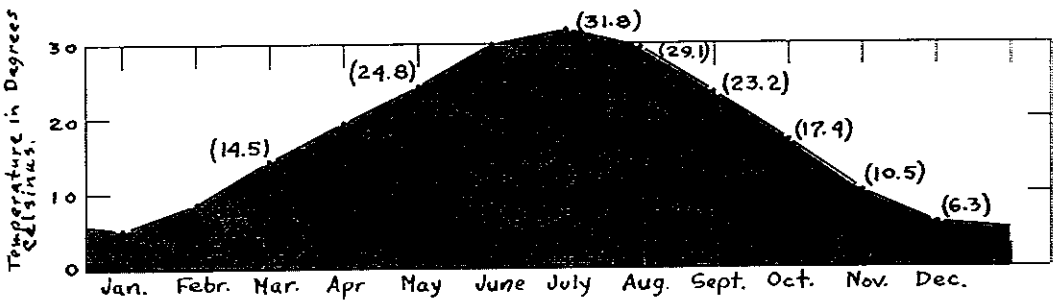
Climate

The climate of the region is that typical of a continental arid zone. The graph of figure 2 illustrates the salient features. It is of interest to note that a comparison of climatic records for the period 1940-1960 (Brigham, 1964, p. 207-215) with those of 1963-1970 (Meteorology Department, Afghan Air Authority) reveals that the climate of the 1960s in Kandahar was slightly hotter and significantly drier than the climate of the preceding 20 years. The average of the monthly minimum temperatures increased from 9.2°C. to 10.5°., while the average annual precipitation for the two periods of record decreased from 178 millimeters (mm) to 141 mm, a change of 21 percent. A change of 28 percent has been observed at Lashkar Gah where average annual precipitation decreased from 136 mm (1955-1960) to 98 mm (1960-1970). These statistics appear to support the conclusions reached during USGS investigations of the Zamin Dawar and Naw Zad areas that ground-water levels in much of southern Afghanistan have generally declined during the 1960s, and that the probable major cause is a cyclic climatic change.



Mean Wind Speed (Meters Per Second)

Jan.	Febr	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Av.
4.0	3.6	2.9	3.0	3.0	2.5	2.7	2.3	2.2	2.2	2.2	2.9	2.8



Number Of Days With Maximum Temperature ≥ 30° C

Jan	Febr	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
0	0	1	8	27	30	31	31	25	13	0	0	166

Number OF Days With Minimum Temperature ≤ 0° C

Jan	Febr.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
16	6.4	0.4	0	0	0	0	0	0	0.2	7.2	14.6	44.8

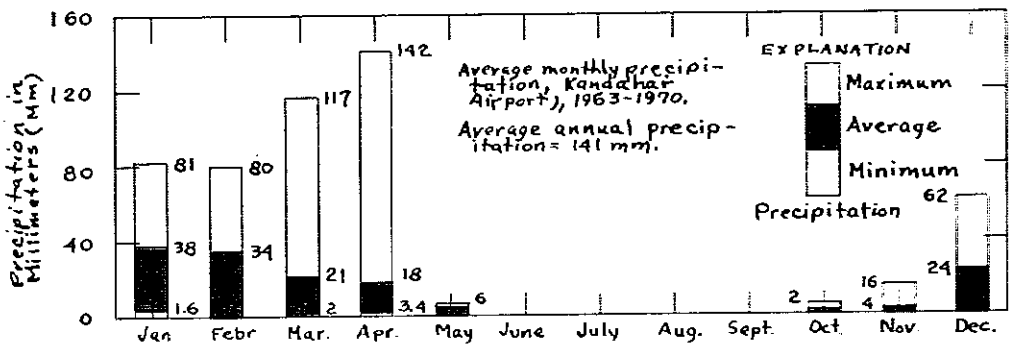


Figure 2-Graphs Summarizing Climatic Data At Kandahar (From Meteorology Department, Afghan Air Authority, except as noted)

Surface Water Resources

The principal source of water for Kandahar and the surrounding area is the Arghandab River. The average annual streamflow, measured at the Arghandab Reservoir north of Kandahar, has been approximately one million acre-feet (40 m^3 per second) for the period of record 1948 to 1968. Within the report area, more than 60 major diversion canals and numerous small diversions have for centuries taken water from the Arghandab to villages and irrigated fields, some of them situated more than 35 kilometers (km) from the point of diversion. Since 1953, the South and Tarnak Canals have diverted a large proportion of the river flow for use in the Central Arghandab and Tarnak Units. As the result of regulated releases from the Arghandab Reservoir, water is now available throughout the year at most diversion points, in contrast to the prior natural flow conditions in which river flow often ceased during critical summer months.

South of Kandahar, the Arghastan, and Dori, and Tarnak Rivers enter the project area. Although the combined catchment areas of these three rivers are twice that of the Arghandab, the average annual flow available in the Kandahar area from the three is little more than one-half that contributed by the Arghandab. This disparity may be due in part to lesser amounts of precipitation, particularly snowfall, in the basins of the Arghastan, Dori, and Tarnak, but some of the difference can be attributed to the greater consumptive use of water in the basins of these rivers upstream from Kandahar. Flow in the Arghastan, Dori, and

Tarnak Rivers is usually confined to the months, February through May, thus shutting down more than 25 diversion canals during the remainder of the year.

Local storms bring flood flows into the Kandahar area through several large ephemeral watercourses (washes) which parallel the Tarnak and Arghastan, as well as by way of innumerable gullies which drain from the bedrock ridges. Although these flood flows are often destructive to irrigation works which they supply, most of them can be used fairly efficiently to irrigate many acres of land. In the Central Arghandab Unit, the Shorab Wash is a major channel which, prior to the construction of a diversion dam in the 1950s, annually inundated some thousands of acres of land south of Kandahar. The flow from this wash was led downvalley through a network of fields and ditches, and eventually any excess flow drained into the Tarnak River. At present, owing to the diversion dam these flows reach the Tarnak River upstream from Kandahar.

The urban population of Kandahar, estimated to be more than 100,000, obtains most of its water supply from the Arghandab River, water being brought several kilomaters in the old Patow Canal and in several more recent diversions from the Tarnak Canal. Although at least 10 drilled wells and numerous dug wells are in use (see section on Ground Water Resources), most of the water for domestic and commercial use is taken from ditches along the streets in the manner employed by villages, large and small, for

centuries. These canals and ditches thus serve both as sewers and water supply for much of the urban population.

For hundreds of years the population and food supply of the Kandahar area has undoubtedly existed in delicate balance with the amount of surface water provided by the four rivers. Water was tediously transported and carefully husbanded, and new fields were planted in an area only when an additional water supply had been assured. The advent of the new dam and diversion structures changed this pattern rather suddenly by making a supply of water available year around in much of the area. New land has been brought under irrigation at a rapidly accelerating pace in recent years, in advance of sufficient progress in necessary adjuncts such as diversion control systems, a legal basis for use priorities, and increased knowledge of good irrigation practices.

The summer of 1971 brought an abrupt halt to the rapid pace of development in the Kandahar area, as a water shortage of unprecedented magnitude arose. As the result of 2 successive years of less than normal precipitation over much of Afghanistan, streamflow in the Arghandab River dwindled to 16 percent of normal for the year, and the Arghandab Reservoir was essentially emptied prior to the end of the irrigation season. Crop losses were high, and a heavy loss of investments in orchards and vineyards was anticipated. Although periodic shortages of water had been predicted in the engineering studies which accompanied the development of surface water (U.S. Bureau of Reclamation, 1970 p. 114-137), nothing of the magnitude of the current crisis had

been foreseen. For the first time, in the spring and summer of 1971, many farmers in the Kandahar area were confronted with the necessity for developing supplemental sources of water. In order to cope with the shortage, first attempts to develop irrigation water from wells on even a moderate scale were begun.

Ground Water Resources

Ground Water Reservoir

Extent and Thickness: In the Kandahar area the potentially usable supply of ground water is contained in the unconsolidated stream deposits which partly fill the broad alluvial valleys. Ground water in these deposits moves generally to the south and west in response to a regional gradient which is similar to the overall gradient of the land surface.

Altitudes of bedrock beneath the valley floors are unknown, and the deepest known wells have penetrated 180 m of alluvial deposits without reaching bedrock. Therefore, although the areal extent of the ground-water reservoir can be readily measured, its thickness cannot even be estimated on the basis of present knowledge. As a consequence, no estimate can be made of the total amount of ground water stored in the valley fill.

Lithology of Ground Water Reservoir: The characteristics of the valley-fill deposits in the Kandahar area are not well known below a depth of 5 or 6 m. A few drilled wells have provided logs for depths to about 100 m, but for most of the area no such information is available. From the field investigation it is concluded that the deposits are mixtures of alluvial and colluvial materials, ranging in size from clay to boulders, and in age from pre-Pleistocene to Recent (Holocene).

The slopes which flank the bedrock outcrops are alluvial fans which are composed of massive, dense, poorly-sorted clayey

silts and angular gravels emplaced largely by slope wash and perhaps mud flows. Thicknesses of these alluvial deposits, as inferred from logs of deep wells at Safdar Karez, about 10 km northwest of Kandahar, and at the silo, 10 km west of Kandahar, measure tens of meters. Locally they are interbedded with strata of gravel or clay. The higher alluvial terraces, remnants of which flank some of the bedrock ridges, are composed largely of poorly sorted gravel in a silt matrix. These deposits may be interbedded with dense slope-wash material. The alluvial fans and terraces may be relatively old (Pleistocene?) and may have been emplaced during a much wetter climatic period than the present.

Toward the axes of the valleys, the sediments are finer grained and more uniform in the upper 5 or 6 m, and at greater depth clays and silts predominate. Especially notable are strata of dense, massive, brown silty clays which were encountered generally at depths greater than 8 or 10 m in the central part of the Central Arghandab Unit. These strata range in thickness from 1 to 34 m, and are commonly interlayered with more plastic clays. The dense clays are so tough as to be difficult to break with the hands, and appear not to be completely saturated. They may be the same material reported as "clay, dry" at 28 m in the log of Well 3 at Kolchabad (U.S. Bureau of Reclamation, 1970, app.D, p. 292). Interbedded with the clays and silty clays are lenses and strata of sand and gravel which are mostly less than a meter in thickness and make up less than one third of the sediments.

The variability of the stratification is extreme and, in the Central Arghandab Unit at least, it is clear that horizontal correlations of stratigraphy cannot generally be made between locations which are separated by more than a few tens of meters. Logs of a number of holes drilled by power auger in the Central Arghandab Unit demonstrate both the predominance of fine-grained sediments and the variability of the stratification. Logs of 25 holes are given in the U.S. Bureau of Reclamation feasibility report (1970, app. D, p. 291-295), and logs of 29 holes drilled under the supervision of the author during the current investigation are given in Appendix A. Most of the holes terminated in material which was interpreted to be coarse gravel, some of which may have been partly or completely cemented (conglomerate). Maximum depths were 22 m and none of the holes reached bedrock. Well 3 drilled in 1969 at the village of Kolchabad, about 3 km south of Kandahar, penetrated 58 m of sediments which apparently did not differ significantly from those sampled by the auger holes. (U.S. Bureau of Reclamation, 1970, app. D, p. 292.) Logs of wells obtained during the current investigation are given in Appendix A.

Dense conglomerates cemented by calcium carbonate have been encountered in nearly all parts of the area, although they are most prevalent in the North Arghandab and South Tarnak Units. The conglomerates occur at depths generally greater than 5 m, and their thicknesses are from 0.1 m to at least 3 m. The hardness and degree of cementation differ from place to place, but

in general the thicker congomerates are nearly impenetrable to hand tools. The origin of these congomerates is not known, and only in parts of South Tarnak and North Arghandab Units can their occurrence be predicted with any certainty. Where they are widespread, as in the area irrigated by the South Tarnak Canal, they form a relatively impermeable barrier to the vertical movement of ground water.

Water Levels: Depths to water are strongly influenced by irrigation and drainage patterns. The investigation of water levels by the USBR (1970, app. D) indicates that much of the land within the command of the South and Tarnak Canals has become waterlogged in modern times as the result of over-application of irrigation water on poorly drained land. Even in the urban area of Kandahar water levels have risen during recent years as the result of seepage from new canals bringing water for domestic use. Many mud houses have been abandoned as the water table reached nearly to the land surface in parts of the city. Elsewhere, notably in the Salawat-Panjwai area southwest of Kandahar, waterlogging probably has been a problem for centuries in poorly drained depressions which receive water from canal seepage, irrigation tailwater, and occasional storm flood flow. The Shorab Wash area has previously been described (see "Surface Water Resources") as a region of perennially high water tables which result from the detention of annual flood flow.

Since 1969 water levels in much of the area south of Kandahar have declined as much as 2 m following installation of a major drainage system. During the first year after the drain was opened, water levels declined at distances of 2 km or more from the drain, even though recharge from the application of irrigation water may have increased during this period.

In contrast to the high water levels which occur in the intensively irrigated areas of Central Arghandab Unit water levels in the peripheral zones of North Arghandab, North and South Tarnak Units are generally from 6 to 12 m below land surface. Maximum depths may be as much as 18 m, for example, northeast of Kandahar and in the western areas of the North Arghandab. The difference in water levels is especially notable to the east of Kandahar, where the water table, which lies 1 to 2 m beneath the surface, drops abruptly at the edge of the irrigated areas to levels of 5 or 6 m below the unirrigated desert lands. Nothing is known about water levels in the bedrock outcrops which occupy about 10 percent of the land surface.

Potentiometric Heads: Three artesian wells near Kandahar have potentiometric heads above land surface (table 3). Measurements at one of these, the municipal well south of the Post Office (Well 44, table 3), indicated a static head of 2.3 m above land surface in November 1971. Heads in two other artesian wells (Wells 45 and 46) were not measured, but may be similar to the head in Well 44. Depths of these wells are not known, however,

an earlier report lists depths of two unspecified artesian wells as 185 and 215 feet (International Engineering Co., 1959, app. B, table 1B) and reports that "three wells drilled near Kandahar have obtained artesian flow at depths of 200 to 300 feet" (ibid., chap. 3, sect. 3.08). With only these apparently contradictory data at hand, it cannot be ascertained whether the three wells located by the author during the present study tap the same aquifer.

The most likely source of the observed potentimetric heads is high land 4 to 5 km northwest of the wells in a gap between two limestone outcrops. Through this gap pass 8 old canals carrying water from the Arghandab River. Seepage from these canals has probably saturated a large volume of sediments downslope to the southeast, and the wells may reflect heads in aquifers which are hydraulically connected with these sediments. Wells 6 and 11, situated directly north of the artesian wells, apparently do not tap artesian aquifers even though Well 11, at least, is probably deeper than any of the artesian wells. It may be tentatively concluded, therefore, that the source of the artesian head does not lie directly to the north. The possibility remains that the source is in the valley deposits to the northeast. This possibility is the less likely, however, because it depends on the existence of a relatively extensive artesian aquifer (or aquifers) in the more gently sloping valley sediments. Furthermore, none of the drilled wells located northeast of the

artesian wells (Wells 41, 43, 47, 54, and 55) is known to have an artesian head.

Fluctuation of Water Table: During the years 1967 through 1970 a network of observation wells was established by the USBR in the Central Arghandab Valley. Hydrographs and locations of 114 of these wells are shown in Appendix D of the USBR feasibility report (1970, p. 278-288). These hydrographs show that annual fluctuations of water levels in the Central Arghandab Unit are generally small (1 m or less), and that they occur almost entirely in response to irrigation applications and drainage measures. The decline in water levels which followed the installation of major drains is particularly striking. No records of water-level fluctuations exist for areas outside the Central Arghandab Unit, and therefore no measurements are available of daily, seasonal, or annual fluctuations which may occur naturally in non-irrigated areas. It may be assumed, however, that in most non-irrigated lands where the water table lies at least 4 or 5 m beneath the surface, seasonal fluctuations are negligible and only long-term changes following climatic cycles would be easily perceptible. Exceptions would be lands which are subjected to periodic flooding from storm runoff, and where significant recharge to the ground-water table may occur through permeable overlying materials. The apparently long life and consistent flow of karezes in and near the area confirm the view that water levels have generally changed little over a period of many years.

Hydraulic Conductivity, Transmissivity, and Specific Yield: In simple terms hydraulic conductivity is a measure of the rate at which water will move through a given aquifer. It may be defined technically as the rate at which a unit area of a medium will transmit a unit volume of water of the prevailing kinematic viscosity under a hydraulic gradient of unity. Tests of in-place hydraulic conductivity conducted by the USBR at more than 1,000 sites in the Central Arghandab Unit show that the conductivity of the upper 3.5 m of sediment is relatively uniform over the area. (U.S. Bureau of Reclamation, 1970, p. 140). The average hydraulic conductivity for this zone is about 7.4 m per day. At a few places where permeable gravels were found, hydraulic conductivities are from 10 to 100 times the average value.

Hydraulic conductivity of the alluvial deposits which lie below 3.5 m is more variable, but in general is appreciably lower than the conductivities observed in the USBR studies. Samples observed from many new wells throughout the area appear to have hydraulic conductivities of 1 to 3 m per day, as judged by the reported performance of the wells. Depths of most of these wells are between 6 and 8 m. Exceptions to the above generalizations are several dug wells of good yield which penetrate thin but permeable gravels at relatively shallow depth, or in which pipes have been sunk by the sludger method (see section on "Discharge from Ground Water Reservoir") in order to tap water under artesian pressure at greater depth. The number of wells,

which have reached relatively permeable zones, is too small to permit prediction of either the place or the depth at which such zones may be encountered. The estimates of hydraulic conductivity are based on information from 40 dug wells inventoried by the author, and about a hundred wells inventoried during the summer of 1971 by Extension Officers of HAVA.

Transmissivity is defined as the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient. It may be thought of as the product of the average hydraulic conductivity and the thickness of the aquifer; its units can be conveniently expressed in the metric system as meters squared (m^2) per day (derived from cubic meters per meter per day). Transmissivity is usually estimated from analysis of data obtained in pumping tests of wells, although it may also be estimated with somewhat less certainty by other means.

So far as is known, only two aquifer tests have been conducted in the Kandahar area which will permit analysis for transmissibity. The first test was conducted in Well 1 (the Silo well). This well had an unusually high yield, and the transmissivity calculated from data provided by the silo contractor was 3,050 m^2 per day (in Meinzer units, 245,000 gallons per day per foot). Because most of the water pumped from the well probably flows from a gravel layer about 10 m thick which is assumed to be in hydraulic

continuity with the channel of the Arghandab River, the characteristics of this aquifer are not typical of the area, and the results of the test cannot be extrapolated throughout the region. Nevertheless, the existence of reasonably conductive zones in aquifers elsewhere in the region has been amply demonstrated by the performance of several deep drilled wells in and near Kandahar, and it is assumed that apparent transmissivities approaching the magnitude estimated for Well 1 (Silo well) could be found elsewhere if wells were drilled to sufficient depths.

The second aquifer test was conducted in a pit dug by dragline in alluvial sands and gravels of the Arghandab River channel, just east of the Kandahar-Herat highway bridge. The apparent transmissivity of the shallow alluvium at this site was calculated by Mr. J. R. Jones of the USGS team to be about 620 or 870 m^2 per day (50,000 or 70,000 gallons per day per foot) depending on the method of analysis. These values are reasonable for the sand and gravel of the river channel, and similar conditions presumably could be found elsewhere in the river channels. The availability of adequate recharge to sustain such yields is open to question, particularly in the channels of intermittent streams such as the Arghastan, Dori, and Tarnak.

Specific yield refers to the amount of water which will be yielded from water-bearing material by gravity drainage, and is defined as the ratio of (1) the volume of water yielded by

gravity drainage to (2) the volume of material which has been drained. The amount of water which can ultimately be derived by pumping from a given volume of sediments is, therefore, a function of the specific yield, and the usefulness of an accurate estimate of specific yeild for quantitative groundwater studies is apparent.

Although there are a number of methods by which specific yield may be measured or estimated, none of the data available to the author permit an accurate estimate for sediments of the Kandahar area. Laboratory tests on more than 1,000 soil samples from southwest Afghanistan are summarized in the International Engineering Company report (1959, v. 1, p. IV 13-16), and although several related parameters such as "saturation percentage" and "available moisture" are reported, specific yields cannot be derived from the published data.

On the basis of observations of materials in dug wells and auger holes, and by comparison with laboratory and field tests in other parts of the world, the author estimates the average specific yield of the Kandahar valley sediments to be in the range 0.01 to 0.05. At most places, the upper 5 to 6 m of material may have a specific yield approaching 0.1, and where extensive gravels occur in the deeper sediments, the apparent specific yields may also reach 0.1. However, for estimates of long-term potential productivity of the mass of sediments, the value used probably should not exceed 0.05.

Recharge to Ground Water Reservoir

Recharge of ground water occurs each year as the result of precipitation on the Arghandab River basin. During the years 1963-70, average annual precipitation for Kanadahar was 141 mm. Over the 1,500 km^2 of the report area the total precipitation is thus about 212 million m^3 (170,000 acre feet). Much of this water is actually applied to the land surface through the efforts of farmers to capture and spread the overland runoff. If 15 percent of the precipitation is assumed to percolate to the water table, recharge to the groundwater reservoir may be as much as 32 million m^3 (26,000 acre feet).

Most recharge to the ground-water reservoir in the Kandahar area occurs as the result of percolation of applied irrigation water to the water table. Because the total amount of the diversions from stream flow in the area is unknown, no basis exists for a reliable estimate of the amount of water which might reach the water table from this source. A further complication is that a large amount of water is reused as it is withdrawn from karezes and drains at successively lower altitudes in the valleys.

By utilizing estimates of diversions and water use reported by Morrison and Knudsen (1957, chap. 3) and by the USBR (1970, v. 1, tables 19-29), and by assuming a 15 percent return flow of ground water withdrawn from wells, the author has arrived at a rough estimate of the average annual recharge to the ground-water reservoir of about 665 million m^3 (530,000 acre feet). Because

the estimate of recharge from precipitation given previously (32 million m^3) is only 5 percent of the total recharge, and estimated return flow from wells (7.6 million m^3) is about 1 percent, the validity of the estimate of annual recharge rests almost entirely on the reliability of the estimate of recharge from surface-water diversions. For the reason given in the paragraph above, the recharge figure is subject to large uncertainties, and no great reliance should be placed on it. For future studies in subareas of interest, more reliable estimates may be made by obtaining information on local stream diversions, consumptive use, and the distribution of the diverted water. Soil-moisture profiles, and the measurement and interpretation of water-level fluctuations will also be required for more accurate estimates of recharge.

Discharge from Ground Water Resources

Withdrawals from Wells and Karezes: Estimated current annual withdrawals of ground water from wells and karezes are given in table 1. The estimate of pumpage in the category "New Wells Dug for Irrigation" is for pumping rates as of October 1971, and is based on the assumption that pumping will occur annually at these rates during a 6-month period. The estimate is based on a sample of more than a 100 wells inventoried by the author and Extention Officers of HAVA. Both the number of wells in future use and the amount of pumpage from each will depend greatly on the available supply of surface water. The estimate given in table 1 does not include pumpage from the pits currently (1971) being dug by dragline in the Arghandab River channel. The quantities of water potentially available from these pits could significantly increase the estimated pumpage for irrigation.

It was not possible to obtain a complete inventory of active karezes. The rates of flow used for the estimate in table 1 are based on a relatively small sample of karezes which were actually visited. The estimates for the final category, "Domestic and Village Wells," is based partly on population estimates for the rural areas drawn from a sample of 128 farm families in interviewed by the USBR (1970, Appendices, p. 13), and partly on the author's estimate of the number of domestic wells in Kandahar. It is hoped that the resulting estimate of water use is a "reasonable guess."

Table 1. Annual Withdrawals of Ground Water in the Kandahar Area (1971)

	Millions of Cubic Meters	Millions of Gallons	Acre Feet
Drilled Wells			
Estimated from rates known or assumed as of October 1971 for 23 wells----------	1.70	450	1,380
New Wells Dug for Irrigation			
Number of wells in use as of October 1971 estimated to be 250; pumping period assumed to be 6 months----------	5.68	1,500	4,600
Karezes			
Number of active karezes estimated; average flow estimated from representative sample			
Central Arghandab Unit (17)---	13.52	3,570	10,960
North Arghandab Unit (12)-----	7.15	1,890	5,800
Tarnak North and South Units (17)	10.15	2,680	8,225
Domestic and Village Wells			
Based on estimates of rural population by USBR (1970), and a sampling of wells and daily usage----------	0.21	55	170
Totals	38.41	10,145	31,135

In each category, the estimate of water use is thought to be somewhere near the probable upper limit, and the intention is to suggest the maximum role which ground water might play in the current water situation. It is apparent that even if the projected use of water for irrigation from dug wells is realized, the amount of ground water withdrawn under current conditions in the Kandahar area will be a small fraction of the total water used.

Evapotranspiration: The term evapotranspiration includes water discharged to the atmosphere both by plants and by direct vaporization from the soil. Estimates of the annual evapotranspiration ("consumptive use") for the irrigated areas of Kandahar range from 0.54 m to 0.78 m (USBR, 1970, p. 111, and USBR, unpublished data, 1970). These estimates, however, have little bearing on the discharge of ground water, as it can be assumed that most of the consumptive use represents water that is intercepted before it reaches the water table.

The upward movement of ground water from the saturated zone occurs in both the liquid and vapor phases under gradients resulting from thermal, chemical, and mechanical potentials. In arid regions of high evaporation potential, the gradients in the upper soil zone become large. Thus, in the Kandahar area where average annual pan evaporation is about 1.84 m (HAVA records, Manzel Bagh, 1939-1957), it must be expected that large amounts of water are lost each year from areas where the water table is near the land surface. Studies have shown that rates of loss may be significant from unsaturated zones 2 or 3 m thick.

In order to arrive at an order-of-magnitude estimate of discharge of ground water by evapotranspiration, assume that annual evapotranspiration from the areas having water levels less than 2 m below land surface is 0.15 m (0.5 foot), from areas with water levels between 2 and 5 m is 0.03 m (0.1 foot) and from the remaining area is negligible. Evapotranspiration from river-bottom land is assumed to be 0.3 m or 0.6 m annually depending on channel conditions and river flow. These assumed values are arbitrary but they represent reasonable estimates based on experience in similar climates.

On the basis of the above assumptions total annual evapotranspiration from the ground-water reservoir is calculated to be about 70 million m^3 (56,000 acre feet) for the 1,500 km^2 of the report area, which is more than double the amount of recharge from precipitation estimated above. The actual amount of evapotranspiration for this area is not likely to be greater than this figure, and may be as little as half the calculated value. The amount depends largely on the extent to which applied irrigation water satisfies the evaporation potential over the approximately 200 km^2 in which water levels are within 2 m of the land surface. A more reliable estimate will require data on soil-moisture profiles in the unsaturated zone and on the hydraulic conductivity as a function of moisture content.

Discharge to Streams: Flow of the Arghandab River through the Kandahar area is augmented by ground-water discharge during much of the year. The river probably loses water to the ground-water body only during periods of reservoir spill or at other times when streamflow greatly exceeds diversion requirements. Evidence for the Arghastan, Dori, and Tarnak Rivers is scanty, but it is likely that these are also gaining streams during much of their flow periods. In the summer months, when surface flow ceases in the Arghastan, Dori, and Tarnak Rivers, ground water probably continues to discharge from the area as underflow in the relatively permeable sands and gravels which underlie the channels.

Since October 1968 ground water has discharged from the eastern part of Central Arghandab Unit through a major drain system (the Kars-Zakir system) which collects water from several spurs located south of Kandahar. The drain outlet is in the Tarnak River about 14 km south of Kandahar (see map, figure 1). Flow of ground water from this drain system is estimated to have been about 31 million m^3 (24,500 acre feet) during 1969 and about 32 million m^3 (25,500 acre feet) in 1970 (A. K. Long, written commun., 1970). During 1971 large-scale pumping from the drains was begun in order to provide irrigation water, and no estimates of ground-water discharge are available. Field observations indicate, however, that flow was greatly reduced during 1971 In addition to the Kars-Zakir drainage system, two drains in North Tarnak Unit conduct a small but unmeasured

amount of ground water to a large dry wash leading to the Dori River.

The patterns of diversion, water use, and return flow are extremely complex in the Kandahar area, particularly because of the large diversions which transport water from the Arghandab to the Dori and Tarnak basins, and the reuse of water within the basins. No data are available on which to base a reliable estimate of ground water discharge from the area. It is probable, however, that during recent years the discharge of ground water has been roughly in balance with the recharge. Thus, the net discharge to streams plus evapotranspiration plus withdrawals from wells and karezes should equal the net recharge from stream diversions, precipitation, and return of ground water from wells. Inserting the previously estimated amounts into this equation, the annual discharge of ground water to streams is estimated to be about 560 million m^3 (450,000 acre feet). The reliability of this calculation is largely dependent on the accuracy of the estimate of ground-water recharge from streamflow, which is the dominant factor in the equation. The uncertainties in the latter estimate have been discussed in the section on "Recharge to Ground Water Reservoir," and these uncertainties apply also to the present estimate of ground-water discharge.

Quality of Ground Water

The quality of ground water has been a matter of concern during previous investigations, and a small number of analyses were made by Morrison and Knudsen and later by the HAVA laboratory at Chah-i-Anjir. For the purposes of this report, however, only a summary of published and unpublished data is presented (table 2). Because all ground water in the Kandahar area is of the same general type the values of total dissolved solids provide a fair index to the changes in quality over the area. For comparative purposes, a summary of surface-water data is also included.

Analyses performed thus far have included chiefly the major cations and anions (Na, K, Ca, Mg, Cl, HCO_3, and SO_4). The SO_4 has generally been computed as a residual by balancing the cations and anions. In particular, cations such as Fe, Mn, and Si, and anions such as NO_3, PO_3, and F, for which analyses are not available, may be important in delineating the effects of irrigation practice in leaching elements from the soil. The reported total concentrations may be seriously in error in some instances as a result of failure to analyze for some major ions. For these reasons, the analyses do not provide a sound basis for investigating the changes in the ground water as it moves through the soil, and they must be regarded only as general indices to the quality of the water.

Analyses show that water of the Arghandab River, which is the principal source of irrigation water in Central Arghandab Unit, is dominantly a calcium bicarbonate water and relatively low (less than 350 mgl) in dissolved solids. Ground water in Central Arghandab Unit, however, is dominantly a sodium chloride-sulfate water with relatively high concentrations of dissolved solids. Because much of the ground water in the Central Arghandab Unit is residual from irrigation applications, it appears that much of the dissolved solids concentration in the ground water is derived from the soils by leaching, and has been built up by long-continued irrigation applications. It also appears that the geochemistry of the water has been modified intransit from the surface to the ground, possibly by ion exchange and/or precipitation of calcium carbonate. In the irrigated areas of the North and South Tarnak Units, initial concentrations of dissolved solids in the waters of the Tarnak and Arghestan Rivers are higher than the concentrations in the Arghandab River. Consequently, ground water in the North and South Tarnak Units is generally of poorer quality than ground water in the Central Arghandab Unit.

Because the element boron is particularly detrimental to many crops, tests have been made for this element in many of the analyses. Concentrations of boron ranging from a trace to several milligrams per liter have been found in the ground water, although no detectable concentrations have been found in the river water. The quantity of boron appears to vary generally

Table 2.--Quality of Water in Wells, Drains, Karezes, and Streams of Kandahar Area

Wells

Type, Location, Number	Date Sampled	Dissolved Solids (mgl)	Source of Data
Drilled Wells			
*Artesian Well (185 ft deep)	Prior to 1959	1,387	2
*Artesian Well (215 ft deep)	Prior to 1959	1,534	2
*Artesian Wells (Average of 4 wells) (See wells 44, 45, 46)	2/68	1,316	3
*Tarnak Camp (Morrison-Knudsen)	Prior to 7/57	861	1
*New Airport	Prior to 7/57 6/68	2,950 2,250	1 4
Manzel Bagh HAVA Compound; Morrison-Knudsen numbers:			
Well *1	Prior to 1959	638	2
Well *4	Prior to 1959	1,101	2
*Combined system (See well 51)	11/68	1,218	3
Well 1, Silo; Grid: E24,200-S91,000	9/71	619	5
Well 2, Safdar Karez; Grid: E114,000-S20,500	12/71	310	5

*Location not specified

Table 2 (continued)

Wells			
Type, Location, Number	Date Sampled	Dissolved Solids (mgl)	Source of Data
Drilled Wells (continued)			
Well 3, Kolchabad; Grid: E104,000-S27,500	6/69	2,524	3
Well 6, X-Ray Hospital; Grid: E100,500-S24-500	12/71	370	5
Well 11, German Technical School; Grid: E99,000-S24,500	7/71 12/71	426 470	5 5
Well 41, AID Compound; Grid: E107,500-S25,000	4/68	915	3
Well 44, Municipal Artesian Well; Grid: E100,200-S25,700	7/71 12/71	1,470 1,400	5 5
Well 45, Artesian Well; Grid: E100,500-S26,700	12/71	1,540	5
Well 46, Artesian Well; Grid: E100,400-S26,500	12/71	1,720	5
Well 47, Old Airport; Grid: E106,800-S24,400	11/71	840	5
Well 48, Military Farm; Grid: E109,800-S20,000	11/71	300	5
Well 51, Manzel Bagh, HAVA: Grid: E100,200-S24,700	12/71	1,320	5
Well 54, DMA School; Grid: E103,000-S24,500	11/71	700	5
Well 56, Spozmey Hotel; Grid: E100,700-S24,800	11/71 12/71	380 430	5 5

Table 2 (continued)

Wells

Type, Location, Number	Date Sampled	Dissolved Solids (mgl)	Source of Data
Dug Wells			
North Arghandab Unit:			
*Diversion Dam	Prior to 1959	569	2
*Well 24A; Morrison-Knudsen number	Prior to 1959	253	2
*Well 33; Morrison-Knudsen number	Prior to 1959	554	2
*Well 104; Morrison-Knudsen number	Prior to 1959	1,060	2
*Girisk Road; Morrison-Knudsen number	11/68	560	4
Well 7, Grid: E72,500-S28,000	6/71	531	5
Central Arghandab Unit:			
*Village Well, Panjwai Area	5/69	665	4
*Auger Hole, Panjwai Area	7/71	1,050	4
*Kanjakak Village	5/69	1,540	4
*Kasimerbad Village	5/68	770	4
*Biladei Village	9/68	2,580	4

*Location not specified

Table 2 (continued)

Wells			
Type, Location, Number	Date Sampled	Dissolved Solids (mgl)	Source of Data
Dug Wells (continued)			
Central Arghandab Unit: (continued)			
Auger Hole 4-7/28, Grid: E78,200-S37,200	7/71	10,100	4
5-7/28, Grid: E77,800-S36,400	7/71	1,540	4
2-7/29, Grid: E82,400-S35,400	7/71	2,100	4
1-7/29, Grid: E81,700-S35,200	7/71	1,120	4
2-7/31, Grid: E80,500-S35,600	7/71	4,200	4
Well 9, Grid: E104,300-S31,700	7/71	2,570	4
Well 32, Grid: E106,600-S25,200	7/71	1,050	5
	10/71	900	5
	11/71	1,050	5
	12/71	770	5
Well 33, Grid: E69,600-S30,000	12/71	5,600	5
Well 37, Grid: E90,900-S30,700	10/71	1,340	5
Well 39, Grid: E102,400-S26,400	11/71	930	5

Table 2 (continued)

Wells			
Type, Location, Number	Date Sampled	Dissolved Solids (mgl)	Source of Data
Dug Wells (continued)			
Central Arghandab Unit: (continued)			
Well 58, Grid: E100,300-S35,500	12/71	2,100	5
Well 59, Grid: E76,000 S28,700	12/71	365	5
Well 63, Grid: E78,600-S35,700	7/71	490	4
Well 64, Grid: E76,900-S36,500	7/71	1,190	4
Well 65, Grid: E76,900-S37,600-	7/71	665	4
North and South Tarnak Units:			
Tannery Well	6/68	1,820	4
*Rhorabad Village Well	9/68	2,940	4
*Airport road near Tarnak Rūd	6/69	1,880	4
Well 13, Grid: E115,300-S31,200	8/71	1,750	5
Well 27, Grid: E117,200-S40,700	10/71	3,150	5
Well 34, Grid: E115,700-S32,400	9/71	1,880	5

*Location not specified

Table 2 (continued)

Wells			
Type, Location, Number	Date Sampled	Dissolved Solids (mgl)	Source of Data
Dug Wells (continued)			
North and South Tarnak Units:			
Well 60, Grid: E115,100-S31,200	12/71	1,750	5
Well 61, Grid: E115,500-S31,000	12/71	1,100	5

Table 2 (continued)

Drains				
Location	Number of Locations	Date Sampled	Dissolved Solids (mgl) Min. Max. Average	Source of Data
Central Arghandab Unit:				
Drains south of Kandahar	6	3/69	735 - 2,950 1,596	4
Drains south of Kandahar	6	12/69	770 - 3,210 1,607	4
Drains south of Kandahar	6	3/71	700 - 2,800 1,435	4
Drains south of Kandahar	5	7/71	665 - 2,800 2,023	4
Military Farm, north of Kabūl Road	1 1	1/69 3/69	2,580 1,540	4 4

Table 2 (continued)

Karezes

Location	Date Sampled	Dissolved Solids (mgl)	Source of Data
Central Arghandab Unit:			
Adrack	2/69	770	4
Gurgan	4/68	1,880	4
	5/68	1,815	4
Kanjakak	5/69	1,815	4
Karezak	12/68	770	4
Kasimerabad	5/68	2,380	4
Mhd. Ali	5/68	1,815	4
Mosque Road	1/69	840	4
(Unknown)	4/68	490	4
North and South Tarnak Units:			
Akdad	Prior to 7/57	818	1
Ismael	Prior to 7/57	2,240	1
Kalantar	Prior to 7/57	1,079	1

Table 2 (continued)

Karezes

Location	Date Sampled	Dissolved Solids (mgl)	Source of Data
North and South Tarnak Units: (continued)			
Mukum	Prior to 7/57	2,474	1
Shamshir	Prior to 7/57	2,383	1
Tarnak	Prior to 7/57	835	1
Zarac	Prior to 7/57	2,077	1

Table 2 (continued)

Stream	Streams			
	Number of Samples	Date Samples	Dissolved Solids (mgl)	Source of Data
Arghandab	5	Prior to 7/57	321 (ave.)	1
	Spring Runoff	1967-1970	192 (ave.)	3
	Winter lows	1967-1970	320 (ave.)	3
	Annual Average	1967-1970	256	3
Arghastan	1	Prior to 7/57	960	1
Tarnak	2	Prior to 7/57	1,100 (ave.)	1
	1	5/68	1,470	4
	1	6/68	1,540	4

Sources of Data:

1. Soil and Water Resources of S.W. Afghanistan, Supplemental Report No. 1: Soils and Drainability Surveys, Tarnak Area: Morrison and Knudsen, 1957
2. Soil and Water Resources of S.W. Afghanistan: International Engineering Co., Inc., 1959
3. Central Arghandab Valley Unit Feasibility Report: U.S. Bureau of Reclamation, 1970.
4. U.S. Bureau of Reclamation, HAVR, Lashkar Gah, unpublished data.
5. Estimated from field measurement of specific conductivity by USGS.

Note: Analyses made prior to 1957 by Morrison-Knudsen Afghanistan; subsequent analyses by HAVA Laboratory, Chah-i-anjirs.

with the quantity of dissolved solids, and it is apparent that boron is being leached from the soil along with other elements.

Although the available evidence is scanty, there appears to be a trend toward increasing dissolved solids concentrations southward and westward through Central Arghandab Unit along zones of increasing use and reuse of groundwater. However, high concentrations of dissolved solids occur in the ground water wherever, as in local areas south of Kandahar, intensive irrigation in the absence of adequate drainage has permitted solids to precipitate and build up in the soil. In areas not intensively irrigated, such as parts of the North Arghandab and westward into the Maiwand area, concentrations of dissolved solids are relatively low, and more nearly approach the Arghandab River water in type.

Some evidence suggests that trends in water quality occur in the vertical profile. For example, data obtained during the drilling of the Kolchabad well (Well 3) showed that concentrations of dissolved solids are greater at successively greater depths. Concentrations in the finished well reached 2,524 milligrams per liter (mgl). The highest concentrations reported from drilled wells are those from the Kandahar Airport well system (maximum 2,950 mgl), and although depths of these wells could not be ascertained by the author, they are reported to be relatively deep. On the other hand, the two deepest wells known in the area, at the Manzel Bagh HAVA Compound, reportedly 180 m deep, produce water with 1,218 mgl dissolved solids. Water from the well at the German Technical School (90 m deep) tested at 426 mgl.

From the available evidence therefore, it is concluded that the quality of water in wells of the Kandahar area reflects the general quality of ground water in the vicinity of the well and is strongly dependent on the specific local conditions of recharge. Thus, wells situated so as to intercept water of good original quality, which does not drain through extensive irrigated areas, are most likely to produce water of good quality. Examples are the wells at Manzel Bagh, the German Technical School, AID Compound, and the Silo well. The Kandahar artesian wells (Wells 44, 45, and 46), which produce water of relatively good quality, tap permeable aquifers which may transmit water from the limestone outcrops to the northwest. The fact that the "Tarnak Camp Well" (not located on map) produced water of good quality (861 mgl) suggests that deep wells may encounter relatively good water as the result of anomalous conditions of recharge even in areas where the shallow ground water is of poor quality.

Development of Ground Water

Current Status

During recent years prior to 1971, use of ground water in the Kandahar area was limited to withdrawals from about 20 drilled wells, 46 karezes, and an undetermined number of domestic and village dug wells. The use of wells for irrigation, except for domestic gardens, was essentially unknown. The total annual withdrawal from all these sources is estimated to have been about 32 million m^3 (26,000 acre feet).

In 1971, the shortage of streamflow in all rivers forced attention to alternative sources of supply for irrigation and gave impetus to construction of a large number of wells put down by hand labor. Approximately 100 of these wells were inventoried in July 1971, by Extension Officers of HAVA. By October 1971, an estimated 300 wells had been started or finished and about 200 of these were being pumped. The majority of pumps in use were 4-inch Jangalak centrifugal pumps, with 1-cylinder German diesel engines. The estimate of annual withdrawal from these wells in table 1 is based on the assumption that most of the planned wells would be completed and that pumping would occur at maximum rates for 6 months each year. The realization of the second assumption is obviously contingent on the availability of streamflow, and the withdrawal figure should be taken as the probable maximum withdrawal under the prevailing adverse conditions. The estimate of annual withdrawal of ground water from

drilled wells in table 1 includes 109 million gallons per year for the well at the German Technical School, which was the rate at which pumping began during 1971 in response to the emergency need for water.

The figures for pumpage from wells in table 1 include the estimates described above for the new dug wells and the Technical School well, on the assumption that the rates of pumping observed or estimated at the end of the summer 1971 would be continued for several months. The figures for total pumpage, computed on this basis, show that annual use of ground water for 1971 will be about 38 million m^3 (31,000 acre feet), an increase of 19 percent over previous years.

The number of dug wells used for domestic purposes, mosque ablutions, and garden irrigation is unknown, and can be estimated only crudely from known samples. Although the number of such wells is probably greatest in the Kandahar urban area, and is known to be increasing as new houses are built, the amount of water produced annually from these wells is a small fraction of total water use. (See estimate, table 1.)

The number of active karezes has decreased from the 92 known to exist prior to 1950 to approximately 46 in 1971. Most karezes still in use are located in an arc along the southern and western periphery of the area, on lands served neither by old ditches nor by the new irrigation canals, although a number of karezes are still active in the populous area just south of Kandahar.

The supply of ground water for many of these karezes is derived largely from seepage of irrigation water applied to upvalley lands, and the generally poor quality of the kareze water is probably the result of leaching of salts from the soil during percolation.

There is a widening interest in the Kandahar area in the possibilities of deep drilled wells; three were completed during 1971. Table 3 summarizes information available to the author on 23 known or reported drilled wells in the Kandahar area. Most information on depths, logs, and even the locations of several reported wells, is apparently no longer available, and many useful data have thus been lost or mislaid.

During the summer of 1971, a number of pits were dug by dragline about 4 to 5 m deep in the Arghandab River channel in the hopes of intercepting sufficient underflow to supply water to a number of diversion canals. Locations of the pits completed prior to November 1971, are shown in figure 1. Several of the pits were estimated to be capable of individually supplying at least 1,000 m^3 per hour (10 cubic feet per second - cfs), and the transmissivity of the shallow alluvium at one location (Herat-Kandahar highway bridge) is encouragingly high. Pits of sufficient depth may, at some places, supply up to 1,500 m^3 per hour (15 cfs). (See section on "Hydraulic Conductivity, Transmissivity, and Specific Yield.") Work is continuing on

additional pits at several locations along the Arghandab River, and the quantities of water available from these sources are large enough to be of considerable use in the current water shortage. For long-term needs, however, the potential of these sites is entirely unknown.

Table 3.--Hydrologic Data on Drilled Wells in Kandahar Area

(incomplete list)

Field Number	Name and Location	Depth (meters)	Static Water Level (meters below land surface)	Yield (cubic meters per hour)	Specific Conductance (micromhos)
1	Silo; 10 km west of Kandahar Grid: E91,000-S24,200	44m	10.9m (8/25/71)	100m	750 (9/8/71)
2	Safdar Karez; 8 km NE of Kandahar Grid: E114,000-S20,500	44r	12r	3e	440 (12/8/71)
3	Kolchabad; 3 km SE of Kandahar Grid: E104,000-S27,500	58m	4.2m (6/7/69)		3,700 (6/69)
6	Men's Hospital, X-Ray Bldg, Kandahar Grid: E100,500-S24,500	48r	3.6		530 (12/8/71)
11	German Technical School, Kandahar Grid: E99,900-S24,500	90r		100e	500 (7/71)
12 12a	Kandahar International Airport, housing area Grid: E116,900-S38,800		6r		3,000 (6/68)
41 41a	USAID Compound, east of Kandahar USAID Compound, east of Kandahar Grid: E107,500-S25,000	50r 40r		55e	1,300 (4/68)
43	Private house, Kandahar Grid: E104,200-S24,100				

m = measured
r = reported
e = estimated

Table 3 (continued)

Field Number	Name and Location	Depth (meters)	Static Water Level (meters below land surface)	Yield (cubic meters per hour)	Specific Conductance (micromhos)
44	Municipal artesian well, south of Post Office Grid: E100,200-S25,700		2.3 m above land surface (11/16/71)	17e	1,900 (2/68)
45	Artesian well, about 1 km SW of Kandahar Grid: E100,500-S26,700		above land surface	15e	2,200 (12/9/71)
46	Artesian well, about 0.9 km SW of Kandahar Grid: E100,900-S26,500		above land surface	17e	2,450 (12/9/71)
47	Former airport, east of Kandahar Grid: E106,800-S24,400	180r			1,200 (11/17/71)
48	Military farm, 7.5 km NE of Kandahar Grid: E109,800-S20,000	120r		40e	420 (11/15/71)
49	Afghanistan Air Authority Transmitter Station, 19 km S of Kandahar. Grid: E118,200-S37,000				
50	Municipal well, Kandahar Grid: E101,200-S25,200	85r			
51	Manzel Bagh HAVA Compound, SW well Grid: E105,000-S23,700	180r	3	90e	1,900 (12/9/71)

m = measured
r = reported
e = estimated

Table 3 (continued)

Field Number	Name and Location	Depth (meters)	Static Water Level (meters below land surface)	Yield (cubic meters per hour)	Specific Conductance (micromhos)
52	Manzel Bagh HAVA Compound, NW well Grid: E105,000-S23,600	180r			(900-1,400 prior to 1957)
53	Manzel Bagh HAVA Compound, NE well Grid: E105,100-S23,600	120r			(900-1,400 prior to 1957)
54	DMA School, Kandahar Grid: E103,000-S24,500			11e	1,000 (11/16/71)
55	Marustan Institution, Kandahar Grid: E102,000-S24,000	140r	>6r		
56	Spozmey Hotel, Kandahar Grid: E100,700-S24,800	120r	4.1r	75e	550 (11/16/71)

m = measured
r = reported
e = estimated

Future Development

Irrigation farming has long been, and will long continue to be, the major source of livelihood and the economic base for the Kandahar area. The need for supplemental sources of water to meet growing needs on irrigated land has been apparent for more than 20 years. As early as 1948 it was predicted that streamflow could not meet the demand for water on all potentially irrigable land and pumping of ground water to supplement the streamflow was proposed (Youngs, 1948). Although the concept proposed by Youngs was abandoned, the critical shortage of water in 1971 has once again focused attention on the possibility of developing large supplies of ground water. The reconnaissance investigation conducted by the USGS team in the summer of 1971 has perhaps served to define the limits of several of the possibilities for development, although the conclusions and evaluations given below must be regarded as tentative.

Shallow Aquifers: The water table is accessible by hand digging at most places within the Kandahar area. In about one-third of the area the water table can be reached by wells not more than 6 m deep. Only the South Tarnak Unit have serious problems been encountered owing to the presence of tightly cemented conglomerates above the water table.

In spite of the relatively shallow depths at which ground water occurs, the prospects for large-scale development of water from the shallow alluvium are generally poor. Observations

of the lithology and permeability of the shallow alluvium indicate that the probability of obtaining more than about 10 m^3 per hour (45 gpm) is extremely small. (See section on "Ground Water Reservoir.") In terms of water available for irrigation, for example, assuming a well 6 m on a side, dug 3 m below the water table and pumped with a 150-gpm pump, on the average about 100 m^3 of water might be produced in 4 hours, at the end of which time the well would be dry. Recovery would take more than half a day. Therefore, in a 16-hour working day sufficient water would be produced to permit the application of roughly 5 centimeters of water on 1 jirib _/ of land, assuming no transmission losses. Thus, although the efficiency of irrigation with small water supplies varies considerably depending on land conditions and the skill of the farmer, it is apparent that irrigation from dug wells in the Kandahar area will be limited to a few jiribs of land per well.

Because labor is cheap and abundant, a dug well must be considered a relatively good investment risk during a time of severe shortage of water from other sources. The few wells of high yield (up to 100 m^3 per hour) presently known in the area allow some hope that permeable strata may be encountered elsewhere at shallow depths. However, the occurrence of such permeable strata is not predictable on the basis of present knowledge, although the probabilities are undoubtedly highest near the present channels of rivers and dry washes.

_/ 1 jirib = approximately 2.2 acres

At places where dug wells have failed to yield useful quantities of water, there is the possibility of achieving deeper exploration at relatively small additional cost by means of the "sludger" method. In this method a small-diameter pipe is sunk by a simple hydraulic-percussion technique, generally through the bottom of a dug well. Providing no cemented strata or large rocks are encountered, sludger wells in the Kandahar area may reach depths of 40 m or more below land surface. Success by this method depends on encountering a permeable stratum in which the hydraulic pressures are great enough to bring water above the bottom of the dug well. Several wells have been emplaced by the sludger method with results ranging from excellent to poor.

A more sophisticated version of this method would employ a small centrifugal pump and a jetting bit on the pipe for greater efficiency, but to the author's knowledge the jetting method has not been attempted in the Kandahar area. Costs of the sludger method range from 250 to 1,000 afghanis _/ per meter and average about 500 afghanis per meter depending on the ease of penetration. Costs of the more efficient jetting method should not be higher if there is sufficient demand to permit a reasonable amortization of the initial investment in a pump, drill bit, and pipe fittings.

The collecting galleries or deep trenches which are currently being dug in the channel of the Arghandab River are described in the section on "Current Status." Pumped at rates, which could be as much as 1,500 m^3 per hour, the immediate benefits of these

_/ 1 afghani = $US 0.0133

trenches during the current water shortage could be considerable, but because the hydrologic conditions beneath the river channels are not well known, the long-term productivity of the trenches is uncertain. It is clear, however, that during periods of low flow in the river, these trenches could utilize large amounts of underflow which would otherwise be lost to the area. The consequences of such pumpage in reducing downstream channel flow ar direct and relatively rapid, so that these consequences must be considered before large-scale pumping begins.

In evaluating the potential development of ground water from shallow wells, data available at present suggest strongly that such wells cannot economically provide more than a small fraction of the water required for irrigation, and at best will be adequate mainly for domestic use, small garden plots, and for emergency supplies over limited areas. Although many landowners are making strenous efforts to save their crops by the only means available to them, it is apparent that other measures will be required to satisfy the longterm needs for supplemental water supplies.

Deep Aquifers: Information available to the author on the drilled wells in and near Kanadahar is so minimal as to make conclusions regarding ground water in deep aquifers extremely tentative. Of the 24 drilled wells which are known or reported to exist, depths are known or reported for 15, yields have been estimated for 11, and quality of water data are available for 17 (table 3). Not all this information can be identified with

specific wells. Drillers' logs are available only for the three wells most recently drilled.

All the known depths of drilled wells are greater than 40 m, and it is reasonable to assume that it was necessary to drill to the reported depths in order to produce the required quantity or quality of water. At least one exception to this assumption, however, is the Silo well which obtains most of its production from a zone between 10 and 24 m deep, although the drilling was continued to 44 m. Other wells may have been deepened in hope of obtaining increased production which did not materialize.

In the absence of drilling records, therefore, it is not possible to draw conclusions as to the depths, lithologic character, or continuity of deep aquifers in the Kandahar area. Similarly, the lack of pumping-test data precludes meaningful estimates of transmissivity for the major producing zones. (See section on "Ground Water Reservoir" for a discussion of the two available pumping tests.) Without these data, it is not possible to make a quantitative evaluation of the potential for development of ground-water in the area.

Taking into account the known facts of geology and physiography, however, the probability would seem to be fairly good that moderate to large quantities of ground water can be produced at many places from drilled wells. The performance of existing wells in and near Kandahar, for example, suggests that an adequate municipal supply for Kandahar could readily be provided by

several additional drilled wells, and this possibility is strengthened by the relatively good quality and quantity of water withdrawn from the wells at the German Technical School, Manzel Bagh, and the AID Compound.

The occurrence of artesian aquifers tapped by at least three drilled wells near Kandahar encourages the hope that additional artesian wells may be drilled. In the absence of hydrologic data from known wells, however, the location of the source or sources of the artesian heads can only be surmised, and there is little basis for predicting the occurrence of artesian conditions. Based on assumptions described in the section on "Ground Water Reservoir," it might be concluded that wells drilled to depths between 50 and 100 m will have the best chance of encountering artesian aquifers if located within a few kilometers of the bedrock ridges. However, the conditions of recharge postulated for the known artesian wells probably are not common in the area, and if the author's analysis of these conditions is correct, locations where potentiometric heads are near or above land surface may be also uncommon. From surficial indications, the best possibilities appear to be the area westward from the present artesian wells to the base of the nearest limestone outcrop (grid location E 95 to 100, S 25 to 30); the area west of this limestone ridge traversed by the Demrazi, Kasimerabad, and Chilghore Canals (grid location E 90 to 95, S 30); and possibly the area south of Panjwai between grid lines E 75 and E 80.

The quality of water in the deeper alluvium is largely unknown, but the possibility must be considered that saline water may be encountered even at great depths. Although data on quality of water are scanty, they suggest that even for the deeper wells, local conditions in the aquifer may largely determine the quality. There is the possibility, for example, that stratified zones of fresh and saline water exist at depth. Such a condition, if found, would necessitate careful testing, construction, and development of wells.

Perennial Yield: Assuming that large quantities of ground water can be withdrawn from aquifers in the region, the perennial yield of these aquifers must be considered. For practical purposes, perennial yeild may be defined as the quantity of water that can be perennially withdrawn without inducing adverse effects. An adverse effect may be any negative result of withdrawal such as seriously declining water levels, drawing saline water into wells, or drying up karezes.

The perennial yield of aquifers in the Kandahar area cannot be estimated at this time. However, in order to compare some possible withdrawals with estimates of annual recharge two examples may be considered which are based on fairly reasonable assumptions. (1) Assume a density of 1 well for every 4 km^2 on the land included in current irrigation projects (150 wells on 610 km^2); and assume a withdrawal rate from each of 200 m^3 per hour (2 cfs) for 240 days per year. The annual withdrawal would

be about 180 million m^3 (144,000 acre feet), or 27 percent of estimated annual recharge to the ground water reservoir over the entire area. (2) Assume the same well density over the entire land area exclusive of rock outcrops and river bottoms (about 1,300 km^2). At the same rate of withdrawal, the assumed 325 wells would produce 375 million m^3 (300,000 acre feet), or about 56 percent of the annual recharge.

Whether or not withdrawals of this magnitude could be sustained will depend on the actual effects of pumping, including drawdowns in the wells, declines in the water table or potentiometric head, effects on water quality, reductions in stream flow, and the amount of additional recharge which might be captured. Some possible consequences are considered in following.

Effects of Future Development: As the result of large-scale pumping of ground water from shallow aquifers the water table will decline in the vicinity of pumping wells. If pumping continues in a number of adjacent wells, the dewatered zones, termed cones of depression, will eventually coalesce, and the regional water table will decline. Such a decline may have beneficial effects at places where increased amounts of recharge may be captured from irrigation water or flood flows, where crop growth may benefit from lowered water levels, or where salty land may be reclaimed by leaching. However, adverse effects may also occur locally. Shallow wells may require deepening, pumping lifts become greater, and the costs of pumping rise rapidly. Of

particular concern would be the effects of lowering the water table in areas where karezes are still utilized. Unlike wells, karezes can rarely be deepened appreciably without jeopardizing the flow to their outlets, and a significant decline in water levels in some areas might entirely cut off flow in a number of karezes.

The effectiveness of the Central Arghandab Unit drain system in lowering the water table over many square kilometers illustrates the reason for concern about the effects of pumping. Although the alluvial deposits penetrated by most wells are probably less permeable than those affected by the drains, the better wells may locally share the same aquifer and the decline in the water table could be substantial.

The distances at which the effects of pumping may be observed in a uniform aquifer can be roughly approximated by calculations based on the Thiem equation for steady-state flow radial flow. For wells of the average dimensions and average yields determined for dug wells in the area Kandahar, drawdowns of the water table may be about 1 m at a radius of 10 m, and should be negligible (less than 0.1 m) at a radius of 20 m. However, for wells of maximum probable yield (about 100 m^3 per hour), drawdowns may be as much as 1 m at a radius of nearly 300 m, and will be less than 0.1 m only at distances of over 1,000 m. Interference effects of neighboring wells would greately increase the calculated values.

Although similar calculations can be made for deep wells in the Kandahar area by assuming that the aquifers are confined or semi-confined, the results would be nearly meaningless in the absence of data on the transmissivity and stratification of the alluvial deposits penetrated by the wells. It is possible, for example, that pumping could occur in a deep well tapping a confined aquifer with only small effects on the water table in the immediate vicinity of the well. However, the decline in potenio-metric head produced by the pumping might seriously effect pumpage from other deep wells tapping the same aquifer at large distances from the first well. In a region such as the valley of the Arghandab in which water supply is precariously balanced against demand, it is almost inevitable that an increase in consumptive use at one place will necessitate a decrease elsewhere. In other words, any withdrawal of water, whether from the ground or a surface source, would in time be competitive with other withdrawals in the region; the effects would show as lowered ground water levels and reduced streamflows so that less water would be available for consumptive use.

Pumping from wells may induce flow from nearby canals and streams. While such induced recharge benefits the well owner, it deprives other users of water which may be rightfully theirs. It has been pointed out in a preceding section ("Discharge from Ground Water Reservoir") that the flow of streams during low-flow periods may be largely supported by discharge of ground water.

The development of wells near the river channels would intercept some of the normal ground water discharge, and the low flows in the channel would consequently decline even further as the result of delayed return flow and consumptive use.

The quality of water withdrawn from a well may change as the result of prolonged pumping. It is possible, for example, that in the deeper valleys water of several different qualities may exist in more or less stratified layers. Withdrawal of water from a stratum containing water of good quality may lower the potentiometric head sufficiently to induce appreciable flow of water of poor quality from adjacent strata. Subsequent contamination of the producing aquifer may be irremediable within any reasonable length of time.

The consequences of large-scale development of ground water should be assessed, in so far as possible, in advance of development, in order to avoid harmful conflicts of interest and irreversible damage. Every effort should also be made to establish a legal foundation which will not only cover priorities of use for streamflow, but which would also consider the problems arising from the close interrelationship of surface water and ground water. Both analytical and empirical methods are available for predicting the effects of pumping, provided the necessary basic data have been collected. There is an equal need, therefore, for both basic data on the occurrence of groundwater and for a legally based administrative structure to insure effective use of the data.

Further Studies

In order to make a quantitative evaluation of the potential for ground-water development in the Kandahar area and to predict its effects, further studies will be needed. Continued development, or attempted development, of ground water in advance of such studies may result in serious waste of resources and conflicts of interest among water users.

First priority should be given to a test drilling program which will provide information on thickness, extent, and lithologic characteristics of deep aquifers. Depths to bedrock should be explored, if possible. The drilling of deep test holes will then make it possible to obtain information of equally high priority on the hydraulic characteristics of the aquifers. All the holes drilled for exploration should be test pumped, but the most valuable data will come only from thorough aquifer tests using sufficient observation wells to enable reliable calculations of the hydraulic parameters to be made.

During the drilling of each test hole information should be obtained on the quality of water as a function of depth and lithology. Complete analysis of all major ions are needed. Additional complete analyses should be made on the shallow ground water from a sufficient number of places to delineate the areal variation of water quality and the relationship to soil characteristics and irrigation practices.

Programs for the inventory of wells and karezes and for the monitoring of ground water should be started as soon as possible. For ground water monitoring a network of observation wells is needed in which periodic measurements of water levels and water quality are made. Additional information will be required on low flows at several locations in each of the four rivers, and refined estimates should be made of surface water diversions and comsumptive use of water in the whole area. With these data and some additional information on the occurrence of water in the unsaturated zone, obtainable from moisture profile studies, more reliable estimates of ground water recharge and discharge may be made. Such estimates are a necessity if the perennial yeild of ground water is to be determined.

Full development of the water resources of the Kandahar area will require the use of ground water as a supplement to the surface water supply. Although the relationships between ground water and surface water supplies are complex, it is clear that developments and changes in one will have far reaching effects on the other. Knowledge of these interrelationships, however, is not yet available and must be obtained from a program of studies incorporating all or most of the elements described above. The orderly and timely development of the water supply in the Kandahar area will depend greatly on the implementation of such a program.

Summary and Conclusions

Background

1. Surface water provided by the Arghandab Arghastan, Dori, and Tarnak Rivers has been for many the primary source of irrigation water in the Kandahar area. The Arghandab River supplies most of the water used, but in the lands served by the Arghandab, shortages of water are predicted in about 3 years out of 10. Lands served by water from the Arghastan, Dori, and Tarnak Rivers are chronically short of water.

2. A decrease in the average annual precipitation during the decade 1960-1970 resulted in below normal streamflow, and may also account for a regional decline of ground water levels observed in large areas in southwest Afghanistan.

3. A critical shortage of surface water in 1971 forced attention to ground water as a source which might be used to save endangered orchards and vineyards and make possible a winter wheat crop. Many farmers became aware of the possibility of using ground water from wells as a supplementary source for longterm agricultural development.

Ground Water Resources

1. A large volume of ground water is contained in the alluvial deposits of the Kandahar area. The deepest drill holes (maximum 180 m) have not reached bedrock. From geological evidence it is postulated that the saturated alluvium may be several hundred meters thick.

2. Measured depths to the water table range from 0 to 18 m but in most of the area hand dug wells can reach water less than 8 m below land surface. The water table fluctuates mainly in response to the application of irrigation water or the functioning of drains. Seasonal fluctuations are probably small in non-irrigated areas. High water tables which have water logged nearly one-quarter of the land in the Central Arghandab Unit are sustained by the application of irrigation water on poorly drained soil. Recently completed drains have lowered the water table from 1 to 3 m in areas south of Kandahar, and future drainage measures may be expected to have similar effects elsewhere.

3. The shallow alluvial deposits are predominantly silt, clay, and fine sand, and in consequence, hydraulic conductivities observed in the upper 6 to 8 m are relatively low. The average hydraulic conductivity, as observed in nearly 100 dug wells, may be about 2 m per day.

4. Specific yields of the shallow alluvium may range up to 0.1, but the average value for the long-term specific yield of the sediments to depths of about 40 m is probably in the range 0.01 to 0.05.

5. Annual recharge to the ground water reservoir may be about 665 million m^3 (530,000 acre feet), of which probably less than 5 percent is derived directly from precipitation on the area. Development of ground water will therefore be almost entirely dependent on recharge from valley underflow and the seepage from irrigation water.

6. Discharge from the ground water reservoir sustains streamflow in the four rivers during their low-flow periods and continuously drains from the area as underflow in the river channels. The average net discharge of ground water annually to the streams may be in the neighborhood of 560 million m^3 (445,000 acre feet). Discharge through wells and karezes at current rates of use is estimated at about 38 million m^3 (31,000 acre feet) and direct evapotranspiration from ground water may be in the range 35 to 70 million m^3 (28 to 56 thousand acre feet) annually.

7. The quality of ground water in the Kandahar area differs greatly from place to place but the water is generally of the same type throughout the area. Concentrations of dissolved solids measured in wells, karezes, and drains ranged from 300 to 10,100 mgl. Concentrations of boron range from a trace to several milligrams per liter. Water containing the higher concentrations of dissolved solids has been found to be detrimental to some crops, and at best must be judiciously applied to avoid

salt build-up in the soil. High concentrations of dissolved solids are the result of long-continued application of irrigation water on poorly drained land. Significant differences in concentrations of dissolved solids probably occur in the vertical profiles of the alluvial deposits.

Development of Ground Water

1. During 1971, the rate of withdrawal of ground water from wells increased from about 32 million m^3 per year (26,000 acre feet) to about 38 million m^3 per year (31,000 acre feet). Total annual use of ground-water for irrigation will have increased by 19 percent, if rates of withdrawal continue during the remainder of 1971.

2. Collection trenches dug by dragline in the alluvial deposits of the Arghandab River channel may produce as much as 1,500 m^3 per hour (15 cfs) by pumping at some places. These trenches are the only known sources of large supplies of ground water, and they should do much to alleviate the critical conditions resulting from a shortage of streamflow. Pumping from these trenches will directly reduce streamflow or underflow to downstream areas.

3. Most dug wells in the Kandahar area will produce only small quantities of water, generally less than 10 m^3 per hour (45 gpm); several dug wells are known to have yields of up to 100 m^3 per hour (450 gpm). It is not presently possible to predict the locations or depths at which highly permeable strata may occur and where wells of high yield may be located, although the chances of success are better in the large dry washes and immediately adjacent to river channels than elsewhere.

4. The prospects for production of moderate to large supplies of ground water from deep drilled wells in the Kandahar area are good. Both the performance of existing deep wells and the known facts of the geology and physiography suggest that permeable strata may be encountered at many places in the alluvial valleys. Depths of the valleys are unknown, but are estimated to be at least several hundred meters at places. Therefore, large quantities of ground-water are available providing that sufficiently permeably strata are encountered to permit high rates of flow to the wells. The chemical quality of the ground water, however, may eliminate some water from the total amount useful for irrigation.

5. Recharge to the ground water reservoir, both from applied irrigation water and from underflow in the alluvium, is sufficient to sustain greatly increased withdrawals of ground water.

6. One consequence of a large increase in withdrawal of ground water from shallow aquifers will be a decline of water levels in the vicinity of pumping wells. Although beneficial effects of such a decline may include increased crop yields in areas of presently high water levels and the recovery of additional water from irrigation and flood flows, adverse effects on neighboring shallow wells and karezes must be considered. Other consequences may include reduced stream flows and the induction of saline water into productive aquifers.

7. A quantitative evaluation of potential ground water production and its effects will require a program of investigations which should include extensive test drilling, test pumping, and monitoring of ground water levels and quality.

References

1. Benz, J.S., and Holmgren, F.N., 1962, The Helmand Valley-an overall review: USAID, Kabul, Afghanistan.

2. Brigham, Robert H., 1964, Compilation of hydrologic data, Helmand River Valley, Afghanistan, through September 1960: U.S. Geological Survey open-file report.

3. Food and Agricultural Organization of the UN, 1965, Survey of land and water resources, Afghanistan, v. 1, General; v. 2, Geology: FAO, Rome.

4. International Engineering Company, 1959, Report on soil and water resources of southwest Afghanistan, v. 1, General; v. 2, Project areas: IECO Inc., San Francisco, Calif.

5. Maierhofer, Charles R., 1954, Drainage and related problems of irrigation development in the Helmand Valley of Afghanistan: U.S. Bureau of Reclamation, Denver, for the Foreign Operations Administration, Washington, D.C.

6. _____, 1961, Helmand Valley Development Project, Afghanistan: Drainage and related problems: U.S. Bureau of Reclamation, Denver, Colo.

7. Morrison and Knudsen, 1957, Soil and water resources of southwest Afghanistan, Supplement 1 Report no. 1 Soils and Drainability Surveys, Tarnak Area: Morrison-Knudsen Afghanistan, Inc., consultants' report.

8. Tudor Engineering Co., 1956, Report on development of Helmand Valley, Afghanistan: Tudor Engineering Co., for ICA, Washington, D.C.

9. U.S. Bureau of Reclamation, 1968, Shamalan Unit, Helmand-Arghandab Valley Development Project, Afghanistan, Feasibility Report: U.S. Bureau of Reclamation for HAVA and USAID, Afghanistan.

10. _____, 1970, Central Arghandab Valley Unit, Helmand Arghandab Valley Project, Afghanistan, Feasibility Report: U.S. Bureau of Reclamation for HAVA and USAID, Afghanistan.

11. _____, 1970, Operation and Water Management Manual: U.S. Bureau of Reclamation for HAVA, unpublished report.

12. Youngs, F.O., 1948, Soils and agriculture of the Arghandab Valley, Afghanistan: Morrison-Knudsen Afghanistan, Inc. Consultants' report.

Appendix A. Logs of Wells and Power Auger Holes in the Kandahar Area (Depths in meters below land surface)

Wells

Well 1 1/ Grid E91,000 - S24,200.

0 - 5	Clay, very silty, with fine sand, some layers of gravel, sub-angular to round
5 - 6	Silt, clayey, with some fine sand
6 - 7	Gravel, fine to coarse, rounded, silty and sandy; cemented, very hard
7 - 8	Sand, coarse, fine gravel, some fine sand; dense, not consolidated
8 - 9	Silt and clay; very dense; dry
9 - 10	Gravel, fine to coarse, rounded, fine sand; dense; not consolidated
10 - 11	Conglomerate, fine to coarse, rounded
11 - 12	Conglomerate, coarse gravel and cobbles; matrix silty
12 - 12.5	Sand, very fine to medium, gray; cemented
12.5 -- 13	Conglomerate coarse; matrix sandy and silty
13 - 14	Sand, gravel, rounded; loose
14 - 24	Sand, gravelly, cobbles, some silt layers
24 - 26	Silt, sandy
26 - 31	Silt, sand, some gravel
31 - 39	Gravel, silty, sandy
39 - 44	Conglomerate, matrix silty and sandy Static water level 11.12 m (8/25/71)

Well 2 2/ Grid E114,000 - S20,500.

0 - 3	Gravel, angular, and cobbles, rounded, matrix clay
3 - 7	Gravel, sandy, cobbly, matrix silt
7 - 11	Gravel, angular, matrix clay
11 - 15	Clay, massive, blocky fracture
15 - 18	Sand and clay
18 - 19	Clay, tough, sticky
19 - 25	Clay and sand
25 - 26	Gravel, cobbles, matrix silty clay
26 -	Clay, reddish-brown; dense, very tough Log incomplete. Depth of hole 44 m. Static water level 12.5 m (estimated, 10/4/71)

Well 3 2/		Grid E104,750 - S27,900 Log: See log published in Feasibility Report, Central Arghandab, U.S. Bureau of Reclamation, v. 2, Appendix D, p. 292 (1970)
Well 4 1/		Grid E88,200 - S22,500
0	- 2	Silt, clayey, brown dense
2	- 8.8	Gravel and cobbles, matrix clay, brown; dense, tough Static water level 7.80 m (7/29/71)
Well 5 1/		Grid E81,300 - S26,400
0	- 1	Silt, brown, sand, fine
1	- 11	Gravel and cobbles, angular to rounded, matrix silty sand; dense, tough Static water level below 11 m (7/29/71) Well not completed
Well 6 2/		Grid E100,500 - S24,500
0	- 2	Silt, clayey, light brown, some sand
2	- 24	Gravel, sandy, silty, rounded to angular
24	- 39	Gravel, matrix clayey silt
39	- 48	Gravel, sand, loose; caved during drilling Static water level 3.92 (9/9/71)
Well 7 1/		Grid E72,500 - S28,000
0	- 17.8	Gravel and cobbles, matrix silty clay. Layer of coarse sand and gravel at 9 m Static water level 15.68 m (6/9/71)
Well 8 1/		Grid E63,500 - S31,700
0	- 8	Gravel and cobbles, matrix clayey silt; very dense. Conglomerate; very tough, dense, solution openings. Static water level 6 m (reported) (7/28/71).
Well 9 1/		Grid E104,300 - S31,700
0	- 6.1	Silt, clayey, light brown
6.1	- 6.5	Gravel, silty, some sand; permeable.
6.5	- 8	Conglomerate and partly cemented gravel Static water level 3.64 m (8/25/71)

Well 10 1/	Grid E88,900 - S21,700
0 - 7.5	Silt, clayey, light brown; very dense; discontinuous layers of gravel and cobbles Static water level 5.80 m (7/14/71)
Well 15 1/	Grid E114,800 - S28,500
0 - 5.1	Silt, clayey; dense, tough; some layers of gravel and cobbles Static water level 4.80 m (7/27/71)
Well 23 1/	Grid E100,900 - S11,000
0 - 5	Silt, clayey; sand, gravel in discontinuous strata
5 - 10	Conglomerate; very hard
10 - 15.6	Gravel, cobbles, boulders, matrix sandy silt Static water level 14.90 m (8/14/71)
Well 27 1/	Grid E117,200 - S40,700
0 - 6	Gravel, cobbles, angular to rounded, matrix silty sand; dense, layered
6 - 12.7	Conglomerate; very hard, becoming less cemented at bottom Static water level 12.2 m (10/5/71)
Well 29 1/	Grid E70,000 - S39,000
0 - 7.1	Gravel, angular to rounded, matrix clayey silt Some partly cemented layers Static water level 4.5 m (9/8/71)
Well 30 1/	Grid E108,400 - S23,400
0 - 2	Silt, sand, gravel, cobbles, brown
2 - 6	Conglomerate, partly cemented, matrix clay
6 - 14	Clay, silty, brown; massive, blocky fracture Static water level 9.2 m (10/4/71)
Well 32 1/	Grid E106,600 - S25,200
0 - 1	Sand, gravel, matrix silty
1 - 7	Gravel, angular, matrix clayey silt; very dense
7 -	Gravel, silt, sand, loose Static water level (water table) 4 m; (artesian) 2 m (9/22/71) Note: Pipe driven to 29 m through bottom of well encountered no conglomerate or dense gravel

Well 33 1/		Grid E69,600 - S30,000
0	- 11.8	Gravel, angular, matrix silty clay; uniform; very dense Static water level 8.25 m (9/22/71)
Well 34 1/		Grid E115,700 - S32,400
0	- 4.7	Clay, silty; some layers of carbonate cement
4.7	- 9.7	Silt, sand, gravel, cobbles; very dense
9.7	- 10	Sand, gravelly; looser than above Static water level 7.4 m (10/4/71)
Well 37 1,2/		Grid E90,000 - S30,700
0	- 3.7	Clay, silty, light grayish tan; changes to brown at 2.5 m
3.7	- 4.7	Gravel
4.7	- 18	Clay, silty
18	- 19	Gravel
19	- 22	Clay, silty
22	- 23	Gravel
23	- 26	Clay, silty Static water level 3.7 m (10/5/71)
Well 40 1/		Grid E97,500 - S22,700
0	- 3.1	Silt, clayey, some gravel, angular
3.1	- 3.7	Gravel, matrix sandy clay; partly cemented
3.7	- 7.6	Silt, clayey, gravelly, angular
7.6	- 12.2	Clay, silty, gravelly Static water level below 12.2 m (11/17/71)
Well 58 1/		Grid E100,300 - S35,500
0	- 18	Silt, clayey, gravelly
18	- 23	Gravel, matrix clay, silt; dense
23	- 30	Clay, brown; dense, blocky fracture
30	-	Gravel, dense; possibly cemented Static water level 6.22 m (12/13/71)
Well 59 1/		Grid E76,000 - S28,700
0	- 13	Silt clayey, gravelly, angular; few layers of cross bedded fine sand; very dense, tough Static water level 12.65 m (12/14/71)

Well 60 1/		Grid E115,100 - S31,200
0	- 5.7	Clay, silty, light tan; some discontinuous layers of angular gravel
5.7	- 5.8	Conglomerate, partly cemented at bottom
5.8	- 7.0	Gravel, matrix clayey silt; very dense Static water level 6.55 m (12/15/71)
Well 61 1/		Grid E115,500 - S31,000
0	- 5	Silt, clayey, brown
4	- 6	Silt, sandy, light gray; discontinuous lenses of silty sand and gravel
6	- 9.8	Gravel, angular, matrix silt; very dense Static water level about 7 m (12/15/71)
Well 62 1/		Grid E96,200 - S31,100
0	- 4	Silt, clayey
4	- 6	Sand, fine to medium, silty; loose
6	-	Sand, fine, silty; loose Static water level 4 m (12/21/71)
Well 66 1/		Grid E69,200 - S30,200
0	- 15	Gravel, angular, matrix silty clay; very dense, tough
15	- 16.7	Hard layer (conglomerate?); very hard Static water level 8 m (1/3/72)
Well 67 1/		Grid E87,800 - S30,200
0	- 4.5	Gravel, angular, matrix silty clay
4.5	- 6	Clay, gravelly, brown
6	- 6.5	Gravel, matrix clay
6.5	- 10	Clay, brown; massive, blocky fracture, dense
10	- 11	Clay, gravelly; some water seeps Static water level 6.5 m (1/5/72)
Well 68 1/		Grid E108,900 - S20,600
0	- 7	Gravel, angular, matrix silty clay; dense Static water level 10.00 m (1/11/72)

1/ Logged by author
2/ Driller's log

Power Auger Holes

PA 10 1/ Grid E107,800 - S25,000

0	- .1.37	Sand, medium to coarse, brown, some fine gravel
1.37	- 1.93	Gravel, cobbles, rounded; dense
1.93	-	Refusal: probably boulder
		Static water level below 1.93 m (8/16/71)

PA 11 1/ Grid E102,500 - S27,600

0	- 1.22	Sand, fine silty, brown
1.22	- 5.04	Silt, clayey, brown
5.04	- 5.95	Silt, gravelly
5.95	-	Refusal: probably conglomerate
		Static water level 2.9 m (8/17/71)

PA 12 1/ Grid E103,100 - S28,200

0	- 1.52	Silt, light brown, some fine sand
1.52	- 5.50	Silt, clayey, dark brwon
5.50	- 5.65	Gravel and cobbles, matrix silt
5.65	-	Refusal: cobbles or conglomerate
		Static water level 3.8 m (8/18/71)

PA 13 1/ Grid E101,700 - S29,400

0	- 6.10	Clayey silt, dark brown, some fine sand
6.10	- 7.63	Gravel and cobbles, matrix silty; loose
7.63	- 7.93	Gravel and cobbles; dense
		Static water level 3.0 m (8/18/71)

PA 14 1/ Grid E101,500 - S30,600

0	- 1.52	Silt, clayey, some fine sand
1.52	- 7.02	Clay, silty, brown; becomes denser with depth
7.02	- 7.32	Gravel and cobbles
7.32	- 7.62	Clay, silty, brown
7.62	- 8.54	Gravel, matrix silty clay
8.54	- 8.85	Clay, dense
8.85	- 10.37	Gravel, cobbles, matrix clayey silt; dense
10.37	-	Refusal: gravel, dense
		Static water level 3.6 m (8/18/71)

PA 15 1/ Grid E104,800 - S26,800

0	-	1.22	Silt, fine, clayey, light brown, some fine sand
1.22	-	1.83	Silt, clayey, dark grown; moist
1.83	-	3.67	Clay, silty
3.67	-	3.82	Gravel
3.82	-	5.03	Clay; dense, tough
5.03	-	5.78	Gravel, matrix clayey silt
5.78	-		Refusal: probably large boulder
			Static water level 1.77 m (8/19/71)

PA 16 1/ Grid E100,600 - S27,200

0	-	1.53	Clay, silty, brown, some fine sand
1.53	-	6.10	Clay, silty, thin layers of gravel, fine to medium
6.10	-	6.42	Gravel, coarse, dense
6.42	-		Refusal: probably conglomerate
			Static water level 3.8 m (8/19/71)

PA 17 1/ Grid E100,600 - S27,200

0	-	3.82	Clay, silty, dark brown
3.82	-	4.12	Gravel, cobbles, matrix silty clay
4.12	-		Refusal: probably conglomerate
			Static water level 1.2 m (8/29/71)

PA 18 1/ Grid E100,500 - S27,600

0	-	0.61	Silt, clayey, brown, some fine sand
0.61	-	6.10	Clay, silty, dark grayish brown; very dense near bottom
6.10	-	7.02	Silt, clayey, sandy; soft
7.02	-	8.54	Clay, silty; very dense
8.54	-		Gravel, fine, matrix clay, very hard
			Static water level 1.95 m (8/29/71)

PA 19 1/ Grid E100,000 - S27,800

0	-	0.61	Silt, clayey, light brown
0.61	-	6.41	Clay, silty, dark brown
6.41	-	7.93	Clay, thin layers of sandy silt; alternately dense and loose
7.93	-	9.15	Gravel, cobbles, matrix clay; very dense, tough
9.15	-		Refusal: probably conglomerate
			Static water level 1.94 m (8/29/71)

PA 20 1/ Grid E99,400 - S28,500 (continued)

11.25	- 11.87	Gravel, matrix clayey silt; dense
11.87	- 12.80	Clay, soft, plastic
12.80	- 13.10	Gravel, matrix clayey silt; loose
13.10	-	Clay, gravelly; dense, tough
		Static water level 2.6 m (8/30/71)

0	- 1.83	Silt, clayey, light brown; dense
1.83	- 8.54	Clay, silty, dark br n; soft
8.54	- 10.25	Clay; tough, cohesive
10.25	- 10.96	Gravel, sandy; loose
10.96	- 11.58	Gravel, matrix clayey silt; dense, tough
11.58	- 11.88	Clay; tough, cohesive
11.88	- 12.80	Gravel, matrix clayey silt
12.80	- 14.34	Clay, silty, sandy; soft, plastic
14.34	- 14.50	Clay; tough, cohesive
		Static water level 2.8 m (8/30/71)

PA 22 1/ Grid E99,200 - S29,700

0	- 3.66	Silt, clayey, dark brown, some fine sand; loose
3.66	- 7.63	Clay, silty, dark brown; soft, plastic
7.63	- 8.54	Clay; stiff, cohesive
8.54	- 9.15	Clay; soft, plastic
9.15	- 9.75	Gravel, matrix clayey silt; moderately dense
9.75	- 10.05	Clay; tough, cohesive
10.05	- 10.66	Clay; soft, plastic
10.66	- 11.88	Gravel layers, matrix silty clay
11.88	- 17.95	Clay, silt, alternating in layers with fine sand; alternately dense and loose
17.95	- 18.25	Gravel; dense, compact
18.25	- 18.60	Clay; tough, cohesive
18.60	- 19.20	Gravel; dense, compact
19.20	- 20.75	Clay, silty
		Static water level 2.32 m (9/2/71)

PA 23 1/ Grid E70,300 - S39,000

0	- 2.44	Silt, clayey, tough, hard
2.44	- 4.26	Clay, silty; moderately soft
4.26	- 5.80	Gravel, fine to coarse, cobbles, sandy; dense compact
5.80	- 6.10	Gravel, fine to coarse; very compact
6.10	- 7.63	Gravel, sandy; loose
7.63	-	Refusal: probably conglomerate
		Static water level 4.40 m (9/8/71)

PA 24 2/ Grid E97,500 - S30,200

0	- 1.80	Clay, silty, brown, some fine sand; soft
1.80	- 7.30	Silt, clayey, sandy layers
7.30	- 8.45	Gravel, silt, clay; loose
8.45	- 10.21	Clay; tough, cohesive
10.21	- 14.80	Clay, silty, sandy layers
14.80	- 15.35	Clay, silty, gravel layers
15.35	- 21.95	Clay, silty and silt; alternating hard and soft layers

Static water level 2.25 m (9/13/71)

PA 25 2/ Grid E96,800 - S31,500

0	- 3.10	Silt, clayey, sandy; loose
3.10	- 9.03	Clay, silty; tough, cohesive
9.03	- 9.85	Silt, clayey; soft
9.85	- 10.47	Clay; tough, cohesive; cobbles at base
10.47	- 11.05	Clay, silty; tough, cohesive
11.05	-	Refusal; probably conglomerate

Static water level 3.20 m (9/14/71)

PA 26 2/ Grid E95,200 - S32,500

0	- 5.50	Silt, clayey, sandy; soft
5.50	- 10.52	Clay, silty; tough, cohesive
10.52	- 11.17	Clay; tough, cohesive
11.17	- 12.40	Clay; soft, plastic
12.40	- 15.00	Clay, silty; tough, cohesive
15.00	-	Refusal: hard layer

Static water level 2.40 m (9/14/71)

PA 27 2/ Grid E95,700 - S33,600

0	- 2.40	Silt, clayey, sandy
2.40	- 2.99	Clay; moderately tough
2.99	- 4.52	Clay, silty; soft
4.52	- 5.16	Clay; tough, cohesive
5.16	- 11.57	Clay, silty, some sand layers
11.57	- 21.90	Clay, silty, and clay in alternating soft and hard layers

Static water level 4.0 m (9/15/71)

PA 28 2/ Grid E96,600 - S38,200

0	- 4.48	Silt, clay; soft
4.48	- 4.70	Clay; moderately tough
4.70	- 10.25	Clay, silty, sandy
10.25	- 12.00	Gravel, matrix silty clay; loose
12.00	- 14.50	Gravel, matrix silty clay; dense, compact
14.50	- 16.25	Gravel, matrix silty clay; very compact
16.25	-	Refusal: probably conglomerate
		Static water level 3.1 m (9/20/71)

PA 29 2/ Grid E93,900 - S33,000

0	- 2.38	Silt, clay; soft
2.38	- 8.70	Clay, some silt layers; soft; hard layer at at 8.42 m
8.70	-	Refusal: hard layer
		Static water level 2.2 m (9/21/71)

PA 30 2/ Grid E91,900 - S34,600

0	- 0.98	Clay, silty; moderately hard
0.98	- 3.82	Clay; tough, cohesive
3.82	- 8.25	Clay, silty; moderately soft
8.25	-	Refusal: hard layer

PA 31 2/ Grid E90,300 - S35,400

0	- 0.70	Silt, clayey, sandy, soft
0.70	- 8.00	Silt, clayey; soft; sandy at 3.95 m
8.00	- 8.35	Clay; very tough, cohesive
8.35	-	Refusal: hard layer
		Static water level 5.95 m (9/21/71)

PA 32 2/ Grid E88,300 - S35,500

0	- 0.43	Silt, clayey, sandy; soft
0.43	- 7.40	Clay, silty; soft, plastic
7.40	- 8.00	Clay; tough, cohesive
8.00	-	Refusal: hard layer
		Static water level 3.3 m (9/21/71)

PA 33 2/ Grid E85,900 - S35,900

0	- 1.75	Silt, clay, sand
1.75	- 6.00	Clay, moderately tough
6.00	- 8.75	Clay, silty; soft
8.75	- 8.90	Clay; very tough, cohesive
8.90	-	Refusal: hard layer
		Static water level 2.5 m (9/22/71)

PA 34 2/ Grid E84,100 - S36,800

0	- 0.34	Silt, clayey, sandy; soft
0.34	- 5.75	Clay, silty; soft
5.75	- 6.65	Clay; moderately soft
6.65	- 9.15	Clay; very tough, cohesive
9.15	-	Refusal: hard layer
		Static water level 2.55 m (9/22/71)

PA 35 2/ Grid E92,500 - S30,300

0	- 0.49	Silt, clayey, sandy
0.49	- 4.50	Silt, clay, some gravel and cobbles
4.50	- 4.80	Gravel, fine, matrix clayey silt
4.80	- 5.50	Clay, silt; soft
5.50	- 5.67	Gravel, cobbles; dense, hard
5.67	-	Refusal: probably conglomerate
		Static water level 3.7 m (10/5/71)

PA 36 _/ Grid E91,200 - S31,000

0	- 2.40	Silt, clayey, sandy, some gravel; soft
2.40	- 4.40	Gravel, matrix clayey silt; dense, hard
4.40	- 6.00	Clay, silty; soft
		Static water level 4.0 m (10/5/71)

PA 37 2/ Grid E89,900 - S32,700

0	- 1.50	Silt, clayey, some fine sand; hard
1.50	- 4.50	Silt, clay; soft
4.50	- 10.50	Silt, clay; gravel layers
10.50	- 12.15	Gravel, matrix clayey silt; dense, hard
12.15	-	Refusal: hard layer
		Static water level 2.3 m (10/5/71)

PA 38 2/ Grid E88,400 - S34,000

0	- 7.80	Silt, clay; soft
7.80	- 9.80	Clay; tough, cohesive
9.80	- 10.10	Clay; soft, plastic
10.10	- 10.50	Clay; tough, cohesive
10.50	-	Refusal: hard layer
		Static water level 3.7 m (10/6/71)

PA 39 2/ Grid E87,100 - S34,700

0	- 2.25	Silt, clayey, sandy
2.25	- 2.65	Sand, fine, silty; loose
2.65	- 5.60	Clay, silty, with hard, dense layers
5.60	- 6.90	Clay; very tough, cohesive
6.90	-	Refusal: hard layer
		Static water level 2.0 m (10/6/71)

PA 40 2/ Grid E85,600 - S34,800

0	-	2.40	Silt, clayey; soft
2.40	-	5.60	Silt, clayey, sandy; loose
5.60	-	6.90	Clay; moderately tough
6.90	-		Refusal: hard layer
			Static water level 2.0 m (10/6/71)

1/ Logged by the writer.

2/ Driller's log.

Appendix B. Orthographic List of Geographic Names

Names used in this report are from Afghanistan sources. This familiar usage is followed throughout the report. A glossary of the names used, with their equivalents in the Board on Geographic Names (BGN) system, follows this description. The glossary may aid in cross-reference to U.S. Geological Survey reports using the BGN system.

The glossary is arranged in two columns, (1) Report Names and (2) Board on Geographic Names (BGN). The BGN name is followed by its feature description. If the BGN name is shown as nv (not verified), the Board is not able to verify this existing name from current sources.

Report Name	Board on Geographic Names (BGN)	
Asrat Canal	Not verified (Nv)	canal
Ambar	Anbār Kalay	pop
Arghandab Diversion Dam	nv	
Arghandab Reservoir	Kāseh-ye Band-e Arghandāb	reser
Adrack	nv	
Akdad	nv	
Arghastan	Arghastān	stm
Arghandab Dam	Band-e Arghandāb	dam
Arghandab River	Daryā-ye Arghandāb	stm
Baba Wali W W	nv	channel
Bela Kars	Lowy Bālā Karz	pop
Baladay	Baladay	pop
Baladey	Belandey	pop
Babaran	De Bāborānow Kalāchah	pop
Baghlan	Baghlān	pop
Biladei Village	nv	pop
Chilgore	Chalghowr	pop
Chaman (Pakistan)	Chaman	pop
Charikar	Chārīkār	pop
Chah-i-Anjir	Chāh-E Anjīr	pop
Chilgore Canal	nv	canal
Dua-Ab	Do Āb	pop
Dimasey	Dīmrāsī	locality
Desabs	Deh Savzī	pop
Demrazi Canal	nv	canal
Dagulamon	Deh Gholāmān	pop
Derajab	Deh Rajab	pop
Da Kudja Canal	nv	canal
Dilaram	Delārām	pop
Dahla	nv	locality
Emolai	nv	pop
Emorat	'Emārat	pop
Fakiran	nv	pop

Report Name	Board on Geographic Names (BGN)	
Gondigan	Gondīgān	pop
Gulam Nabi	nv	pop
Gurgan	Gorgān	pop
Ghundi	Manṣūr Kalay	pop
Gulam Hussein	nv	pop
Gulistan	Golestān Kalay	pop
Ghazi	Ghaznī	pop
Girishk	Gereshk	pop
Hazim Khan	Hājī ʿAzīz	pop
Herat	Herāt	pop
Helmand River	Daryā-ye Helmand (Afghan) Rūd-e Hīrmand (Iran)	stm
Islam Qala	Eslām Qalʿeh	pop
Ismael	nv	pop
Jalawar Canal	nv	canal
	Jelāwur	pop
Jabar	Jabār Kalay	pop
Juma Khan	nv	pop

Koulk	Kolk	locality
Kadhil Canal	nv	canal
Kadhil	Kadahal	pop
Kasimerbad	De Qasem Robāṭ Kalay	pop
Khiske	Deh Kheshkī	pop
Kohoc	Kūhak	pop
Kandahar Cemetary	nv	cemetary
Kolchabad	Kolchehābad	pop
Kars	Karz	pop
Kohoc Canal	nv	canal
Koulk Canal	nv	canal
Kasimerbad Canal	nv	canal
Kojalai	Khvājeh ʿAlī Bābā	pop
Khankali	nv	pop
Kan	nv	pop
Kaze Karez	Qāẕī Kārīz	pop
Khush Ab	Khvosh Āb	pop
Kandahar National Airport	nv	airport
Kalantar	Kalāntar Kalay	pop
Kazi	Qāẕī Kalay	pop
Kalaige	nv	pop
Kajakai Reservoir	Band-e Kajakī	reservoir
Kunduz	Qondūz	pop
Kabul	Kābul	pop
Kalat	Qalāt	pop
Kanjakak	Khenjakak	pop
Karezak	Lowy Karīzak	pop
Kandahar	Qandahār	pop
Lashkar Gah	Lashkar Gāh	

Meshah Mir	nv	pop
Mushan Canal	nv	canal
	Mūshān	pop
Mazar Ashi	nv	pop
Madruk	nv	pop
Mazara Abas	Mazra ʻeh-ye ʻAbbās	pop
Manar Canal	nv	canal
Mira Koran	Mīr Āb Khvorān	pop
Mazarai	Mazra ʻeh	pop
Manzal Bagh	Manzel Bāgh	pop
Mullah Dar	nv	pop
Meon Canal	nv	canal
Majirin	Mohājerīn	pop
Mart Khala	Mard Kalā	pop
Massangan	nv	pop
Mullah Kuchai	Mollā Kūchay	pop
Mandazar	Mandī Sār	pop
Mullah Abdullah	Mollā ʻAbdollāh Kārīz	pop
Mundab	Mond Āb	pop
Miragul	Mīrūgol Kalay	pop
Mukkur	Moqor	pop
Mhd Ali	Mohammad ʻAlī Kalācheh	pop
Mukum	nv	pop
Maiwand	Maywand Kārīz	pop
Musa Qala	Mūsá Qal ʻEh	pop
Mirohur Canal	nv	canal
Mullah Dost	Mollā Dūst	pop
Nalgam Canal	nv	canal
	Nalgham	pop
Nara	Lowy Manārah	pop
Nagahan	Nāgahān	pop
Nashay Jan Canal	nv	canal
Nachigan	nv	pop
Nazari	Naṣerān	pop
Nawadak Canal	nv	canal
Narirowza Canal	nv	canal
	Nār-e Rowẕeh	pop
Nawadak	Nākūdak	pop
Naw Zad or Nauzad	nv	locality
Okel	nv	pop

Report Name	Board on Geographic Names (BGN)	
Pashmool	Pashmūl	locality
Pashmool Canal	nv	canal
Panjwai	Bāzār-e Panjvā' ī	pop
Punjab Canal	nv	canal
Peshawar (Pakistan)	Peshāwar	pop
Patow Canal	nv	canal
Rigay	Regay	pop
Rorabad Canal	nv	canal
Rawani	Rawānay	pop
Registan Desert	Rīgestān	region
Regwa	nv	pop
Saulagay	Sablaghay	locality
Saijui	Sīāh Chūb	pop
Sperwan Canal	nv	canal
Surk Shalar	nv	pop
Shamgul	Changol	pop
Senzari Canal	nv	canal
Salon Canal	nv	canal
Shir-e-zur	Shēr Sorkh	pop
Salian	Ṣālehān	pop
Salakhan	Žalakhān	pop
Shasda Khan	nv	pop
Shamshir	Shamshīr Kalay	pop
Shaswar	nv	pop
Shorab Diversion Dam	nv	dam
Shorab Wash	De Shūr Āb Shēlah	stm
Shurudam	Shūr Andām	pop
Sukta	Sūkhteh-ye Mohammad Haqq Ākhvond	pop
Sukta(31°24-65°46)	nv	pop
Sandersa	nv	pop
Shindand	Shīndand	pop
Sarobi	Sorūbī	pop
Spin Baldak	Spīn Bāldak	pop
Safdar Karez	Ṣafdar Kalay	pop
Salawat	Ṣalavāt	pop
Sukta(31°25-65°48)	nv	pop
Shorab Diversion Channel	nv	channel

Report Name	Board on Geographic Names (BGN)	
Tulukhan	Talūkān	pop
Timor Karez	Teymūr Kalay	pop
Tarnak Canal, South Br.	nv	canal
" " , North Br.	nv	"
Tarnak River	Tarnak Rūd	stm
Tarnak Canal	nv	canal
Walakhan	Walakān	pop
Yak Karez	Yakh Kārīz	pop
Zangizar Canal	nv	canal
Zangizar	Sangsār	locality
Zangawat Canal	nv	canal
Zangawat	Zangābad	pop
Zakir	Zāker-E Sharīf	pop
Zarac	Zarak Kalay	pop
Zamin Dawar	nv	locality