

The Water Well Drilling Team under
The China National Complete Plant Export Corporation

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Preface

I. Tasks

In line with the stipulations of Item II in Article II of the "Agreement on Technical and Economic Cooperation" signed in Beijing on April 18, 1978, between the Government of the People's Republic of China and the Government of the Somali Democratic Republic, the China National Complete Plant Export Corporation dispatched a study group to Somalia in November, 1978, and, on April 28, 1979, signed in Mogadishu the "Notes on the Talks about the Project of Well Drilling in Tug Dher, Sanag, Bari and Jugal". The "Notes" stipulates that the Chinese Government would undertake the project of drilling 30 wells and of their wellhead assembly in the four northern regions of Somalia.

Besides, China agreed to drill 6 wells for Hargeisa water supply expansion project, which was proposed by the Ministry of Minerals and Water Resources. Meanwhile, the Somali Government complied to reduce the estimated 30 wells to be drilled in the four northern regions to 24, the distribution of which would be adjusted in each region correspondingly

II. The Work That Is Completed

The Chinese Well Drilling Team arrived in Somalia in September, 1981, and on December 20, that very year, started its drilling work. Up to October 25, 1985, the drilling work had been thoroughly completed, which took 47 months in all (of which there were 11 months for holidays, waiting of oil and local expenses). The actual time for drilling was only 36 months, three months earlier than originally designed. The total completed footage was 7740.73 m and the average footage completed by one rig per year was 1290 m. The drilled boreholes in the project area amounted to 43, of which there are 30 wells that are able to be used. The success

rate is 70%. Within the list below in the quantity of the work actually completed

| item region | amount of drilling work | | | amount of geophysical exploration | | well-head project | note |
|----------------|-------------------------|--------------|-------------------|-----------------------------------|-------------------------|-------------------|------|
| | footage (meter) | No. of wells | No. of good wells | surface electric sounding | electric logging (each) | finished | |
| Hargeisa | 908.5 | 7 | 6 | 55 | 7 | | |
| Tug Dher | 4139.94 | 21 | 12 | 120 | 16 | 12 | * |
| Sool | 403.51 | 2 | 2 | 24 | 1 | 1 | |
| Sanag | 1083.1 | 7 | 5 | 24 | 5 | 5 | ** |
| Bari | 912.04 | 4 | 3 | 20 | 4 | 3 | |
| Nugal | 293.64 | 2 | 2 | 5 | 1 | 2 | |
| total | 7740.73 | 43 | 30 | 248 | 34 | 24 | |

* The footage includes the useless footage of 424.06 m.

** The footage includes the useless footage of 201.65 m.

The Chinese Well Drilling Team have received a lot of support and help from the Somali people and the governments at different levels during the construction period. Having been well cooperated with by the Somali technicians and workers, the Well Drilling Team has got over all the difficulties and the barriers and triumphantly completed this project.

Section One An Outline of Natural Geology

. Geographical Location

The project area is located in the North of Somalia, geologically at 8° - 12° N and 43° - 45° E, having a coverage of 264,000 square kilometers across 6 regions.

(I. Topography and Geomorphology

The North of Somalia bears a plateau landscape with comparatively high terrain in its northern part and with lower terrain along the beach and in the southern part. Its geomorphological types can be classified as three sections, that is, (1) the coastal plain of erosion and accumulation of the Gulf of Aden; (2) the mountainous area of erosion and tectonism of the Northern Somalia and (3) the wavy plateau of tectonism-denudation of the Northern Somalia. The geomorphological characteristics of these three sections will be expounded in details below:

(1) the coastal plain of erosion and accumulation of the Gulf of Aden

The coastal plain of the Gulf of Aden varies a lot in width, with the erosion-accumulation plain of Zeila-Berbera as the most developed and with the erosion-accumulation plain of Bossaso as the second most developed. It has an undulating topography with a large number of remnant hills and sand dunes scattered on its surface. Blown by the sea wind continually, the crescent dunes are formed on the wide river courses and the vast sandy beach, which is very difficult for traffic and transport. The climate is extremely arid because of the burning sunlight and the strong evaporation. Separated by the high mountains, the plain is swept with heat waves all day long as the hot air and the cold air can not be convected so that it becomes the hottest area of the world. The vegetation is sparse and withered, taking on a tropical barren landscape.

(2) the mountainous area of erosion-tectonism of the Northern Somalia

Stretched from east to west and influenced by the NW fault zones of Eril Afwein and of Bossaso, the whole mountain range is cut into three divisions. The north side and the south side of this range are obviously unsymmetrical in this mountainous area. The north slope is like a series of terraced positive faults, forming steep cliffs. As it is sharply eroded and denudated by the late-formed rivers, the range appears like a series of mountain chains, with mountains high, valleys deep, with cap rock looking like a sawtooth-shaped roof after the denudation, and with granite mass looking like perfectly round hills. Because of the large dipangle of the cap rock, rows after rows of single-sided mountains ranging from east to west are often formed.

The cap rock in the south slope has a flat occurrence, thus forming the table-like mountains or gradually becoming the plateau of the Northern Somalia. Its altitude ranges from 1500 to 1800 m with the midpart in the north of Erigavo amounting to 2408 m in height, which has a drop of 2000 m as against the coast of the Gulf of Aden.

Because of many tectonisms between the mountains and because of the erosion by the rivers, a few wide valleys are formed, which have become the important communication lines from the inland to the Gulf of Aden.

(3) the wavy plateau of tectonism-denudation of the Northern Somalia

The main body of the plateau of the Northern Somalia is composed of the Haud and the Sawl plateaux and its top has a wavy surface rising and falling constantly. The occurrence of the strata is flat and gradual as if having a gradual syncline. In the wide valleys, the loose sedimentary deposit is

thick and during the rainy seasons there are transient water flows. So it is an excellent pasture with exuberant vegetation. Upon the wide flatish hills, exposed are the Karkar dolomitic limestone with thin capping. The weathered clastic stratum is predisposed to receiving the infiltration water supply by the rainfall while the region of gypsolyte abounds in huge sink-holes.

Owing to tectonism, there appear downcast river valleys on various scales between the large plateaux or on their tops, for example, the Tug Dher-Nugal river valley, the Daror river valley and the channel zone between Erl Afwein and Sarmanyo. These river valleys become the catchment places of the seasonal surface runoffs from various plateaux and mountainous regions and also become the catchment zones of underground runoffs. Due to the sparse rainfall and the strong evaporation, the river courses turn very wide and they get very faintly dissected. The underground runoffs flow very slowly and in the course of their slow flowing, they are gradually growing mineralized, thus forming the highly mineralized water. Yet, some sinkholes which are distributed like strings of beads can directly receive the supply of the rainfall. Their water quality and level change according to the seasons. Therefore, they have become the main water sources for the supply of the livestock on the pastoral areas.

III. Meteorology and Hydrogeology

The Northern land of Somalia, under the influence of the dry northwest monsoon, is quite arid with sparse rainfall. It falls into the category of the tropical continental monsoon climate region. The mean temperatures of the year vary from 24°C to 18°C with the lowest temperature occurring in December and January, (The temperature drops below 0°C in Erigavo) and with the highest temperature occurring in July and August (The mean temperature of July reaches as high as 41.7°C in Berbera). According to the supersession of the NE and SW monsoons, the year can be divided into four seasons, namely,

(1) the dry-hot season (December to March), which is called locally Jilal. During this season, the northeast wind blows rampant; the climate becomes extremely arid and hot; rivers turn dry and herbage grows withered; water and grass are in urgent want. So drought and epidemic diseases are very liable to occur; (2) the heavy-rainy season (April to June) which is roughly known as Gu. In this season, with the northeast wind receding, there appears temporarily a windless period. It is the major rainy season; (3) the dry season (July to September), also called Hugal, during which there is a rampancy of the southwest monsoon with arid hot weather and little rainfall; (4) the light-rainy season (October to November), which is also known as Der. In this season, with the northwest monsoon receding, there appears another temporary windless period. The temperatures drop and the quantity and the frequency of the rain is both less great than in the heavy-rainy season. The annual rainfall ranges from 300 to 500 mm, with the least rainfall in Bari --- usually less than 100 mm.

The rainfall in this area is typically characterized by "the desert storm". It pours down with the arrival of the cloud and with the passing of the rain, the sky becomes as clear as a mirror. During the years 1984-1986, the Northern Somalia has had plentiful rainfall so that the cattle, sheep and camels have a very high reproduction.

Most rivers in this area are seasonal ones which are dry usually but which function for draining flood after the rain. Several hundreds of the rivers in the Northwest Region and on the north side of the mountainous area are all included in the hydrographic net of the Gulf of Aden. With steep slopes, the swift current flows over the unfixed riverbeds into the sea. Under general circumstances, the river water mostly infiltrates into the river bank beach and takes shape of undercurrent. Belonging to the hydrographic net of the Indian Ocean, the Tug Dher-Kugal river and the Daror river have their sources in the Northern mountainous region or in the plateau

of the Northern Somalia, with the upstream river beds wide and shallow, and with the midstream and downstream beds even wider. Therefore, it usually becomes the flooded plain.

Only in the access section to the sea are the river beds obviously downcut. Because of the sluggishness of the runoffs and the vertical evaporation, the underground water is gradually mineralized, thus composing the highly mineralized water which is undrinkable by the population and the livestock.

Section Two Regional Geology and Hydrogeological Condition

I. Strata

The exposed strata in this area are mainly the Pre-Cambrian metamorphic system, Jurassic and Cretaceous systems of the Mesozoic Era and the Tertiary and the Quaternary systems of the Cenozoic Era. There is an extrusion of the volcanic rock of the Quaternary along the clastic zone in the Northern mountainous region. They will be expounded in details respectively as follows:

1. Pre-Cambrian metamorphic rocks

They are majorly distributed in the Hargeisa Region and in the mountainous area of the Northern Somalia, which are composed of quartz-feldspar gneiss, hornblende-feldspar gneiss, crystalline schist and phyllite. Intruded into them is such igneous rock body as granite gabbro, diorite, and quartz vein. They had been vehemently weathered and razed before the sediments of the Mesozoic Era.

2. the strata of Jurassic system

This set of strata is very little exposed in this area. At its bottom are gravel stone, sandstone, and limestone interbedded with mud. At its mid-upper part are very thick sedimentary deposits of carbonate rocks containing many marine fossils.

3. the Nubi sandstone of the Cretaceous

This layer is mainly within the Hargeisa Region and Burao Region with the western part the thickest--reaching 170-300 m. At its bottom is parti-coloured claystone; at its lower part is coarse-grained sandstone with gravels; at its midpart is feldspar-quartz sandstone; at its upper part is siliceous-cemented fine sandstone; at its mid-upper part is quartzite and on its top is yellowish shale with shelly fossils.

4. the Auradu limestone of Lower Eocene of the Tertiary Period

It is mainly dispersed in the mountainous area of the Northern Somalia and the Haud plateau, with a thickness of 120-200 m. At its bottom is gravel limestone; at its lower part are crystalline limestone and biogenetic limestone; at its midpart is limestone with chert nodules (their diameters range from 40 to 50 cm), at its upper part is argillaceous limestone and mudstone.

5. the gypsolyte of the Taleh suite of Mid-Eocene of the Tertiary Period

It is extensively exposed in the Ainabo and Las Anod-Taleh belt and the Halin-Erl Afwein belt. Around the Taleh village it is exposed more thoroughly. At its lower part is the thick gypsolyte interbedded with greyish green shale; at its midpart is gypsolyte of medium thickness with the interlayer of brown clay rock and at its upper part is the yellowish green shale with interlayers of crystalline gypsolyte. The occurrence is almost horizontal and through the erosion and denudation, it takes shape of table-like and mammillary hills with plenty of sinkholes along runoff belts which are like strings of beads. These sinkholes directly get the supply of the rain so they become the chief water sources for the local population and the livestock.

6. the Karkar-suite dolomitic limestone of Upper Eocene of the Tertiary Period

It is dispersed over the top of the Sawl plateau and over the plateau on both sides of the Nugal river valley. At its lower part occur the greyish white and greyish green mudstone and marl interbedded with calcareous sandstone which contain plentiful shelly fossils; at its mid-upper part occur the greyish white dolomitic limestone, and the dolomitite of chert stripes interbedded with the greyish white mudstone.

7. the sedimentary deposit of the Pleistocene of the Quarternary

This kind of deposit is composed of the Pre-Quarternary deposits through erosion, denudation and removal. Its lithology and thickness vary greatly with its depositional environment.

Western Part. In the river valleys of the metamorphic region to the north of Hargeisa, there exists a set of loose deposits of gravel sandstone, clay, sandy loam. It exceeds 200 m in thickness, thus forming the buried old channel, which serves as the main water source for Hargeisa.

Eastern Part. In the downcast river valleys of Ber-grassland-Waridad-Ban Ade-Tug Dher, there exists a set of greyish white gypsiferous fine sandstone, gravel-cemented stone, brown, grey-black mudstone, secondary gypsolyte and etc. which are 160-180 m thick.

In front of the Bossaso mountains, the Daban gravel stone forms a very thick alluvial fan with pebble gravels through erosion and transportation.

8. the sedimentary deposit of the Holocene of the Quarternary

This deposit originates from the alluvial-proluvial, marine and eolian sediments, whose lithology contains gravel sandstone, secondary cemented gravel stone, secondary gypsolyte and etc. They are mostly dispersed along the modern river beds and over the beach region, containing vadose water. They

requently become the important drinking water sources in the pastoral areas.

II. Structure and Tectonics

This area is part of the Eastern African-Arab Platform and its tectonism belongs to the platform type mainly characterized by the high-angled positive dislocation and the unobvious plicated structure.

The basement formed by the Pre-Cambrian metamorphic rocks was razed. Not until the Mesozoic Era did the Jurassic start sinking to receive the sediments. At its bottom was a set of sand gravel stone with interlayers of mudstone and limestone. During the Mid-Upper Jurassic, the carbonate rock was continually deposited to hundreds-of-meters thickness, containing plenty of marine fossils (brachiopod, cephalopod). In the end of the Jurassic, with the regression of the sea, the basement rose and denudated.

At the beginning of the Cretaceous, the basement sank once again but with various regressions, it formed the Nubi sandstone (Jesomma sandstone). And at the same time, it formed a series of NN-E faults along the Indian coast with the west side upwarping and the east side falling. Thus the downcast belt of the Indian Ocean was formed.

From the Palaeocene to the Eocene of the Tertiary Period, the North African Old Land rose and fell for another few times which caused the transgression and regression of the sea, thus forming the Aurodu-suite gravel limestone, the thick limestone and the chert nodule limestone of half-depthed and shallow marine facies. Apart from these, it also formed the Taleh-suite gypsolyte, marl, and mudstone of the lagoon facies. In the mid and later period of the Eocene, it sank once more, which caused the extensive transgression of the sea, thus forming the Karkar-suite biogenic limestone of the marine facies.

During the Oligocene and the Miocene, the Horn of Africa was extensively upwarping and developing in the NEE direction along the coasts of the Gulf of Aden. A series of positive faults formed the graben of the Gulf of Aden with a drop of 2000 m. Meanwhile, it developed in the NW direction into another series of faults with translational role, which are known as the tectonic zones of the Red Sea system, for example, the Sheikh zone, Erl Afwein zone and the Bossaso zone. The Hudun fracture was shaped approximately in this period, which caused the downcast river valleys of the Hudun mountain and Tug Dher.

The NEE-direction and the NW-direction fractures along the coast of the Gulf of Aden resulted in the extrusion of the volcanic rock, forming a set of basalt, rhyolite and andesite of the exposure of thermals. The volcanic activity continued until the beginning of the Quaternary.

III. Aquifer Formation

1. pore-crevice aquifer formation of the Nubi sandstone

The Nubi sandstone is composed of feldspar-quartz fine sandstone or medium- and coarse-grained sandstone with gravels. The roundness is very elaborate and it is with excellent infiltration. The water of this water-bearing formation on the piedmont zone falls into the category of underground water while, in Burao, it is grouped into the type of pressure water. Therefore, the water quality there is fine and the mineral intensity is about 1 g/l. The water discharge of a single well is 200-500 m³/day. The Nubi sandstone in Hargeisa City and in the area to its south is the most developed but the water quality is poor. As the water contains a mineral intensity of 3-5 g/l, it is unfit for drinking.

2. the karst crevice-cavern aquifer formation of the Taleh gypsolyte

Thick and medium-thicknessed sandstones, through tectonism and weathering, have many well-grown joints and crevices. As they have been corroded by the rainfall and the seasonal flood, they often form various-scaled sinkholes and caverns with the water quality as the type of $\text{SO}_4.\text{Cl}-\text{CaMg}$. Its mineral intensity and its wateriness are determined by the scope of the water catchment and by the circulation of the water.

3. the crevice-cavern aquifer formation of the Karkar-suite dolomitic limestone

In the Karkar-suite limestone, muded limestone, calcareous sandstone, dolomite, there are well-grown crevices and corroded holes. In both the valleys and the cutoff and semi-cutoff hollows on the Sawl plateau occurs the crevice-pore-cavern water, whose level is comparatively deep and whose wateriness is somewhat ungreat. The deepest level can reach 300 m (the well depth is 420 m in Rako-Kadmo). The yield of a single well is reached of 60-200 m^3/day with fine quality and a mineral intensity of 1.0-1.7 g/l.

4. the crevice aquifer formation of the gravel sandstone of the buried old channel

The alluvial deposit in the river beds of Hargeisa Region is quite developed. In the buried channels, the deepest alluvial deposit surpasses 200 m. The total thickness of the gravel sand, medium- and coarse-grained sand reaches 20-90 m. The water discharge of a single well is 800-1500 m^3/day (2214 m^3/day). The water quality is the HCO_3-Ca type with a mineral intensity of 0.2-0.5 g/l. It has become the precious water source for supplying the city population and the livestock.

In the downcast river valleys of the eastern part, occur the slightly cemented sandstone, gravel stone and gypsolyte containing pore water and crevice-cavern water. Because of

- the slow runoff and intense vertical evaporation, it gets highly mineralized and undrinkable for the population and
- the livestock. The pore water in the proluvial fan in front of the Bossaso mountain has a future for development.

-

5. the pore water of the alluvion in the modern riverbeds and the vadose water of the marine sediments and of the oelian sand barriers and sand hills have a fine quality, which are shallowly buried, possessing a brilliant future for development. The wells can be dug by hand and can serve as the water source for the scattered population.

- Besides, the bed rock crevice water in the tectonoclastic zone or the weathered clastic zone of metamorphic rocks and granite should not be neglected. In the suitable geological and geomorphic conditions, it can also become meaningful water source for supply. Though the karst of the Aurodu limestone is quite developed, it is a water infiltrating formation but not an aquifer formation because its exposition topography is higher.

- Section Three Division of Hydrogeological Sections

- I. The Hydrogeological Section of the Alluvial-Proluvial-Marine Coastal Plain of the Gulf of Aden

- 1, the inferior section of the pore water of the alluvial-proluvial gravel sandstone of Zeila-Berbera

- Many rivers originating from the southern mountainous area roam into the sea and they have formed the piedmont alluvial plain. The buried channels and the modern channels are deposited with sand and gravel sandstones in various depths. In the normal year the seasonal surface runoffs mostly turn into the underground runoffs. The underground water level is

getting from deep to shallow from the peidmont to the beach. The water quality is affected by the tides within the scope of 5-10 km near the sea and gradually gets mineralized. The underground water in this section has a bright future for development.

2. the inferior section of the pore water of the pebble sandstone of the Bossaso proluvial fan

As the Daban gravel stone on the piedmont in the northern part of Bossaso was greatly eroded, it was redeposited to form the piedmont proluvial fan with pebble gravel. The rainfall in the normal year is infiltrated to become the undercurrent. This water source can be under consideration for the supply for Bossaso.

II. The Hydrogeological Section of the Mountainous Area of the Northern Somalia

1. the inferior section of the crevice water of the gravel sand of the river valleys

The metamorphic basement between Ged debleh and Sheikh is covered with a set of alluvial deposits. The modern river beds and the buried channels are deposited with sand and gravel sand in various depths, containing plentiful pore water. Take Ged debleh water source for example, the yield of a single well is 2210 m³/day. In the metamorphic weathered clastic zone or in the metamorphic weathered tectonoclastic zone, there is also a watery sector which contains bedrock crevice water. It can serve as the water source for the population point or for the small towns. Generally speaking, it is preferable to dig shallow wells by hand, (equiped with hand-pumps). In case any wells be drilled in the tectonoclastic zone. there should be a large scope of enough water catchment.

2. the inferior section of the karst pore-cavern water of limestone and gypsolyte

Owing to the fine development of the NW fault zone, the karst crevices and caverns along the fault zone or along the secondary fractured zone in the river valleys are comparatively more developed. They have a great water yield and their water quality is determined by the lithology of their supply regions. For example, the Hukur well is drilled in the gypsiferous clastic zone, so its yield is 800-1000 m³/day with a mineral intensity of 3.4 g/l.

III. The Hydrogeological Section of the Northern Plateau of Somalia

1. the Hargeisa-Burao inferior section of the pore-crevice water of the Nubi sandstone

The Nubi sandstone in Hargeisa Region is buried 268 meters deep with a thickness of 370 m. The water level is deep and the quality is poor, so it is unfit for drinking.

In the vicinity of Burao, the Nubi sandstone is distributed from the northwest to the southeast looking like a horst. Its EW width reaches 15-20 km; its depth gets to 100-150 m with the water level 70-150 m deep. The discharge of a single well is 200-500 m³/day with a mineral intensity of about 1.0 g/l.

2. the inferior section of the pore water of Tug Dher-Nugal river valleys and of the highly mineralized karst cavern water of gypsolyte.

In the downcast river valleys on the eastern side of the Waridat-Ban Ade-Hudun fault, below the depth of 90-120 m, there is a set of sediments of fine sandstone, gypsiferous sandstone and clay rock, which are slightly consolidated and

which have a poor wateriness. Because of the slow runoffs, the horizontal mode of discharge is rather awkward. The underground water is gradually mineralized, falling into the Cl-Na, Cl-NaMg Ca type of highly mineralized water.

In the secondary gypsolyte and the secondary gypsiferous mudstone occur many well developed sinkholes. The water level, quantity and quality vary obviously with the supplement of the seasonal rainfall. These varied sinkholes become the water sources for the supply of the local population and the livestock.

3. the inferior section of the karst crevice-cavern water of the Karkar limestone on the Sawl plateau

The Karkar-suite strata are extensively exposed in the Sawl plateau. At its upper part occur dolomitic limestone and chert-stripped dolomite rock, which are hard, brittle, with well developed joints and crevices. It is easy for them to receive the supply of the rainfall. At its mid-lower part exist the mudstone interbedded with muded limestone, calcareous sandstone and the thick mudstone and shale. Under the favourable geomorphic conditions (for example, the river valleys, or semi-cutoff hollows), this aquifer formation often contains a certain quantity of karst crevice-pore water. The depth of its water level varies tremendously from 60 m to 140 m. (In some places, the water level is 300 m deep, for example, in Rako Kodma, the well is 420 m deep). The water discharge of a single well is 80-200 m³/day with fine water quality. It is fit for drinking. In the pastoral areas with exuberant herbage and sparse rainfall, it is very dear and precious though with a small water quantity.

4. the inferior section of the karst crevice-cavern water of limestone and gypsolyte in the piedmont river valleys
- Between the mountainous area in the North and the Sawl

plateau is developed a series of seasonal rivers, which are originated in the northwest but gradually turn in the south direction or in the east direction. In the rainy season, the flood from the mountainous area is gathering there and then flowing dispersively into the vast grassland. In some sectors of the rivers occur the exposed stratum and the minute faults, thus forming the watery sector of the karst crevice-cavern water. Take Erl Afwein and Darar weyne for example, the water quality and quantity are determined by the lithology of its aquifer formation.

Conclusion

1. In the northern part of Hargeisa Region or in the inferior section of the metamorphic crevice water and of the pore water of the gravel stone of the river valleys, the soil is very fertile. The rainfall is sufficient, so there exists a potentiality for the agricultural development. The metamorphic clastic zone and the buried channels are rich in the underground water source which can serve as the water source for the supply of the small towns, for the water quality is very good. In view of the above mentioned facts, it is preferable that there should be a detailed investigation and exploration. With regard to the gravel stones in the buried channels, it is very effective to have an exploration of vertical electrical sounding. As for the buried metamorphic clastic zone, it is better to adopt the exploration of the "quadripole-electrical profiling".
2. The pore water in the Nubi sandstone in the vicinity of Burao has a good quality and quantity. It will play a very important part in the development of Burao City. As for the distribution direction and scope of the Nubi sandstone, especially the extension scope of the NW and SE positions, there should be another further investigation and exploration.

3. On the vast lush plateau of Sawl, the Karkar limestone aquifer formation has a priority in being considered in order to tackle the problem of water supply for the pasture. Wells should be drilled in the valleys and hollows which have a large scope of water catchment.
4. On both sides of the Ainsbo-Gorowe highway and on the area to the south of the highway occur a series of NE river valleys in which there are sinkholes on surface like strings of beads. If wells are drilled to the depth of 100-200 m on the runoff zone, there is hope to obtain the water source of appropriate quality.
5. In the Tug Dher-Nugal downcast river valleys, the deep-water quality is poor, so it is unfit for drilling deep wells. As the shallow water has a great supersession, it is easy to receive the supplement of the rainfall. It is preferable to dig shallow wells on the runoff zone.

MAP OF HYDROGEOLOGICAL SECTIONS OF THE NORTHERN SOMALIA

Legend symbols for geological units and features.

QUATERNARY ALLUVIUM
 PLEISTOCENE
 MIOCENE
 MIOCENE-OLIGOCENE
 OLIGOCENE
 EOCENE
 PALEOCENE
 CRETACEOUS
 MIOCENE OLIGOCENE VOLCANICS
 PRE-CAMBRIAN
 BASEMENT COMPLEX

LEGEND

DEMARCATION LINE

CONTACT LINE

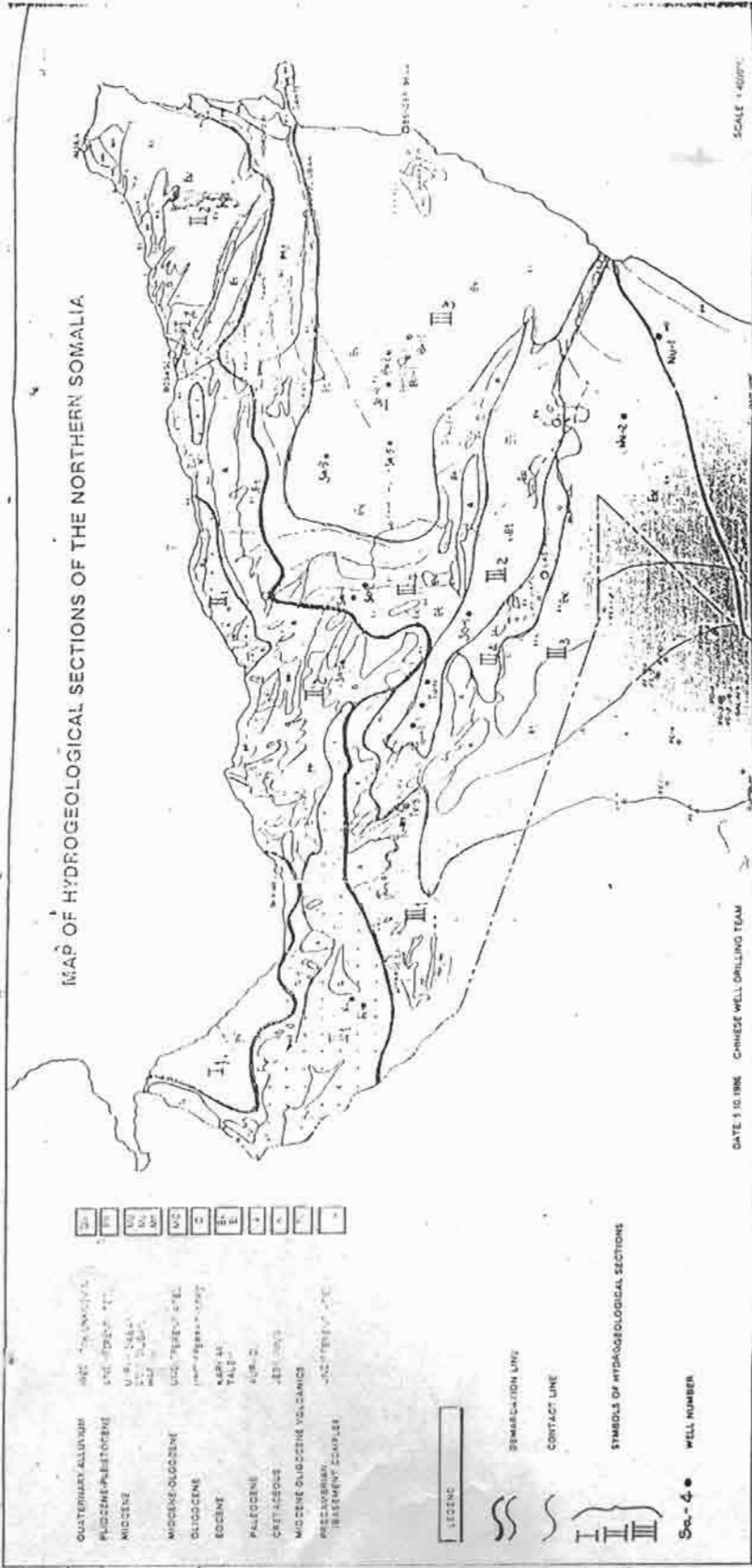
SYMBOLS OF HYDROGEOLOGICAL SECTIONS

So. 4

WELL NUMBER

DATE: 10.10.1986 CHINESE WELL DRILLING TEAM

SCALE: 1:600000



Well No: K11

Well location: at 1215m, 39 degrees of Well K7, Ged-debleh,
Hargeisa.

Construction date: December 6th, 1981 to January 10th, 1982

1, Lithological profile:

- 1, 0 - 31.90m: clayey sand: brown-yellow, with high silt content, slightly consolidated.
- 2, - 35.41m: medium-coarse sand with gravel: brown-yellow, light yellow-green, slightly consolidated.
- 3, - 38.29m: clay.
- 4, - 42.27m: basalt: grey and black, compact.
- 5, - 46.00m: clay.
- 6, - 63.50m: clayey sand: light yellow, with higher sand content, slightly consolidated, intercalated with thin layer of sand.
- 7, - 69.30m: medium-coarse sand: light brown-yellow, loose.
- 8, - 74.00m: clayey sand.
- 9, - 78.59m: medium-coarse sand with gravel.
- 10, - 86.00m: clayey sand: light yellow, with sand and clay/silt
- 11, - 88.65m: medium-fine sand.
- 12, - 94.00m: clayey sand: light yellow, slightly consolidated
- 13, - 103.00m: medium-coarse sand with gravel: brown-yellow, loose.
- 14, - 111.92m: medium-fine sand: light yellow, slightly consolidated.
- 15, - 116.74m: clayey sand.
- 16, - 133.50m: medium-coarse sand with gravel: light yellow, loose.
- 17, - 138.00m: clayey sand.
- 18, - 151.45m: medium-coarse sand with gravel: brown-red, loose.
- 19, - 156.20m: medium-fine sand.
- 20, - 163.05m: medium-coarse sand with gravel: light yellow, loose.
- 21, - 166.03m: granitic gneiss.

2, pumping test data:

- 1, Well depth: 162.85m
- 2, depth of screen: 74-159.85m
- 3, pumping equipment: air compressor
- 4, static water level: 43.05m
- 5, drawdown: 4.16m
- 6, well yield: 709m³/24hr
- 7, stability time: 43 hours and 10 minutes

3, data of simple water quality analysis:

1, physical property: colorless, odourless, smellless, clear.

2, Chemical composition:

| | |
|---------------------------------|------------|
| K ⁺ +Na ⁺ | 105.8mg/l |
| Ca ⁺⁺ | 46.09mg/l |
| Mg ⁺⁺ | 35.24mg/l |
| Cl ⁻ | 63.90mg/l |
| SO ₄ ^{''} | 33.62mg/l |
| HCO ₃ ['] | 262.39mg/l |
| CO ₃ ^{''} | 90.00mg/l |

3, Total dissolved solid: 0.506g/l

4, Total hardness: 15.58 (German hardness)

5, Permanent hardness: -

6, Temporary hardness: -

7, PH value: 8

Well No: K12

Well location: at 5074m, 32degrees of Well K11, Ged- debleh, Hargeisa

Construction date: January 30th, 1982 to February 20th, 1982

1, Lithological profile:

- 1, 0 - 3m: medium-coarse sand: light yellow-white, loose.
- 2, - 7m: clayey sand: brown-yellow, slightly consolidated.
- 3, - 18.34m: medium-coarse sand: light brown, loose.
- 4, - 26.00m: clayey sand: light brown-yellow, principal ingredient
: clay/silt, slightly consolidated.
- 5, - 41.51m: gravel with sand: light brown-yellow, 1-2cm in
diameter, good sorting, loose.
- 6, - 58.76m: clayey sand: light brown-yellow, principal ingredient
clay/silt, slightly consolidated.
- 7, - 63.36m: arenaceous clay: light brown with light green, principal
ingredient: clay/silt, slightly consolidated.
- 8, - 70.98m: fine sand: light brown with grey-green, loose.
- 9, - 73.00m: arenaceous clay.
- 10, - 90.43m: mica schist: grey-green with white, intense wea-
thering, harder lithological character on the bottom.

2, data of pumping test:

- 1, well depth: 51.66m
- 2, depth of screen: 9-41.51m
- 3, pumping equipment: air compressor
- 4, static water level: 6.05m
- 5, drawdown: 10.50m
- 6, well yield: 2016m³/24hrs
- 7, stability time: 42 hours and 25 minutes

3, data of simple water quality analysis:

1, Physical property: colorless, odourless, smellless, clear.

2, Chemical composition:

| | |
|---------------------------------|------------|
| K ⁺ +Na ⁺ | 117.3mg/l |
| Ca ⁺⁺ | 40.08mg/l |
| Mg ⁺⁺ | 25.54mg/l |
| Cl ⁻ | 21.30mg/l |
| SO ₄ ^{''} | 153.70mg/l |
| HCO ₃ ['] | 268.49mg/l |
| CO ₂ ['] | 30.00mg/l |

| | |
|------------------------------------|------------------------|
| 3, Total dissolved solids: | 0.52g/l |
| Total hardness: | 11.50(German hardness) |
| 5, Permanent hardness: | - |
| 5 , Temporary hardness: | - |
| 7, PH value | 7.8 |

Well No: K13

Well location : at 3750m,northeast of well K11,Ged-debleh,Hargeisa

Construction data:March 1st,1982to March 19th, 1982

1, Lithological profile:

- 1, 0 - 3m: medium-coarse sand:light yellow-white,with small gravel,loose.
- 2, - 8m: arenaceous clay:brown-yellow,principal ingredient clay/silt,slightly consolidated.
- 3, - 13m: clayey sand:brown-yellow,principal ingredient:clay/silt,slightly consolidated.
- 4, - 15m: medium-fine sand:brown-yellow,slightly consolidated.
- 5, - 24m: clayey sand:brown-yellow,principal ingredient: clay/silt,slightly consolidated.
- 6, - 36m: medium-coarse sand:brown-yellow,with small gravel loose.
- 7, - 41m: clayey sand:brown-yellow with grey-green,principal ingredient: clay/silt,with high content of sand.
- 8, - 44m: medium-fine sand:brown-yellow with white,with small gravel,loose.
- 9, - 56m: clayey sand:brown-yellow,consolidated,principal ingredient:clay/silt.
- 10, - 62m: medium-coarse sand:grey,with gravel,loose.
- 11, -74.12m:clayey sand:brown-yellow,principal ingredient: clay/silt,slightly consplidated.
- 12, - 76.4m: medium-coarse sand:light yellow,grey,with gravel loose.
- 13, - 87.0m: arenaceous clay:brown-yellow,principal ingredient: clay/silt,slightly consolidated.
- 14, - 95.4m: medium-coarse sand:grey,with small gravel,loose.
- 15, -101.31m: granitic gneiss : flesh red.

2, pumping test data:

- 1, well depth : 93.75m
- 2, depth of screen: 24-87.75m
- 3, pumping equipment: air compressor
- 4, static water level: 19.42m

- 5, drawdown: 22.45m
6, well yield: 968.4m³/24hrs
7, stability time: 42 hours and 10 minutes
- 3, data of simpl water quality analysis:
- 1, Physical property: colorless, odourless, smelless, clear.
2, Chemical composition.:
- | | |
|---------------------------------|------------|
| K ⁺ +Na ⁺ | 126.04mg/l |
| Ca ⁺⁺ | 32.06mg/l |
| Mg ⁺⁺ | 19.46mg/l |
| Cl ⁻ | 63.19mg/l |
| SO ₄ ^{''} | 14.41mg/l |
| HCO ₃ ⁻ | 402.73mg/l |
| CO ₃ ^{''} | - |
- 3, Total dissolved solids: 0.46g/l
4, Total hardness: 9.0(German hardness)
5, Permanent hardness: -
6, Temporary hardness: -
7, PH value: 8

Well No: K14

Well location : at 1498m, 34 degrees of well K11, Ged-debleh, Hargeisa

Construction date; April 6th, 1982 to April 30 th, 1982

1, Lithological profile :

- 1, 0 - 3.5m: medium-coarse sand.
- 2, - 15.85m: arenaceous clay: light brown-yellow, principal ingredient: clay/silt, slightly consolidated.
- 3, - 18.25m: clayey sand.
- 4, - 21.15m: medium-fine sand: light brown-yellow, loose.
- 5, - 28.35m: arenaceous clay: brown-red, principal ingredient: clay/silt, slightly consolidated.
- 6, - 30.60m: medium-fine sand: brown-yellow, loose.
- 7, - 43.27m: arenaceous clay: light brown-yellow, slightly consolidated, principal ingredient: clay/silt.
- 8, - 59.00m: clayey sand: light brown-yellow, with high content of fine sand and clay/silt, slightly consolidated.
- 9, - 64.00m: medium-coarse sand: grey-yellow, grey, loose.
- 10, - 76.00m: clayey sand: light brown-yellow, with high content of clay/silt, slightly consolidated.
- 11, - 87.00m: medium-coarse sand with gravel: brown-yellow, gravel diameter: 1-3cm, loose.
- 12, - 98.00m: clayey sand: brown-yellow with slightly grey-green, with fine sand, slightly consolidated.
- 13, - 126.00m: medium-coarse sand with gravel : light brown-yellow, with gravel, 1-3cm in diameter consolidated.
- 14, - 132.00m: clayey sand: brown-yellow, slightly consolidated.
- 15, - 143.00m: medium-coarse sand with gravel: grey, light brown-yellow, loose.
- 16, - 144.92m: clayey sand.

2, Pumping test data:

- 1, well depth : 142.24m
- 2, depth of screen : 59-139.24m
- 3, pumping equipment : air compressor
- 4, static water level: 23.20m
- 5, drawdown : 11.54m
- 6, well yield : 1538m³/24hrs
- 7, stability time : 40 hours and 5 minutes

3, Data of simple water quality analysis :

1, Physical property: colorless, odourless, smellless, clear.

2, Chemical composition :

| | |
|---------------------------------|-----------------------|
| K ⁺ +Na ⁺ | 140.30mg/l |
| Ca ⁺⁺ | 68.14mg/l |
| Mg ⁺⁺ | 23.1mg/l |
| Cl ⁻ | 71.00mg/l |
| SO ₄ ^{''} | 129.68mg/l |
| HCO ₃ ['] | 336.12mg/l |
| CO ₃ ^{''} | 33.00mg/l |
| 3, Total dissolved solids: | 0.64g/l |
| 4, Total hardness: | 14.7(German hardness) |
| 5, Permanent hardness: | - |
| 6, Temprrary hardness: | 14.7 |
| 7, PH value : | 7.6 |

Well No : K15

Well l ocation :at 950m,north of Well K14, Ged-debleh,Hargeisa

Construction date: May 27th, 1982 to June 11th, 1982

1, Lithological profile :

- 1, 0 - 22.00m: clayey sand with thin layey of sand.
- 2, - 28.00m: fine silt.
- 3, - 34.50m; arenaceous clay.
- 4, - 38.00m: coarse gravel with sand.
- 5, - 44.50m: arenaceous clay.
- 6, - 56.00m: clayey sand with thin layer of sand.
- 7, - 64.00m: coarse gravel with sand.
- 8, - 69.00m: clayey sand.
- 9, - 72.00m: medium sand.
- 10, - 83.00m: coarse gravel with sand.
- 11, - 87.00m: pelitic medium-fine sand.
- 12, - 94.00m: clayey sand.
- 13, - 97.00m: fine sand.
- 14, - 115.00m: coarse gravel with sand.
- 15, - 119.00m: clayey sand.
- 16, - 123.77m. pelitic gravel.

2, Pumping test data :

- 1, well depth : 117.79m
- 2, depth of screen: 34.50-115.0m
- 3, pumping equipment: air compressor
- 4, static water level: 23.02m
- 5, drawdown : 16.65m
- 6, well yield : 1054m³/24hrs
- 7, stability time : 40 hours and 45 minutes

3, data of simpl water quality analysis :

- 1, Physical property : colorless, odourless, smelles, clear.

2, Chemical composition:

| | |
|---------------------------------|-------------------------|
| K ⁺ +Na ⁺ | 103.50mg/l |
| Ca ⁺⁺ | 46.09mg/l |
| Mg ⁺⁺ | 31.62mg/l |
| Cl ^{''} | 78.10mg/l |
| SO ₄ ^{''} | 76.85mg/l |
| HCO ₃ ['] | 317.30mg/l |
| CO ₃ ^{''} | 12.00mg/l |
| 3, Total dissolved solids : | 0.5g/l |
| 4, Total hardness: | 13.74 (German hardness) |
| 5, Permanent hardness: | 0 |
| 6, Temporary hardness: | 13.74 |
| 7, PH value : | 8.4 |

-Well No. : K16

Well location: at 850m, southwest of Well K14, Ged-debleh, Hargeisa

Construction date: June 23rd, 1982 to July 10th, 1982

1, Lithological profile :

- 1, 0 - 8.00m: clayey sand.
- 2, - 21.00m: arenaceous clay.
- 3, - 29.80m: fine silt.
- 4, - 32.40m: basalt.
- 5, - 37.00m: medium coarse sand.
- 6, - 49.00m: clayey sand.
- 7, - 56.00m: arenaceous clay.

- 8, - 72.00m: silt intercalated with thin layer of clayey sand
- 9, - 77.00m: clayey sand.
- 10, - 80.00m: fine sand.
- 11, - 86.00m: clayey sand.
- 12, - 90.00m: fine sand.
- 13, - 99.50m: interbedded with medium sand and clayey sand.
- 14, - 109.00m: clayey sand.
- 15, - 122.00m: medium coarse sand with gravel.
- 16, - 129.00m: arenaceous clay.
- 17, - 133.00m: medium-coarse sand with gravel.
- 18, - 137.00m: clayey sand.
- 19, - 153.00m: medium-coarse sand with gravel.
- 20, - 154.10m: granitic gneiss.

2, Pumping test data :

- 1, well depth : 148.63m
- 2, depth of screen : 62-145.63m
- 3, pumping equipment: air compressor
- 4, static water level: 30.00m
- 5, drawdown : 5.88m
- 6, well yield : $1679\text{m}^3/24\text{hrs}$
- 7, stability time : 41 hours and 20 minutes

3, data of simpl water quality analysis :

- 1, Physical property : colorless, odourless, smellless, clear
- 2, Chemical composition :

| | |
|----------------------------------|------------|
| K ⁺ + Na ⁺ | 94.30mg/l |
| Ca ⁺⁺ | 42.08mg/l |
| Mg ⁺⁺ | 38.91mg/l |
| Cl ⁻ | 81.65mg/l |
| SO ₄ ^{''} | 9.61mg/l |
| HCO ₃ ['] | 360.02mg/l |
| CO ₃ ^{''} | 30.00mg/l |

- 3, Total dissolved solids : 0.5g/l
- 4, Total hardness : 14.86 (German hardness)
- 5, Permanent hardness : -
- 6, Temporary hardness : 14.86
- 7, PH value : 8.4

Well No. Tu - 1

Well location: at 1000m, southeast of Dubur, Sheikh District

Tug Der Region.

Construction date: November 20th, 1982 to December 6th, 1982

, Lithological profile:

1. 0 - 14.00m: medium sandstone: light yellow, loose,
ingredient: quartz, feldspar, pelitic
cementation.
2. - 24.50m: rock clay of mixed colors: blue-grey and
rusty into mixed colors, with gravel, close
texture, plastic.
3. - 26.50m: sandstone
4. - 30.50m: rock clay: blue-grey, with gravel.
5. - 33.50m: fine sandstone: grey-yellow, with pelite.
6. - 36.00m: rock clay.
7. - 37.20m: coarse sandstone: ingredient: quartz, feldspar.
8. - 45.00m: rock clay of mixed colors: purple, with
gravel, plastic.
9. - 48.17m: granite: flesh red, ingredient: quartz, feld-
spar, mica. granulitic texture, massive
structure, hard.

2, Pumping test data:

1. well depth: 45.97m
2. depth of screen: 3.41-37.32m
3. pumping equipment: air compressor
4. static water level: 3.90m
5. drawdown: 24.90m

6. well yield: 136.20m³/24hrs

7. stability time: 24 hours

3, Data of simple water quality analysis:

1. Physical property: colorless, odourless, smellless, clear.

2. Chemical composition:

| | |
|----------------------------------|-------------|
| K ⁺ + Na ⁺ | 253.00 mg/l |
| Ca ⁺⁺ | 34.07 mg/l |
| Mg ⁺⁺ | 57.15 mg/l |
| Cl ⁻ | 173.95 mg/l |
| SO ₄ ^{''} | 216.14 mg/l |
| HCO ₃ ['] | 366.12 mg/l |
| CO ₃ ^{''} | 60.00 mg/l |

3. Total dissolved solids: 0.98 g/l

4. Total hardness: 17.95 (German hardness)

5. Permanent hardness: 1.12 (German hardness)

6. Temporary hardness: 16.83 (German hardness)

7. PH value 8.4

4, Well facilities:

1. type of casing: seamless pipe, thread connection.

standard: 168 mm (outside diameter), 152 mm (inside diameter)

2. pump brand: Caprari E6R 30/36 + C615 (Italy)

standard: 1/1" 100/230 m355/170

3. generator brand: DEUTZ F31912 (Germany)

standard: 5kW 1500/min

4. discharge pipe: 2" iron pipe

- depth of pump: 44.50 m
5. water tank structure: reinforced concrete volume: 5.5 m^3
6. water pond structure: reinforced concrete volume:
 $5.0 \times 0.4 \times 0.28 \text{ m}^3$
7. pumping house structure: galvanized iron sheet and timber
frame, area: 9 m^2

Well No. : Tu - 2

Well location : at 2500m, southwest of Dubur, Sheikh District,
Tug Der Region.

Construction date : December 14th, 1982 to January 11th, 1983

1. Lithological profile :

1. 0 - 6.40m: clay: brown, with gravel and sand.
2. - 18.00m: gravel with sand: ingredient: quartz, feldspar and black magnetite, rounded gravel.
3. - 22.00m: clay with gravel: grey, angular gravel.
4. - 52.00m: medium-fine sandstone: light yellow-brown, with small gravel, intercalated with multilayer mudstone.
5. - 60.00m: mudstone of mixed colors: grey and mixed with purple, brown and brown-yellow.
6. - 76.00m: medium-coarse sandstone; light yellow-brown, principal ingredient: quartz, angular.
7. - 81.00m: mudstone of mixed colors: purple-grey, with content of sand.
8. - 96.00m: medium sandstone: light yellow-brown,

poor sorting, with gravel.

9. -117.28m: mudstone of mixed colors: purple-grey, apricot,
• rusty.

2, Pumping test data:

- | | |
|------------------------|-----------------------------|
| 1. well depth: | 106.05m |
| 2. depth of screen: | 5.33-97.27m |
| 3. pumping equipment: | air compressor |
| 4. static water level: | 49.10m |
| 5. drawdown: | 11.35m |
| 6. well yield: | 94.56 m ³ /24hrs |
| 7. stability time: | 24 hours |

3, Data of simple water quality analysis:

1. Physical property: colorless, odourless, smellless, clear.
2. Chemical composition:

| | |
|----------------------------------|------------------------|
| K ⁺ + Na ⁺ | 154.10 mg/l |
| Ca ⁺⁺ | 28.06 mg/l |
| Mg ⁺⁺ | 21.89 mg/l |
| Cl ⁻ | 60.35 mg/l |
| SO ₄ ^{''} | 139.29 mg/l |
| HCO ₃ ['] | 213.57 mg/l |
| CO ₃ ^{''} | 54.00 mg/l |
| 3. Total dissolved solids: | 0.56 g/l |
| 4. Total hardness: | 9.00 (German hardness) |
| 5. Permanent hardness: | 0 |
| 6. Temporary hardness: | 9.00 (German hardness) |
| 7. PH value | 8.2 |

4, Well facilities:

1. type of casing: seamless pipe, thread connection.
standard: 168 mm (outside diameter), 152mm (inside diameter)
2. pump brand: Caprari E6R 30/36 + C615 (Italy)
standard: 1/1 100/230 m³55/170
3. generator brand: DEUTZ F31 912 (Germany)
standard: 34HP 25KW A6270 1599l/min
4. discharge pipe: 2" iron pipe
depth of pump: 78 m
5. water tank structure: reinforced concrete
volume: 5.5 m³
6. water pond structure: reinforced concrete
volume: 5.0x0.4x0.28 m³
7. pumping house structure: galvanized iron sheet and
timber frame
area: 9.0 m²

Well No.: Tu - 3

Well location : at about 100m, on the east side of the secondary, north of Burao.

Construction date: January 14th, 1984 to February 21st, 1984

1, Lithological profile:

1. 0 - 18.00m: arenaceous clay: brown-red, principal ingredient: clay/silt.
2. - 24.00: gravel with sand: light brown, rounded gravel, loose.
3. - 71.00m: argillaceous limestone: grey, purple, breccia texture, ingredient: argillo-calcareous.
4. - 74.00m: argillaceous sandstone: rusty yellow.
5. - 86.50m: argillaceous limestone: ingredient: argillo-calcareous, plastic.
6. - 88.00m: sandstone.
7. - 90.50m: argillaceous limestones: grey, grey-green, ingredient: argillo-calcareous.
8. - 92.50m: sandstone: brown-red, rusty yellow.
9. - 124.00m: arenaceous mudstone: rusty yellow, principal ingredient: pellite, with content of sand partially.
10. - 139.00m: sandstone: white, fine sand mainly, loose, ingredient: quartz, feldspar secondly.
11. - 143.00m: mudstone: grey, ingredient: pellite, plastic.
12. - 172.00m: sandstone; light brown-yellow, loose, intercalated with several layers of mudstone.
13. - 189.00m: shale: rusty yellow, grey-green, grey-black,

clear bedding, with fossil.

14. - 197.00m: mudstone: grey, light, plastic.
- 15. - 201.41m: gypsum rock: grey, grey-black, thick bedded.

2, Pumping test data:

- | | |
|------------------------|---------------------------|
| 1. well depth: | 200.80m |
| 2. depth of screen: | 124-172.00m |
| 3. pumping equipment: | air compressor |
| 4. static water level: | 103.02m |
| 5. drawdown: | 1.62m |
| 6. well yield: | 220 m ³ /24hrs |
| 7. stability time: | 8 hours |

3, Data of simple water quality analysis:

1. Physical property: colorless, odourless, smellless, clear.

2. Chemical composition:

| | |
|----------------------------------|-------------|
| K ⁺ + Na ⁺ | 164.01 mg/l |
| Ca ⁺⁺ | 118.64 mg/l |
| Mg ⁺ | 43.54 mg/l |
| Cl ⁻ | 342.93 mg/l |
| SO ₄ ^{''} | 113.83 mg/l |
| HCO ₃ ['] | 234.32 mg/l |
| CO ₃ ^{''} | 24.00 mg/l |

- | | |
|----------------------------|-------------------------|
| 3. Total dissolved solids: | 0.93 g/l |
| 4. Total hardness: | 26.64 (German hardness) |
| 5. Permanent hardness: | 15.87 (German hardness) |
| 6. Temporary hardness: | 10.77 (German hardness) |
| 7. PH value | 8.1 |

1, Well facilities:

1. type of casing: plastic pipe, thread connection.

standard: 8", 200mm in diameter

2. pump brand: Caprari E6R 30/36 + C615 (Italy)

standard: 1/1 100/230 m355/170

3. generator brand: DEUTZ F31 912 (Germany)

standard: 34HP 25KW A6270

4. discharge pipe: 2" iron pipe

depth of pump: 150m

5. water tank structure: reinforced concrete

volume: 5.5 m³

6. water pond structure: reinforced concrete

volume: 5.0 x 0.4 x 0.28 m³

7. pumping house structure: galvanized iron sheet and timber
frame.

area: 9 m²

Well No. : Tu - 4

Well location: at 1000m, south Check-point, southeast of Burao.

Construction date: February 8th, 1984 to February 22nd, 1984

4. Lithological profile:

1. 0 - 25.00m: arenaceous clay: yellow-brown, ingredient:
quartz, feld-spar, limestone debris, loose.
2. - 28.00m: arenaceous rock with gravel: loose.
3. -- 48.00m: pelitic limestone with sand: grey, ingredient
of sand: quartz, feldspar.
4. - 68.00m: mudstone: red-brown and mixed colors, with
fine and smooth strain-slip section.
5. - 86.70m: pelitic limestone with sand: with sand,
gravel, good roundness.
6. - 109.00m: limestone of chert nodules: rich in chert
nodules on the top, hard, 5-10 cm in diameter.
7. - 112.00m: shale: yellow, developed foliation.
8. - 123.00m: sandstone: grey, ingredient of sand: quartz
feldspar, with small content of gravel.
9. - 185.71m: sandstone: grey, medium sized sand mainly,
fine gravel occasionally.

2. Pumping test data:

1. well depth: 185.61m
2. depth of screen: 114.25-180.94m
3. pumping equipment: air compressor
4. static water level: 90.29m
5. drawdown: 0.85m

6. well yield: 242 m³/24hrs

7. stability time: 9 hours and 25 minutes

3, Data of simple water quality analysis:

1. Physical property: colorless, odourless, smellless, clear.

2. Chemical composition:

| | |
|----------------------------------|-------------|
| K ⁺ + Na ⁺ | 123.97 mg/l |
| Ca ⁺⁺ | 163.13 mg/l |
| Mg ⁺⁺ | 63.96 mg/l |
| Cl ⁻ | 386.95 mg/l |
| SO ₄ ^{''} | 136.89 mg/l |
| HCO ₃ ['] | 258.73 mg/l |
| CO ₃ | 24.00 mg/l |

- 3, Total dissolved solids: 1.03 g/l

4. Total hardness: 37.6 (German hardness)

- 5. Permanent hardness: 25.7 (German hardness)

6. Temporary hardness: 11.9 (German hardness)

- 7. PH value 8.1

4, Well facilities:

1. type of casing: seamless pipe, thread connection.

standard: 168mm (outside diameter), 152mm (inside diameter).

2. pump brand: Caprari E6R 30/36 + C615 (Italy)

standard: 1/1 100/230 M 355/170

3. generator brand: DEUTZ F31 912 (Germany)

standard: 34 HP 25 KW A 6270 1500 l/min

4. discharge pipe: 2" iron pipe

depth of pump: 132m

5. water tank structure: reinforced concrete
volume: 5.5 m^3
6. water pond structure: reinforced concrete
volume: $5.0 \times 0.4 \times 0.28 \text{ m}^3$
7. pumping house structure: galvanized iron sheet and
timber frame
area; 9 m^2

Well No. : Tu - 5

Well location: at 6 km, north river bank, west of Burao.

Construction date: March 5th, 1984 to March 25th, 1984

1. Lithological profile:

1. 0 - 30.80m: arenaceous clay: brown-red, principal ingredient: clay/ silt, with small content of sand, viscosity.
- 46.30m: conglomerate: grey with rusty-yellow, gravel of good roundness, argillo-calcareous cementation.
- 50.12m: mudstone: purple, principal ingredient: clay/ silt, with chalybeate on the fracture section.
- 59.12m: argillaceous sandstone: brown-yellow, with grey, ingredient: feldspar, quartz, argillo-calcareous cementation.
5. -- 65.74m: mudstone: purple with white stripes, ingredient: clay/silt, smooth feeling on the compressive section.

6. 0 - 78.34m: mudstone with gravel: purple with grey, most gravel are calcareous nodules, others pellite.
7. - 103.23m: argillaceous limestone with gravel: grey with rusty yellow, most gravel with angles, argillo-calcareous cementation.
8. - 114.07m: arenaceous mudstone: rusty-red with grey, principal ingredient: pellite, with coarse sand grains.
9. - 125.34m: rock clay: brown-red, smooth, principal ingredient: clay/silt, plastic.
10. - 142.50m: argillaceous limestone: grey, ingredient: argillo- calcareous, with small content of chert, with small cavities.
11. - 157.11m: arenaceous mudstone: brown-red, grey, principal ingredient: pellite, with small content of sand grains.
12. - 171.32m: sandstone: grey, medium-fine grains, principal ingredient: quartz.loose.
13. - 189.73m: mudstone:grey, principal ingredient: pellite with intense plasticity and smooth feeling.
14. - 193.73m: sandstone: principal ingredient: quartz, feldspar, loose.
15. - 198.23m: arenaceous mudstone:with small content of sand.
16. - 214.79m: sandstone: grey with rusty yellow, more coarse sand grains, loose.

17. - 218.50m: greywacke: grey with rusty yellow, ingredient: quartz, feldspar, calcareous cementation and with solution cavities, harder lithological characters.

2, Pumping test data:

- | | |
|------------------------|---------------------------|
| 1. well depth: | 218.40m |
| 2. depth of screen: | 157-215.40m |
| 3. pumping equipment: | air compressor |
| 4. static water level: | 112.20m |
| 5. drawdown: | 7.44m |
| 6. well yield: | 158 m ³ /24hrs |
| 7. stability time: | 8 hours and 30 minutes |

3, Data of simple water quality analysis:

1. Physical property: colorless, odourless, smellless, clear.
2. Chemical composition:

| | |
|----------------------------------|-------------|
| K ⁺ + Na ⁺ | 269.10 mg/l |
| Ca ⁺⁺ | 189.18 mg/l |
| Mg ⁺⁺ | 34.33 mg/l |
| Cl ⁻ | 568.00 mg/l |
| SO ₄ ^{="} | 118.15 mg/l |
| HCO ₃ ⁻ | 295.34 mg/l |
| CO ₃ ^{="} | 19.20 mg/l |

- | | |
|----------------------------|-------------------------|
| 3. Total dissolved solids: | 1.35 g/l |
| 4. Total hardness: | 34.32 (German hardness) |
| 5. Permanent hardness: | 20.75 (German hardness) |
| 6. Temporary hardness: | 13.57 (German hardness) |

7. PH value 8.1

4, Well facilities:

- 1. type of casing: seamless pipe, thread connection.
 - standard: 168mm (outside diameter), 152mm (inside diameter)
- 2. pump brand: KSB CORA 10 -199/23
 - standard: (Q 6 - 14 m³/h, H 210 - 150 m)
- 3. generator brand: ATALANTA VOLCAN ML 250 (England)
 - standard: PHASE 3, HZ 50, RPM 1500, KVA 25,
AMPS 38, VOLTS 380/220
- 4. discharge pipe: 2" iron-pipe
- depth of pump: 210 m
- 5. water tank structure: reinforced concrete
 - volume: 5.5 m³
- 6. water pond structure: reinforced concrete
 - volume: 5.0 x 0.4 x 0.28 m³
- 7. pumping house structure: galvanized iron sheet and
timber frame
 - area: 9 m²

Well No.: Tu - 6

Well location: at 4.5 km, north of Cahlkabood, Odweina,

Tug Der Region

Construction: June 1st, 1983 to July 1st, 1983

Lithological profile:

1. 0 - 37.00m: arenaceous clay: intercalated with layer of conglomerate with sand, brown-red.
2. - 50.00m: limestone: yellow-grey, pure on the top, with pellite on the bottom, with chert nodules.
3. - 62.00m: pellitic limestone: brown-yellow, with more pellite.
4. - 71.50m: calcareous sandstone: brown-yellow, calcareous cementation, solution cavities can be seen.
5. - 85.00m: shale: grey-yellow intercalated with less purple-grey, clear bedding, with ferromanganese nodules on the bedding surface.
6. - 118.00m: fine sandstone: light yellow, principal ingredient: quartz, small gravel occasionally.
7. - 122.00m: fine sandstone: light yellow, with higher content of clay/silt.
8. - 127.00m: medium-fine sandstone: light yellow.
- 131.00m: rock clay: yellow.
9. - 135.00m: fine sand: yellow.
- 139.50m: rock clay.
- 150.00m: medium fine sandstone: white-light yellow.

with more coarse sand grains and gravel inside.

13. - 152.06m: rock clay.
14. - 164.00m: medium sandstone: yellow, ingredient: quartz.
15. - 169.02m: fine sandstone: yellow.
16. - 177.50m: coarse sandstone and coarse sandstone with
gravel: white, light yellow.

2, Pumping test data:

1. well depth: 164.00m
2. depth of screen: 85-160m
3. pumping equipment: air compressor
4. static water level: 108.03m
5. drawdown: 23.30m
6. well yield: 39.40 m³/24hrs
7. stability time: 15 hours and 10 minutes

3, Data of simple water quality analysis:

1. Physical property: colorless, odourless, smellless, clear.
2. Chemical composition:

| | |
|----------------------------------|-------------|
| K ⁺ + Na ⁺ | 184.00 mg/l |
| Ca ⁺⁺ | 30.06 mg/l |
| Mg ⁺⁺ | 14.59 mg/l |
| Cl ⁻ | 39.05 mg/l |
| SO ₄ ^{''} | 220.94 mg/l |
| HCO ₃ ['] | 305.10 mg/l |
| CO ₃ ^{''} | - |

3. Total dissolved solids: 0.64 g/l
4. Total hardness: 10.37 (German hardness)

5. Permanent hardness: 10.37 (German hardness)
6. Temporary hardness: 10.37 (German hardness)
7. PH value: 7.0

, Well facilities:

1. type of casing: seamless pipe, thread connection.
standard: 168 mm (outside diameter), 152 mm (inside diameter)
2. pump brand: KSB CORA 10-199/23
standard: Q 6 - 14 m³/h, H 210 - 150 m.
3. generator brand: ATALANTA VOLCAN ML 250 (England)
standard: PHASE 3, HZ 50, RPM 1500, KVA 25, AMPS 38,
VOLTS 380/220
4. discharge pipe: 2" iron pipe
depth of pump: 160 m
5. water tank structure: reinforced concrete
volume: 5.5 m³,
6. water pond structure: reinforced concrete
volume: 5.0 x 0.4 x 0.28 m³
7. pumping house structure: galvanized iron sheet and
timber frame
area: 9 m²

Well No.: Tu - 7

Well location: at 11 km, south-west of Burao.

Construction date: May 14th, 1984 to May 26th, 1984.

Lithological profile:

1. 0 - 17.43m: arenaceous clay: brown-yellow, principal ingredient: clay/silt, with sand grains.
2. - 97.00m: calcareous mudstone: brown-yellow, grey, etc. intercalated with gravel, calcium partially.
3. - 101.00m: sandstone: grey, purple- brown, medium-fine sand maily, loose.
4. - 104.00m: shale; grey, light yellow, pellicitic texture, not very obvious bedding.
5. - 107.05m: greywacke: grey, purple-brown, medium-fine grains, calcium-shalybeate cementation, hard.
6. - 113.31m: fine siltstone: grey, principal ingredient: fine sand grains, loose.
7. - 124.83m: greywacke: white with light yellow, calcareous-silicon cementation, hard.
8. - 133.31m: medium-coarse sandstone: white-light yellow, principal ingredient: coarse grains of quartz, loose.
9. - 137.00m: mudstone: grey, principal ingredient: pellicite.
10. - 168.75m: medium-coarse sandstone: grey, with gravel, principal ingredient of sand is quartz. loose.
11. - 170.00m: greywacke.
12. - 176.00m: medium-coarse sandstone: looser, coarse grains, principal ingredient: quartz.

13. - 185.00m: greywacke: principal ingredient: quartz,
calcareous cementation, hard.

2, Pumping test data:

- | | |
|------------------------|---------------------------|
| 1. well depth: | 184.66m |
| 2. depth of screen: | 112.00-180.66m |
| 3. pumping equipment: | air compressor |
| 4. static water level: | 108.74m |
| 5. drawdown: | 3.95m |
| 6. well yield: | 220 m ³ /24hrs |
| 7. stability time: | 8 hours |

3, Data of simple water quality analysis:

1. Physical property: colorless, odourless, smelless, clear.
2. Chemical composition:

| | |
|----------------------------------|------------------------|
| K ⁺ + Na ⁺ | 266.80 mg/l |
| Ca ⁺⁺ | 49.30 mg/l |
| Mg ⁺⁺ | 38.67 mg/l |
| Cl ⁻ | 174.66 mg/l |
| SO ₄ ^{="} | 405.50 mg/l |
| HCO ₃ ⁻ | 203.81 mg/l |
| CO ₃ ^{="} | 18.00 mg/l |
| 3. Total dissolved solids: | 1.05 g/l |
| 4. Total hardness: | 15.8 (German hardness) |
| 5. Permanent hardness: | 6.4 (German hardness) |
| 6. Temporary hardness: | 9.4 (German hardness) |
| 7. PH value: | 8.1 |

4, Well facilities:

1. type of casing; seamless pipe, thread connection.

- standard: 168mm (outside diameter), 152mm (inside diameter).
2. pump brand: KSB CORA 10 - 199/23
standard Q 6 - 14 m³/h, H 210 -150 m
3. generator brand: ATALANTA : VOLCAN ML 250 (England)
standard: PHASE 3, HZ 50, RPM 1500, KVA 25, AMPS 38
VOLTS 380/220
4. discharge pipe: 2" iron pipe
depth of pump: 180m
5. water tank structure: reinforced concrete
volume: 5.5 m³
6. water pond structure: reinforced concrete
volume: 5.0 x 0.4x 0.28 m³
7. pumping house structure: galvanized iron sheet and timber
frame.
area: 9 m²

Well No.: Tu - 8

Well location: at 9 km, north river bank, southeast of Burao.

Construction date: November 5th, 1983 to November 29th, 1983.

Lithological profile:

1. 0 - 7.70m: gravel with sand: light yellow-brown, loose,
principal ingredient: medium-coarse sand,
with gravel.
2. - 17.80m: arenaceous clay: brown-yellow, slightly
consolidated, with calcareous nodules.
3. - 21.20m: gravel layer: loose, gravel of good roundness.
4. - 45.20m: sandstone with gravel: rusty yellow,

ingredient of sand: quartz, feldspar, with calcareous and gravel cementation.

5. - 66.00m: limestone: grey, with pellite, small cavities can be seen on the bedding surface.
6. - 79.00m: argillaceous limestone: grey, with much pellite, with chert nodules on the bottom.
7. - 95.50m: limestone of chert nodules: grey, close, hard, with small solution cavities.
8. - 107.00m: argillaceous limestone: grey, with high content of mud, soft.
9. - 143.60m: limestone of chert nodules: grey, yellow-brown, hard, with big chert nodules.
10. - 150.60m: argillaceous limestone: grey, grey-green, ingredient: argillo-calcareous, smooth feeling on the cross section.
11. - 165.00m: dissolutive limestone: grey, pure, with small content of chert, developed solution cavities.
12. - 173.00m: shale: light yellow, developed bedding, with ferromanganese nodules.
13. - 213.96m: medium sandstone: grey, with yellow-brown, ingredient: medium-coarse grains, quartz, feldspar, calcareous-cementation.

, Pumping test data:

1. well depth 213.73 m
2. depth of screen: 160-210 m
3. pumping equipment: air compressor
4. static water level: 73.82 m

5. drawdown: 6.02 m
6. well yield: 256.56 m³/24hrs
7. stability time: 8 hours and 55 minutes

3. Data of sample water quality analysis:

1. Physical property: colorless, odourless, smellless, clear.

2. Chemical composition:

| | |
|----------------------------------|-------------|
| K ⁺ + Na ⁺ | 38.41 mg/l |
| Ca ⁺⁺ | 33.88 mg/l |
| Mg ⁺⁺ | 85.85 mg/l |
| Cl ⁻ | 551.67 mg/l |
| SO ₄ ^{="} | 329.00 mg/l |
| HCO ₃ ⁻ | 139.13 mg/l |
| CO ₃ ^{="} | 30.00 mg/l |

3. Total dissolved solids: 1.138 g/l
4. Total hardness: 67.3 (German hardness)
5. Permanent hardness: 60.9 (German hardness)
6. Temporary hardness: 6.4 (German hardness)
7. PH value 8.4

Well facilities:

1, type of casing: seamless pipe, thread connection.

standard: 168mm (outside diameter), 152mm (inside diameter)

2. pump brand: Caprari E6R 30/36 + C615 (Italy)

standard: L/L 100/230 m355/170

3. generator brand: DEUTZ F 31 912 (Germany)

standard: 34 HP 25 KW A 6270 1500 l/min

. discharge pipe: 2" iron pipe

depth of pump: 144 m

5. water tank structure: reinforced concrete

volume: 5.5 m^3

6. water pond structure: reinforced concrete

volume: $5.0 \times 0.4 \times 0.28 \text{ m}^3$

7. pumping house structure: galvanized iron and timber
frame.

Well No.: Tu - 9

Well location: at 3 km, east of Burao Airport.

Construction date: March 8th, 1984 to March 26th, 1984

1, Lithological profile:

1. 0 - 12.00m: clayey sand: yellow-brown, with slight plasticity, with high content of sand, quartz mostly.
2. - 45.63m: conglomerate with sand: red-brown, ingredient: argillo-calcareous, with less content of limestone gravel.
3. - 54.43m: arenaceous mudstone: red-brown, with black-green, smooth feeling on the cross section, plastic.
4. - 78.00m: chert limestone: milk-white, with banded or nodular chert, pure limestone.
5. - 82.00m: grave pelitic limestone: grey, most gravel are pelitic-calcareous, with higher content of pellite.

6. - 110.00m: interbedded with arenaceous mudstone and conglomerate with sand: grey, grey-green, argillo-calcareous cementation.
7. - 120.00m: limestone: grey, with chert, dissolution can be seen. with calcite vein.
8. - 123.00m: sandstone with gravel: cream yellow, principal ingredient: quartz, poor consolidation.
9. - 134.00m: shale: cream yellow, developed foliation.
10. - 180.65m: sandstone: grey, light yellow, principal ingredient of sand: quartz, less feldspar and small black minerals, grains become coarse on the bottom, loose.

2. Pumping test data:

1. well depth: 180.12m
2. depth of screen: 134-176.12 m
3. pumping equipment: air compressor
4. static water level: 85.45m
5. drawdown: 3.23m
6. well yield: 485.50 m³/24hrs
7. stability time: 11 hours and 5 minutes

Data of simple water quality analysis:

1. Physical property: colorless, odourless, smellless, clear.

2. Chemical composition:

| | |
|----------------------------------|-------------|
| K ⁺ + Na ⁺ | 262.43 mg/l |
| Ca ⁺⁺ | 106.21 mg/l |
| Mg ⁺⁺ | 30.64 mg/l |
| Cl ⁻ | 344.35 mg/l |
| SO ₄ ⁼⁼ | 116.71 mg/l |

HCO_3' 384.40 mg/l

CO_3'' 24.00 mg/l

3. Total dissolved solids: 1.08 g/l
4. Total hardness: 21.93 (German hardness)
5. Permanent hardness: 4.2 (German hardness)
6. Temporary hardness: 17.73 (German hardness)
7. PH value: 8.1

, Well facilities:

1. type of casing: seamless pipe, thread connection.
standard: 168mm (outside diameter), 152mm (inside diameter)
2. pump brand KSB CORA 10 -199/23
standard: $Q\ 6 - 14\ \text{m}^3/\text{h}$, $H\ 210 - 150\ \text{m}$
3. generator brand: ATALANTA VOLCAN ML 250 (England)
standard: PHASE 3, HZ 50, RPM 1500, AMPS 38, VOLTS 380/220
4. discharge pipe: 2" iron pipe
depth of pump: 170 m
5. Water tank structure: reinforced concrete
volume: $5.5\ \text{m}^3$
6. water pond structure: reinforced concrete
volume: $5.0 \times 0.4 \times 0.28\ \text{m}^3$
7. pumping house structure: galvanized iron sheet and timber
frame
area: $9\ \text{m}^2$

Now
(Soal)
regr

Well No. : Tu - 10

Well location: at 3 km, north west of Berkadgosha, Tug Der
Region.

Construction date: March 17th, 1983 to April 24th, 1983

1, Lithological profile:

1. 0 - 93.50m: interbedded with mudstone and gypsum rock:
grey with dark red stains, dissolution on
the gypsum.
2. - 111.50m: thin layer of fine sandstone intercalated
with mudstone: grey, light yellow-brown,
medium-fine grains, loose.
3. - 135.00m: interbedded with thick layer of sandstone
and mudstone: grey-green, fine grains, loose.
4. - 148.00m: fine sandstone: grey-green, fine grains,
calcareous cementation, with small content
of quartz, gravel, loose.
5. - 154.58m: gypsum rock: grey-green, close, hard.
6. - 162.00m: mudstone: grey-green, yellow-brown, close,
hard, plastic when wet.
7. - 165.00m: sandstone: grey-green, with small content
of quartz, gravel, argillo-calcareous
cementation.
8. - 173.56m: mudstone; brown-red, ingredient: pellite,
plastic, smooth feeling on the cross section.

2, Pumping test data:

1. well depth: 173.36m
2. depth of screen: 93.50-165.00m
3. pumping equipment: air compressor

4. static water level: 90.21m
5. drawdown: 10.23m
6. well yield: 98.67 m³/24hrs
7. stability time: 25 hours and 10 minutes

1. Data of simple water quality analysis:

1. Physical property: colorless, smellless, clear, slightly salty and bitter.

2. Chemical composition:

| | |
|----------------------------------|--------------|
| K ⁺ + Na ⁺ | 1152.99 mg/l |
| Ca ⁺⁺ | 833.66 mg/l |
| Mg ⁺⁺ | 34.05 mg/l |
| Cl ⁻ | 3170.15 mg/l |
| SO ₄ ^{="} | 88.55 mg/l |
| HCO ₃ ⁻ | 207.47 mg/l |
| CO ₃ ^{="} | 0 mg/l |

3. Total dissolved solids: 5.384 g/l
4. Total hardness: 124.50 (German hardness)
5. Permanent hardness: 114.96 (German hardness)
6. Temporary hardness: 9.54 (German hardness)
7. PH value: 8.0

4. Well facilities:

1. type of casing: seamless pipe, thread connection.
standard: 168mm (outside diameter), 152mm (inside diameter)
2. pump brand: KSB CORA 10 -199/23
standard: Q 6 - 14 m³/h, H 210 - 150 m
3. generator brand: ATALANTA VOLCAN ML 250 (England)
standard: PHASE 3, HZ 50, RPM 1500, KVA 25, AMPS 38
VP:TS 38C/207

4. discharge pipe: 2" iron pipe
depth of pump: 160m
5. water tank structure: reinforced concrete
volume: 5.5 m^3
6. water pond structure: reinforced concrete
volume: $5.0 \times 0.4 \times 0.28 \text{ m}^3$
7. pumping house structure: galvanized iron sheet and timber
frame
area: 9 m^2

Well No.: Tu - 11

(Soil region)

Well location: at 12 km, east of Waridad, Tug Der Region.

Construction date: December 23rd, 1982 to January 29th, 1983

, Lithological profile:

1. 0 - 18.65m: mudstone: dark red, principal ingredient:
pellite, with nodule-grain gypsum.
2. - 37.95m: argillaceous limestone: grey, principal
ingredient: argillo-calcareous.
3. - 53.20m: mudstone: dark red, principal ingredient:
pellite, harder after dry, with gypsum crystal.
4. - 121.00m: mudstone: grey, dark red, with small content
of pellite, loose, softer.
5. - 146.00m: fine sandstone: grey, gypsum sand, nonhomo-
geneous degree of grains.
6. - 151.50m: mudstone: grey-green, plastic when wet,
with small content of gravel.

7. - 161.00m: fine sandstone: grey, ingredient of sand: gypsum, quartz, small content of black minerals.

8. - 172.00m: mudstone: grey-green, ingredient: pellite, plastic, with crystalline gypsum.

9. - 187.66m: mudstone: grey-green, soft, plastic when wet.

2. Pumping test data:

1. well depth: 186.10m
2. depth of screen: 120-178.00m
3. pumping equipment: air compressor
4. static water level: 93.66m
5. drawdown: 8.71m
6. well yield: 141.52 m³/24hrs
7. stability time: 25 hours

3. Data of simple water quality analysis:

1. Physical property: colorless, smellless, clear, salty and puckery.

2. Chemical composition:

| | |
|----------------------------------|--------------|
| K ⁺ + Na ⁺ | 648.60 mg/l |
| Ca ⁺⁺ | 795.59 mg/l |
| Mg ⁺⁺ | 411.01 mg/l |
| Cl ⁻ | 3386.70 mg/l |
| SO ₄ ^{="} | 110.47 mg/l |
| HCO ₃ ⁻ | 183.60 mg/l |
| CO ₃ ^{="} | 30.00 mg/l |

3. Total dissolved solids: 5.474 g/l

4. Total hardness: 206.09 (German hardness)

5. Permanent hardness: 197.68 (German hardness)

6. Temporary hardness: 8.41 (German hardness)

. PH value: 8.4

Well facilities:

1. type of casing: seamless pipe, thread connection.

standard: 168mm (outside diameter), 152mm (inside diameter)

2. pump brand: KSB CORA 10 - 199/23

standard: Q 6 - 14 m³/h, H 210 - 150 m

3. generator brand: ATALANTA VOLCAN ML 250 (England)

standard: PHASE 3, HZ 50, RPM 1500, KVA 25, AMPS 38

VOLTS 380/220

4. discharge pipe: 2" iron pipe

depth of pump: 170 m

5. water tank structure: reinforced concrete

volume: 5.5 m³

6. water pond structure: reinforced concrete

volume: 5.0 x 0.4 x 0.28 m³

7. pumping house structure: galvanized iron sheet and

timber frame

area: 9 m²

Well No. : Tu - 12

Sool

Well location: at 12 km, north west of Waridad, Tug Der Region.

Construction date: September 19th, 1982 to December 6th, 1982

1, Lithological profile:

1. 0 - 18.29m: arenaceous clay: yellow-brown, loose with gypsum and limestone gravel.
2. - 60.16m: mudstone: dark red, round-block distribution of gypsum, and with limestone gravel.
3. - 74.50m: mudstone: grey and dark red stains, loose, rough.
4. - 102.63m: mudstone: white, grey-green, crystal distribution of gypsum.
5. - 108.93m: mudstone: dark red and grey stains, with high content of pellite, plastic.
6. - 122.73m: mudstone: grey, brown-red, round-block appearance of gypsum mostly.
7. - 146.27m: interbedded with fine sandstone and mudstone: grey, grey-green, homogeneous grains, calcareous cementation.
8. - 172.06m: mudstone: grey-green, close, smooth cross section.
9. - 193.19m: argillaceous sandstone: grey-green.
10. - 200.86m: interbedded with sandstone and mudstone: grey-green, with gypsum and calcareous.

2, Pumping test data:

1. well depth: 199.10m
2. depth of screen: 122.73-195.00m

- 3. pumping equipment: air compressor
- 4. static water level: 98.33m
- 5. drawdown: 8.70m
- 6. well yield: 111.97 m³/24hrs
- 7. stability time: 18 hours

3. Data of simple water quality analysis:

- 1. Physical property: colorless, clear, smellless, salty and puckery.

2. Chemical composition:

| | |
|----------------------------------|--------------|
| K ⁺ + Na ⁺ | 177.10 mg/l |
| Ca ⁺⁺ | 444.89 mg/l |
| Mg ⁺⁺ | 752.70 mg/l |
| Cl ⁻ | 2836.45 mg/l |
| SO ₄ ⁻ | 187.32 mg/l |
| HCO ₃ ⁻ | 240.00 mg/l |
| CO ₃ ⁻ | 0 |

- 3. Total dissolved solids: 4.519 g/l
- 4. Total hardness: 235.82 (German hardness)
- 5. Permanent hardness: 213.38 (German hardness)
- 6. Temporary hardness: 22.43 (German hardness)
- 7. PH value: 8.4

, Well facilities:

- 1. type of casing: seamless pipe, thread connection.
standard: 168mm (outside diameter) 152mm (inside diameter)
- 2. pump brand: Caprari E6R 30/36 + C 615 (Italy)
standard: L/L 100/23/ m 350/170

3. generator brand: DEUTZ F3 L 912 (Germany)
standard: 34 HP 25 KW A 6270 15001/min
4. discharge pipe: 2" iron pipe
- depth of pump: 150m
5. water tank structure: reinforced concrete
volume: 5.5 m^3
6. water pond structure: reinforced concrete
volume: $5.0 \times 0.4 \times 0.28 \text{ m}^3$
7. pumping house structure: galvanized iron sheet and
timber frame
area: 9 m^2

Well No. : Sa-1

Well location : at 4 km, river bank, southeast of El-Afwein, Sanag Region.

Construction date : April 11th, 1985 to April 20th, 1985

1, Lithological profile :

- 1, 0 - 4.80m: arenaceous clay: broken on the bottom.
- 2, - 7.20m: shale.
- 3, - 13.80m: gypsum rock.
- 4, - 16.80m: mustone or shale.
- 5, - 18.60m: gypsum rock.
- 6, - 20.00m: shale.
- 7, - 23.40m: gypsum rock.
- 8, - 24.40m: shale.
- 9, - 30.10m: gypsum rock.
- 10, - 32.20m: shale.
- 11, - 43.40m: gypsum rock.
- 12, - 44.40m: shale.
- 13, - 51.00m: gypsum rock.
- 14, - 52.90m: shale.
- 15, - 61.20m: gypsum rock: broken rocks, developed karst, serious leakage.
- 16, - 63.80m: gypsum rock.
- 17, - 64.60m: shale.
- 18, - 81.14m: gypsum intercalated with thin layer of shale.

2, Pumping test data:

- 1, well depth : 81.14m
- 2, depth of screen: 54-75.64m
- 3, pumping equipment: air compressor.
- 4, static water level: 6.43m
- 5, drawdown: 24.77m
- 6, well yield: 421.92m³/24hrs
- 7, stability time: 14 hours and 5 minutes.

data of simpl water quillity analysis :

1, Physical property: colorless, smellless, puckery, clear.

2, Chemical composition:

| | |
|---------------------------------|------------|
| K ⁺ +Na ⁺ | 226.32mg/l |
| Ca ⁺⁺ | 571.14mg/l |
| Mg ⁺⁺ | 263.87mg/l |
| Cl ⁻ | 54.85mg/l |

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| | |
|--------------------|-------------|
| SO ₄ '' | 1858.76mg/l |
| HCO ₃ ' | 263.61mg/l |
| CO ₃ '' | 9.6mg/l |

- 3, Total dissolved solids: 3.8g/l
- 4, Total hardness: 104.8(German hardness)
- 5, Permanent hardness: 128.8(" ")
- 6, Temporary hardness: 12.0(" ")
- 7, PH value: 8.2

4, Well facilities :

- 1, type of casing: steel pipe and rolled steel plate pipe,
threed connection.

standard : 8''

- 2, pump brand: Caprari E6R 30/36 + C615 (ITALY)

standard : 1/1' 100/230 M 355/170

- 3, Generator brand: DEUTZ F31 912 (GERMAN)

standard: 34HP 25KW A 6270 1500/min

- 4, discharge pipe: 2" iron pipe

- 5, depth of pump: 60m

- 5, water tank structure: reinforced concrete

volume: 5.5m³

- 6, water pond sturcture: reinforced concrete

volume: 5.0x0.4x0.28M³

- 7, pumping house sturcture: galvanizad iron sheet and

timber frame

area : 9 m³

Well No. : Sa - 2

Well location: at 2km, 75 degrees, northeast of hulur, sanag region

Construction data: June 11th, 1985 to July 6th, 1985

1, Lithological profile:

- 1, 0 - 31.00m: pellictic gypsum: grey-yellow, medium-thick layer, intercalated with thin layer of gypsum rock and grey-yellow shale.
- 2, - 59.70m: gypsum rock: grey-yellow, medium-thick layer, serious dissolution, leakage at 33m, 36m.
- 3, - 61.70m: shale: grey-green.
- 4, - 67.50m: gypsum rock: grey-yellow, loose.
- 5, - 73.50m: shale: grey-green.
- 6, - 95.00m: gypsum rock: yellow-white, thin layers, close
- 7, - 100.28m: shale: grey-yellow.

2, Pumping test data:

- 1, well depth: 99.47m
- 2, depth of screen: 16-95.00m
- 3, pumping equipment: air compressor
- 4, static water level: 13.8m
- 5, drawdown: 2.9m
- 6, well yield: $737\text{m}^3/24\text{hrs}$
- 7, stability time: 6 hours and 30 minutes

3, data of simple water quality analysis:

1, Physical property: colorless, smellless, clear, puckry

2, Chemical composition:

| | |
|----------------------------------|-------------|
| K ⁺ + Na ⁺ | 127.88mg/l |
| Ca ⁺⁺ | 675.35mg/l |
| Mg ⁺⁺ | 209.40mg/l |
| Cl ⁻ | 1001.10mg/l |
| SO ₄ ^{="} | 1206.50mg/l |
| HCO ₃ ⁻ | 192.82mg/l |

3, Total dissolved solids: 3.4g/l

4, Total hardness: 143.0 (German hardness)

5, Permanent hardness: 134 (" ")

6, Temporary hardness: 9.0 (" ")

7, PH value: 8.2

Well facilities:

1, type of casing: seamless pipe, thread connection

- standard: 168mm (outside), 152mm (insite)
- 2, pump brand: KCB CORA 10- 199/23 (Cora 15) *d*
standard: Q 6- 14 m³/h, H 210- 150m
- 3, generator brand: ATALANTA VOLCAN ML 250 (English)
standard: PHASE 3, HZ50, RPM 1500, KVA 25, AMPS38,
VOLTS 380/220
- 4, discharge pipe: 2" iron pipe
depth of pump: 80m
- 5, water tank structure: reinforced concrete
volume: 5.5m³
- 6, water pond structure: reinforced concrete
volume: 5.0x0.4x0.28m³
- 7, pumping house structure: galvanized iron sheet and
timber frame
area: 9m²

Well No. : Sa - 3

Well location: Elbuh, sanag Region

Construction date : July 5th, 1985 to July 24th, 1985

1, Lithological profile:

- 1, 0 - 5.00m: arenaceous clay: yellow-brown, loose,
with limestone broken stone.
- 2, - 27.00m: mudstone: mixed with red and white,
with content of pelinite, harder, inter-
calated with thin layer of conglomerate
with sand.
- 3, - 46.00m: limestone: grey, loose texture, developed
into small hollow dissolution holes,
2-5 cm in diameter.
- 4, - 53.00m: mudstone: yellow, fine and smooth, close,
harder.
- 5, - 60.78m: argillaceous limestone: grey, smooth on
bedding surface, with chert nodules.
- 6, - 68.16m: limestone: white, loose, small hollow dis-
solution holes can be seen 1cm in diameter
- 7 - 85.00m: argillaceous limestone: grey-yellow, grey,

with content of pellenite, and with small chert
nodules, dissolution holes can be seen 2cm
in diameter.

- 8, - 90.42m: limestone: white, close, hard and brittle,
- 9, - 98.00m: muddy limestone: white, close,
- 10, - 152.00m: mudstone: grey, fine and smooth, with high
content of clam fossils.
- 11, - 156.50m: limestone: grey, hard and brittle,
- 12, - 169.00m: interbedded with mudstone and limestone
black-grey, developed bedding, clam fossils
- 13, - 176.00m: mudstone: black-grey, with clam fossils
- 14, - 185.50m: dolomitic limestone: white, hard and brittle
- 15, - 213.00m: mudstone: black-grey, fine and brittle
developed bedding, with clam fossils

, Pumping test data:

- 1, well depth: 211.15m
- 2, depth of screen: 131.77-211.15m
- 3, pumping equipment: air compressor
- 4, static water level: 137.45m
- 5, drawdown: 42.55m
- 6, well yield: 39.42m³/24hrs
- 7, stability time: 9 hours

data of simple water quality analysis:

1, Physical property: colorless, odourless, smellless, clear

2, Chemical composition:

| | |
|----------------------------------|------------|
| K ⁺ + Na ⁺ | 317.86mg/l |
| Ca ⁺⁺ | 104.21mg/l |
| Mg ⁺⁺ | 99.71mg/l |
| Cl ⁻ | 457.16mg/l |

- | | |
|----------------------------|-----------------------|
| SO_4'' | 466.85mg/l |
| HCO_3' | 280.69mg/l |
| 3, Total dissolved solids: | 1.73g/l |
| 4, Total hardness: | 37.6(German hardness) |
| • 5, Permanent hardness: | 24.7(" ") |
| 6, Temporary hardness: | 12.9(" ") |
| 7, PH value: | 8.1 |
- 4, Well facilities:
- 1, type of casing: 0- 162.43m :8" rolled steel platepipe,
welded; 162.43m-211.15m: 168mm steel pipe,
thread connection.
standard: 0--161.43m: 8"
161.43m--211.15m: 169mm(outside)
152mm(inside)
 - 2, pump brand: KSB CORA 10-199/23
standard: Q 6--14m³/h, H 210--150m
 - 3, generator brand: ATALANTA VOLCAN ML 250 (England)
standard: PHASE 3, HZ 50, RPM 1500, KVA 25, AMPS 38,
VOLTS 380/220
 - 4, discharge pipe: 2" iron pipe
depth of pump: 210m
 - 5, water tank structure: reinforced concrete
volume: 5.5m³
 - 6, water pond structure: reinforced concrete
volume: 5.0 x 0.4 x 0.28m³
 - 7, pumping house structure: galvanized iron sheel and
timber frame
area : 9m²

Well No. : Sr-- 7

Well location : at 50m, southeast of dahar village, Sanag
Region

Construction date: April 17th, 1985 to May 5th, 1985

1, Lithological profile :

- 1, 0 - 15.57m: arenaceous clay: yellow-brown, with sand and gravel.
- 2, -22.00m: dolomitic limestone: grey, hard and brittle
- 3, - 58.00m: muddy limestone: grey, close and brittle
- 4, - 70.00m: limestone: leakage at 66.56m.
- 5, - 98.99m: interbedded with mudstone and limestone
- 6, - 113.00m: limestone: grey, hard, leakage at 108.47m
- 7, - 123.19m: mudstone: yellow with grey-green mudstone with clam fossil on the bottom.
- 8, - 141.47m: limestone: grey, hard, karst fracture development under 134m.
- 9, - 164.60m: mudstone: dark grey, light grey, with clam and conch fossils. bedded.

2, pumping test data:

- 1, well depth: 164.35m
- 2, depth of screen : 102.24-164.35m
- 3, pumping equipment: air compressor
- 4, static water level: 102.24m
- 5, drawdown : unavailable
- 6, well yield : $200\text{m}^3/24\text{hrs}$
- 7, stability time: 8 hours

3, data of simple water quality analysis:

- 1, Physical property: colorless, odourless, smellless, clear
- 2, Chemical composition:

- 70 -

| | |
|----------------------------------|------------|
| K ⁺ + Na ⁺ | 126.04mg/l |
| Ca ⁺⁺ | 66.33mg/l |
| Mg ⁺⁺ | 106.28mg/l |
| Cl ⁻ | 330.15mg/l |
| SO ₄ ["] | 124.88mg/l |
| HCO ₃ ⁻ | 330.73mg/l |
| CO ₃ ["] | 4.8mg/l |

3, Total dissolved solids: 1.1g/l

4, Total hardness: 33.7 (German hardness)

5, Permanent hardness: 18.7 (" ")

6, Temporary hardness: 15.0 (" " 0

7, PH value : 8

4. Well facilities:

1, type of casing: seamless pipe, thread connection.

standard : 168mm (outside), 152mm(inside)

2, pump brand: KSB CORA 10-199/23

standard : Q 6- 14m³/h, H 210- 150 m

3, generator brand: ATALANTA VOLCAN ML 250 (England)

standard: PHASE 3, HZ 50, RPM 1500, KVA 25,

AMPS 38, VOLTS 380/220

, discharge pipe: 2" iron pipe

depth of pump: 160m

5, water tank structure: reinforced concrete

volume : 5.5m³

6, waterpond structure : reinforced concrete

volume : 5.0 x 0.4 x 0.28 m³

7, pumping house structure:galvanized ironsheet and

timber frame

area : 6m²

Well No. : Sa- 5

Well location: Hingalol Village, Sanag Region

construction date : May 26th, 1985 to June 9th, 1985

1. Lithological profile:

- 1,0 - 13.00m: arenaceous clay: with limestone debris
- 2, - 30.00m: muddy limestone: grey, with gypsum crystal
- 3, - 42.97m: mudstone: grey, with content of gypsum
and calcareous.
- 3, - 49.25m: limestone with chert nodules: grey, nodules
present round and blocky, hard, with gypsum
crystal in cracks.
- 5, - 56.00m: mudstone: grey, with content of calcareous
and gypsum crystals.
- 6, - 68.00m: limestone: grey, with brown-red bands.
- 7, - 75.00m: mudstone: grey-green.
- 8, - 83.00m: muddy limestone: grey-green, small
karst holes at 81.56m
- 9, - 95.00m: mudstone: grey-green, with current bedding
on the bottom.
- 10, - 109.00m: dolomitic limestone: grey, with karst
holes at 95m.
- 11, - 120.19m: mudstone: grey-green.

, Pumping test data:

- 1, well depth: 113.35m
- 2, depth of screen: 30-113.35m
- 3, pumping equipment: air compressor
- 4, static water level: 59.93m
- 5, drawdown : 15.07m
- 6, well yield: 157.92m³/24hrs

7, stability time: 6hours and 50 minutes

3, data of simple water quility analysis :

1, Physical property: colorless, smelles, slightly
puckery, clear.

2, Chemical composition:

| | |
|----------------------------------|-------------|
| K ⁺ + Na ⁺ | 53.82mg/l |
| Ca ⁺⁺ | 755.51mg/l |
| Mg ⁺⁺ | 208.42mg/l |
| Cl ⁻ | 1349.00mg/l |
| SO ₄ ^{="} | 799.22mg/l |
| HCO ₃ ⁻ | 154.99mg/l |

3, Total dissolved solids : 3.3g/l

4, Total hardness: 153 (German hardness)

5, Permanent hardness: 146 (" ")

6, Temporary hardness: 7 (" ")

7, PH value : 8.2

4, Well facilities :

1, type of casing : seamless pipe, thread connection
standard : 168mm (outside), 152mm(inside)

2, pump brand: KSB CORA 10-199/23
standard: Q 6- 14m³/h, H 210-150m

3, generator brand: ATALANTA VOLCAN ML250 (England)
standard: PHASE 3, HZ 50, RPM 1500, KVA 25
AMPS 38, VOLTS 380/220

4, discharge pipe: 2" iron pipe

depth of pump: 110m

5, water tank structure: reinforced concrete

volume : 5.5m³

6, water pond structure: reinforced concrete

volume : $5.0 \times 0.4 \times 0.28 \text{ m}^3$

7, pumping house structure: galvanized iron sheet

and timber frame

area : 9 m^2

Well No : Ba - 1

Well location: Gardo, Bari REgion

Construction date : August 11th, 1985 to August 22th, 1985

1, Lithological profile:

1, 0 - 7.00m: clay: yellow-brown, loose, intense plasticity, with limestone broken stone

2, - 72.00m: mudstone: yellow-brown, loose and soft, plastic, slightly consolidated, with limestone broken stone

3, - 78.00m: limestone: brown, coarse, soft, with pellite

4, - 114.00m: mudstone: brown, loose and soft, plastic, with calcareous.

5, - 131.00m: argillaceous limestone: grey-yellow, loose and soft, with chert nodules and gypsum crystal

6, - 154.00m: mudstone: yellow-brown, loose, position of calcareous riching is grey.

7, - 174.00m: interbedded with mudstone and limestone, yellow-green, grey, with chert nodule, riching in clam fossils, with dissolution

- 8, - 202.00m: mudstone:black-grey,soft and plastic,
developed bedding.
- 9, - 225.25m: argillaceous limestone: grey,soft,inter-
calated with thin layer of mudstone,with
karst cracks.

2, Pumping test data:

- 1, well depth: 222.89m
- 2, depth of screen: 122 - 222.89m
- 3 pumping equipment: air compressor
- 4, static water level: 139.04m
- 5, drawdown: 9.46m
- 6, well yield: $47.04\text{m}^3/24\text{hrs}$
- 7, stability time: 6 hours

3, data of simple waterquality analysis:

- 1, physical property: colorless, odourless,smelless, clear

2, chemical composition:

| | |
|----------------------------------|------------|
| K ⁺ + Na ⁺ | 45.08mg/l |
| Ca ⁺⁺ | 320.64mg/l |
| Mg ⁺⁺ | 104.58mg/l |
| Cl ⁻ | 479.25mg/l |
| SO ₄ ^{''} | 449.56mg/l |
| HCO ₃ ['] | 225.77mg/l |

- 3, total dissolved solids: 1.63g/l
- 4, total hardness: 69 (German hardness)
- 5, permanent hardness: 59 (" ")
- 6, temporary hardness: 10 (" ")
- 7, PH value: 8

4, Well facilities:

1, type of casing: seamless pipe, thread connection

standard: 168mm (outside), 152mm(inside)

2, pump brand: KSB CORA 10 - 199/23

• standard: Q 6 - $14\text{m}^3/\text{h}$, H 210 - 150m

3, generator brand: ATALANTA VOLCAN ML 250 (England)

standard: PHASE 3, HZ 50, RPM 1500, KVA 25,

AMPS 38, VOLTS 380/ 220

4, discharge pipe: 2" iron pipe

depth of pump: 210m

5, water tank structure: reinforced concrete

volume : 5.5m^3

6, water pond structure: reinforced concrete

volume : $5.0 \times 0.4 \times 0.28 \text{ m}^3$

7, pumping house structure: galvanized iron sheet

and timber frame

area : 9 m^2

Well No. : Ba - 2

Well location: Goud Ad, Bari Region

Construction date: August 28th, 1985 to September 14th, 1985

1, Lithological profile:

- 1, 0 - 50.00m: mudstone:red-brown,loose and soft,with
limestone broken stoneon the top
- 2, - 120.00m: argillaceous limestone:red-brown,
with non-uniform content of pellite,
with chert nodules.
- 3, - 131.00m: mudstone:white,loose,and soft,plastic
position of calcaraeous riching presents
state of argillaceous limestone.
- 4, - 166.65m: argillaceous lime-stone: grey,loose ,soft
- 5, - 177.00m: dolomitic limestone:white,close and soft,
plastic.
- 6, - 189.00m: argillaceous limestone: grey,loose and soft
- 7, - 201.00m: dolomitic limestone: white,close,
hard and brittle,pure.
- 8, - 220.00m: mudstone: grey-green,loose andsoft,plastic
- 9, - 230.33m: gypsum rock: grey,with pellite,loose
and softer..

2, Pumping test data:

- 1, well depth: 210m
- 2, depth of screen: 95 - 210m
- 3, pumping equipment: air compressor
- 4, static water level: 128m
- 5, drawdown: 23m
- 6, well yield: 59 m³/24hrs
- 7, stability time: 8 hours

3, data of simple water quality analysis:

1, Physical property: colorless, smellless, odourless, clear

2, Chemical composition:

| | |
|----------------------------------|------------------------|
| K ⁺ + Na ⁺ | 44.83mg/l |
| Ca ⁺⁺ | 317.77mg/l |
| Mg ⁺⁺ | 103.77mg/l |
| Cl ⁻ | 475.02mg/l |
| SO ₄ ^{="} | 446.68mg/l |
| HCO ₃ ⁻ | 223.33mg/l |
| 3, Total dissolved solids | 1.61g/l |
| 4, Total hardness: | 68.4 (German hardness) |
| 5, Permanent hardness: | 58.1 (" ") |
| 6, Temporary hardness: | 10.3 (" ") |
| 7, PH value | 8 |

4, Well facilities:

1, type of casing: seamless pipe, thread connection.
standard: 168 mm (outside), 152 mm (inside)

2, pump brand: KSB CORA 10 - 199/23
standard: Q 6 - 14 m³/h, H 210- 150m

3, generator brand: ATALANTA VOLCAN ML 250 (England)
standard: PHASE 3, HZ 50, RPM 1500, KVA 25,
AMPS 38, VOLTS 380/220

4, discharge pipe: 2" iron pipe

5, water tank structure: reinforced concrete
volume: 5.5 m³

6, water pond structure: reinforced concrete
volume: 5.0 x 0.4 x 0.28 m³

7, pumping house structure: galvanized iron sheet
and timber frame
area : 9 m²

Well No. Ba - 3

Well location Aldosony, East Region

Construction date : October 1st, 1985 to October 15th 1985

1, Lithological profile:

- 1,0 - 7.00m: sandstone and sedimentary sandstone
- 2, - 41.00m: argillaceous limestone: yellow-grey, soft,
with chert pebbles.
- 3, - 78.00m: limestone interbedded with argillaceous
limestone; limestone: white-grey, hard and
brittle, small karst with slight leakage
- 4, - 100.00m: argillaceous limestone: yellow-grey, soft
- 5, - 146.00m: dolomitic limestone interbedded with
argillaceous limestone;
dolomitic limestone: hard, and brittle,
small karst appeared in the upper part with
slight leakage.
- 6, - 166.00m: dolomitic limestone: white-grey, hard and
brittle, with chert strips.
- 7, - 185.00m: argillaceous limestone interbedded with
dolomitic limestone.
- 8, - 209.00m: dolomitic limestone: white-grey, hard and
brittle, with chert strips in the upper part
- 9, - 220.44m: mudstone interbedded with argillaceous
limestone.

2, Pumping test data:

- 1, well depth : 217.78m
- 2, depth of screen: 107- 217m
- 3, pumping equipment: air compressor
- 4, static water level: 139m

- 5, drawdown : 14.4m
6, well yield: 32.6m³/24hrs
7, stability time: 8hours

3, data of simple water quality analysis:

1, Physical property: colorless, odourless, smellless, clear

2, Chemical composition:

| | |
|----------------------------------|------------|
| K ⁺ + Na ⁺ | 208.15mg/l |
| Ca ⁺⁺ | 207.41mg/l |
| Mg ⁺⁺ | 78.68mg/l |
| Cl ⁻ | 405.06mg/l |
| SO ₄ ^{="} | 524.49mg/l |
| HCO ₃ ⁻ | 216.27mg/l |

- 3, Total dissolved solids: 1.64g/l
4, Total hardness: 47.2 (German hardness)
5, Permanent hardness: 37.2 (" ")
6, Temporary hardness: 10 (" ")
7, PH value : 8.1

4, Well facilities:

1, type of casing: seamless iron pipe, thread connection

standard: 168mm (outside), 152 mm (inside)

2, pump brand: KSB CORA 10 - 199/23

standard: Q 6 -14m³/h, H 210-150m

3, generator brand: ATALATA VOLCAN ML 250 (England) well

standard: PHASE 3, HZ 50, RPM 1500, KVA 25, x

AMPS 38, VOLTS 380/220

4, discharge pipe: 2" iron pipe

depth of pump: 210m

5, water tank structure: reinforced concrete

volume : 5.5 m³

*No installation
x had been done
on this particular*

*using the
stated equipment*

*which is from
Sam/84/1601 Project
Refer to Consultant*

*Macris report and
p/Counterpart report
as regard to this well*

6, water pond structure: reinforced concrete
volume : $5.0 \times 0.4 \times 0.28 \text{ m}^3$

7, pumping house structure: galvanized iron sheet
and timber frame.
area : 9 m^2

Well No : So - 1

Well location : Ban Ade grass bank, Sool Region

Construction date: September 7th, 1984 to November 22th, 1984

Lithological profile:

- 1,0 - 20.80m: mudstone: grey, with brown-yellow, rounded block gypsum and gypsum crystal can be seen
- 2, - 23.90m: gypsum rock with mud: grey, with brown-yellow principal ingredient: gypsum, with small content of arrillaceous.
- 3, - 34.52m: mudstone: grey with brown-yellow, with briqueting gypsum.
- 4, - 73.56m: mudstone: brown-red, slightly consolidated, ingredient: peliite, sand and gravel can be seen occasionally.
- 5, - 84.34m: arenaceous mudstone with gravel: brown-red, slightly consolidated, ingredient of muddy, with small content of sand and gravel.
- 6, - 100.59m: mudstone: brown-red, thick layer, plastic.
- 7, - 115.98m: sandstone:

- 123.56m: arenaceous mudstone: grey, with brown-red, principal ingredient: pellite, with small content of small gravel.
- 183.07m: shale: light yellowgrey, grey-purple, black-grey, clear foliation, rich infossils.

Pumping test data:

well depth : 127.50m
depth of screen: 19-32m, 104-115m.
pumping equipment: air compressor
4. static water level: 14.00m
drawdown: 43.10m
6. well yield: 107 m³/24hrs
satbility time: 8hours and 15 minutes

Data of simple water quality analysis:

Physical property: colorless, bitter, puckry, clear

Chemical composition:

| | |
|----------------------------------|-------------------------|
| K ⁺ + Na ⁺ | 6609.05mg/l |
| Ca ⁺⁺ | 1518.00mg/l |
| Mg ⁺⁺ | 390.34mg/l |
| Cl ['] | 12502.40mg/l |
| SO ₄ ["] | 545.14mg/l |
| HCO ₃ ['] | 152.55mg/l |
| CO ₃ ["] | 30.00mg/l |
| 3. Total dissolved solids: | 21.7g/l |
| , Total hardness: | 302.4 (German hardness) |
| , Permanent hardness: | 295.4 (" ") |
| 6. Temporary hardness: | 7.0 (" ") |
| , PH value: | 8.1 |

, Well facilities:

- 1, type of casing: seamless pipe, thread connection
standard: 8"
- 2, pump brand : Caprari E6R 30/36 ÷ C615 (ITALY)
standard: 1/1' 100/230 M 355/170
- 3, generator brand: DEUTZ F 3.L 912 (Germany)
standard: 34HP, 25KV, A 6270, 1500L/min
- 4, discharge pipe : 2" iron pipe
depth of pump: 106m
- 5, water tank structure: reinforced concrete
volume : 5.5 m³
- 6, water pond structure: reinforced concrete
volume : 5.0 x 0.4 x 0.28 m³
- 7, pumping house structure: galvanized iron sheet and timber frame
area : 9 m²

Well No : So -- 2

Well location: at 500m, northwest of Daraweiny, Sool Region

Construction : July 24th, 1985 to August 24th, 1985

1, Lithological profile :

- 1,0 - 8.00m: arenaceous clay: 2m gravel with sand on the bottom.
- 2, - 16.60m: clay intercalated with gravel: yellow-brown, gravel diameter become small on the bottom.
- 3, - 40.00m: marl: grey-yellow, developed solution cavities partially.
- 4, - 49.00m: shale: grey-green, developed foliation.
- 5, - 52.00m: mudstone.
- 6, - 62.00m: shale: grey-green, developed foliation.
- 7, - 73.50m: mudstone: dark grey, soft lithological characters. rich in clam fossils.
- 8, - 116.00m: shale: grey-green, rich in clam fossils and star-spot yellow iron ore.
- 9, - 135.00m: mudstone: grey-yellow, soft lithological characters.
- 10, - 152.00m: marl: yellow-grey, intercalated with thin layer of shale, broken partially.
- 11, - 155.50m: mudstone:
- 12, - 164.00m: interbedded with marl and shale.
- 13, - 173.00m: mudstone.
- 14, - 184.00m: limestone: grey, hard, with content of water.
- 15, - 189.00m: marl intercalated with shale.
- 16, - 196.00m: mudstone.
- 17, - 207.00m: limestone: grey, hard, with content of water.
- 18, - 220.44m: marl intercalated with shale.

, Pumping test data:

- 1, well depth: 218.62m
- 2, depth of screen: 106-217 m
- 3, pumping equipment: air compressor.
- 4, static water level: 102.78m
- 5, drawdown : 42.6m
- 6, well yield: 44.6 m³/24hrs
- 7, stability time: 8hours

, data of simple water quality analysis:

1, Physical property: colorless, odourless, smellless, clear.

2, Chemical composition:

| | |
|----------------------------------|------------|
| K ⁺ + Na ⁺ | 99.36mg/l |
| Ca ⁺⁺ | 309.82mg/l |
| Mg ⁺⁺ | 98.25mg/l |
| Cl ⁻ | 247.44mg/l |
| SO ₄ ²⁻ | 941.87mg/l |
| HCO ₃ ⁻ | 78.11mg/l |

- 3, Total dissolved solids: 1.8g/l
- 4, Total hardness: 66 (German hardness)
- 5, Permanent hardness: 62.4(" ")
- 6, Temporary hardness: 3.6(" ")
- 7, PH value: 8.0

Well facilities:

1, type of casing: seamless pipe, thread connection.

standard: 168mm (outside), 152mm (inside)

2, pump brand : KSB CORA 10 - 199/23

standard: Q 6 - 14 m³/h, H 210- 150m

- 3, generator brand: ATALANTA VOLCAN ML 250 (England)
standard: PHASE 3, HZ 50, RPM 1500, KVA 25, AMPS 38,
VOLTS 380/220
- 4, discharge pipe : 2" iron pipe
depth of pump: 215 m
- 5, water tank structure: reinforced concrete
volume: 5.5 m³
- 6, water pond structure: reinforced concrete
volume: 5.0 x 0.4 x 0.28 m³
- 7, pumping house structure: galvannized iron sheet
and timber frame
area : 9 m²

Well No : Nu - 1

Well location: Gudubjiran, Nugal Region

Construction date : September 19th, 1984 to November 18th, 1984

, Lithological profile:

- 1,0 - 3.00m: arenaceous clay: red-brown, sticky and plastic
- 2, - 61.28m: dolomitic limestone: milk-white, with calcite
veins, not very developed karst.
- 3, - 63.00m: pelitic limestone with sand: grey.
- 4, - 91.00m: interbedded with limestone and mudstone:
limestone is milk-white dolomitic limestone.
mudstone is brown.
- 5, - 98.00m: biogenetic limestone; grey-yellow, with many kinds
of molluscs fossils, more developed karst.

- 6, - 146.64m: arenaceous mudstone with organisms: grey-black,
with many kinds of molluses fossils.

2, Pumping test data:

- | | |
|------------------------|-----------------------------|
| 1, well depth : | 145.91m |
| 2, depth of screen: | 78.16- 145.91m |
| 3, pumping equipment: | air compressor |
| 4, static water level: | 77.11m |
| 5, drawdown: | 0.79m |
| 6, well yield: | 181.44m ³ /24hrs |
| 7, stability time : | 8 hours |

3, data of simple water quality analysis:

- 1, Physical property: colorless, odourless, clear, smellless.

2, Chemical composition:

| | |
|----------------------------------|------------|
| K ⁺ + Na ⁺ | 462.99mg/l |
| Ca ⁺⁺ | 115.40mg/l |
| Mg ⁺⁺ | 62.50mmg/l |
| Cl ⁻ | 828.57mg/l |
| SO ₄ ²⁻ | 182.82mg/l |
| HCO ₃ ⁻ | 177.40mg/l |
| CO ₃ ²⁻ | 40.80mg/l |

- | | |
|----------------------------|-------------------------|
| 3, Total dissolved solids: | 1.87mg/l |
| 4, Total hardness: | 30.5 (German hardness) |
| 5, Permanent hardness: | 22.4 (" ") |
| 6, Temporary hardness: | 8.1 (" ") |
| 7, PH value: | 8.1 |

, Wellfacilities:

- 1, type of casing: seamless pipe, thread connection
standard: 168 mm (outside), 152 mm (inside)
- 2, pump brand: Caprari E6R 30/36÷ C 615 (ITALY)

standard: 1/5 100/100, M 355/170, (ITALY)

3 generator brand: LEBITZ F31 512 (GERMAN)

4, discharge pipe: 2" iron pipe

depth of pump: 120m

5, water tank structure: reinforced concrete

volume: 5.5 m^3

6, water pond structure: reinforced concrete

volume: $5.0 \times 0.4 \times 0.28 \text{ m}^3$

7, pumping house structure: galvanized iron sheet and timber
frame

area : 9 m^2

Well No : Nu - 2

Well location: Owulos, Nugal Region

construction date: January 21st, 1985 to March 4th, 1985

, Lithological profile:

1,0 - 90.00m: drilling without core.

2, - 92.40m: limestone: milk-white, with fine calcite veins.

3, - 94.10m: argillaceous limestone: serious leakage at
94-96m.

4, - 101.00m: limestone.

5, - 102.60m: mudstone.

6, - 105.10m: limestone.

7, - 106.90m: argillaceous limestone. yellow-white, with high
content of pellite.

8, - 108.40m: limestone.

9, - 110.90m: argillaceous limestone.

10, - 113.00m: limestone.

- 11, - 118.60m: argillaceous limestone.
- 12, - 120.20m: limestone.
- 13, - 121.40m: argillaceous limestone.
- 14, - 122.80m: limestone.
- 15, - 124.00m: argillaceous limestone.
- 16, - 147.00m: limestone.

2, Pumping test data:

- 1, well depth : 134.00m
- 2, depth of screen: 71.5 - 134m
- 3, pumping equipment: air compressor
- 4, static water level: 87.26m
- 5, drawdown : 9.22m
- 6, well yield : 68.60 m³/24hrs
- 7, stability time: 8 hours

3, data of simple water quality analysis:

1, Physical property: colorless, odourless, smellless, clera.

2, Chemical composition:

| | |
|----------------------------------|------------|
| K ⁺ + Na ⁺ | 132.02mg/l |
| Ca ⁺⁺ | 143.49mg/l |
| Mg ⁺⁺ | 93.39mg/l |
| Cl ⁻ | 464.24mg/l |
| SO ₄ ^{="} | 57.63mg/l |
| HCO ₃ ⁻ | 335.61mg/l |
| CO ₃ ^{="} | 24.00mg/l |

- 3, Total dissolved solids: 1.25g/l
- 4, Total hardness: 41.6 (German hardness)
- 5, Permanent hardness: 26.2 (" ")
- 6, Temporary hardness: 15.4 (" ")
- 7, pH value 7.6

4, Well facilities:

1, type of casing: seamless pipe, thread connection.

standard: 168 mm (outside), 152mm (inside)

2, pump brand: KSB CORA 10 - 199/23

standard: Q 6 - 14/h , H 210- 150m

3, generator brand: ATALANTA VOLCAN ML 250 (England)

standard: PHASE 3, HZ 50, RPM 1500, KVA 25,

AMPS 36, VOLTS 380/220

4, discharge pipe: 2" iron pipe

depth of pump: 130m

5, water tank structure: reinforced concrete

volume: 5.5 m³

6, water pond structure: reinforced concrete

volume: 5.0 x 0.4 x 0.28 m³

7, pump house structure: galvanized iron sheet, timber frame

area : 9 m²

Completion Report
on
The Water Well Drilling Project
in
The Northern Four Regions
of
The Democratic Republic of Somalia

Chinese Well Drilling Team
under
CHINA NATIONAL COMPLETE PLANT EXPORT CORPORATION

October, 1986