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MINISTRY OF PUBLIC WORKS & COMMUNICATION

SURFACE AND UNDERGROUND WATER RESOURCES OF THE SHEBELI VALLEY

by

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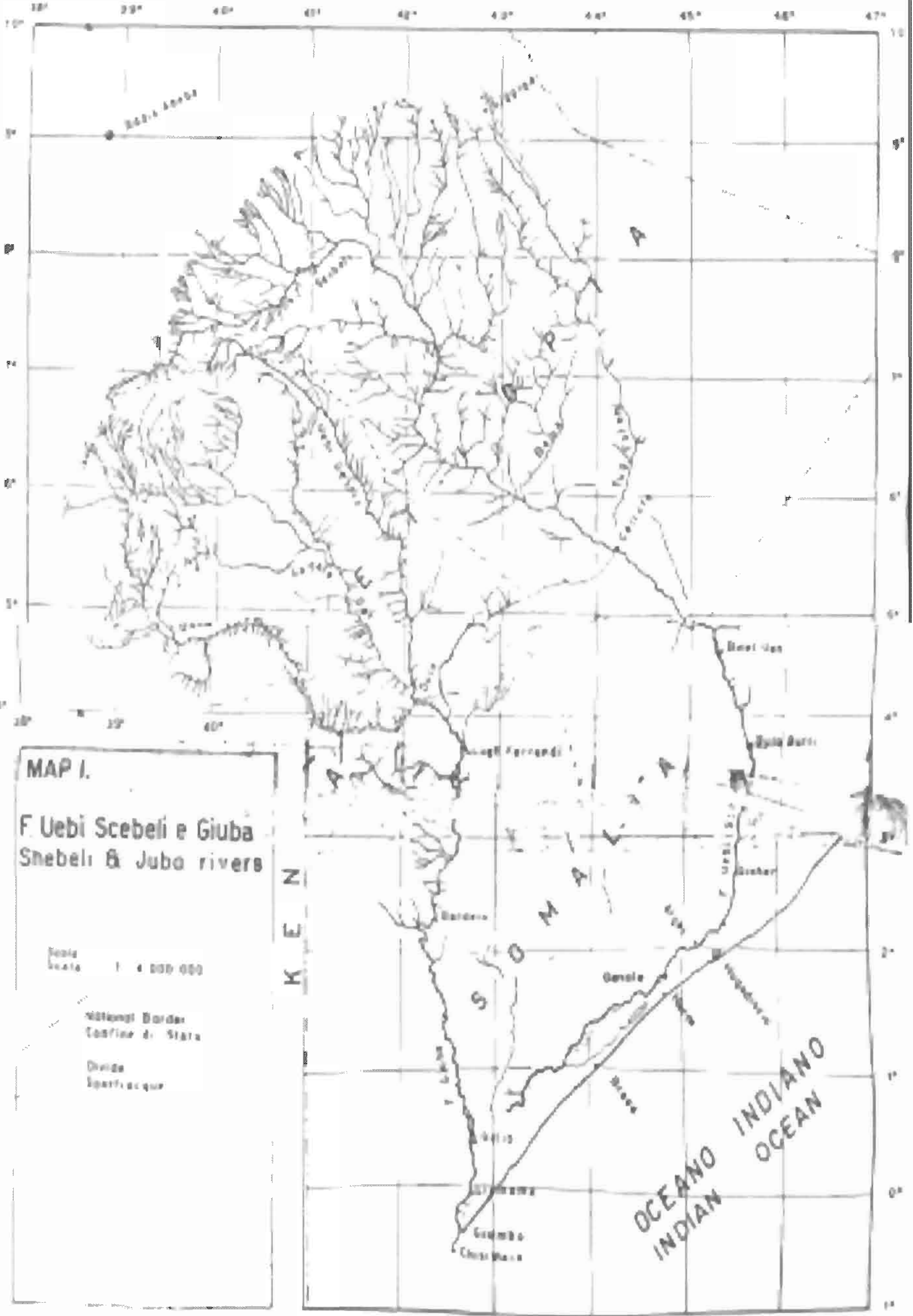
FOREWORD

My reasons for writing and publishing this study are, first, that much of the data now available might be lost if not recorded, in progress of time; secondly, that I hope to contribute to the general knowledge of water resources in the Shebeli Valley, in view of a more effective approach to the water research programme included in the First Five Year Plan.

Obviously, if the Ministry of Public Works, with which I have been associated for the last five years, had been adequately staffed, i.e. with a geophysicist, an analyst, a draftsman and other qualified personnel, a far greater amount of data would have been collected, and it would have been possible, inter alia, to obtain information on the contacts between fresh and saltywater, seasonal variations of salinity and level of water in the wells, etc. This would also have permitted to acquire a full knowledge of the hydrogeological characteristics presented by the alluvial deposits in the Shebeli Valley, which will be discussed in this paper.

This study is divided into three parts. Part I deals briefly with the characteristics of the Shebeli river as well as with the hydraulic works already completed or recommended to dispose of excess water, which is often damaging to agricultural crops. This first part is actually an introduction to Part II, which in turn deals with the water supplies of the huge alluvial deposits accumulated in the valley during the Pliocene and the Quaternary. The reader who is interested in more detailed information on the hydrological characteristics of this important and interesting river is referred to the bibliography listing the many authors who have written on this subject at greater length. Part III is an appendix containing all the data so far available on the wells and information on water surveys conducted in the Shebeli Valley.

Although, as mentioned earlier, such information is frequently not complete, it may be used to advantage, in the future, in compiling an economically profitable programme for the utilization of surface and ground water resources existing in this important area.


MAP I.
F. Uebi Scebeli e Giuba
Shebeli & Jubo rivers
Scala 1 : 4 000 000
National Border
Confine di Stato
Divide
Spartiacque
KEN
SOMALIA
OCEANO INDIANO
INDIAN OCEAN
Beled Uen
Bulo Burti
Gherfani
Bardera
Genale
Lugh Ferrandi
Chisimaio
Gobwin
Gelib
F. Uebi Scebeli
F. Giuba

PART I

A BRIEF SURVEY OF THE HYDROLOGY OF THE SHEBELI RIVER

The Shebeli, one of the major rivers in East Africa, rises in a large catchment basin, extending, in its upper part, as far as the southern boundary of the Harar plateau in Ethiopia (see map No.1).

The river traverses Somalia heading approximately in a NS direction, until, some 40 km away from Mogadiscio, its course is diverted southwestwards by a line of coastal dunes, which prevent its outflow into the sea. Its tributaries in Somalia are few and short: they all discharge into the Shebeli a short distance away from the Ethiopian border. These streams contribute little water to the Shebeli, owing to the scarcity of rainfall (200-250 mm per year approximately) in their respective catchment areas. Therefore the regime and the flow of the river are mainly conditioned by the amount of rainfall drained in its extensive Ethiopian basin. Some measurements taken at Mahaddei Uen would show a flow of 1600 million cu.m per year, from a peak of 150-160 in April-May to a few cu.m/sec, or altogether nil, in February-March. This is an evident indication of the torrential nature of the Shebeli. As the volume of flow decreases in Somali territory, the river channel grows narrower and eventually spreads into a number of anastomosing channels, causing the formation of extensive marshes. In fact the riverbed, which is 65 m wide at Belet Uen, and could accept a flow of 300 cu.m/sec in the flood season, is reduced to a width of 22 m at Hawai and its capacity is of only 43 cu.m/sec.

The very large accumulation of silt and sand which the river deposits annually, owing to the absence of a natural outlet into the sea, have caused the aggradation of the river-bed, which is, in places, higher than the surrounding alluvial plain. Besides, the limited capacity of the riverbed, which cannot contain all of the water flowing down in peak flood periods, has favoured the formation of minor channels: these tend to divert water from the river towards lateral depressions which are entirely submerged by flood water for thousands of hectares. The water overflowing in the middle reaches of the river causes minor damages, and at times is actually beneficial, for it transports fertile mud which provides a good cover for the cultivable land. Owing to evaporation (estimated at 6-7 mm per day) and infiltration, the soil dries up in a few months and is ready for tillage and sowing. On the other hand, salts and fine clay particles are deposited in the terminal marshy area; here the soil becomes harder, impervious, salt-laden and is no longer suitable for certain kinds of crops. The velocity of flow in the terminal portion of the river is at the minimum. Gatti reports that "...a distance of 30 km between Mocoi Shelele and Billich Durre was covered in 20 days (16 December - 4 January 1956); in other words, the water was flowing in the riverbed at the rate of 1½ km in 24 hours."

The conclusion reached by almost all the authors in their hydrological reports on the Shebeli river is that this watercourse, in the past discharged into the Juba, the most important river in Somalia, with an average flow of 5250 million cu.m per year; that it was subsequently separated from it, owing to the silting up of its bed, and gave rise to marshes which kept gradually advancing inland. The marshes grow in extension at a fairly rapid rate: in fact, comparatively recent records show that the length of the river has decreased by several kilometres. Areas formerly grown to bananas and quite flourishing a few decades ago, are now turned into unhealthy marshy land; a good number of farmers who subsisted on their agricultural activities were forced to abandon the land due to the invasion of water.

The Flood Disaster of November-December 1961

The exceptional floods of November-December 1961 confirm the assumption that the Shebeli and the Juba originally mingled their waters and ran together to the sea. On that occasion, owing to the heavy and persistent rain in Ethiopia and Somalia, the water overflowing from the Shebeli reached the Juba. On 27 November 1961 the "Corriere della Somalia" wrote: "The Shebeli has merged its waters with those of the Juba at Lake Haranago, some 25 km west of Gelib. Our information is that the flood water has attained the following villages, all situated on the left bank of the river: Bulo Omar Mussa, Homboi, Bulo Alio, Gudo, Bulo Daar, Bulo Here, Bulo Tukleh, Bilik Omano and Bulo Amino." Again, on 7 December 1961, the same newspaper informed: "Although the rain has stopped, the situation is very serious and at times alarming in the Lower Juba Region. Following its old buried bed, south of Hawai, the Shebeli has joined the Juba in the proximity of Ghinis farm, near Bulo Naghib village; the water is dangerously turbulent where the t o rivers meet , and there is danger of erosion, landslides and overflowing in other places also." Two days later, the newspaper, in an article on the evacuation of the Isle of Alexandra, carried the following news: "Information from Kisimayu is that as a result of the merging of Shebeli and Juba, the following villages have been flooded: N'gambo, Moffi, Bulo Jak, Bulo Masciaga, Migua, Bulo Dumbilo, Sciagola, Faffule and Magalango. The farms situated near these villages have also been inundated, despite the efforts of the local population, especially at N'gambo, to stop the advancing water. After flooding the farms, the water seems to be flowing in the direction of the national road...". The exceptionally high flood caused the inundation of almost all the areas adjoining the river - practically from the entry of the river into Somali territory up to and beyond the District of Gelib. At times, as in the area comprised between Mahaddei and Jowhar (formerly called Villabruzzi) on the left bank of the river, the water reached the foot of the coastal dunes and formed 30-40 km wide marshes.

The damages were enormous. The population was driven away from the villages and had to abandon all their possessions.

Heavy losses, in terms of human lives and cattle, due to disease or drowning, were also registered.

The cause of this disaster is to be found not only in theheavy rain falling in Ethiopia, but is also due to the exceptional amount of rainfall in Somalia in the September-November period. Land submersion was further favoured by the scarce permeability of the surface cover of alluvial clay, which facilitated stagnation of water and the formation of marshes. The marshes extended by the effect of additional rainfall and renewed overflowing of the river.

The exceptional character of rainfall in 1961 is shown by the recordings made at the pluviometric station in the Shebeli Valley:

Average up to 1959		1960	1961
Belet Uen	= 204.0 mm	208.7 mm	467.3 mm
Bulo Burti	= 329.1 "	337.0 "	429.6 "
Villabruzzi	= 502.4 "	498.3 "	630.0 "
Uanle Uen	= 565.2 "	582.5 "	880.6 "
Balad	= 468.2 "	588.4 "	959.8 "
Mogadiscio	= 400.9 "	402.8 "	1144.7 "
Genale	= 447.1 "	621.1 "	1347.0 "

Turbidity and Salinity

No careful and systematic study has yet been made on the turbidity and salt content of the Shebeli river. All the same, it is well known that its waters carry considerable quantities of silt and salts. In his book "La Valle dell'Uebi Scebeli", Conforti reports: "The aggradation of the river is chiefly due to the large quantities of materials transported in its water during flood seasons; in fact, it has been observed that silt content in the gu season is as much as 10%, and sometimes even more; this percentage is reduced to 2-7% during the months in which the river flow is at a medium level and in the second flood period;

it then falls even lower when the water decreases to a lower level." Personally, I have inspected the area several times and have collected samples of water, which I then analyzed for specific conductivity. I have thus formed the opinion that the percentages given by the above mentioned author are somewhat exaggerated. In any case, only a periodic and systematic analysis of the river water over a number of years will permit to determine its average turbidity. In order to attempt a rough evaluation of the magnitude of this phenomenon, let us assume that the quantity of solids transported is equal to 1% (the real percentage is undoubtedly higher); then, on the basis of a flow measurement taken at Mahaddei Uen, we would find that the average flow in the period 1918-1933 is 1,600,000 cu.m per year, or 50 cu.m/sec. In other words, the river transports 30 cu.m of silt per minute, or 15,760,000 cu.m in a year, depositing them in the low-lying areas beyond Mahaddei and in the terminal marshes.

The data concerning salinity is also far from encouraging. The data obtained from SAIS, based on the averages of several years, would show that the yearly average of total solids per 100 litres is 71.57 g, 13.36 of which consist of sodium chloride. On the basis of the Mahaddei measurement (1,600,000 cu.m of flow) we would find that in a year the total solids carried by the river amount to 1,145,120 tons, including 213,760 tons of sodium chloride. This salt poisons the soil in the depressions and in the marshy areas. These data, however summary, explains the phenomenon of aggradation and the gradual expansion of the marshes, which causes the river to become gradually shorter. This means that the now flourishing agricultural area of Genale will soon be doomed, unless proper and timely action is taken to protect it.

Some Values of Specific Conductivity of the Shebeli
(in Microhm ./cm)

Belet Uen	= 230	(28.8.60)	Balad	= 1600	(29.1.57)
" "	= 400	(9.10.61)	"	= 1350	(28.2.62)
Bulo Burti	= 900	(23.1.60)	"	= 1400	(3.3.60)
" "	= 1600	(3.3.60)	"	= 1850	(1.4.57)
" "	= 690	(1.4.57)	"	= 450	(24.6.60)
" "	= 400	(9.10.61)	"	= 750	(12.6.61)
" "	= 350	(28.8.60)	"	= 1050	(5.11.60)
" "	= 420	(1.8.61)	Afgoi	= 1600	(29.1.57)
Mahaddei Uen	= 850	(23.1.60)	"	= 1350	(9.1.58)
" "	= 1500	(5.11.60)	"	= 1020	(20.2.61)
Jowhar (former			"	= 1000	(19.4.62)
Villabruzzi)	= 1650	(20.3.62)	"	= 520	(27.7.61)
"	= 450	(24.6.60)	"	= 350	(15.8.60)
"	= 800	(5.7.61)	"	= 510	(2.8.57)
"	= 370	(9.10.61)	"	= 700	(25.11.60)
"	= 445	(1.8.61)	"	= 710	(5.12.58)
"	= 1500	(5.11.60)	"	= 1000	(16.12.59)
			Genale	= 820	(22.4.61)
			"	= 820	(22.6.61)

Salt content is highest in low water periods: salt, in fact, concentrates as a result of evaporation.

The average flow, calculated on the basis of measurements taken at Mahaddei Uen over a period of 11 years, is as follows:

	cu.m/sec		cu.m/sec		cu.m/sec		
January	24	April	18	July	41	October	86
February	11	May	71	August	58	November	78
March	9	June	65	September	86	December	48

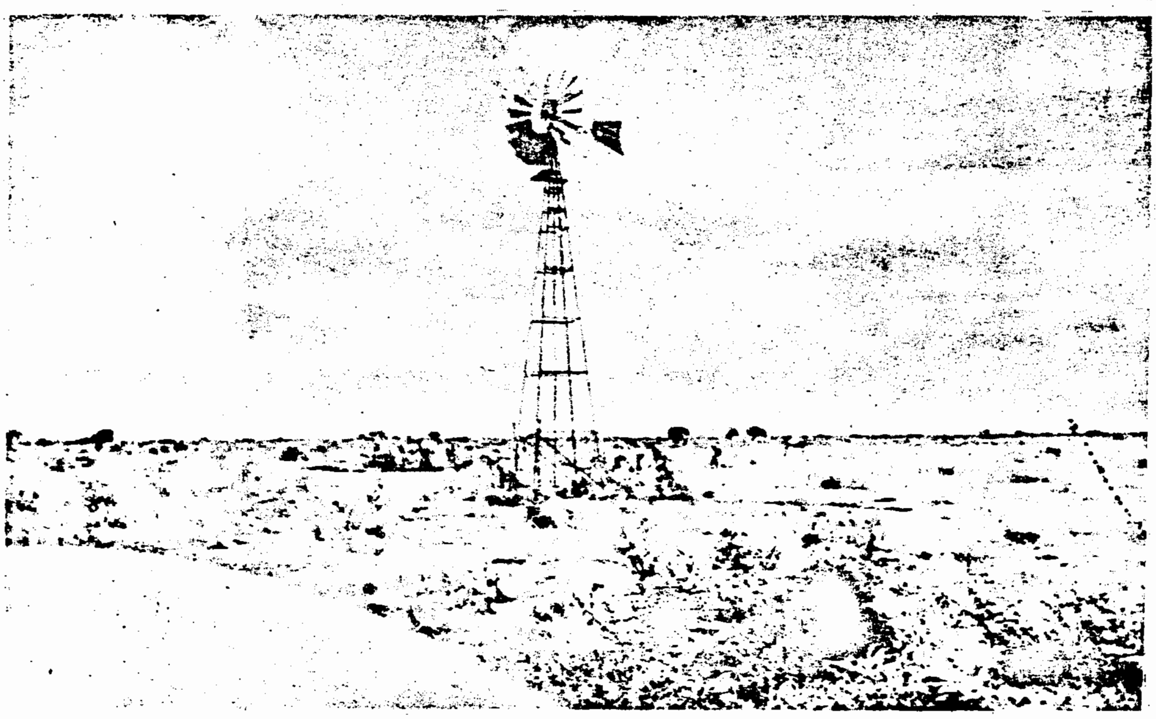
Utilization of Excess Flood Water of the Shebeli

Natural conditions in Somalia are not favourable to the construction of impounding dams for the control of river flow. Before World War II, the Mustail area, which Somalia is now claiming back from Ethiopia, had been considered suitable for such river engineering works.

Also in the past the powerful floods which periodically inundated the farmland irrigated by the European methods in the Genale-Goluin district, the invasion of marshes and the barrenness of the soil due to silt and sand depositing at the tail end of the river were a cause of serious concern. Several research teams conducted surveys designed to provide a solution to all these problems. Particularly worthy of note are the findings of the following scientists: T. Zammarano (1921-22; see his report "Esplorazione del Basso Uebi Scebeli"); Ansaldi (1929; Ansaldi-Grotti Project); Zaccarini-Tedeschi (1930); Gatti-Lucidi (1955-56); Tozzi-Conforti (1955); Favilla (1958-60). The most recent studies all agree that the only solution is to construct canals which would convey excess flood water to natural depressions: these could be utilized to store the water for the stock or to put new land under irrigation. Actually, the river engineering works in the middle and lower reaches of the Shebeli were constructed with the intention to create flood irrigation canals, to be used only during peak flood seasons (May-June and October-November), when the water would attain and exceed the hydrometric level of the intakes.

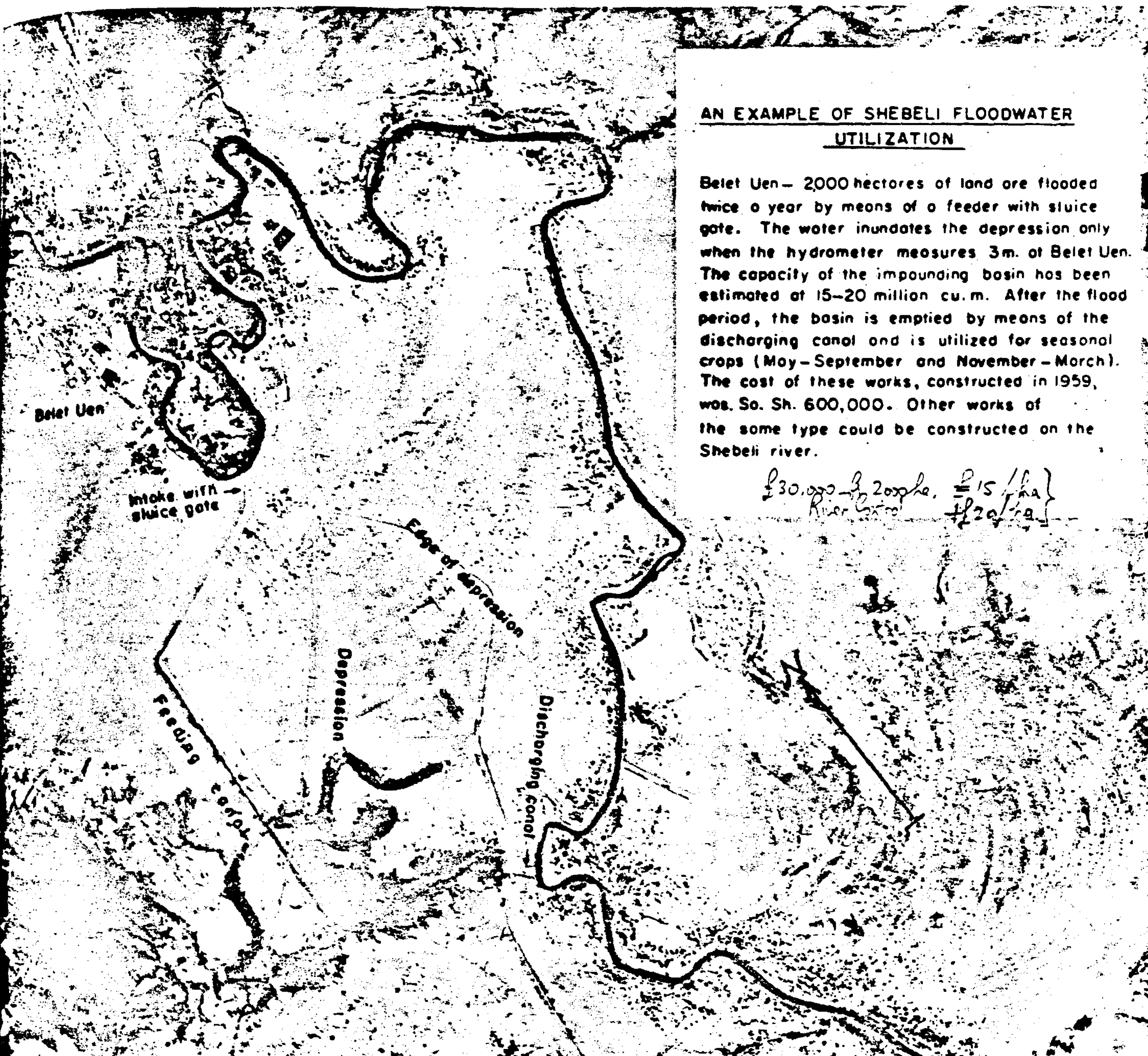
Among the major works completed by the Public Works Department in these last years, we should mention the following:

The Shebeli at Balad



Fidda Gudut well — 78 Km from Mogadiscio on road to Merca - A typical aspect of the alluvial plain of the Shebeli.

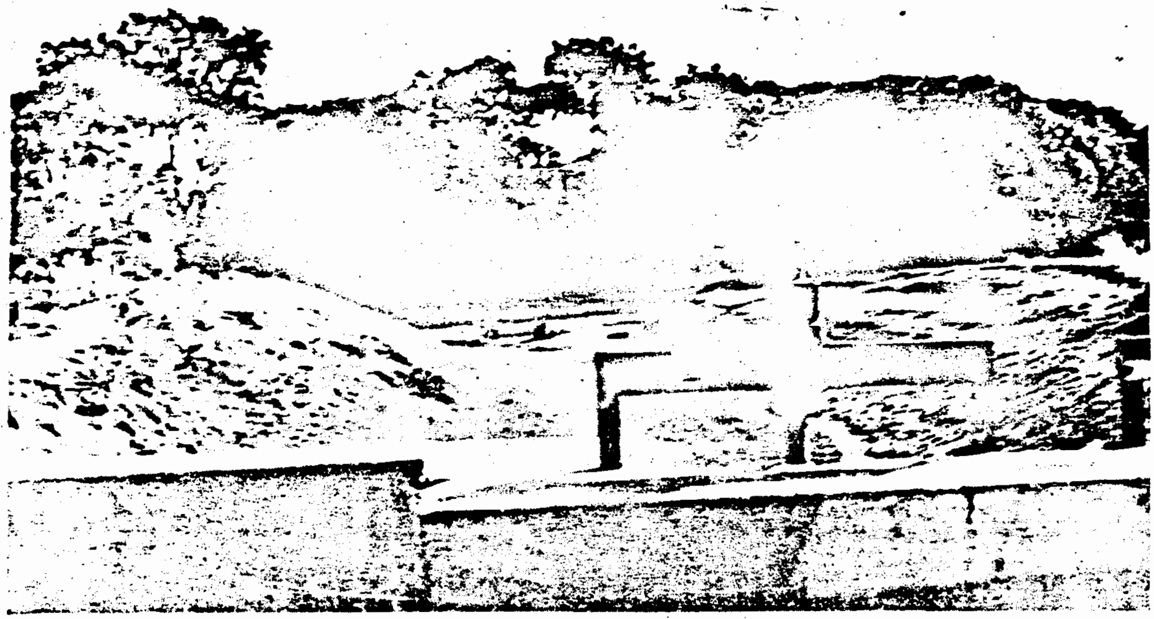
10,000 × 2000



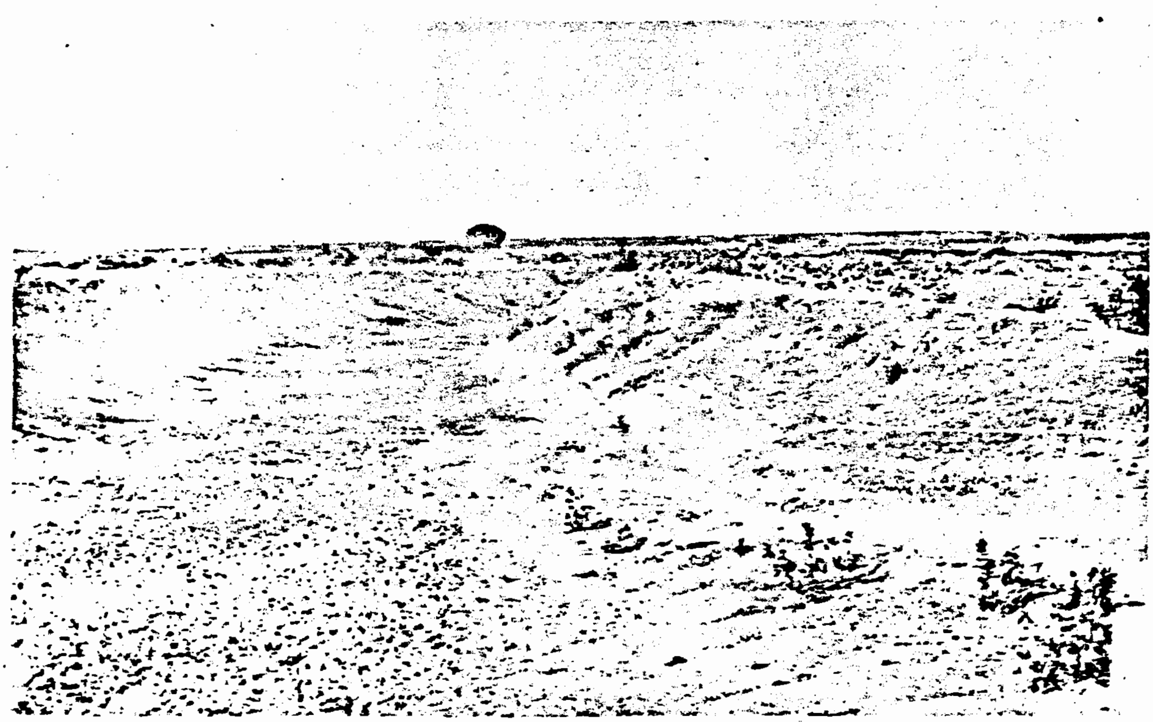
AN EXAMPLE OF SHEBELI FLOODWATER UTILIZATION

Belet Uen – 2000 hectares of land are flooded twice a year by means of a feeder with sluice gate. The water inundates the depression only when the hydrometer measures 3m. at Belet Uen. The capacity of the impounding basin has been estimated at 15–20 million cu. m. After the flood period, the basin is emptied by means of the discharging canal and is utilized for seasonal crops (May – September and November – March). The cost of these works, constructed in 1959, was So. Sh. 600,000. Other works of the same type could be constructed on the Shebeli river.

£30,000 ÷ 2000 ha. £15/ha }
River Control £20/ha }



Belet Uen — Intake, with sluice gate, of the feeding canal (detail see ariphoto).



Belet Uen — The feeder of the depression (detail, see airphoto).

- main canals and feeders, conveying water from the river to the irrigable areas;
- cement works with adjustable sluice gates;
- rehabilitation of natural channels, for a total length of 35 km;
- consolidation of river embankments;
- construction of two dams consisting of reinforced concrete blocks;
- opening up of new tracks.

These works have resulted in the agricultural transformation of several thousand hectares of land.

However, a final solution has not yet been reached. There are other areas, lying slightly below the level of the river, which extend for several thousand hectares: their very fertile soil could absorb part of the excess flood water and could be profitably grown to flood-irrigated crops, such as maize, sorghum, cotton, groundnuts; another possibility would be to create in this area reservoirs providing water for the stock. Leaving aside the more or less pronounced depressions found in the area extending from the Ethiopian border to Belet Uen and Bulo Burti, which are, on the whole, of considerable importance, there are, nevertheless, other zones which would benefit greatly from agricultural reclamation works involving the utilization of water from the Shebeli. They are, in the order in which they are encountered following the course of the river, as follows (see map No.2):

1) Bulo Burti-Mahaddei Uen

Burdere-Giallalassi depression, on both sides of the river; Manour depression (123 km from Mogadiscio, on the Mogadiscio-

Zone of Gololei — 55 Km from Mogadiscio on the road to Jowar - overflooded by the Shebeli annually during peak flood.

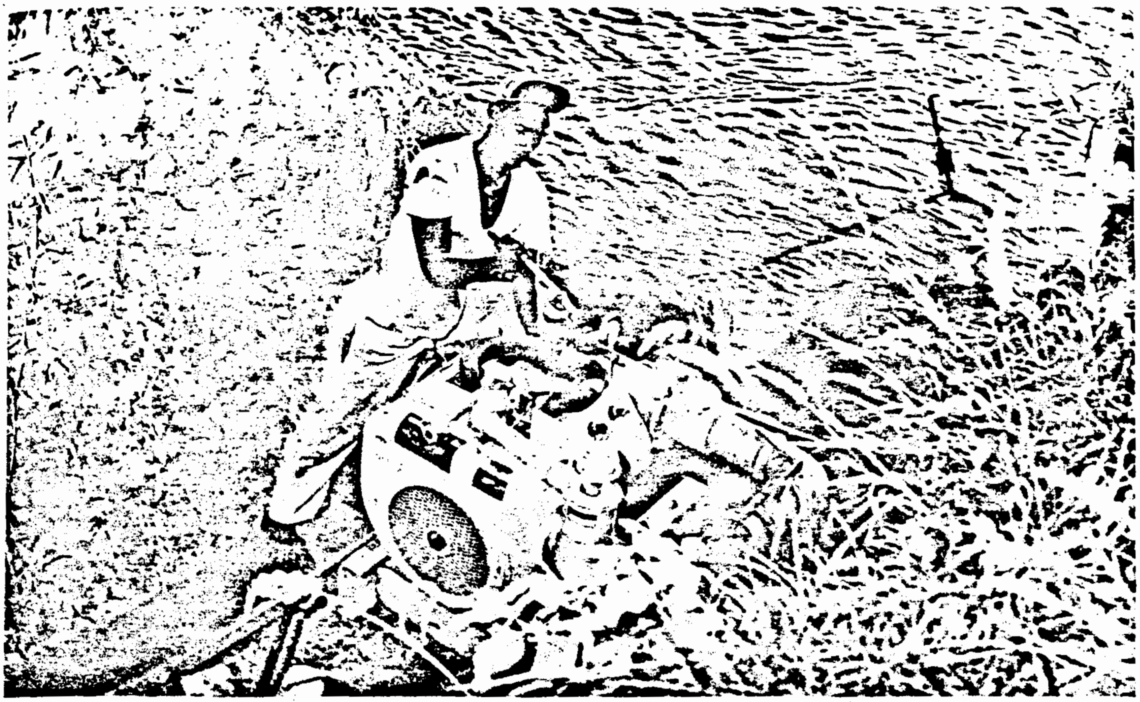
The Shebeli between Jowhar and Balad and canal feeding a depression

Bulo Burti road on the right side. In the latter zone, if appropriate intake works and canals were provided, extensive tracts of land, including Mabilen and Dafet, could be flood-irrigated. In fact, an old bed of the Shebeli, which traverses Adalei between Lamma Donca and Uer Mahan and runs into the marshes WSW of Coriole, forms a very long depression: it would be interesting to ascertain whether it could be used to divert part of the water flowing into the Shebeli during peak floods. If such a project should prove feasible, it would offer the dual advantage of preventing overflow in the Genale-Goluin-Bulo Mererta district and of improving this floodable tract of land.

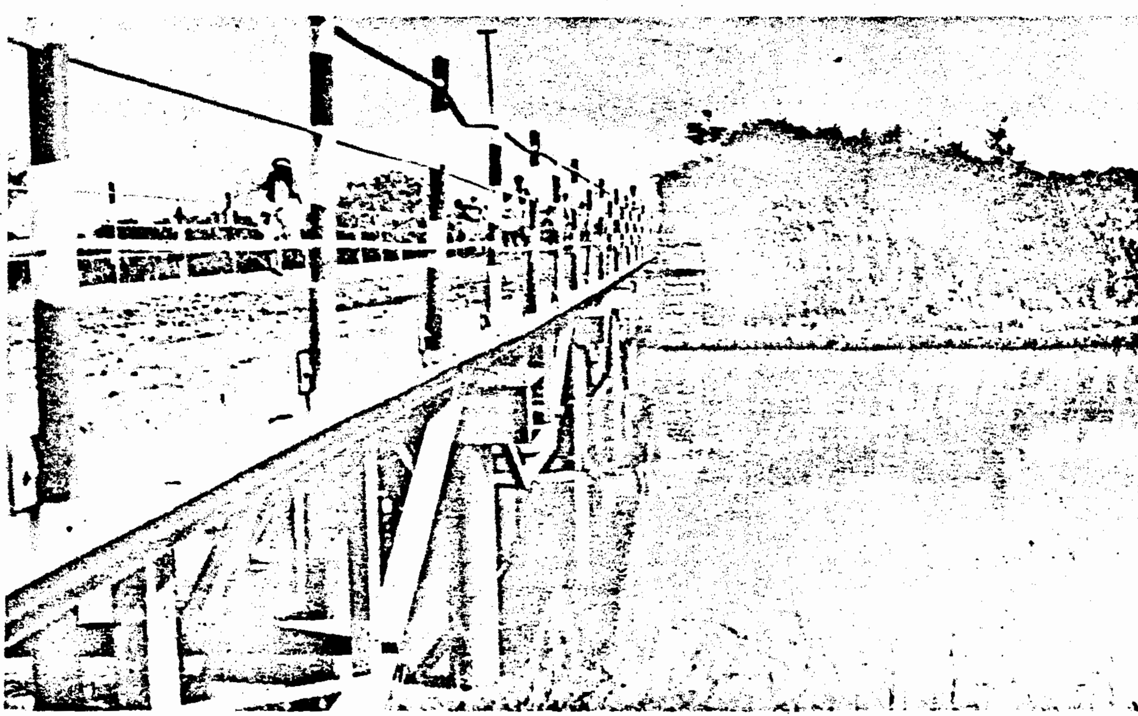
2) Mahaddei Uen-Balad area

It is a broad belt of land extending S of Mahaddei, and at a short distance from it, as far as the outskirts of Jowhar, on the left bank of the river. It lies lower than the flood level of the Shebeli and is submerged annually. When the river flow rises exceptionally high, the overflowing water covers approximately 700 to 800 sq.km of land, as far as the foot of the dunes in the Uar Dagah area (some 30 km away from the river).

On the right bank: a) the area comprising the villages of Mandere and Balade, which may be inundated each year for a few kilometres both along and transversely to the river; b) the area comprising the villages of Moccoidere and Mererei, upstream from Balad: the water overflowing annually may inundate a long strip of land a few kilometres wide, exceptionally extending beyond Gululei village, in the direction of Jowhar.



Afgoi Experimental Farm — The pumping station on the Shebeli.



The Shebeli at Afgoi during a peak flood

3) Balad-Afgoi area

In this tract, the banks of the river are higher than the flood level of river flow and there is no overflow; in fact, the banana plantations at Afgoi must be irrigated by means of pumping stations.

4) Afgoi-Audegle-Coriole

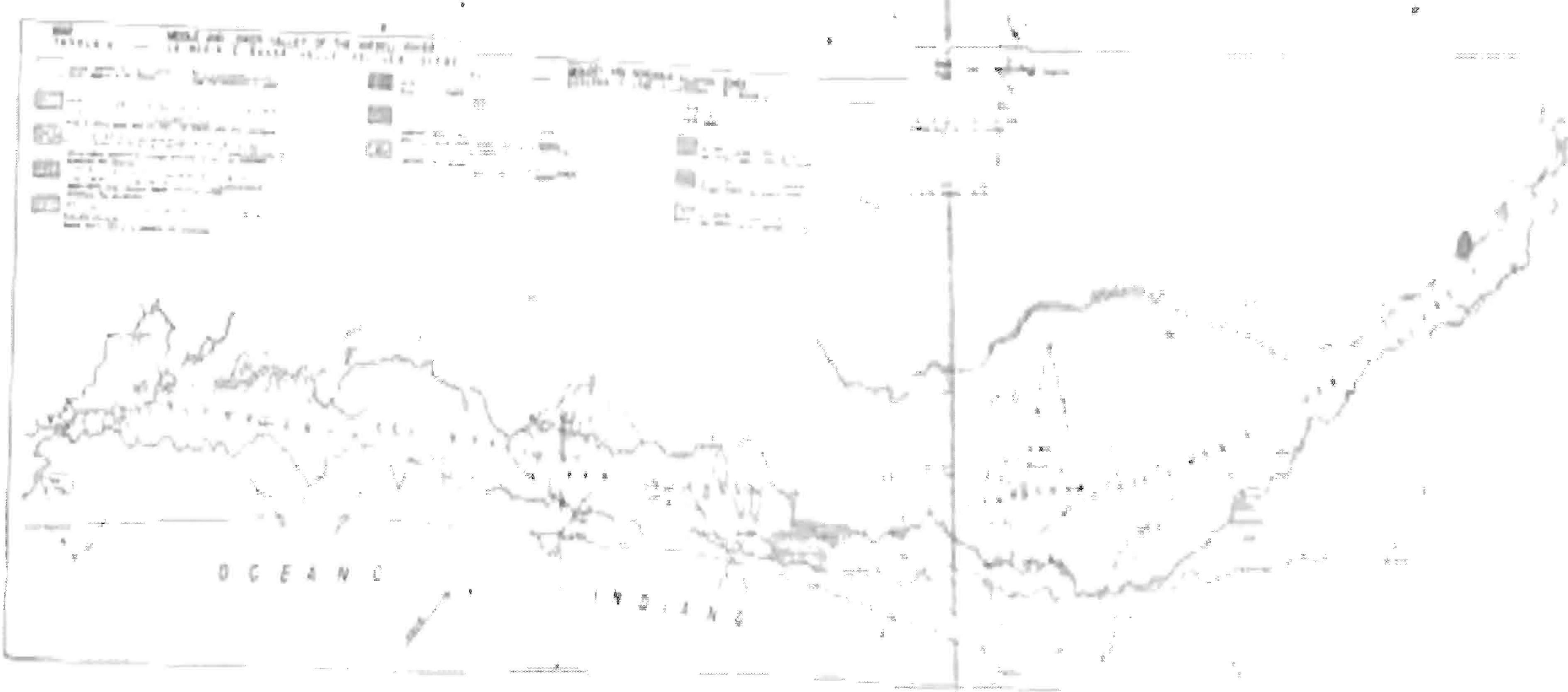
Beyond Afgoi the land bordering the river falls to a lower level and is therefore flooded each year; this permits the growth of flood-irrigated crops at an intensive rate in the first tract; but after Audegle we come to the agricultural district of Genale, where engineering works allow water to be rationally distributed by means of irrigation canals. In practice, from Audegle on the bed of the river is inadequate to contain the volume of water flowing down during the flood seasons; therefore, each year a large area is inundated, with very serious damage to the crops. This situation remains unchanged as far as and beyond Coriole, where the marshes originate.

5) Coriole-Ido Gudo-Avai area

Here the river forms marshes and effluents in the direction of the surrounding plain, which is inundated for a width of several kilometres. Due to the presence of the many effluents, the course of the river is no longer clearly defined.

6) Avai-Ballei Ier area

In this last tract, the above mentioned peculiarities are enhanced, and the river loses its distinct physiognomy altogether; in fact, it forms a network of minor effluents and depressions, which are subject to inundation during the floods, so that also in this area the marshes are quite extensive.


OCEANO
INDIANO

The characteristics of the tracts of the river described above are not new to us; in fact, they have already been the object of study in the past, and have been mentioned here as an illustration of the maps annexed to this report; this map has been drawn up on the basis of a photogeological study which evidences and permits us to determine the alluvial areas subject to inundation; these could be studied in future for the purpose of controlling river flow by means of diversions leading flood water to the depressed areas and by means of agricultural reclamation works, in the sense that dry farming areas could be converted to irrigated crops. There would be the added benefit of decreasing the danger of overflow, which is very prejudicial to rationally irrigated crops. Other benefits deriving from such a scheme would be: the transformation of bushland into agricultural land; the availability of abundant water supplies for the stock in areas removed from the river; the settlement of nomadic and semi-nomadic populations in the reclaimed areas. This would ultimately cause an increase in the national income.

The Need for a National Hydrological Service

Our earlier conclusions are based on the forecast of what would happen as the result of a river training scheme for a more profitable utilization of the water of the Shebeli.

There is no need to stress the enormous importance of the two rivers of Somalia for the national economy. It is therefore necessary to establish as soon as possible an efficient national hydrological service with the task of planning and undertaking the works required for utilizing mainly the waters of the Juba and the Shebeli. The experts participating in the FAO-assisted project of agricultural reclamation in the inter-riverine area are now planning the organizational structure of such a service. It is, however, necessary that timely action is taken by selecting a well-trained and qualified person to be put in charge of the service. Minimum staff requirements are:

(i) a hydraulic engineer (as Head of the Service), who would plan and conduct mapping surveys, construction of intakes and diversions, canals, processing of data, etc.;

(ii) two land surveyors to map the inundable areas, supervise the construction of the canal network, repairs, desilting, embankments; they would also act as inspectors of the water gauging stations;

(iii) a draftsman;

(iv) supporting personnel (mechanics, tractor operators, drivers, etc.);

(v) river guards, to prevent illegal breaching of embankments, inspect canals and notify any stoppage or leakage of flow.

The service should obviously be organized on a permanent basis, with the following tasks:

1) to provide and complete works for the utilization of excess flood water;
2) to provide for maintenance;
3) to allot water supplies to farmers for irrigation purposes in the different seasons;
4) to make studies on evaporation and infiltration;
5) to construct small earth or masonry dams elsewhere in the territory.

For the more important and complicated projects the services of consulting engineers should be obtained.

It is felt that, if the service is provided with sufficient means to tackle and solve the various problems connected with water resources in Somalia, the whole country will derive great and unexpected economic benefits.

PART II

THE ALLUVIAL DEPOSITS OF THE UEBI SHEBELI VALLEY AND ITS LARGE GROUNDWATER POTENTIALITIES

After briefly reviewing, in Part I, the characteristics of the Shebeli and its development prospects, it is now proposed to consider, in some of its aspects, the hydrogeological structure of the extensive alluvial deposits which were accumulated in the river valley.

The information on the subject is very abundant, thanks to the remarkable contributions made by C.I.S.A. and Sinclair Somal Company, which carried out researches in the Afgoi, Genale and Coriole districts _; this makes it possible to predict with good approximation the depth of the aquifers and the quality of the water occurring in the different alluvial zones.

1. Geological Formations in the Shebeli Valley

The Cretaceous rocks outcropping on both sides of the Shebeli valley are the oldest geological formations. They can be divided into four series, which present a scarcely noticeable SE dip. Small localized foldings and moderate faults have been observed in the Belet Uen area; in all other areas, the series run generally sub-horizontally with a gentle slope westward, and do not appear disturbed.

a) Mustail Series - Barremian-Cenomanian

It outcrops alongside a belt of land as the river enters Somali territory, particularly on the right bank of the river, up to and beyond Bulo Burti. This series is formed by fossiliferous limestone, mostly consisting of Rudistes, marls and marly limestone; after Bulo Burti, it is hidden by strata of limestone-gypsum caliche and alluvium transported by the river. In all likelihood, this formation undergoes a change of facies as one proceeds from north to south, with an increase of marl and clay. Information on the quality of the water occurring in this series is scarce; the only wells are at Bur Uen and El Bilal (see Part III, Nos.19 and 22) and the water at these two locations shows marked salinity. This does not exclude, however, that better quality water may be found elsewhere in the same series. The water table generally lies at a comparatively modest depth, usually not exceeding 50 m.

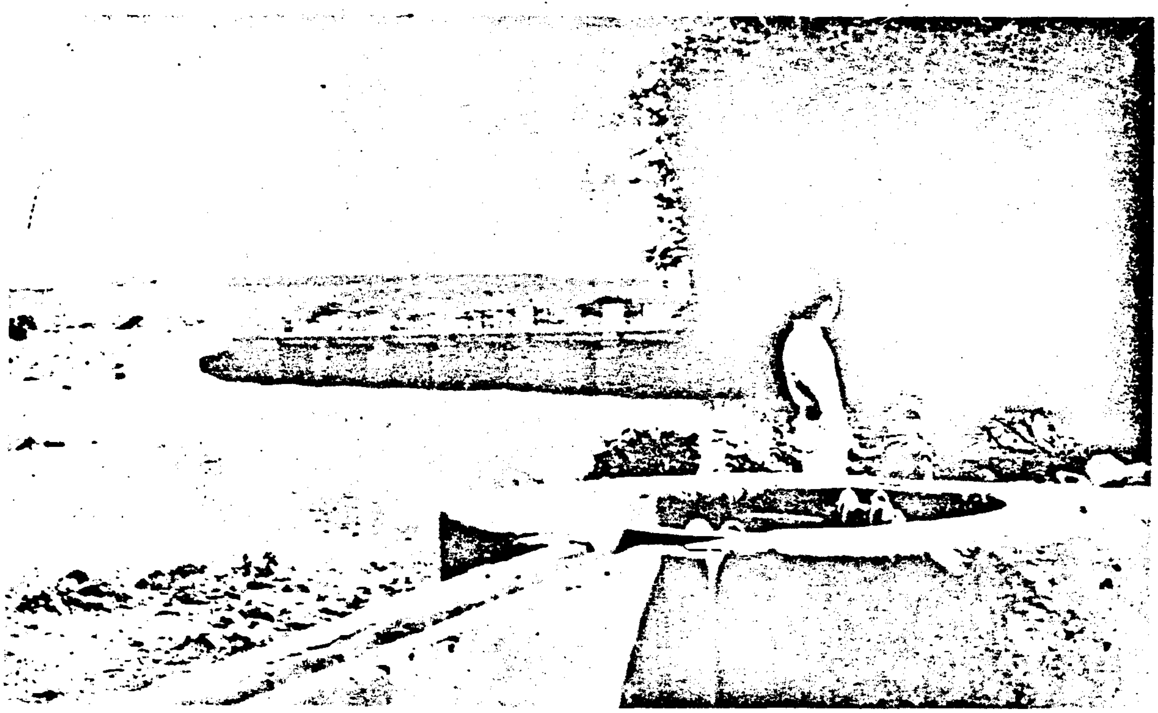
b) <u>Fer Fer Series</u> - Cenomanian

It consists mainly of limestone and marly clay, interbedded with layers of gypsum. It outcrops in a belt of land on the left bank of the river, i.e. from Fer Fer halfway to the road and from Belet Uen to Bulo Burti; it then thins out, probably due to a change of facies, and tends to disappear under river alluvium. The quality of the water found in this formation is poor and at times definitely unacceptable, such as the water supplied by the well bored at 300 km on the road to Belet Uen (see Part III, No.9) and by a well at Fer Fer (see Part III, No.1): in both cases the water has a high degree of salinity.

c) <u>Belet Uen Series</u> - Cenomanian

It consists mainly of fossiliferous sandy limestone, grayish-blackish thin-bedded clay alternating with sandstone

The Cretaceous hills of the Belet Uen Series - between Belet Uen and Bulo Burti - left bank of the river



Kili Ara — one of the largest tributaries of the Shebeli - The hand-dug well taps water from the sands of its alluvial bed.

strata. A considerable percentage of sand is to be found in the area NE of Belet Uen. This formation outcrops along a continuous belt on the left side of the river, up to Bulo Burti; thereafter, it disappears under alluvial formations. The water from the wells at Berghedit and Avorei (Part III, No.13) shows considerable salt content.

d) <u>Jessoma Series</u> - Turonian?

It overlies the preceding series and forms an escarpment consisting essentially of rust-coloured quartz sandstone. Here originate a few streams which, after cutting into the preceding series, flow into the Shebeli river. Below the escarpment, this series consists essentially of a thick bed of siliceous sand with intercalations of varicoloured clay and calcareous sandstone strata. The quality of the water occurring in these deposits is mostly good, or excellent, as for instance at Mataban and Jessoma.

All of the above series are the only ones outcropping in the Shebeli valley. Their thickness is comparatively modest; according to estimates, the Mustail series is not more than 80 m thick; the same goes for the Fer Fer series; the Belet Uen series may reach, in places, a thickness of 300 m, whereas the Jessoma series may even reach 500 m. These data refers, of course, to outcrops along the Shebeli valley, which forms the line of demarcation of the Cretaceous basin; as a matter of fact, at Obbia the Sinclair Company had to drill through a few thousand metres of Cretaceous formations.

d) Continental Deposits of the Lower Tertiary-Quaternary

(i) "Caliche"

Arenaceous limestone, with frequent nodules, clayey or marly, compact, of a whitish or brownish colour, at times containing continental fossils. These calcareous materials form a surface crust, a few metres thick, which overlies Jurassic and Cretaceous formations extending in a long strip NE of Uanle Uen. The wells at Ologof, Olobiole and Uambatti were bored through this limestone. Also the gypsiferous marly crusts extending between the limestone and recent clayey alluvial deposits of the Shebeli are to be considered as "caliche" as far as their origin is concerned, for the nature of the underlying formation is completely different. These crusts cover completely the underlying formations. Groundwater is very close to the surface: all the numerous wells sunk in the arenaceous limestone and in gypsum or gypsiferous marl strike abundant water at a depth of a few metres. It is quite probable that this cover formed after the water-table had risen to a level higher than the present one; in all likelihood, this happened simultaneously with, or immediately after, the Pluvial period. The original rock, the surface of which was weathered, was cemented again by salt-laden solutions, which had found their way to the surface. The quality of the water may vary from rather good to good in the wells sunk in arenaceous limestone, and from poor to very poor in the wells sunk into gypsiferous marls.

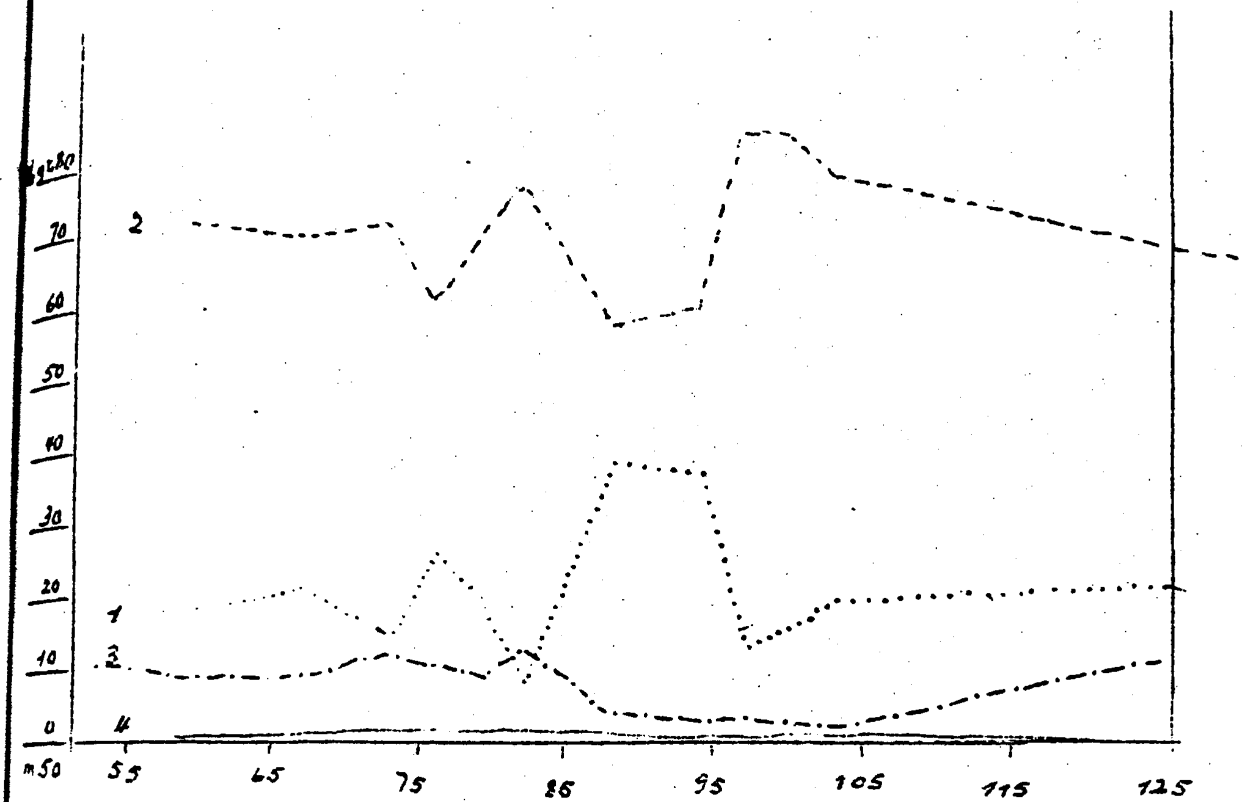
(ii) Eluvial Quartz Sand

This sand was formed as a result of the alteration of the crystalline basement, and particularly of the granite rocks in the "Bur Region". Because of their presence, there is no clearly defined contact between crystalline rocks and river alluvium. Clayey alluvium is gradually replaced by coarse quartz sand, often interbedded with reddish clayey sand and a sandy laterite formation, the sand of which must be, partly, of aeolian origin. The thickness of these sandy strata varies from place to place. In areas where they come in almost close contact with the clayey alluvium deposited by the river, they may even be some 10 m thick. Rainwater percolates through this sand and recharges both the deep-lying strata resulting from the disgregation of the crystalline formations and the aquifer in the pebbly and sandy deposits accumulated by the river.

(iii) Coastal Sand Deposits

This formation prevents the river from draining its waters into the sea. It runs on the left bank of the river in the lower part of the valley. The origin of this huge sandy deposit - which, according to the electrolog of Merca well No.1, is estimated to be some 450 m thick - is partly due to aeolian sand and shore deposits. In the strips of land bordering the river it consists of fine-grained quartz material, often loose, or in any case insufficiently cemented, and of small sparse calcareous concretions. Grain size is shown by the graph on next page, based on samples of the aquiferous sand found at a depth of 55 to 125 m in the well bored at Rahole village, at 50 km on the road from Mogadiscio to Merca.

Granulometric Profile of Well drilled at Rahole village



LEGEND

1 ·········· granules from 0.80 to 0.42 mm in diameter
2 - - - - - - granules from 0.42 to 0.15 mm in diameter
3 -·-·-·- granules from 0.15 to 0.074 mm in diameter
4 ——— granules 0.074 in diameter

2. Topography and Drainage

The river meanders all the way from the Somali border to its tail end, due to its scarce gradient. In fact, after its entry into Somali territory the river travels a little over 1000 km, but the total difference in level over this distance is of only 160 m. (More detailed studies on the subject are being conducted by the UNIFAO Agricultural and Water Survey Project.) This explains the formation of the extensive alluvial deposits.

As concerns topography and drainage, the Shebeli valley can be divided into two zones:

a) from the Ethiopian border to Bulo Burti;

b) from Bulo Burti to the tail-end marshes.

The first of the two zones is a large valley, the sides of which are clearly marked by exposed rocks. The escarpments on the left side consist of sandstone, limestone and gypsum, which can be dated back to the Cretaceous; the streams cutting into them often fail to rejoin the main river due to their insufficient gradient and to the formation of alluvial fans. Underflow occurs in the case of the more important streams: this water is partly utilized by means of shallow wells.
On the right side, outcrops consist essentially of gypsum, limestone and clay, dating back to the Jurassic and the Cretaceous; the slope of this side is more gentle than the left one. The streams cut less deep into these formations and are shorter.

The width of the alluvial belt may vary from 5 to 15 km. At a distance of approximately 30 km from Belet Uen, the left side of the valley rises to over 400 m; the left side rises gently up to nearly 500 m.

The second zone is a very flat one, with a gentle southward slope. In the northern part, from Bulo Burti almost as far as Mahaddei Uen, a few rocks outcrop and the alluvium, varying in thickness from a few to several tens of metres, covers only riverine land. From Mahaddei to the former junction with the Juba, the alluvial deposits spread over 80 km wide and form an absolutely flat expanse: it consists prevalently of blackish, brown and gray-blackish clay, with an often negligible sand content.

The eastern, southern and south-western margins of the plain are bounded by the coastal line of dunes; on the NE-SW side the limit of the plain is not as clearly marked, for the eluvial and alluvial materials covering the basement rock mix without a definite line of demarcation; on the SW side, the alluvial deposits formed by the Shebeli and the Juba come in contact and mix together.

3. A Paleogeographic Reconstruction of the Shebeli Valley

Different views have been advanced by different authors in the attempt to determine the age of the alluvial deposits of the Shebeli valley and to explain the phenomena which caused the bedrock of the alluvial deposits to fall below the present level of the sea. Among the chief authorities on this subject, Dainelli, Stefanini and Ahrens will be cited. These three authors, while disagreeing in certain details, share the view that the Shebeli originally ran into the sea somewhere near Mogadiscio, and that its course must have been diverted by a barrier of coastal dunes created by the wind and by marine currents. As to the age of the dunes, which Stefanini believes were formed in the interglacial period, Dainelli writes: "It is rather risky to date back to an interglacial period a phenomenon of which one can hardly establish the age. However, we think that during the pluvial period, considering the volume of water which must have been carried by the rivers descending from the Somali plateau, the accumulation of sand due to the action of the wind along the coast may hardly have entirely choked the old river course, causing its diversion. This is one more reason for attributing to the post-pluvial period the formation of the barrier of dunes; if we accept the assumption that an older dune formation existed, before the coastal area sank to a lower level, in this case also we come to the conclusion that the barrier of dunes is of more recent origin". Dainelli thus does not disavow Stefanini's assumption that the Shebeli discharged into the sea near Mogadiscio, but only questions the fact that in the interglacial period the dunes could prevent the outflow of the river into the sea.

In any case, this hypothesis has not been confirmed by the findings obtained from two wells drilled at Alialo, halfway between Mogadiscio and Balad, in the presumed direction of the old river. The deeper of the two wells sinks to 102 m, i.e. about 10 m below sea level, and the only materials encountered were aeolian and litoral sand. Today additional data suggest that the Shebeli river never reached the sea, at least in the Mogadiscio area.

It would appear that the alluvial deposits accumulated by the Shebeli overlie the Miocene. This conclusion was reached on the basis of the findings made in drilling the Merca No.1 and Duddumai No.1 wells. If these data are assumed to be correct, then during the Miocene the sea must have extended as far as and beyond Mahaddei, continuing in an approximately NE-SW direction, past Uanle Uen and beyond Gelib. At the end of the Miocene the sea began to withdraw. This phenomenon continued through most of the Pliocene and a wide belt of land in the Benadir Region emerged, except the coast, which was still covered by shallow sea water in which the coral formations found the ideal environment to build their reefs, which can be imagined as a continuing series of islets scattered along the coast, like the isles facing the coast between Kisimayu and Ras Chiambone. In this period, the Shebeli accumulated thick alluvial deposits near Mahaddei or between Mahaddei and Balad, where a sort of lagoon was formed. The river may also have been obstructed and diverted in this period, owing to the higher level attained by the coral formations in the coastal zone. Some foraminifers typical of a brackish environment were found in the alluvial deposits between Gelib and Avai: this suggests that the zone must, at some points, still have been connected with the open sea. The presence of the foraminifers, a few metres below the surface, suggests also that the environmental conditions remained unchanged until comparatively recent times. In the Lower Quaternary a movement took place along the coast; this phenomenon was, on the whole, negative, and caused the coastal belt in the Benadir Region to fall to a lower level, together with the hinterland; at the same time, the level of the sea also became lower, as a result of glaciation. In fact, the old coral reefs lie several tens of metres below the level of the sea . Evidence of this is offered by the data obtained from the many wells excavated in the Mogadiscio area, and in particular the well for the new hospital: at this well, at a distance of 4 km from the sea and 45 m below sea level, a coral limestone was found, ivory white in colour, porous, slightly crystalline; the nature of the underlying materials is not known, because deeper drillings were not carried out, but they are supposed to consist of Miocene formations,i.e. the same which underlie the alluvium of the Shebeli valley. The same type of limestone was found in a well drilled 15 km inland on the road to Balad. The negative movement which occurred in the Quaternary was characterized by pronounced oscillations; this permitted the accumulation of huge alluvial deposits which, in places, are as much as 250 m thick; for instance, in Coriole oil well No.1 340 m of fluvial alluvium were encountered: over 250 m of this material lies below sea level (see Table No.1). During glaciation, as the level of the sea dropped,new land emerged and was eroded by weathering agents; the river and its tributaries could therefore transport and deposit enormous quantities of solids, consisting of gravel, sand and clay; at the same time, marine currents and strong winds carried enormous quantities of sand, which added to the size of the coral formations which had barred the way to the river. The action of winds as well as of marine currents must have been formidable, considering that the deposits accumulated by them are a few hundred metres thick. It is thought that the sinking of the land was facilitated by the re-activation of the old NE-SW faults: this would have led to the lowering of the coastal belt and the uplifting in the Bur Region, which represents the basement rocks. In more recent times, the coastal belt was subjected to a rising movement, which is probably going on even now; in a few new wells at Mogadiscio, at depths varying from 35 to 70 m above sea level, fossil remains were found in sands which were once considered of aeolian origin. This suggests that the dunes may also have been formed as a result of shore emersion.(+) The recent occurrence and probable persistence of this phenomenon would appear to be confirmed by the presence of coral reefs, which emerge sparsely from the sea a few metres from the shore, for a width of 500-600 km; in fact, on the road from Mogadiscio to Gesira (SW of Mogadiscio and 20 km away from it), we find one of these coral formations, partly hidden under recently accumulated and scarcely cemented sand of aeolian origin. In all likelihood, the

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(+) The following specimens of fossils were found by Dr. Barbieri in two wells drilled in the Mogadiscio area:

1) Well for Low-Cost Housing Project, 4 km from the shoreline and 50 m approx. above sea level:

movement has also affected the hinterland, as would be shown by the fact that some zones on the left side of the Shebeli, near Afgoi, were, up to some 100 years ago, irrigated by means of water diverted from the river, whereas now the gravity irrigation method is no longer possible. The chief reason must, of course, have been that such areas were filled with alluvial material; however, it is not to be excluded that

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9 to 21 m: Polymorphinides sp., Amphistegina sp., Nonion Elphidium crispum, Rotalia beccarii, fragments of Echinids.

21 to 60 m: samples missing.

60 to 66 m: Amphistegina sp., Elphidium semistriatum, Elphidium (incrusted specimen), Rotalia (keel-shaped), Rotalia aff. calcar, fragments of Echinids.

66 to 82 m: Elphidium crispum, Rotalia (keel-shaped), Cibicides cfr. lobatulus, Rotalia beccarii, Polymorphinides sp, Amphistegina sp.

2) Well for the new radio station, located at about 6 km from the shoreline and about 70 m above sea level:
0 to 27 m: no fossils.
27 to 39 m: Amphistegina sp., Elphidium crispum, Rotalia (keel-shaped), Rotalia aff. calcar, fragments of Echinids.
39 to 51 m: Anomalina sp., Rianulina sp., Amphistegina sp., Rotalia (keel-shaped), Rotalia aff. calcar, Polymorphinides sp., Briozoes.
51 to 66 m: Polymorphinides sp., Rotalia sp. (keel-shaped), Nonion Eocoenum, Robulus aff. calcar, Elphidium crispum, Rotalia sp. (keel-shaped), Quinqueloculina sp., fragments of Echinids.
66 to 81 m: samples missing.

the rising movement along the coast affects, although to a lesser extent, the hinterland.

4. Physical Characteristics of the Alluvial Deposits

The alluvial cover of the Shebeli Valley in the central belt consists of marly clay with scarce sand content, which at the two margins of the valley turns into clayey sand and sand.

Below this clayey cover, there are banks of more or less coarse sand and gravel, often alternating with clay-sand strata, and at times calcareous pebbles. On the other hand, at the margins the sand banks increase in thickness, while the clayey stratum thins out progressively and ultimately disappears. Very fine sand is to be found in the areas next to the dunes; sand is coarse near the point where it comes in contact with eluvial quartz sand resulting from the weathering of crystalline rocks in the Bur Region.

The strata of coarse gravel and sand deposits, alternating with clay and very fine silt in the longitudinal al-

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81 to 108 m: Rotalia aff. calcar, Rotalia aff. inflata, Amphistegina sp., Elphidium crispum (small specimens).

108 to 147 m: Elphidium crispum, Elphidium semistriatum, Rotalia beccarii, Amphistegina sp., Rotalia aff. calcar, Cibicides aff. italicus, Radiolaria, fragments of Echinids, fragments of sponges, Polymorphinides.

luvial belt, are logically to be related to the seasonal phenomena of the Quaternary in Ethiopia and Somalia: in this period the upper part of the catchment basin was subjected to glaciation (traces of moraine were found in several places on the Ethiopian plateau), while rain fell in its middle and lower parts. During these weather extremes, the river had an enormous carrying strength, as would appear from the presence of sub-angular stones and big pebbles at a depth of 100 m in a well in the Genale district. The greater volume of water favoured overflowing, and the river water could freely invade the flatland of the Benadir Region: it thus covered huge expanses of land and filled the depressions, giving rise to marshes, at the bottom of which, in subsequent periods of meteorological calm, very fine clay and salts would deposit. It has in fact been frequently noted that, particularly in the vicinity of gypsiferous rocks, clay deposits present a considerable percentage of selenitic gypsum, and the water connected with or flowing through them shows marked salinity, due to the high degree of solubility of this salt.

The gravel constituents, which are mainly in the nature of sandstone and limestone, may be attributed to the weathering of the sandstone formation at Jessoma, and of the calcareous series of the Middle Cretaceous outcropping along the Shebeli Valley in the Ethiopian and Somali territories. The small and not very frequent siliceous pebbles have been carried a long distance and in all likelihood come from the outcrops in Ethiopian territory, or from the continental accumulations of the Jessoma series. The sand contains a high percentage of more or less coarse-grained quartz, and its origin is partly aeolian and partly alluvial: it also probably comes from the basement rocks.

In general, the sand and gravel constituents are not cemented, but not unfrequently one finds banks of gravel and calcareous concretions with a certain degree of cementation; they form a porous, though compact, aggregate. Porosity and permeability are generally very high in the gravel beds and in the scarcely cemented gravelly and sandy ones, with minimum clay content;they are, however, somewhat reduced when sand and gravel have a clay matrix. A good indication of the high degree of porosity and permeability of the sandy and gravelly beds is given by the excellent results of wells in the Genale area. These wells, which have a 10" diameter casing, reach an average depth of 70 m and their static level varies between 10 m and 15 m: the variation in level after continuous pumping is minimal and the yield is, on an average, 100 cu.m of water per hour.

It is difficult to correlate the data obtained from wells sunk in the alluvial belt, due to the frequent and often sudden lateral change of facies. The deposits have a lenticular structure and result from the filling up of old streamlets and depressions. The change in facies is so sudden that at times the samples from wells located only a few hundred metres apart show an entirely different granulation and do not allow comparison.

5. Recharge of the Alluvial Aquifer

On the basis of present knowledge, it is practically impossible to calculate to what extent the alluvial aquifer is recharged by river and rain water respectively. Very few pluviometric stations exist in the vast alluvial area, and there are no stations to measure evapotranspiration. Furthermore, the size of the area which would permit percolation is not known; at the same time, no provision has been made for measuring seasonal and yearly variations of level in the wells. It is therefore impossible to evaluate the volume of recharge and its origins. This problem, then, can be dealt with only in a general way, without any pretense of adding to present knowledge on the hydraulic balance.

In an earlier part of this paper (Part II, 2) the Shebeli Valley was divided, from a geomorphological viewpoint, into two zones. This distinction holds good also as concerns the recharge and flow of the aquifer connected with the alluvial deposits.

In the first zone, where the alluvial belt comprised between the two sides of the valley has a width of a few kilometres only, the aquifer does not lie any too deep below the surface and is to be considered as an "underflow", fed by the river and by the streams discharging into it. Detritus, sand and clay-sand deposits at the margins of the alluvium permit easy infiltration, whereas the reddish-blackish clay in the central part of the belt, owing to its scarce permeability, does not contribute much to the recharge of the aquifer; infiltration remains satisfactory in the riverbed. The underflow certainly follows the same direction of the river.

In the second zone, where the alluvium covers immense tracts of land and forms a transverse surface cover, the aquifer is recharged mainly along the line of contact between the alluvial deposits and the otherformations by which they are bounded, since a good part of the extensive alluvial plain consists, on the surface, of clay, marly clay and slightly sandy clay: these materials are scarcely permeable or not at all, as would appear from the fact that in some areas rain or flood water stagnates for long periods and disappears, mostly by evaporation (at an estimated rate of 5-6 mm per day) only after a number of months.

The absence of percolation in the clayey and clay-sandy zones is also confirmed by the fact that no well has been sunk which draws water from perched aquifers. The many wells that have been drilled, although they sink through porous strata lying between the surface clay stratum and the watertight clay beds, strike water only at the level of the deep regional watertable, i.e. at a depth ranging from 45 to 65 m. Recharge from the river is considerable upstream, and tends to be reduced downstream, owing to the reduced permeability of the riverbed and of the banks, which show an increasing clay content as one draws nearer to the marshes. Wells supplying abundant water, at a depth varying from 6 to 20 m, are to be found only in the riverine zone which is, at best, a few kilometres wide. These wells are obviously fed by the river.

6. Quality of the Water

The water to be found in the alluvial deposits of the Shebeli varies in salt content from one place to the next. The main factors determining the quality of the water are the different degree of porosity and the chemical nature of the sediments in the recharge zone and in the saturated zone.

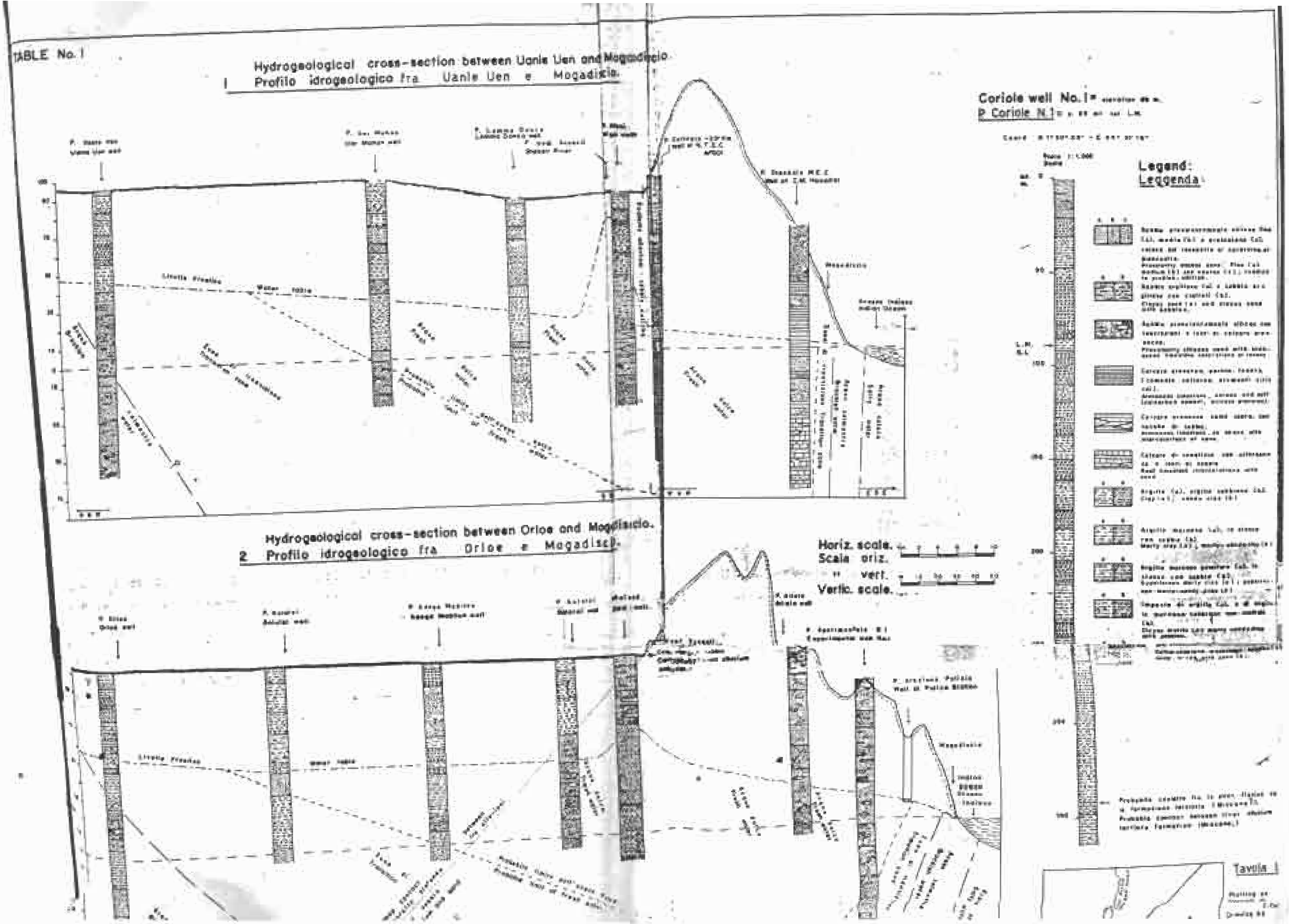
Salt content in the underflow and in the water held by the bedrock of the alluvial belt comprised between Fer Fer and Mahaddei varies from place to place, owing mainly to the variety of rocks outcropping on the two sides of the valley (gypsum, sandstone, limestone, etc.). The highest percentage is to be found at Fer Fer, in the tract between Belet Uen and Giglei, and from Bulo Burti to a distance of 130 km on the road from Mahaddei to Bulo Burti.

In these zones the water is at times very salty and is refused even by camels, which generally tolerate brackish water.

Also in the large alluvial plain from Mahaddei to the terminal marshes, the central part of which is over 80 km wide, shows the presence of brackish water in the various boreholes. Highly salty water, beyond the limits of tolerance of both men and animals, is to be found between Jowhar and Uanle Uen, west of Uanle Uen, north of the ideal line joining Audegle and Coriole, east of Mahaddei and in the area comprised between Modun and Billik Tale'. From the data available to us it would appear that only a very narrow belt, a few km wide, bordering the river on both sides, could provide water for irrigation and for consumption by humans and animals. This belt extends from Mahaddei to Jowhar, Afgoi, Genale and Goluin. As to the last two localities, the belt running on their left side seems to offer better prospects. The excellent physical characteristics of the alluvial deposits, mostly consisting of gravel, sand and a few clay beds, in the tract from Mahaddei to Goluin, permit us to assume that the wells which could be sunk for irrigation purposes would yield abundant water.

The fresh water zone described above is probably a lens of limited thickness varying from one place to the next and lying above the water flowing from the Jowhar-

TABLE No. 1


1 Hydrogeological cross-section between Uanle Uen and Mogadiscio.
Profilo idrogeologico fra Uanle Uen e Mogadiscio.
2 Hydrogeological cross-section between Orioe and Mogadiscio.
Profilo idrogeologico fra Orioe e Mogadiscio.
Horiz. scale.
Scala oriz.
" vert.
Vertic. scale.
Livello freatico
Water table
Mogadiscio
Coriole well No. 1
P. Coriole N. 1
Legend:
Leggenda
Tavola 1

Uanle Uen area and from areas beyond this zone, as well as above the water flowing from the zone north of Audegle-Coriole, which is generally brackish, since it comes in contact with gypsum rocks and sediments rich with soluble salts.

Ground water in the zone between Modun and Gelib is extremely salty and is found at a depth slightly lower than sea level. The reason for the excessive salt content probably lies in the absence or inadequacy of percolation of rainwater and of water from the nearby extensive marshes. In fact, the area is entirely covered with impervious marly clay. This not only explains the low level of the aquifer, but also suggests the intrusion of sea water inland.

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CONCLUSIONS AND RECOMMENDATIONS

The Shebeli valley is inhabited by nomads and semi-nomads, i.e. shepherds and shepherd-farmers. The area between the Ethiopian border and Giglei is populated by nomads and seminomads. The farmers, who are a settled population, inhabit the middle and lower reaches of the valley, together with some semi-nomads.

In order to prepare programmes for the development of this important region, it will be necessary to take into account, in addition to climatic, geological and agricultural conditions, also the environmental factors (propensity of the local populations for farming or stock raising, existing types of farming, etc.), so as to avoid failure, as was the case with 19 agricultural cooperatives established in some parts of the valley in the period 1950-1954. In this connection Fumaioli investigated the reasons for such failure and found them in the absence of a cooperative spirit on the part of the members. Also Cortese, the author of "La valle dell'Uebi Scebeli", has clearly pointed out the danger of neglecting to take into account the local environmental factors in preparing development programmes.

The areas which could be developed in the Shebeli valley are very extensive, and before any planning is undertaken it will be necessary to select those which offer the best economic prospects, once the morphological, structural and environmetal factors have been found to be favourable.

The data concerning the Shebeli valley is abundant, even though not always exhaustive. Flow measurements and analyses of the farmland in the valley are at the moment being conducted by experts of the UNIFAO Agricultural and Water Project . Very soon the results of this research will be submitted in the form of a final report which will certainly constitute a remarkable contribution to our knowledge and, if additional information will be made available in a few particular cases, we shall have a clear insight into the agricultural prospects of the area in question, based on the selection of the areas which are most suited to river engineering works and agricultural reclamation, by introducing various types of crops.

One of the major problems awaiting solution is obviously that of preventing, or at least limiting, the overflowing of the river and inundation of cultivated areas during flood seasons.

Table 2, which was prepared on the basis of aerial photographic interpretation, shows four zones affected by the behaviour of the river. The first zone lies in the marshes; the second is inundated each year during the floods; the third is a zone where the river overflows only exceptionally, i.e. following heavy and persistent rainfall in Ethiopia and Somalia; the fouth zone is grown to valuable and rationally irrigated crops (bananas, sugar cane). The table also shows the abandoned river beds, mostly filled up with sand but still visible in the aerial photographs.

Leaving aside the areas grown to valuable crops, the three remaining ones could be divided as follows:

) marshes: rice growing experiments could be intensified, with a view to selecting the variety which could best withstand the climatic and chemico-physical characteristics of the land, for large-scale production.

) Annually inundated area: a network of canals, sluice gates and embankments would permit to control the overflow of river water during flood periods, so as to avoid a waste of water supplies and to prevent indiscriminate breaking down of bank edges by farmers, whose intention is only to flood just a few hectares of land.

) Exceptionally inundated areas: drainage canals should be built, so as to convey to these areas flood water , with a view to limiting as much as possible the damages resulting from the inundation of these areas, as well as improving the areas grown to valuable crops such as cotton, groundnuts, sesame, maize, sorghum, etc. These areas are at the time only partly utilized by cultivating sorghum and maize, and are generally devoted to temporary grazing.

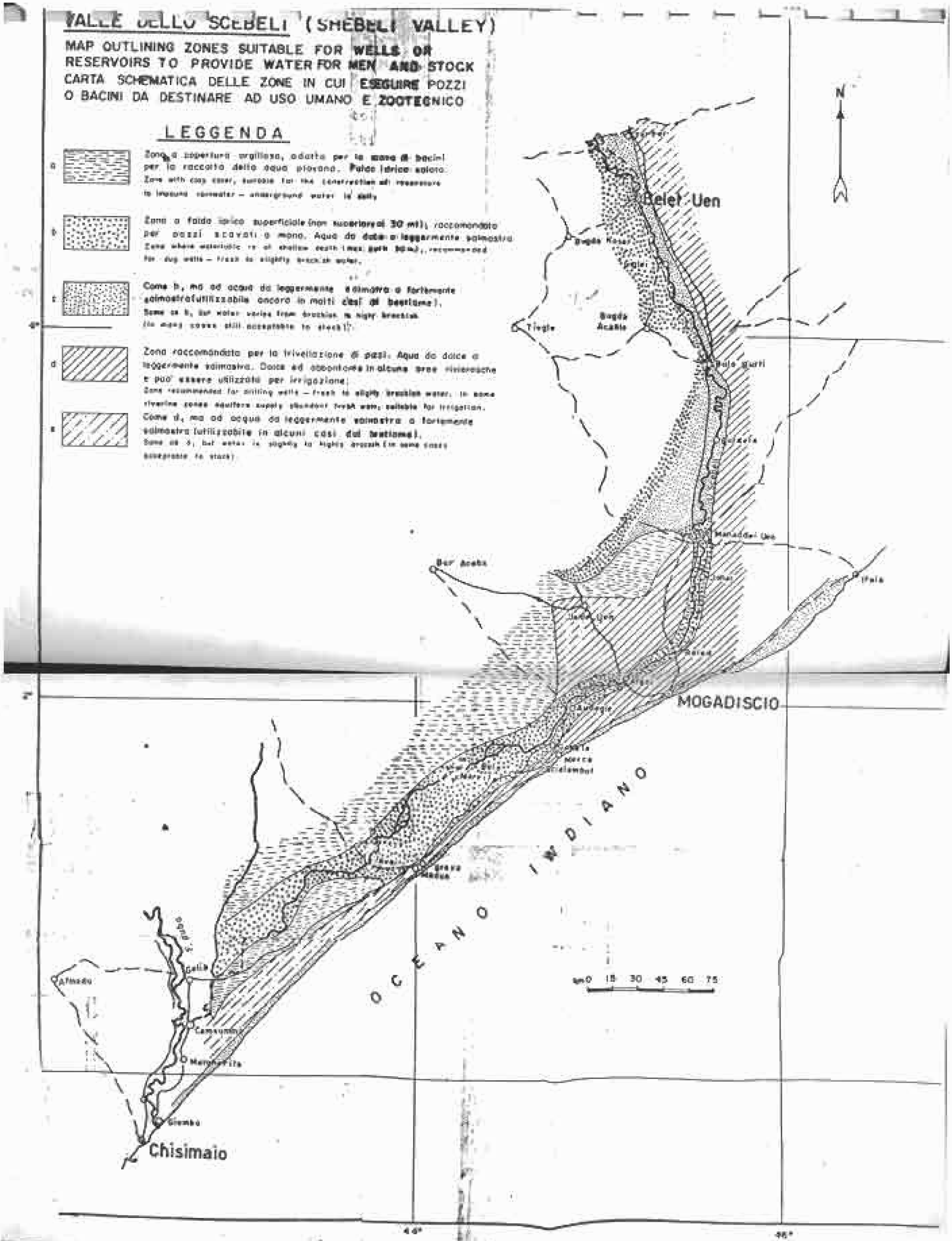
To plan these works it will be necessary to survey all the areas which can be flooded by gravity, both in view of growing waterlogged crops and of draining part of the excess flood water. An accurate survey should not be limited to the areas bordering the river, but should be extended also to an old bed of the Shebeli, probably abandoned only recently, but still visible in the aerial photos and identifiable on the ground. The old bed starts from the Mahaddei Uen area, continues past Adalei, between War Mahan and Lamma Denca, as far as the Audegle-Bur Acaba road, proceeds further 5 km from Coriole and ends in the marshy area. As will be readily understood, if the old bed could be again put to use, it would be possible not only to avoid the harmful flooding of farmland around Genale, but also to improve a long belt, including the Mobilen and Dafet areas, which at the moment draw their supplies of water from a few wells and uars. Unfortunately, as long as the survey work is not carried out, it will not be possible to determine the feasibility of this project. This work is therefore of utmost importance and should be given top priority.

The above considerations apply, of course, only to the belts of land bordering the river; as to those that lie some distance away, and cannot be reached by flood water, it will be necessary to utilize ground and rain water to meet the requirements of the cattle concentrated in that area. Considerable benefits have been brought by drilling a good number of wells in the valley. In fact, in the past the stock had to be led all the way to the river, where a good number would be killed by the tse-tse fly; at present, a large number of them can be watered at the wells. In addition, the drilling of wells has provided additional information on the hydrogeological characteristics of the valley and it is now possible to define the areas which, thanks to their hydrogeological characteristics, should be taken into consideration for the purpose of developing ground or surface water resources. Taking into account the depth and salinity of the aquifer connected with the alluvial deposits and with the rocks bounding the valley, Table No. 3 shows three main areas suited for the purpose. In the first the aquifer is to be reached only by means of drilled wells, for it is estimated that the wells should be over 50 m deep; in the second, water can be reached by means of dug wells and in the third, owing to the excessive salt content. it would be advisable to build uars for collecting rainwater.

In the last ten years about 200 wells have been drilled in the Shebeli valley; it is regrettable that none of them was drilled for the purpose of obtaining data on the yield and salinity of the various aquifers, and that no analysis was made of the variations in level caused by prolonged pumping. It is therefore recommended that future drilling programmes include a number of stratigraphic wells, to be later used also as pumping stations. Some of the wells already in operation could also be used for the same purpose. It is also necessary to determine the elevation of the existing wells: this is the only way to establish correlations and determine any variation of the aquifer.

As to the area in which uars should be excavated, it is strongly recommended that a certain number of stations be set up for collecting data on precipitation and evapotranspiration; it is, in fact, the lack of this data which prevents any forecast as to the length of time during which water would be available in the uars and the volumes that could be impounded in them.

The chemical and bacteriological analysis of all well water is imperative and urgent: these findings would in fact permit the establishment of correlations among the different wells and the making of classifications; they would also permit to determine whether any well provides water harmful to crops, humans and animals. It is well known that, while deep wells mostly offer no danger of pollution, in dug wells, which do not generally reach great depths, such danger is much greater and many of them will contain harmful bacteria. The pollution of these wells is favoured chiefly by the absence of hygienic precautions, so that animal excreta is abundant in their vicinity. In view of these facts, future projects for dug


VALLE DELLO SCEBELI (SHEBELI VALLEY)
MAP OUTLINING ZONES SUITABLE FOR WELLS OR RESERVOIRS TO PROVIDE WATER FOR MEN AND STOCK
CARTA SCHEMATICA DELLE ZONE IN CUI ESEGUIRE POZZI O BACINI DA DESTINARE AD USO UMANO E ZOOTECNICO
LEGGENDA
a
Zona a copertura argillosa, adatta per la messa di bacini per la raccolta della aqua piovana. Falda idrica salata.
b
Zona a falda idrica superficiale (non superiore ai 30 mt), raccomandata per pozzi scavati a mano. Aqua da dolce a leggermente salmastra
c
Come b, ma ad acqua da leggermente salmastra a fortemente salmastra (utilizzabile ancora in molti casi al bestiame).
d
Zona raccomandata per la trivellazione di pozzi. Aqua da dolce a leggermente salmastra.
e
Come d, ma ad acqua da leggermente salmastra a fortemente salmastra (utilizzabile in alcuni casi dal bestiame).
N
Belet Uen
Tiegle
Bur Acaba
MOGADISCIO
OCEANO INDIANO
Chisimaio
Afmadu
Gelib
Giumbo
km 0 15 30 45 60 75

wells should contemplate hygienic measures to ensure the prevention of water pollution. Aside from this, it is strongly recommended to organize an efficient campaign for the education of the population in matters of hygiene.

Many of the past failures, if duly taken into account, can be avoided in the future. Unfortunately, the lack of a reliable governmental organization which would ensure a scientific planning of hydraulic researches prevents the implementation of economically profitable programmes, with the result that many of them do not come off successfully, as for the past. When planning the individual water development projects, account should be taken of the economic and social aspects, without lending attention to political or group pressure. It is therefore necessary that a technical-political committee prepares the annual work programme on the basis of studies and researches carried out in the areas selected: priority should be given to those which are found to be economically more profitable from the point of view of agriculture, animal husbandry and industry.

The Shebeli valley offers potential prospects of excellent development, and should therefore be given priority attention.

The available data, although not exhaustive, are already sufficient to outline a programme of economic and social development in the hydraulic field, as a very valuable contribution towards Somalia's self-sufficiency.

PART III

MAIN WELLS IN THE SHEBELI VALLEY

A good number of boreholes draw water from the aquifers of the Shebeli valley: most of them were dug or bored in the last ten years.

The wells mentioned here are those on which some data are available. It will be noted that information on many wells, especially of the drilled type, is not complete, owing to the fact that in many cases stratigraphic data were not collected and a scarce number of pump tests and chemical analyses were made.

The water from most of the wells was mainly tested for specific conductivity (measured in micro-ohms/cm) by means of the Benz Conducto-Bridge apparatus, Model HB 14, manufactured by the H. & L.D. Benz Co., Philadelphia, U.S.A.

As is known, evaluations on the quality of the water, particularly in arid or semi-arid zones, are, to a certain extent, subjective. In fact, the population who are used to drinking fresh water react very unfavourably to brackish water, whereas the same water is considered as almost fresh by those who are accustomed to water containing a much higher percentage of salt. In view of this consideration, the water supplies of the Shebeli valley have been classified in five groups, according to their specific conductivity:

1) Specific conductivity up to 2500:
   excellent to good. Acceptable by humans and animals.

even when the aquifer is a gypsiferous formation.

2) Specific conductivity from 2500 to 5000:
good to fair; its taste varies from slightly to distinctly brackish. If too rich in sulfates, it may be refused by humans, but will be accepted by the stock.

3) Specific conductivity from 5000 to 7500:
brackish to strongly brackish. It is not used if better quality water is available from nearby sources(it is refused by all riparian populations). It usually has laxative effects. It is, however, still accepted by animals, but is refused if supplied from a gypsiferous formation.

4) Specific conductivity from 7500 to 10,000:
Strongly brackish to salty. It usually has a laxative effect and is rarely accepted by goats and camels.

5) Specific conductivity exceeding 10,000:
Cannot be utilized.

All data available concerning total depth of wells, depth to water level, drawdown and specific conductivity, temperature and percentages of total dissolved solids are tabulated in the following pages. Stratigraphic descriptions, in the cases where such information is available, are given separately.

As to the wells in the Afgoi and Genale areas, these have been omitted in this paper. In fact, owing to the abundance of data obtained from the numerous wells drilled in these areas for irrigation purposes, the author of this report has prepared a separate publication, to which the readers may refer (see Bibliography).

ABBREVIATIONS
in "Record of Wells in Shebeli Valley"

Chem. An. (...g/l): chemical analysis (grams per litre)

Dr.: drawdown.

Elev.: elevation a.s.l.

Hard.: hardness in French degrees (perm.: permanent; tempor.: temporary).

Org. m.: organic matter.

Temp.: temperature in °C.

TSD: total solids dissolved.

Note: A serial number for reference to map and to "Stratigraphic Data" is attributed to each borehole. Some wells are followed by number in brackets corresponding to file number of Well Section of the Public Works Dept. Where no such number is given, borehole is private property.
The mark (+) on left side refers to stratigraphic data given separately after tabulation.

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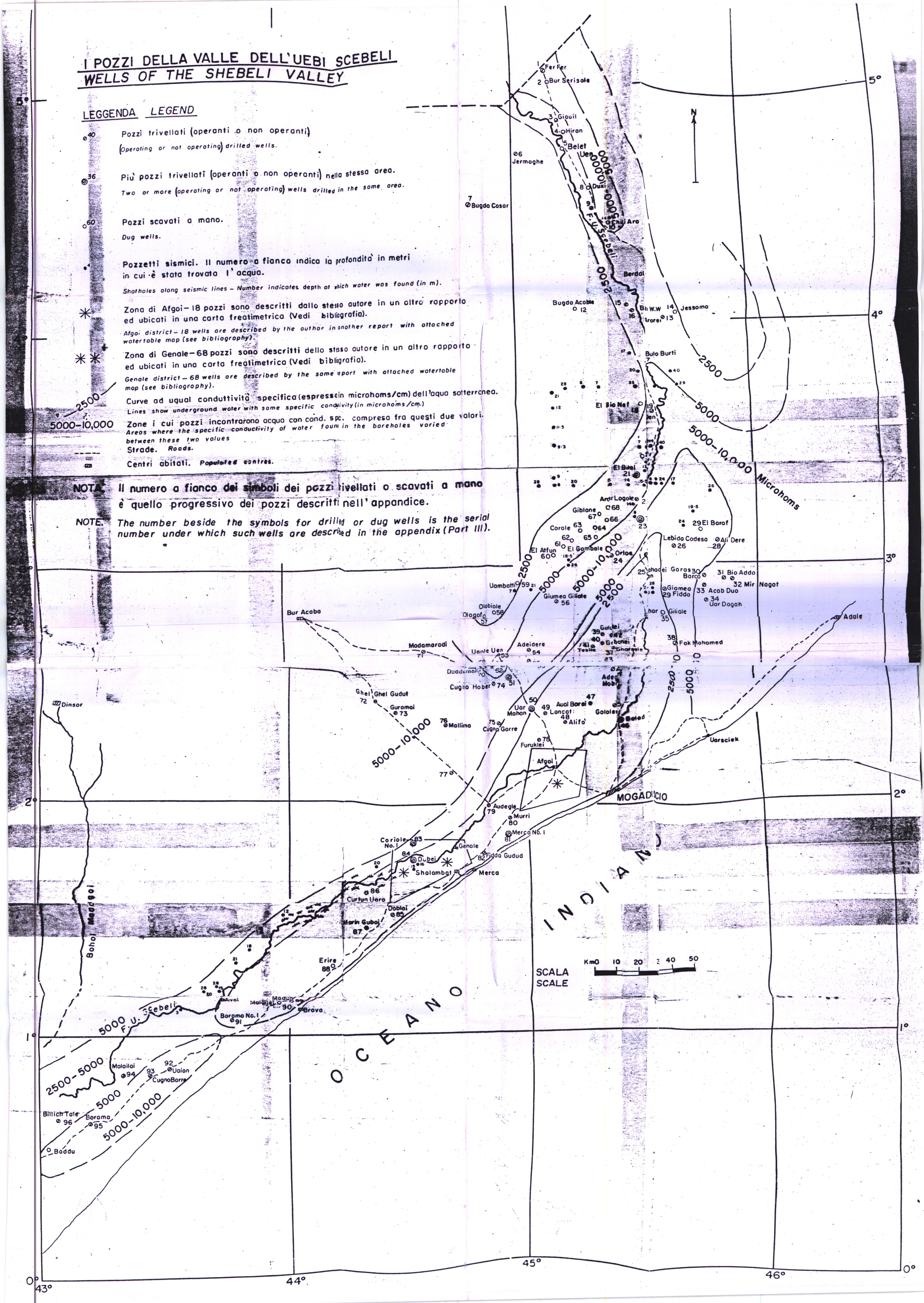
I POZZI DELLA VALLE DELL'UEBI SCEBELI
WELLS OF THE SHEBELI VALLEY
LEGGENDA LEGEND
Pozzi trivellati (operanti o non operanti)
(Operating or not operating) drilled wells.
Più pozzi trivellati (operanti o non operanti) nella stessa area.
Two or more (operating or not operating) wells drilled in the same area.
Pozzi scavati a mano.
Dug wells.
Pozzetti sismici. Il numero a fianco indica la profondità in metri in cui è stata trovata l'acqua.
Shotholes along seismic lines – Number indicates depth at which water was found (in m).
Zona di Afgoi – 18 pozzi sono descritti dallo stesso autore in un altro rapporto ed ubicati in una carta freatimetrica (Vedi bibliografia).
Afgoi district – 18 wells are described by the author in another report with attached watertable map (see bibliography).
Zona di Genale – 68 pozzi sono descritti dallo stesso autore in un altro rapporto ed ubicati in una carta freatimetrica (Vedi bibliografia).
Genale district – 68 wells are described by the same report with attached watertable map (see bibliography).
2500
Curve ad ugual conduttività specifica (espressa in microhoms/cm) dell'aqua sotterranea.
Lines show underground water with same specific conductivity (in microhoms/cm.)
5000–10,000
Zone i cui pozzi incontrarono acqua con cond. spc. compresa fra questi due valori.
Areas where the specific conductivity of water found in the boreholes varied between these two values
Strade. Roads.
Centri abitati. Populated centres.
NOTA. Il numero a fianco dei simboli dei pozzi trivellati o scavati a mano è quello progressivo dei pozzi descritti nell'appendice.
NOTE. The number beside the symbols for drilled or dug wells is the serial number under which such wells are described in the appendix (Part III).
SCALA
SCALE
Km 0 10 20 40 50
OCEANO INDIANO
MOGADISCIO
F. U. Scebeli
Microhoms
1 Fer Fer
2 Bur Serisole
3 Giouil
4 Hiran
5 Belet Uen
6 Jermoghe
7 Bugda Cosar
8 Duzi
Chili Aro
Berdal
Bugda Acable 12
14 Jessomo
Bulo Burti
El Bio Nef
El Baal 21
Arori Logole
Giblane 68
67
66
23
29 El Baraf
Corole 63
64
65
62
61
El Afun 60
El Gambole
Ortoe 24
Lebida Codeso
Ali Dere 28
26
31 Bio Addo
32 Mir Nagat
33 Acab Duo
34 Uar Dagah
29 Fidda
Giamea
35 Giliale
38 Fak Mohamed
Adale
Uambotti 59
Giumea Giliole 56
Olobiole 58
Ologol 57
Bur Acaba
Modamarodi 71
Uanle Uen 53
Adeidere 54
Duddumai 70
Cugno Hober 74
51
Ghel Ghel Gudut 72
Guramai 73
76 Mallimo
75 Cugno Garre
50 Uar Mahon
49 Lancat
48 Alifo
47 Aual Barei
Gololei
Baled
78 Furuklei
Afgoi
Uarsciek
77
Audegle 79
Murri 80
Merca No. 1 81
Coriole No. 1 83
84
Dubei
Genale
82 Fidda Gudud
Shalambat
Merca
Curtun Uaro 86
Dablai 85
Marin Guboi 87
Erire 88
Avai
Madau 90
Brava
Borama No. 1 91
Dinsor
Bohol Macagoi
Malailai 94
93
92 Uaion
Cugno Borre
Billich Tale 96
Borama 95
Baddu
5000
2500
2500–5000
5000–10,000
43°
44°
45°
46°
0°
1°
2°
3°
4°
5°

RECORD OF WELLS IN THE SHEBELI VALLEY

Borehole	Depth (in m) (1)	Depth to water level (m) (2)	Reported yield (cu.m/h) (3)	Specific conductivity (microohms/cm) (4)	Remarks (5)
1. Fer Fer (224- 224b- 224t)	42	3	—	+10,000	Police station on Ethiopian border, N of Belet Uen. Salty, abandoned. Gypsum and clay encountered.
2. Bur Serisale	9	8.5	—	1900 (1/7/61)	4.5 km from Fer Fer on road to Belet Uen. Old dug well, probably polluted, needs cleaning and deepening.
3. Giauil (259)	72	36?	5	1850 (5/10/60) 2050 (31/8/60)	N4°56'45"-E45°12". Perm. hard. 90°. 0-25 m mainly limestone: 25-72 m gypsiferous clay, bluish & whitish marl (Belet Uen series - Middle Cretaceous).
4. Hiran (68)	8.5	7.80	0.300	260 (26/8/60) 350 (9/10/61)	Near bridge on homonymous watercourse. Dug in bed of stream.
5. Belet Uen	10	—	—	1100 (31/10/60) 2000 (9/10/61)	100 m from right bank of river, near Governor's house. Sunk in river alluvium.
6. Jermoghe (182)	120	—	—	—	Dry. No other data avail.
7. Bugda Cosar (R10)	42	18	—	1800	50 km SW of Belet Uen. Gypsum & clay encountered.
8. Duxi (526)	15	14.50	0.200	—	Dug well, 30 km from Belet Uen, 150 m from left side of Belet Uen-Bulo Burti road.

Borehole	(1)	(2)	(3)	(4)	(5)
9. Km 300 (258)	113	—	—	+10,000	On Mogadiscio-Belet uen road. Salty, abandoned. No other data avail.
1[illegible] Chili Ara (529)	6	5.5	0.250	1200 (1/9/60)	Dug in bed of homon. stream, at 285.5 km on Mogadiscio-Belet Uen road.
(+) 11.Berdale (181)	104	45		2200	N4°26'-E45°23'. Chem. An. (g/l): Ca 0.036, Mg 0.030, NaK 1.835, HCo_3 0.760, Cl 2.340, SO_4 0.272, TSD 4.900.
12. Bugda Acable(294)	9	3	—	2500	N4°4'-E45°15', populated centre at margin of karstic depression in gypsum formation. Area flooded in rainy season; several perennial dug wells yield same quality of water. Chem. An.(g/l): Ca 0.788, Mg 0.012, NaK 0.075, HCo_3 0.156, Cl 0.042, SO_4 1.940, TSD 2.900.
(+) 13. Avorei (321)	120	35	—	4200 (23/1/60) Temp. 33° 4000 (16/12/59) 3500 (1/8/61)	N4°2'-E45°15'. [illegible]
14. Jessoma (696)	4	3.80	—	700	Dug in escarpment of Jessoma series; springwater in siliceous sandstone, low yield.
(+) 15. Debi Uadle (26[illegible])	50	20	—	—	30 km from Bulo Burti on old track to Belet Uen.

Borehole	(1)	(2)	(3)	(4)	(5)
16. Bulo Burti Water Well	37.7	28.70	—	—	N4°3'30"–E45°30'. Drilled in Belet Uen series by Mobiloil in 1963. Chem. An. (g/1): Cl 0.2, SO_4 0.5, hard. +100, org. m. in O 0.002; NH_3, NO_2, NO_3: nil. Aband.
17. Bulo Burti					Several dug wells (in river alluvium, aver. depth 8-10 m) but water mostly drawn from river. Variations in its salinity related to periodic changes in quality of river water.
a) school well	—	—	—	2200 (4/12/59) 1400 (22/1/60) 1250 (1/9/60) 1580 (9/10/61)	
b) well near "macaia" in f. of school	—	—	—	2000 (9/10/61)	
18. El Bio Nef	13	12	—	1950 (5/9/60)	N3°39'–E45°30'30". Old well dug at bottom of depression in Mustail series (Cretaceous limestone), needs cleaning and deepening.
(+) 19. Bur Uen (225)	81	12	—	6000	N3°38'–E45°32', elev. 162 m. Considered salty, abandoned. Chem. An. (16/10/57 – g/1): Cl 5.02, SO_4 3.3, org. m. as O 0.0060, Fe nil; Allumine, No_3, NO_2: present; NH_4 nil; hard.: total 480°, perman. 440°, tempor. 40°; residues at 180°: 13.35 g; calcium and magnesium salts (carbonates, sulphates, chlorides): abundant.
Bur Uen	6.5	6	—	6000 (7/7/61)	500 m away from preced. well. Dug well, considered salty, abandoned.

Borehole	(1)	(2)	(3)	(4)	(5)
20. Gimbflei	2.5	2	—	3500 (10/10/62)	N3°30'-E45°34'. Dug in shallow gypsiferous depression.
(+) 21. El Bilal (3?2)	55	11	—	4500 (20/2/60)	N3°27'-E45°31'30". Well supplies water to homon. village.
El Bilal (near infirmary)	5	4.5	—	6000 (2/1/61)	Dug in gypsiferous formation.
El Bilal	4.5	4	—	4000 (22/1/61)	700 m away from preced. well.
22. Arar Lugole	3	2.8	—	3500 (1/9/60)	At 150 km on Mogadiscio-Belet Uen road. Dug in marly gypsum.
Arar L.	3.5	2.8	0.200	3500 (7/2/59) 3500 (10/10/62)	+1 km E of preced. well, dug in marly-sandy gypsum, concrete-lined.
23. Km 140	10	9.8	—	+10,000	On Mogadiscio-Belet Uen road. Salty, abandoned.
(+) Km 140 (320)	102	16	—	3850 (30/8/60) 4600 (10/10/62)	A few m away from preced. one.
(+) 24. Orloe (186)	140	48	abund.	+10,000 (27/5/59) 7500 (Oct. '60)	Km 22 W30°N of Jowhar. Salty, abandoned.
(+) 25. Mahaddei Uen (2?2)	115	21	abund.	1200 (27/5/59) 1450 (6/11/60)	Supplies water to homon. town.
(+) 26. Lebida Codesa (285)	90	40	—	5500 (1/6/59)	20 km E36°N of Mahaddei Uen.
27. Giamea Fiddo (211)	160	32	—	4000	18 km NE of Jowhar.

Borehole	(1)	(2)	(3)	(4)	(5)
(+) 28. Ali Dere (254)	70	40	—	4000	50 km NE of Jowhar.
(+) 29. El Baraf (552)	16	14.7	—	5000 (6/7/57)	40 km from Mahaddei Uen to Ali Dere.
(+) 30. Garas Bargo (273)	127	60	—	5300 (10/1/62) Temp. 34°	26 km E5°S of Mahaddei Uen.
(+) 31. Bio Addo					37 km E6°S of Mahaddei Uen. The two wells are drilled close together; one is abandoned.
(205)	93	63	—	6000	
(205 t)	127	62	—	5500(14/11/61) 5300(12/1/62)	
(+) 32. Mir Nagot					42 km E4°S of Mahaddei Uen. The two wells are drilled close together. Salty, abandoned.
(242)	116	67	—	9500(14/11/61)	
(242 b)	110	67	—	—	
(+) 33. Acab Duo (244)	140	60 ?	—	7000(20/10/61)	32 km E15°S of Mahaddei Uen.
(+) 34. Uar Dagah (210)	120	60	—	6000 (7/3/61)	30 km E20°N of Jowhar.
(+) 35.Giliale	—	—	—	—	15 km E of Jowhar. According to Corni (see Bibliography) well was drilled into alluvium down to 107 m. Stratigraphic data available down to 72 m.

Borehole	(1)	(2)	(3)	(4)	(5)
36. Jowhar					
(+) (237)	112	11	—	1800 (27/5/59) 1100 (24/6/60) 1400 (5/7/61) 1200 (9/10/61)	Drilled in 1957. Located at entrance of town from Mogadiscio.
(+) (235)	85	8	—	1650 (2/4/62)	Drilled in 1962. Salinity decreased from init. 3000 to 1400 during first pumping. Located in front of club at entrance of town from Mahaddei.
ex-SAIS	—	—	—	2400 (5/11/60)	Dug well.
Well near bridge	6	—	—	6000 (5/7/61)	Dug and abandoned.
Entrance from Mog. near "mcaia"	7	—	—	2400 (5/7/61)	
5th & 6th ex-SAIS farms	—	—	—	—	From Corni: "...water was found at a depth of 35 m in one well and 45 m in another; water level then rose to 17 m". Depth indicated by this author is supposed to be depth of wells, not of aquifer which should be nearer to surface.
37. Ghersale	—	—	—	—	70 km from Mogadiscio on road to Jowhar. From Corni: "...A well 91 m deep was drilled at Ghersale". No other data available. Now no well exists at Ghersale.

Borehole	(1)	(2)	(3)	(4)	(5)
(+) 38. Fak Mohamed (313)	100	55	—	2000 (Oct.'60)	22 km SE of Jowhar. Chem.An.(10/8/62 – g/1): residues at 100° 3.236; Hard.: total 72, perm. 16°, tempor. 56; org. m. in active O 0.0016, Cl 0.38, SO_3 1.08, CaO 0.361, MgO 0.052, NaCl 0.75; Fe, NH_4, NO_2, NO_3: nil.
(+) 39. Gululei (196)	105	54	—	2300	13 km E15°N of Jowhar.
(+) 40. Gabanei (139)	96	54	4 Dr.2 m	2400 (28/2/62)	15 km E10°N of Jowhar.
(+) 41. Tesile (140)	96	62	4 Dr. 1 m	1800	12 km from preced. well on track to Gululei.
(+) 42.Donadiga (195)	96	40	—	2000 (28/2/62)	16 km E of Jowhar.
(+) 43.Sarsarre (197)	78	45	—	3000	28 km N16°W of Balad.
Dondere (255)	128	—	—	—	2-3 km away from preced. well.
(+) 44. Hadega Mobile(212)	115	55	—	1400 (27/5/59)	23 km N16°W of Balad.
(+) 45. Gololei (153)	102	54	5 Dr.3 m	2500 (1/4/57)	10 km N30°W of Balad on road to Mogadiscio.
46. Balad (49)	47	45	—		Dug well supplying homon.town.

Borehole	(1)	(2)	(3)	(4)	(5)
(+) (170)	110	44	—	750 890 (29/1/57) 820 (24/6/60) 850 (6/11/60)	Well supplying homon. town.
(+) (170 b)	70	45	—	—	Well supplying homon. town.
(+) 47. Aual Barei (193)	112	62	—	1900 (27/5/59)	15 km W of Balad.
(+) 48. Alifo (317)	146	63	—	—	N2°17'14"-E45°9'52". Elev. 104 m.
49. Lancat					N2°17'14"-E45°9'52". At Uar Mahan farm.
(+) (160)	160	72	10 Dr.10 m	—	
(160 b)	118	68			
(160 t)	136	71		2700 (10/6/57)	Chem. An. (g/1): Hard.: total 76°, perm. 46, tempor. 30; PH: sub-alkali reaction; Cl 0.5035, org. m. 0.0018, NH_4, NO_3, NO_2, Fe: nil; SO_4 abundant. Remarkable percentage of magnesium in the form of sulfates and chlorides.(19/1/57)
50. Uar Mahan					Important water supplying centre 60 km away from Mogadiscio on track to Uanle Uen.
(+) (104)	105	67	2.5 Dr. 3 m	4200 (29/1/57) 2500 (27/2/59)	
(+) (104 b)	90	66	3 Dr. 5 m	2000(10/6/57) 2000(15/12/60) 2100 (27/2/59)	200 m away from preced. well.
(+) (104 t)	120.5	64	8 Dr.16 m	2350 (27/2/59) 3000 (13/8/60)	100 m away from preced. well. Chem. An. (25/3/58 - g/1): Ca 0.134, Mg 0.091, Na 0.582, CO_3 -, HCO_3 0.347, Cl 0.512, SO_4 0.928, TSD 2.420, $CaCO_3$ 0.728.

Borehole	(1)	(2)	(3)	(4)	(5)
51. Duddumai No.1 a), b) c) d)	70 85 66				12 km SSE of Uanle Uen. The four wells, now tapped and abandoned, showed excessive salt content (calcul. 7g/1). Wells a), b), c) utilized during oil prospecting. Well d): no water found down to 66 m.
(+) 52. Duanle (208)	127	61	—	5100 (10/2/63)	6 km S of Uanle Uen.
(+) 53 Uanle Uen (102)	153	50	6 Dr. 4 m	4100 (6/12/56) 4100 (10/11/59) 3000 (15/8/60)	Important populated centre 90 km from Mogadiscio on track to Baidoa.
(+) 54. Adaidere (314)	187	—	—	9500 (5/2/60)	N2°38'-E45°4'. Salty, abandoned.
(+) 55. Ai Buralei (171)	100	56	7 Dr. 4 m	9500 (5/12/56)	17 km from Uanle Uen on track Uanle Uen-Adalei-Afgoi. Windmill installed, but well scarcely utilized due to high degree of salinity. Chem. An. (22/1/55 - g/1): hard.: total 208°, perm. 80°, tempor. 128°; Cl 2.26, org. m. in 0 0.0932; NH_4, NO_3, NO_2, Fe: nil; SO_4 abundant.
(+) 56. Giamea Gigliole (246)	140	46	abund.	5500 (20/3/63)	N2°51'-E45°5'30". Brackish water. Pump installed, but well is little utilized, espec. in months when salinity increases.
57. Ologof	+9	—	—	1800 (5/2/60)	N2°47'30"-E44°50'. Dug in hard, compact ~~arenaceous-~~marly limestone; large dia.

Borehole	(1)	(2)	(3)	(4)	(5)
58. Olobiole	6.50	—	—	1800 (5/2/60)	N2°48'-E44°52'45". Dug in soft whitish sandy-clayey limestone.
59. Uambatti	—	—	—	5000 (5/2/60)	N2°54'-E44°59'. Several wells dug a few m deep in formation analogous to preced. one.
60. El Atfun	2	—	—	5500 (5/2/60)	35 km W10°N of Mahaddei. Several wells dug in calcium-gypsiferous formation.
61. El Gambole	1-2	—	—	7500 (18/7/57) 5800 (5/2/60- aver. of sev. wells)	41 km W16°N of Mahaddei, several wells dug in gypsiferous formation.
62. Cot Cot	2	—	—	5000 (6/2/60)	40 km W19°N of Mahaddei, in gypsiferous-marly formation.
63. Carale	—	—	—	4500 (19/7/57)	36 km E31°N of Mahaddei.
64. Gherbeg	2	—	—	3800 (19/7/57) 3000 (6/2/60) Temp. 26°	32 km W36°N of Mahaddei. Two wells in whitish porous limestone.
65. El Ad	—	—	—	2800 (20/6/57)	26 km W36°N of Mahaddei. Several shallow wells dug in formation similar to preced. one.
66. El Neghei	4	—	—	3600 (6/2/60)	30 km N38°W of Mahaddei in grey porous marly limestone.
67. Giblane	—	—	—	3000 (6/2/60) Temp. 28°	34 km N42°W of Mahaddei. Water springing from bottom of predominantly calcareous karstic depression forms small lake.

Borehole	(1)	(2)	(3)	(4)	(5)
68. Adale Afuen	4	—	—	4500 (6/2/60) Temp. 27°	33 km N24°W of Mahaddei on hard, slightly marly limestone; dia. 2.5 m.

NOTE: The wells from No.57 to 68 were all dug in secondary formations consisting of "caliche" of various types, generally in depressions. Since they are perennial, it is thought that limited perched aquifers with impermeable substratum are to be found beneath these depressions. Wells are named "Galgial wells"; though water is often of poor quality, it is an important resource for Dafet herdsmen.

Borehole	(1)	(2)	(3)	(4)	(5)
(+) 69. Acao (174 b)	110	57	—	7000 (5/12/56) 7000 (June '57) 6200 (5/2/60) 5000 (15/8/60)	7 km from Uanle Uen on track to Bur Acaba. Salinity varies, decreasing in dry season. Pump installed but well is practically not utilized in rainy season.
70. Duddu-mai			—		Village 12 km from Uanle Uen on track to Bur Acaba.
(174)	75	60	—	—	Salty, abandoned.
(+) (319)	130	55	—	5500 (26/3/62)	Near preced. well.
(+) 71. Madamo-Fodi (152)	121	80	—	—	N2°40'-E44°36'. Salty, abandoned.
(+) 72. Ghel Ghel Gudut (129)	121	—	—	—	50 km from Bur Acaba on track to Aude-gle. Abandoned due to frequent col-lapse of borehole and excessive salinity.
(+) Guramai (159)	81	—	—	—	123 km from Afgoi on track Audegle-Bur Acaba. Salty, abandoned.
(+) 74. Cugno Hober (250)	154	61	—	7000 (10/6/59)	N2°34'-E44°46'. Elev. 106 m.

Borehole	(1)	(2)	(3)	(4)	(5)
75. Cugno Garre (316)	140	60	—	+10,000 (1/6/59)	40-50 km NW of Afgoi. Salty, abandoned.
76. Mallima (128)	105	56	—	—	68 km from Afgoi on track to Uar Duguble. Salty, abandoned. Chem. An. (11/12/54 - g/1): Hard.: total 640°, Cl (ion) 7.0565, SO_4 very abundant. Bitter taste, very salty.
77. Km 25 track Audegle-Bur Acaba	80	60	—	—	Drilled in 1934, then abandoned.
(+) 78. Furukulei (240)	100	70		5800 (1/6/59)	15-20 km NW of Afgoi.
79. Audegle	8	—	—	—	Dug well near river.
(+) 80. Pozzo Murri	96	62	60 Dr.12 m	1800 (28/7/63)	55 km from Mogadiscio in road to Merca.
81. Merca Water Wells	—	110	—	1200	N1°52'26"-E44°55'12". Elev. 136 m. Four drilled wells, 160-167 m deep. Good quality water: NaCl 0.360 g/l.
(+) 82. Fidda Gudut (114)	93	60	10 Dr.10 m	1500 (26/2/57) 1200 (28/8/58)	78 km from Mogadiscio on road to Merca.

Borehole	(1)	(2)	(3)	(4)	(5)
83. Coriole Water Wells					N1°50'25"-E44°31'16". Tapped and abandoned.
a)	33	5	—	—	Salinity 15 g/1.
b)	33	10	—	—	Salinity 4.3 g/1.
c)3 wells	+30	12	—	—	3 km S of preced. ones. Salinity 5.7 g/1.
d) well at farm		12	—	—	25 km S of wells a) & b). Water of better quality, used while drilling Coriole Oil Well No.1.
e)		15	—	—	12 km S of well d). Salinity 4 g/1.
84. Dobei Water Wells					For Dobei Oil Wells No.1 & 2. Tapped and abandoned.
a)	30	—	—	—	(Dobei Oil Well No.1) Salinity 6.6 g/1.
b)	30	—	—	—	(Dobei Oil Well No.1) Salinity 6.6 g/1.
c)	30	—	—	—	(Dobei Oil Well No.2) Salinity 6.6 g/1.
d)	30	—	—	—	(Dobei Oil Well No.2) Salinity 6.6 g/1.
e)	46	22.5	—	—	(Dobei Oil Well No.2) 4 km SSE of Dobei Oil Well No.2. Salinity 2.7 g/1.
(+) 85. Diblai (272)	109	55	—	2400 (1/5/62)	"
86. Curtun Uaro	18	17	—	—	11 km W of Muccuidumis. Dug well.
(+) 87. Marin Gubai	110	48	—	2300 (26/2/57) 1300 (27/5/59) 1500 (2/4/62)	150 km from Mogadiscio on road to Brava.
88. Erire	5				27 km NE of Modun. Dug well.

Borehole	(1)	(2)	(3)	(4)	(5)
89. Modun	—	—	—	2800 (26/2/57)	12 km from Brava. Dug well, windmill installed.
90. Malailei	—	—	—	500 (2/6/62)	Near Modun. At foot of dune, aquifer at point of contact between aeolian sand and river alluvium cover. Water percolating through sand collects in pit dug in black clay.
91. Brava Water Well No. 1	—	—	—	—	Km 28 18°S of Modun. Elev. 48 m. Chem. An. (15/8/62 - g/1): residues at 100°: 5.6; alkalinity (in cm of HCL N/10) 18 cm; hard.: total 156, perm. 128, tempor. 28; NO_2, NO_3, NH_4: nil; Cl (ion) 2, Mg 0.396, CoO 0.26, Na_2O 2.85, Fe present.
(+) 92. Uaian	132	32	—	+10,000	63 km on Modun Gelib track Brackish, abandoned. Another well, 100 m deep in same area, was also abandoned due to excessive salinity.
(+) 93. Cugno Barre	36	20	—	+10,000	80 km from Modum on track to Gelib. Brackish, abandoned.
(+) 94. Malailei (209)	80	28	—	4000	
(+) 95. Borama (165)	95	50	—	—	125 km from Modun to Gelib. Brackish, abandoned. Chem. An. (8/5/55 - g/1): hard.: total 720°, perm. 380°, tempor. 320; Cl 9.57, SO_4 abundant.

Borehole	(1)	(2)	(3)	(4)	(5)
(+) 96. Billik Taleh (194)	112	32	--	4700 Temp. 32°	Km 33 E30°N of Gelib. Chem. An. (6/12/58-g/1): hard.: total 60°, perm. 32°, tempor. 28°; Cl 1.2; SO_3 0.34, CaO 0.19, MgO 0.14, NO_3, NO_2, NH , Fe: nil.
97. Baddu	16	15		1700 (12/9/59)	Village 35 km from Gelib, 32 km on track to Modun and 3 km westwards. Dug well.

Stratigraphic data

11) Berdalė

0 - 6 m	whitish, slightly marly limestone with reddish weathered surface;
6 - 9	grey clay;
9 - 18	white calcareous marls, alternating with thin-bedded grey clay;
18 - 39	whitish or reddish limestone, fractured and porous;
39 - 49	white calcareous marls;
49 - 51	soft and finely porous marly limestone;
51 - 54	light-grey clay;
54 - 64	slightly sandy limestone, yellowish, porous and soft.

Cretaceous formation Mustail series.

13) Avorei

0 - 4 m	lateritic sand, siliceous and calcareous;
4 - 22	reddish sandy limestone, initially weathered (caliche), turning into a light colour after a few metres;
22 - 28	slightly marly clay, pinkish and light-green;
28 - 40	green clay alternating with dull-yellow, greenish or reddish sandy limestone; rare occurrences of thin-bedded sand;
46 - 52	Yellow and reddish calcareous strata, alternating with green and reddish clay;
52 - 55	slightly cemented light-brown siliceous sand;
55 - 58	black clay (contains coal particles), thin-bedded sand;

58 - 70	gray-blackish limestone, containing fragments of Lamellibranchia, particularly small black oysters; thin-bedded black clay; grey marly clay and thin strata of compact grey limestone;
70 - 82	grey marly clay, strata of grey marly-sandy limestone, foliated clay with fossils;
82 - 88	coarse sandstone, greyish and light-brown; thin-bedded clay (black and foliated) and marls (greyish);
88 - 115	grey marly clay, of a schistose appearance and black foliated clay at a depth of 88 m; from 106 to 115 m it is intercalated with soft marly limestone and light-grey clay;
115 - 118	greyish marly clay, of a schistose appearance, and black clay; thin strata of soft and greyish sandy limestone;
118 - 120	grey clay, of a schistose appearance, with black foliated clay.

From 0 to 55 m: Jessoma series;
From 55 to 120 m: Belet Uen series, **Middle Upper Cretaceous.**

15) Debi Yadle

0 - 9 m	grey gypsiferous sandy clay, slightly cemented at bottom;
9 - 27	slightly sandy grey-whitish marls with frequent occurrences of selenitic gypsum crystals of a rather consistent type;
27 - 39	loose siliceous sand (rounded grains) and medium- and coarse-grained calcareous sand with a few gypsum crystals;
38 - 48	fragments of siliceous limestone with calcareous pebbles and coarse quartz sand (probable conglomerate);
48 - 50	Very large quartz, limestone and sandstone pebbles.

Age difficult to determine: probably delta of the Shebeli, Lower Tertiary, Covered by more recent deposits.

19) Bur Uen

0 - 6 m	sand, gravel and calcareous fragments;
6 - 36	white-yellowish medium hard limestone;
36 - 51	grey slightly gypsiferous marl, with iron-holding veinlets;
51 - 75	white gypsiferous marl;
75 - 78	soft grey limestone;
78 - 81	white gypsiferous limestone.

Probably Gabredarre formation .
Well may have reached Main Gypsum.

21) El Bilal

0 - 4 m	red sand followed by selenitic gypsum (macrocrystals);
4 - 10	white porous limestone with reddish veining, thin-bedded white marl and isolated gypsum crystals;
10 - 13	white marl with thin limestone strata;
13 - 19	siliceous, sharp-edged sand, white and reddish, slightly cemented by marly clay;
19 - 28	basalt incorporating calcareous fragments and frequent inclusion of a bright leaf-green rock;
28 - 40	dull- yellow, semicrystalline limestone;
40 - 46	light-yellow marls alternating with strata of soft sandy limestone, whitish or brick-red;
46 - 52	white limestone, soft and porous, alternating with thin-bedded light-green foliated marl;
52 - 55	white and reddish limestone with numerous basalt fragments. (other basalt inclusion?)

Formation probably dates from Middle Cretaceous, with more recent basalt inclusions.

23) <u>Km. 140</u>

0 - 4 m	reddish gypsiferous sand;
4 - 9	selenitic gypsum;
9 - 12	marly limestone, reddish and weathered;
12 - 17	gypsiferous sand with weathered calcareous nodules;
17 - 24	fairly cemented limestone, although porous, greyish; frequent selenite crystals;
24 - 30	weathered limestone, reddish, with nodules; thin-bedded sand, white limestone at a depth of 28 m;
30 - 34	reddish siliceous sand, medium- and coarse-grained;
34 - 50	gypsiferous sandy clay, from light-brown to almost grey, alternating with thin-bedded dark-brown marls;
50 - 68	dark-brown and reddish marls, with thin-bedded sandy clay;
68 - 70	very sandy marls;
70 - 85	sand, initially slightly clayey, then loose and fine- and medium-grained;
85 - 102	no samples collected; only sandy materials recovered from boring tool.

This formation may belong to the Middle Cretaceous. Very poor quality water (conductivity exceeding 10,000) down to 60 m: this aquifer was isolated by means of casing and concrete lining; the underlying aquifer, connected with a sand formation, showed an initial conductivity of 5,000, which after pumping decreased to 3,850 (30.8.60) and 4,600 (10.10.62).

24) <u>Orloe</u>

0 - 10 m brown clay with abundant calcareous nodules and gypsum crys-

	tals; from a depth of 4 m on, brown gypsiferous clay with a few calcareous nodules;
10 - 19	hard grey calcareous marls, with fair gypsum content and a few thin strata of limestone;
19 - 28	calcareous pebbles, sandy and marly, and gypsum crystals in a sandy-marly matrix;
28 - 34	marly- sandy limestone, grey and soft, or brownish intercalated with thin-bedded marl;
34 - 45	slightly sandy and marly brown clay, incorporating gypsum crystals; reddish sandy-calcareous stratum at a depth of 37-40 m;
45 - 52	whitish sand, predominantly siliceous, slightly clayey, coarse-grained with abundant calcareous, sandy and siliceous pebbles;
52 - 55	whitish sand, predominantly siliceous, slightly clayey;
55 - 73	dark-brown slightly sandy clay, with a few thin grey strata; a few gypsum crystals;
73 - 79	calcareous-sandy stratum and clayey-siliceous sand incorporating calcareous-sandy pebbles and a few gypsum crystals; low clay content;
97 -118	greyish clayey-marly-sandy stratum, grading into greyish and fairly compact clayey sand;
118 -133	predominantly siliceous sand, medium-grained, sub-rounded, pinkish-grey;
133 -140	very coarse siliceous and calcareous sand.

25) <u>Mahaddei Uen</u>

0 - 4 m	dark-brown sandy clay with a few calcareous nodules;
4 - 10	light-brown earth-like marly, sandy and gypsiferous clay;
10 - 16	greyish predominantly siliceous sand, fine- to medium-grained;
16 - 31	as at 4-10 m;
31 - 43	predominantly calcareous pebbles, gradually increasing in size, up to 7-8 mm, clay matrix near bottom;
43 - 49	whitish calcareous marl, whitish thin-bedded siliceous sand and a few small pebbles;
49 - 51	brown sandy clay with numerous predominantly calcareous pebbles;
51 - 70	siliceous sand, greyish, medium-grained, slightly clayey, with marly-sandy reddish stratum at a depth of 67 m;
70 - 97	whitish sand, fine- to medium-grained, slightly clayey, with abundant gypsum crystals, especially down to 80 m, and abundant calcareous pebbles from 80 m on;
97 - 113	siliceous sand, whitish, fine- to medium-grained, coarse towards bottom; very low percentage of clay and gypsum crystals; rare calcareous pebbles.

26) <u>Lebida Codesa</u>

0 - 3 m	calcareous-sandy gravel, slightly cemented, and gypsum conglomerate;
3 - 6	reddish siliceous sand, a few gypsum crystals and sandy nodules;

6 - 10	greyish sandy limestone, tending to pink, weathered;
10 - 12	clay incorporating nodules and sandy-limey nodules;
12 - 39	sandy limestone, soft, at times finely porous, greyish with a few grey-blackish and whitish-to-pink strata; a few intercalations of thin-bedded calcareous marl towards the bottom;
39 - 43	reddish limestone, weathered and deeply fractured, with veins filled with white calcite;
43 - 51	slightly sandy brown-reddish clay;
51 - 81	calcareous marl, whitish-to-pink and greyish marls with a few intercalations of grey marl (at 63 and 78 m);
81 - 90	grey-reddish siliceous sand, fairly cemented and slightly clayey.

From 0 to 12 m: alluvial formation.
From 12 to 90 m: Cretaceous, Belet Uen series.

28) <u>Ali Dere</u>

0 - 6 m	dark-brown clay incorporating a few weathered calcareous nodules;
6 - 9	weathered reddish limestone;
9 - 21	reddish and greyish limestone with a few intercalations of thin-bedded limestone;
21 - 35	marly limestone, greyish, porous and weathered and whitish calcareous marls;
35 - 48	marly-sandy clay grading into marls towards bottom;
48 - 69	reddish siliceous sand, fine- to medium-grained, weathered down to 55 m, with abundant sandy fragments,

gradually replaced by light-coloured and then greyish sand with a few fragments of sandstone; remarkable percentage of calcareous sand and occurrence of clay towards bottom.

From 0 to 6 m: alluvial formation.
From 6 to 69 m : Cretaceous formation, probably Belet Uen series.

30) <u>Garas Bargo</u>

0 - 4 m	brown sandy clay incorporating quartz and pisolitic nodules (well rounded) and a few calcareous fragments;
4 - 7	coarse quartz sand, white, slightly clayey, then reddish with a few calcareous nodules and fragments of sandstone;
7 - 19	sandy limestone, fairly compact, reddish;
19 - 22	siliceous sand, medium- to coarse-grained, fairly smooth, and a few pinkish nodules of calcareous sandstone;
22 - 28	calcareous and sandy gravel with coarse whitish siliceous sand;
28 - 37	same as above, mixed with reddish clay and rare gypsum crystals; the percentage of clay increases towards bottom;
37 - 43	reddish clay with a few pisolitic nodules and rare calcareous nodules;
43 - 46	gravel, fairly rounded, loose, calcareous and arenaceous;
46 - 52	calcareous gravel, whitish and slightly cemented, with low clay content;
52 - 61	siliceous sandstne, clayey, soft, greyish; the percentage of clay increases near bottom;
61 - 73	siliceous sand, medium- to coarse-grained, slightly clayey, fairly rounded; a few nodules of sandy limestone;

73 - 76 siliceous sand, very coarse and fairly rounded; frequent calcareous nodules;
76 - 91 light-brown sandy clay (sand is fine- to medium-grained from 85 to 91 m);
91 - 97 compact marly clay with a few calcareous nodules;
97 - 118 siliceous sand, whitish, slightly clayey, fine- to medium-grained, with abundant whitish nodules of calcareous sandstone;
118 - 124 siliceous sand, fine-grained, from slightly clayey to clayey;
124 - 127 dark-brown clay, with scarce sand content, compact; a few pisolitic nodules.

31) <u>Bio Addo</u>

0 - 4 m brown clay with calcareous nodules;
4 - 10 light-brown calcareous and arenaceous nodules grading into reddish siliceous sand, slightly clayey, with rare nodules;
10 - 13 sandy limestone, reddish and greyish, hard, with sharp-edged fractures, with inclusions of siliceous sand;
13 - 28 calcareous and arenaceous pebbles, whitish and reddish, up to 1 cm in size, grading into hard and compact conglomerate consisting of coarser pebbles, the constituents of which derive mainly from Cretaceous limestone and Jessoma sandstone; fair percentage of clay at bottom;
28 - 37 pebbles, as above, but not cemented, differently rounded, 3 to 10 mm in diameter, of smaller size, mixed with grey clay from 36 to 37 m;
37 - 46 light-brown clay;
46 - 58 conglomerate bed, hard, compact, consisting of bulky calcareous and arenaceous materials; loose pebbles and clay at 58 m;
58 - 64 coarse pebbles in clayey matrix;

64 - 82 brown clay gradually replaced by grey - light-brown clay, slightly sandy, including pebbles from 68 to 70 m;

82 - 100 siliceous sand, fine-grained, reddish, with abundant pebbles from 82 to 91 m;

100 - 127 siliceous sand, dark-red, medium-grained, light-brown from 112 m, then grey near bottom; rounded.

From 0 to 100 m:river alluvium.
From 100 to 112 m: sandy formation, left exposed for a long time,

32) <u>Mir Nagot (242)</u>

0 - 6 m clayey- sandy topsoil ., blackish, with small calcareous nodules;

6 - 33 thin arenaceous crust and blackish clayey sand with frequent calcareous nodules down to 12 m, then scarcely sandy brown clay (from 12 to 21 m), and hard marls, brownish and grey (from 21 to 33 m) with thin arenaceous crust from 24 to 26 m;

33 - 36 calcareous detritus and calcareous and arenaceous nodules;

36 - 54 siliceous sand, coarse and whitish (36 to 45 m), replaced by sand, fine- and medium-grained, then coarser near bottom;

54 - 65 slightly calcareous sandstone (consistent arenaceous nodules) and reddish sand;

65 - 102 reddish marly clay, with a few intercalations of greyish clay; a few calcareous nodules.

<u>Mir Nagot (242 b)</u>

0 - 12 m marly clay, light-brown, slightly sandy, with calcareous, arenaceous and marly nodules and detritus, particularly near bottom;

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12 - 24	calcareous fragments and small-sized nodules in clayey matrix (from 12 to 15 m); reddish sandstone with a few calcareous nodules; sandy streak (from 19 to 21 m) followed by clayey one (from 21 to 24 m) with arenaceous nodules;
24 - 33	siliceous and calcareous sand, medium-grained, slightly clayey;
33 - 51	light-brown marly-sandy clay with a few gypsum crystals (36 m) then replaced by clayey-siliceous sand, medium- and coarse-grained, then finer-grained;
51 - 60	greyish, hard, compact marls with a few calcareous and arenaceous nodules;
60 - 66	calcareous nodules and detritus, greyish and reddish;
66 - 72	greyish marly limestone and brownish calcareous marls;
72 - 75	brownish marly clay;
75 - 77	whitish marly limestone;
77 - 90	predominantly siliceous sand, fine- to medium-grained, slightly clayey;
90 - 99	calcareous detritus and small pebbles mixed with reddish marly clay, which increases in percentage and is of brownish colour near bottom;
99 - 108	calcareous pebbles mixed with dark clay.

3.3) <u>Acab Duo</u>

0 - 13 m	marly sandy clay with marly sandy nodules, then replaced by dark-brown slightly sandy marly clay;
13 - 18	predominantly calcareous gravel, reddish and whitish, semi-rounded;
18 - 25	siliceous sand, coarse, whitish, sharp-edged; scarce calcareous sand;

25 - 30	dark-brown sandy clay;
30 - 38	calcareous gravel, medium-sized (5-6 mm), whitish, fairly rounded;
38 - 110	sandy clay, brown, at times reddish, with frequent crystals of selenitic gypsum and limey sandy nodules;
110 - 134	siliceous sand, light-brown, fine- to medium-grained;
134 - 140	brown sandy clay with a few calcareous pebbles.

Data are to be considered as approximate, owing to scarce number of samples.

34) **Uar Dagan**

0 - 2 m	brown sandy clay;
2 - 16	calcareous gravel with scarce fine-grained siliceous sand;
16 - 25	brown soft limestone;
25 - 40	hard whitish limestone (chertz);
40 - 64	siliceous sand, light-brown, fine-grained, sub-angular, then well-grained;
64 - 70	same as at 25-40;
70 - 73	same as at 40-64;
73 - 120	no samples.

35) Giliale

0 - 15 m	black clay with a few pebbles; sand (brackish water), clay with calcareous gravel, sand;
15 - 20	sand and gravel (fresh water); white clay, gravel, salty clay;
20 - 35	sand (brackish water); hard calcareous sand; grey clay;

35 - 63	no data available;
63 - 72	coarse gravel (brackish water).

36) <u>Jowhar (237)</u>

0 - 4 m	black sandy clay with predominantly calcareous pebbles (well-rounded);
4 - 7	siliceous and calcareous sand, coarse, slightly cemented, sub-angular;
7 - 10	pebbles (3 mm) mainly calcareous, a few quartz ones, well-rounded;
10 - 17	same as at 0-4;
17 - 31	sand and gravel (up to 1 cm), predominantly calcareous, scarcely rounded;
31 - 43	sand, medium- to coarse-grained, siliceous, scarcely calcareous, sub-angular, light-brown; finer-grained near bottom;
43 - 46	predominantly calcareous well-rounded gravel (5-10 mm);
46 - 55	sand and gravel (up to 5 mm), calcareous and siliceous, silty near bottom;
55 - 58	red-brown marly-silty clay;
58 - 97	gravel and siliceous-calcareous slightly silty sand;
97 - 100	fine-grained silty sand with a few pebbles;
100 - 106	same as at 58-97;
106 - 112	siliceous sand, fine- to medium-grained, sub-angular.

Traces of gypsum almost everywhere.

<u>Jowhar (235)</u>

0 - 7 m	topsoil, blackish to dark-brown, clayey, with abundant gypsum crystals and limonitic nodules;

7 – 10	light-brown hard sandy marls with limestone concretions; some gypsum;
10 – 13	light-brown siliceous sand;
13 – 19	concretioned limestone and pisolitic nodules with abundant sand and gypsum, slightly cemented;
19 – 34	sand, limestone concretions and calcareous and arenaceous pebbles; very scarce clay and a few gypsum crystals;
34 – 40	sub-rounded calcareous and arenaceous pebbles;
40 – 46	ash-grey sandy clay with rare pebbles;
46 – 49	medium-grained sand, predominantly siliceous and slightly clayey;
49 – 55	medium-grained sand, predominantly siliceous; 35% calcareous and arenaceous sand;
55 – 58	fine grey sand;
58 – 64	light-brown – grey sandy clay with concretioned limestone nodules;
64 – 70	grey-light brown sand, predominantly siliceous, fine-grained;
70 – 73	sand of same nature as at 64–70, but coarser, with abundant calcareous nodules and limestone concretions; rare gypsum crystals;
73 – 79	small nodules, predominantly pisolitic, calcareous and arenaceous, 3–4 mm near bottom, small from 73 to 76 m;
79 – 85	siliceous sand, medium-grained, greyish, with frequent pisolitic crystals; rare gypsum crystals.

38) <u>Fak Mohamed</u>

0 – 7 m	siliceous sand, fine- to medium-grained, whitish;
7 – 13	arenaceous stratum, sandy, whitish, soft and porous, of calcined appearance; a few inclusions or thin beds of sand;
13 – 49	very fine-grained sand, at first whitish, then reddish, slightly clayey for the first few metres, then with a considerably higher clay content; frequent calcareous and arenaceous nodules, hard,

	whitish and blackish;
49 - 52	siliceous sand, loose, fine- to medium-grained, light-brown;
52 - 64	arenaceous limestone, hard, porous, nodular, with a few inclusions or thin beds of sand;
64 - 70	siliceous sand, slightly clayey, fine-grained, with a few arenacerus nodules;
70 - 79	same as at 52-64;
79 - 100	fine-grained reddish siliceous sand.

39) <u>Gululei</u>

0 - 9 m	blackish topsoil and greyish marly-sandy clay;
9 - 24	light-brown marly-sandy clay (sand is prevailingly calcareous);
24 - 36	conglomerate of calcareous gravel, medium-grained sand and light-brown marl;
36 - 51	medium- and coarse-grained siliceous and calcareous sand alternating with calcareous marl;
51 - 57	conglomerate of whitish calcareous gravel and calcareous marl;
57 - 69	medium-grained siliceous sand alternating with coarse-grained calcareous sand;
69 - 87	conglomerate of calcareous gravel and clayey-marly cement, alternating with light-brown calcareous marl;
87 - 105	no samples.

40) <u>Gabanei</u>

0 - 3 m	topsoil;
3 - 6	fine-grained, whitish siliceous sand;
6 - 24	clay with calcareous nodules;
24 - 36	medium-grained whitish siliceous sand;

36 - 51	calcareous stratum with inclusions of sand incorporating large calcareous nodules;
51 - 60	compact grey clay;
60 - 66	coarse-grained whitish siliceous sand;
66 - 75	arenaceous limestone;
75 - 90	coarse-grained whitish siliceous sand with calcareous nodules;
90 - 96	compact greyish clay.

41) <u>Tesile</u>

0 - 6 m	clayey topsoil;
6 - 9	very fine-grained whitish sand;
9 - 21	grey clay with calcareous nodules;
21 - 30	coarse-grained whitish siliceous sand;
30 - 39	arenaceous limestone alternating with sand;
39 - 45	same as at 21-30;
45 - 54	soft arenaceous limestone;
54 - 63	coarse-grained whitish quartz sand;
63 - 72	grey clay with streaks of soft limestone;
72 - 81	same as at 54-63;
81 - 96	light-grey compact clay.

42) <u>Donadiga</u>

0 - 6 m	marly-sandy clay;
6 - 15	fine- to medium-grained, predominantly siliceous, reddish sand;
15 - 21	light-brown coarse-grained sand, predominantly calcareous, mixed with silt;
21 - 27	fine- to medium-grained, whitish siliceous sand;

27 - 45	medium- to coarse-grained siliceous and calcareous sand alternating with fine-grained siliceous sand;
45 - 48	coarse-grained calcareous and siliceous sand mixed with silt;
48 - 51	very coarse-grained whitish calcareous sand;
51 - 57	conglomerate of calcareous gravel with sandy clay;
57 - 68	light-brown calcareous marl incorporating a few whitish calcareous nodules and scarce siliceous sand;
68 - 75	same as at 51-57;
75 - 96	same as at 57-68.

43) Sarsarre

0 - 12 m	blackish topsoil grading into light-brown marly clay with rare gypsum crystals;
12 - 24	fine-grained whitish siliceous sand;
24 - 47	coarse-grained whitish calcareous sand mixed with marly silt;
47 - 51	whitish calcareous gravel;
51 - 72	fine-grained calcareous sand mixed with siliceous sand;
72 - 75	whitish calcareous and siliceous sand;
75 - 78	coarse-grained calcareous sand.

Dondere

0 - 10 m	brown marly clay replaced by chiefly gypsiferous sand (65% gypsum), scarcely siliceous, with gypsiferous and calcareous well-rounded granules; coarser sand with traces of secondary light-brown limestone in clayey matrix near bottom;
10 - 16	marly pebbles, sand and abundant granules and gypsiferous and calcareous pebbles in brown clayey matrix;

16 – 19 light-brown silty-clayey sand, fine- to coarse-grained, angular to rounded, with a few gypsiferous and calcareous granules;
19 – 22 sandy marl with abundant gypsiferous grains;
22 – 28 light-brown hard marl;
28 – 31 light-brown silty-clayey sand, fine- to coarse-grained, sub-angular to sub-rounded, with brown concretioned calcareous pebbles;
31 – 34 brown marly pebbles, rounded, and sub-rounded sand;
34 – 37 light-brown hard clay, slightly gypsiferous sand;
37 – 43 pebbles consisting of marly clay, gypsum and white limestone;
43 – 52 silty marl, scarce calcareous granules and eroded Orbituline;
52 – 67 marly pebbles, diffuse calcareous and siliceous sand;
67 – 70 silty-clayey sand, fine- to coarse-grained, sub-angular to sub-rounded, with abundant calcareous and siliceous grains;
70 – 79 light-brown marl with high sand content; predominantly siliceous sand, frequent calcareous sand, scarce gypsum content;
79 – 85 light-brown clayey sand with frequent gypsum;
85 – 94 fine-grained siliceous sand with frequent gypsum;
94 – 128 light-brown silty-clayey sand, fine- to medium-grained, sub-angular to sub-rounded.

44) Hadega Mobilen

0 – 3 m topsoil;
3 – 12 calcareous gravel;
12 – 40 fine-grained sand; medium- to coarse-grained from 17 to 27 m;
40 – 46 sandy clay;
46 – 53 gravel and sand;
53 – 56 sandy clay;

56 - 60	sandy gravel;
60 - 76	sandy clay;
76 - 85	sandy-clayey conglomerate with pebbles;
85 - 90	fine-grained clayey sand;
95 - 105	conglomerate of clayey sand and pebbles.

45) Gololei

0 - 6 m	clayey-sandy topsoil;
6 - 12	grey clay;
12 - 21	grey clay with calcareous nodules;
21 - 41	reddish clay with large calcareous nodules;
41 - 62	fine-grained siliceous sand mixed with calcareous nodules;
62 - 74	medium-grained whitish quartz sand with frequent calcareous nodules;
74 - 87	medium- and coarse-grained, whitish siliceous sand;
87 - 102	medium- and coarse-grained, whitish siliceous sand, with calcareous nodules.

46.) Balad 170

0 - 6 m	black topsoil;
6 - 18	fine-grained quartz sand;
18 - 36	reddish calcareous rock;
36 - 72	reddish quartz sand;
72 - 80	red quartz sand;
80 - 110	white granulated quartz sand.

Balad 170 b

0 - 6 m - topsoil , marly, of a greyish colour at the surface, then of a tobacco colour at the depth of 3 m;
6 - 9 fine-grained, light-grey clayey sand;
9 - 27 fine-grained, pinkish siliceous sand, of aeolian origin;
27 - 48 same as above, but colour is reddish;
48 - 66 same as at 9-27;
66 - 70 as above, but of a very light colour tending to pink.

Considering the very short distance between the two wells (a few tens of m), one wonders why the "reddish calcareous rock " at 18-36 m in the first well is not encountered in this one. It can either be assumed that the the description was made by two persons, one of whom not very competent, or that there is a (too abrupt) lateral change of facies or a tectonic disturbance.

47) Aual Barei

0 - 7 m sandy-marly grey-brown clay;
7 - 10 calcareous and quartz sand, medium-grained, grey-brown with little silt;
10 - 22 fine-grained, sub-rounded quartz sand;
22 - 34 fine-grained slightly silty quartz sand with small calcareous pebbles (their percentage decreases gradually);
34 - 37 medium-sized pebbles with scarce fine-grained quartz sand;
37 - 43 silt, sand and small calcareous and quartz pebbles;
43 - 48 same as above, with pebbles reaching up to 8 mm in diameter;
48 - 51 red silt with sand and pebbles;

51 – 103	coarse gravel with some silty sand, grading into medium (57 to 63 m) and then again into coarse gravel. Percentage of sand increases from 69 m on and its colour turns from brown to red and light brown.

* Four wells were bored at Aual Barrei: their depth is 106 m (well No.193), 125 m (well No.193 bis), 40 m and 163 m (well No.193 ter). This was due essentially to loss of circulation mud.
It is not known to which well the above data refers .

48) <u>Alifo</u>

0 – 4 m	brown, followed by grey sandy clay;
4 – 22	light-brown sand, medium to coarse, with biotites;
22 – 31	light-brown sand, medium, subrounded with fragments of hard marl, grey to brown;
31 – 34	same as at 4–22 m, but of finer grain;
34 – 43	greyish-brownish marl, hard and sandy with rounded quartz grains;
47 – 59	light-brown sand, medium, subrounded to rounded; light-grey sand, fine to coarse, with siliceous pebbles, light-yellow calcareous fragments and marly clay; eroded Orbitoline;
59 – 65	same as at 43–47;
65 – 83	yellowish medium-grained sand;
83 – 134	grey-brownish clay alternating with clayey sand with abundant calcareous pebbles;
134 – 142	clayey sand, fine to medium, subrounded.

—— For the 18 wells in Afgoi area, see Part III, Introduction (with reference to Bibliography). ——

49) Lancat (160)

0 - 4 m	topsoil , clayey-sandy, blackish, with rare gypsum crystals;
4 - 10	grey-reddish sand, siliceous and calcareous, medium-grained;
10 - 16	arenaceous bed, with grey-reddish marly and calcareous cement, a few sandy streaks;
16 - 22	greyish, medium, siliceous and calcareous sand;
22 - 34	sandstone with greyish clayey-marly cement;
34 - 50	gravel consisting of calcareous, marly, and arenaceous materials, fairly rounded, from 1 to 5 mm; scarce sand and clay content;
50 - 62	hard calcareous marl, slightly sandy, incorporating grey-reddish calcareous nodules;
62 - 67	predominantly siliceous sand, white, coarse;
67 - 80	sandy marl, hard, greyish, incorporating calcareous nodules;
80 - 83	siliceous sand, white and coarse, with calcareous and marly nodules;
83 - 98	greyish slightly sandy clay;
98 - 110	marly limestone, compact, grey tending to pinkish, slightly sandy with a few sand streaks at 110 m;
110 - 115	siliceous sand, coarse, whitish, with a few calcareous and marly nodules;
115 - 118	siliceous sand, calcareous and marly nodules and a few calcareous streaks.

From 0 to 98 m: river alluvium; from 98 to 118 m: Oligocene-Miocene?

50) Uar Mahan

0 - 18 m	light-grey sandy marl;
18 - 24	fragments of conglomerate, calcareous marl, calcareous nodules and crystals of selenitic gypsum;
24 - 27	very fine white sand and granules of tourmaline;

27 – 33	calcareous sandy marl;
33 – 39	fine white quartz sand, very minute orange-coloured calcareous detritus and rare granules of tourmaline;
39 – 53	calcareous marl with orange-coloured calcareous sand;
53 – 60	very fine light-coloured quartz sand and fine calcareous sand;
60 – 87	calcareous marl, often sandy;
87 – 93	very fine quartz sand alternating with fine calcareous sand;
93 – 96	calcareous arenaceous bed;
96 – 105	reddish siliceous sand mixed with whitish calcareous detritus.

Uar Mahan (104 b)

0 – 6 m	light-grey sandy marl;
6 – 18	fine whitish quartz sand mixed with clay;
18 – 25	medium whitish quartz sand and calcareous detritus;
25 – 31	whitish quartz sand mixed with clay;
31 – 58	medium whitish quartz sand mixed with calcareous detritus;
58 – 90	calcareous marl, often sandy.

Uar Mahan (104 t)

0 – 7 m	dark brown sandy clay grading into brown clayey sand;
7 – 12	fine-grained light-brown siliceous sand;
12 – 15	dark brown sandy-marly clay;
15 – 18	light-brown fine siliceous sand;
18 – 21	siliceous sand gradually replaced by hard sandy clay;
21 – 31	marly clay incorporating arenaceous concretions, a few gypsum crystals and many minute calcareous nodules;
31 – 62	small calcareous and marly nodules cemented in clayey matrix; fair percentage of sand;
62 – 77	same as above, in dark brown clayey matrix; clayey content decreases and sand percentage increases in last 3 m;
77 – 83	predominantly siliceous fine sand;
83 – 95	brown-greyish clay with some calcareous nodules;

95 – 120	fine to medium sand, predominantly siliceous, slightly silty with frequent small nodules from 95 to 113 m;
120 –120.5	brown clay with some calcareous nodules.

This well had to be rehabilitated after 8 years of operation due to incrustations in filter which reduced water yield and due to accumulation of sand at bottom.

52) Duanle

0 – 10 m	topsoil , clayey, blackish grading into marly clay of a brownish colour; fair percentage of medium and coarse sand;
10 – 16	brown-greyish marly-sandy clay with gypsum crystals;
16 – 19	blackish clayey sand, medium siliceous and calcareous sand;
19 – 22	slightly clayey fine brownish siliceous sand;
22 – 25	coarse calcareous sand and fine brownish siliceous sand;
25 – 28	limonitized calcareous pebbles (1–2 mm);
28 – 40	well rounded calcareous and arenaceous gravel, dia. up to 1.5 cm;
40 – 49	hard marly clay incorporating calcareous pebbles;
49 – 64	brown marly clay;
64 – 76	predominantly siliceous sand with calcareous and arenaceous pebbles; scarce sand content, more abundant near bottom;
76 – 79	fine sand, siliceous and calcareous, clayey;
79 – 82	calcareous and arenaceous gravel with fine siliceous sand and clay;
82 – 91	calcareous, marly and arenaceous pebbles with brown clay;

91 – 100	predominantly siliceous medium and coarse sand, slightly clayey; frequent calcareous and arenaceous pebbles, abundant from 94 to 97 m;
100 – 118	calcareous and arenaceous gravel, 1 to 5 mm, fairly sandy, scarce clay content increasing near bottom;
118 – 127	slightly sandy greenish and dark brown clay with a few pebbles. Hard compact grey-greenish clay found at bottom (probably not of alluvial origin).

53) Uanle Uen

0 – 3 m	dark brown clayey marl;
3 – 13	whitish calcareous detritus mixed with light brown marl;
13 – 24	orange-coloured calcareous marl with very minute calcareous detritus;
24 – 30	calcareous, arenaceous and marly pebbles;
30 – 40	calcareous and gypsiferous pebbles, selenitic gypsum;
40 – 54	rather compact light brown calcareous and gypsiferous marl;
54 – 60	sandy calcareous marl;
60 – 90	fine quartz sand mixed with clayey silt and small arenaceous and gypsiferous detritus; rare crystals of selenite;
90 – 99	very fine quartz sand with calcareous gravel;
99 – 153	fine quartz sand with small calcareous detritus mixed with brown clay.

54) Adaidere

0 – 4 m	topsoil , clayey-sandy, blackish;
4 – 16	siliceous silty sand grading into fine siliceous sand, whitish-pinkish with slight sand content near bottom;
16 – 25	coarse siliceous sand with a few crystals of selenite and fragments of whitish and pink limestone;
25 – 30	whitish arenaceous limestone with some crystals of selenite;

30 – 35	fine whitish siliceous sand with some calcareous nodules;
35 – 40	slightly marly whitishbrownish limestone;
40 – 43	whitish marl;
43 – 46	sandy calcareous gravel, 2-3 mm;
46 – 49	light brown clay;
49 – 55	calcareous gravel, whitish marly limestone, light brown clay;
55 – 81	siliceous sand, fine to medium, with rare nodules and calcareous streaks;
81 – 89	marly clay replaced by sand and then by sandy marl with rare calcareous nodules;
89 – 115	brown clayey marl with frequent calcareous nodules, thin-bedded pinkish limestone and a few crystals of selenite;
115 – 133	siliceous sand, fine to coarse with calcareous nodules, intercalations of light brown marl;
133 – 155	hard light brown marl with sparse thin-bedded limestone;
155 – 187	medium siliceous sand grading into clayey sand of finer grain with laminae of white weathered mica.

55) Ai Buralei

0 – 9 m	brown clayey marl;
9 – 21	calcareous marl with small calcareous fragments;
21 – 30	fine sand mixed with calcareous nodules; traces of gypsum;
30 – 60	medium siliceous sand mixed with silt and calcareous detritus; rare crystals of selenite;
60 – 72	calcareous marl with sand;
72 – 100	sand, fine to medium, siliceous, mixed with calcareous fragments and gypsum.

56) Giamea Gigliole

0 – 3 m	dark brown clayey sand with frequent gypsum crystals;
3 – 6	reddish, medium siliceous sand with laminae of mica;

6 – 9	brown clay with coarse sand and gypsum crystals;
9 – 13	predominantly siliceous sand with a few gypsum crystals;
13 – 25	marly-sandy clay, brown, greyish and reddish, with frequent gypsum crystals (abundant at 25 m) and rare calcareous nodules;
25 – 28	conglomerate consisting of calcareous, gypsiferous and marly materials;
28 – 31	reddish clayey sand with calcareous and marly pebbles;
31 – 34	reddish clayey marl with gypsum crystals;
34 – 46	slightly cemented gravel with scarcely rounded calcareous and marly granules; scarce sand and clay content;
46 – 50	siliceous sand, whitish tending to pink, fine-grained;
50 – 61	calcareous and marly fragments and calcareous-marly gravel (4–5 mm) at 55 m, of smaller size and with higher sand content near bottom;
61 – 79	marly clay, light green and reddish, slightly sandy, incorporating a few calcareous and marly nodules;
79 – 91	coarse siliceous and calcareous sand with a clay-marly-sandy streak from 85 to 88 m;
91 – 109	marly clay, brown-reddish and light green, slightly sandy with frequent calcareous nodules at 97 m, abundant gypsum crystals at 103 m;
109 – 140	greyish sandy clay with frequent calcareous nodules (109–112 and 115–118 m) and horizons with calcareous and marly pebbles, with sandy clay from 124–130 m; clay contains higher percentage of sand near bottom.

69) Acao

0 – 6 m	light brown clayey marl;
6 – 18	clayey marl and fragments of whitish limestone;
18 – 39	gypsiferous and marly limestone;
38 – 48	whitish gypsiferous limestone alternating with thin-bedded marl;

48 – 54	reddish marl;
54 – 69	arenaceous limestone;
69 – 72	arenaceous limestone alternating with thin-bedded marl;
72 – 84	soft calcareous limestone;
84 – 90	whitish arenaceous limestone;
90 – 99	whitish limestone alternating with clayey marl;
99 – 105	whitish limestone alternating with whitish and light brown arenaceous limestone.

70) <u>Duddumai</u>

0 – 7 m	brown sandy clay and small calcareous nodules;
7 – 10	fragments of light brown finely crystallized limestone;
10 – 22	calcareous pebbles, grey, yellowish and reddish with scarce subrounded sand; traces of white gypsiferous limestone;
22 – 25	white granulous limestone;
25 – 53	clay, silty to sandy, reddish-brownish, gypsiferous limestone and disc-shaped gypsum crystals;
53 – 56	dark red and light grey calcareous nodules with sand;
56 – 94	granulous limestone, light grey and light brown, with sandy streaks; brown marly sand from 72 to 75 m;
94 – 100	brown clayey sand;
100 – 130	greyish and light brown marly limestone.

71) <u>Madamorodi</u>

0 – 10 m	siliceous sand, medium to coarse, semi-rounded, whitish and reddish; calcareous sand and clay content scarce;
10 – 13	calcareous and siliceous pebbles in clay matrix;
13 – 88	Granite-like quartzite, reddish and whitish, then replaced by white almost pure quartzite with rare calcareous veinlets;
88 – 97	same as above, but weathered;

97 – 121 as above, but even more weathered, of a rust-red colour; probable fracture line.

From 0 to 13 m: alluvial formation;
from 13 to 121 m: Pre-Mesozoic crystalline rock.

72) <u>Ghel Ghel Gudut</u>

0 – 2 m	calcareous and quartz sand, and silt;
2 – 4	brown weathered sandy marl;
4 – 19	coarse sub-angular calcareous and quartz sand;
19 – 22	same as above, with gravel;
22 – 31	same as above in sandy marl matrix; gravel decreases near bottom;
31 – 43	coarse, angular to sub-angular, predominantly quartz sand;
43 – 46	coarse feldspate and quartz sand in grey marl;
46 – 49	predominantly quartz gravel, sub-angular to angular;
49 – 55	rather uniform sand in grey marl;
55 – 73	whitish sugar-like mainly quartz sand, angular to sub-angular;
73 – 76	coarser sand;
76 – 97	sand as at 55–73;
97 – 100	coarse sand;
100 – 106	sand with gravel.

73) <u>Guramai</u>

0 – 15 m	blackish topsoil' followed by reddish clayey sand with minute fragments of whitish limestone; coarse sand near bottom;
15 – 27	whitish hard calcareous gravel, quartz granules, intercalations of coarse sand and greyish clay;
27 – 30	coarse, whitish, uniform quartz sand;
30 – 48	coarse calcareous and quartz sand alternating with soft

	(rounded) and hard (subrounded) granules; thin-bedded clay;
48 – 63	uniform whitish quartz sand;
63 – 81	subrounded to rounded loose quartz pebbles (1-4 cm) with a few crystals of whitish or pinkish feldspate.

74) <u>Cugno Hober</u>

0 – 7 m	brown calcareous sand, fine to coarse, sub-angular to subrounded quartz; traces of white gypsiferous marly limestone;
7 – 13	brownish gypsiferous marl with abundant quartz sand, fine to coarse, and black minerals; traces of white sandy marl;
13 – 16	varicoloured (light brown, light orange, brownish and whitish) marly-sandy limestone; rare calcareous pebbles;
16 – 22	same as above, but with gypsiferous marl;
22 – 25	highly gypsiferous marl, medium-sized subrounded calcareous pebbles, fine to medium, subrounded to sub-angular quartz sand; traces of white marly limestone and rare black minerals;
25 – 34	light brown gypsiferous marl and fine to medium quartz sand, of a light brown colour near bottom;
34 – 37	light brown limestone;
37 – 58	brownish and whitish gypsiferous marl;
58 – 61	brownish calcareous sand; fine to medium, sub-angular to subrounded quartz sand; grains of black minerals;
61 – 93	light brown and varicoloured marls with brown sand from 58 to 61 m, gypsum;
93 – 103	brownish calcareous and gypsiferous sand; fine to medium, sub-angular to subrounded, clayey quartz sand;
103 – 135	highly sandy brownish and light brown marl with a few traces of calcite and quartz grains near bottom;
135 – 145	dolomite with microgranular limestone and light brown marl; abundant epigenetic chertz, scarce sand;
145 – 154	light brown sandy marl with thin-bedded white dolomite.

Cretaceous at bottom of well; probably all the formation dates from the Cretaceous.

78) <u>Furukulei</u>

0 - 6 m	blackish topsoil with gypsum crystals and calcareous nodules;
6 - 21	fine whitish siliceous sand, with fair clay content at 12 m and from 18 to 21 m;
21 - 33	grey slightly sandy marly clay;
33 - 57	medium to coarse whitish siliceous sand with rare gypsum crystals;
57 - 100	calcareous, marly and arenaceous pebbles, gradually increasing in size from 2 to 6 mm, whitish clay matrix from 78 to 90 m.

80) <u>Murri well</u>

0 - 3 m	sandy clay;
3 - 60	sand alternating with gravel;
60 - 75	gravel;
75 - 81	sandy gravel;
81 - 93	gravel;
93 - 96	clay.

82) <u>Fidda Gudut</u>

0 - 10 m	red sandy clay;
10 - 30	marly clay with fine to medium-grained sand;
30 - 98	whitish sand, fine to medium, with arenaceous fragments.

----- For the 68 wells in Genale district, see separate report (mentioned in Bibliography) including also Afgoi wells. -----

85) <u>Diblai</u>

0 - 24 m	reddish predominantly siliceous sand down to 10 m, grading into grey and pinkish fine to medium sand;
24 - 43	coarse greyish siliceous and calcareous sand;
43 - 49	same as above, but slightly clayey, scarcely cemented, brownish;
49 - 55	conglomerate consisting of sand and small brown pebbles;
55 - 61	predominantly siliceous medium sand and arenaceous concretions;
61 - 64	greyish, fine to medium, loose siliceous sand;
64 - 82	calcareous gravel (1-2 mm), arenaceous concretions and sand;
82 - 85	medium and coarse siliceous and calcareous sand;

85 – 91 calcareous and arenaceous gravel (3–5 mm);
91 – 109 slightly clayey sand, fine to medium, greyish.

87) Marin Gubai

0 – 5 m brown clayey topsoil;
5 – 12 fine quartz-silty sand;
12 – 24 medium calcareous and fine siliceous silty sand;
24 – 33 calcareous gravel with sand and silt;
33 – 42 conglomerate of calcareous detritus with clayey marl;
42 – 48 clayey sand;
48 – 60 clayey quartz sand;
60 – 85 fine to medium reddish siliceous sand;
85 – 100 reddish siliceous sand alternating with arenaceous limestone;
100 – 110 calcareous detritus in marly matrix;

Well was originally 70 m deep and yielded little water; later bored deeper and motor pump with a capacity of 14 cu.m/hour installed.

92) Uaian

0 – 4 m calcareous and quartz sand;
4 – 7 coarse calcareous sand;
7 – 10 calcareous and quartz sand;
10 – 16 medium to coarse calcareous sand;
16 – 40 medium to coarse predominantly calcareous sand;
40 – 61 calcareous mixed with quartz sand;
61 – 112 fine to medium predominantly quartz sand, with fair content of calcareous sand;
112 – 132 fine to medium quartz sand.

93) <u>Cugno Barro</u>

0 - 3 m	dark coloured clayey marl;
3 - 9	fine siliceous marl with calcareous fragments;
9 - 21	soft whitish marly limestone;
21 - 24	soft calcareous limestone;
24 - 33	coarse calcareous sand with quartz granules;
33 - 36	hard whitish calcareous conglomerate, finely fragmented.

93) <u>Malailei</u>

0 - 8 m	no samples;
8 - 16	coarse, whitish, slightly clayey siliceous sand; rare calcareous pebbles;
16 - 49	sandy clay, initially blackish then greyish, with frequent calcareous pebbles and nodules, up to 1 cm;
49 - 62	soft greyish calcareous marl;
62 - 73	medium-sized pebbles and nodules in sandy-clay matrix;
73 - 79	whitish porous nodular arenaceous limestone with a few lenses of fine sand;
79 - 85	no samples.

95) <u>Borama</u>

0 - 6 m	brownish sandy clay;
6 - 18	whitish fine siliceous sand;
18 - 21	predominantly calcareous whitish sand;
21 - 30	calcareous sand;
30 - 48	hard whitish limestone;
48 - 60	whitish siliceous sand and calcareous sand;
60 - 63	greyish marly limestone;
63 - 69	finely fragmented calcareous conglomerate;
69 - 72	grey clayey marl;
72 - 75	calcareous sand;

75 - 78	coarse quartz sand;
78 - 81	calcareous and quartz sand;
81 - 95	fine calcareous conglomerate alternating with thin-bedded grey marl;

96) <u>Billik Taleh</u>

0 - 4 m	blackish clay-sandy topsoil;
4 - 7	greyish sandy-marly clay and grey arenaceous streaks;
7 - 16	sandy clay incorporating calcareous fragments;
16 - 19	calcareous and arenaceous pebbles and coarse siliceous sand;
19 - 31	greyish siliceous sand with calcareous fragments and pebbles, slightly clayey near bottom;
31 - 34	calcareous pebbles in blackish sandy clay matrix;
34 - 43	greyish sandy clay wih calcareous nodules and pebbles;
43 - 52	grey-blackish sandy clay with pebbles gradually diminishing in size near bottom;
52 - 61	ash-grey clay-sand with arenaceous pebbles and concretions;
61 - 76	pebbles and clayey sand, initially dark, then of a lighter colour, with a few soft arenaceous streaks;
76 - 94	sandy clay grading into greyish siliceous sand, coarse and slightly sandy, including pebbles gradually increasing in size near bottom;
94 - 100	ash-grey highly sandy clay with pebbles;
100 - 109	coarse siliceous sand with a few calcareous-arenaceous nodules and fragments grading into fine sand and a few arenaceous streaks;
109 - 112	greyish coarse clayey sand with rare calcareous nodules.

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