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Groundwater

3.1 INTRODUCTION

The main objective of the hydrogeological appraisal was to determine whether the potable water demand of the proposed settlements could be supplied from groundwater sources. Further objectives were to determine the best methods of groundwater abstraction and evaluate the costs of any necessary installations.

The main problem with attaining these objectives has been the weakness of the existing data base. Thus, though some work relevant to the hydrogeology of the region had been done in the past, much of the data appears to have been lost. A particular example of this are the boreholes drilled by the Russians, for which all records seem untraceable. Further, even such scant data as exists has never been systematically analysed and compiled.

The approach of this study has been to collect all the published information, particularly the various development reports, to interview the personnel of various agencies concerned with groundwater work in Somalia and to conduct a field survey to collect geological and hydrogeological data. All this information has been carefully processed and compiled to obtain a regional picture of the groundwater systems. The Project Area itself, for which basically no subsurface data exists, was then viewed within that regional context. The results obtained are not fully conclusive but they are strongly indicative.

3.2 GEOLOGY AND GEOMORPHOLOGY

The Project Area is located at the confluence of the Jubba and Shabeelle flood plains, in the coastal sedimentary basin east of the Great Banta-Gialalassi Fault, which runs along the whole length of Somalia, more or less parallel to the coast and divides the country into two major hydrogeological provinces. The whole region consists essentially of flat lowlands with stabilised coastal dunes forming some more uneven relief in a belt of low hills.

Apparently the southern extremity of the coastal province, which includes the Project Area, is underlain by a great thickness of Tertiary sediments of marine origin. Technital S.p.A. (1975) quoting evidence from deep exploratory oil drillings, report the presence of Tertiary deposits 3,000 to 4,000 metres thick, comprising sandstones and shales with subordinate limestones, sometimes gypsiferous; layers of lignite are common throughout the sequence.

According to Technital S.p.A. this Tertiary succession is overlain by a Quaternary alluvial complex, several hundred metres in thickness. In contrast, Johnson (1978), discussing the groundwater resources of the Jubba Valley, states that no deep alluvials had been identified and that the Lower Jubba region is underlain exclusively by marine sands, marls, clays and gravels. It would seem that this contention is contradicted by evidence from recent drillings, which penetrate gravels, sands and clays of typically fluviatile nature.

The alluvials were presumably deposited by the ancestral Jubba and Shabeelle Rivers. This fluviatile deposition was interrupted at least once by a marine incursion into the area, probably associated with sea level changes during the Pleistocene ice age. This resulted in a period of lagoonal conditions which led to the formation of one of the major geomorphic units of the region, the Marine Plain (Lockwood/FAO, 1968). Subsequent marine recession allowed the resumption of riverain activity with the formation of the present Jubba and Shabeelle flood plains.

The lithological character of the Quaternary strata is not well documented except for the surface deposits which have been mapped by the soil survey. There are some exposures of shallow subsurface formations in sand pits excavated for construction materials; there are also some wells which penetrate deeper into these deposits, but in most cases the lithological information from these was either not collected at all or has been lost since.

The surface deposits over the whole region are mainly clayey, often of swelling montmorillonitic clays. These are virtually impermeable when wet but crack deeply on drying out. There is some evidence that they are often underlain by sand.

A large sand pit near the village of Maqdas showed the following near surface succession:

Depth	Lithology
0 - 1 m	Red lateritic soil.
1 - 3 m	Red fine sand with white calcareous concretions.
3 - 4 m	Grey sandstone, fine grained showing nodular weathering.
4 - 6+ m	Red fine sand with white calcareous concretions.

It appears that the occurrence of the red sand with calcareous concretions is widespread throughout the region as similar material was seen on spoil heaps of excavated material found adjacent to recently constructed dug wells, both in sandy and clayey soil areas.

Information on deeper lithology is available from one drilling only, located outside the Study Area at the Trans-Jubba Project compound along the main Kismaayo to Jilib road some 6 km south of Kamsuuma. The succession at that site is as follows:

Depth	Lithology
0 - 6 m	Clay, loamy.
6 - 12 m	Loam with very fine sand.
12 - 18 m	Gravel, medium to fine, with medium sand and interbedded marl.

18 - 49 m	Sand, fine to medium, with fragments of crystalline rock; contains interbedded layers of calcareous gravel.
49 - 70 m	Gravel, medium to fine, well rounded, calcareous, with fine to medium sand.
70 - 89 m	Clay with sub-angular calcareous gravel and some very fine sand.
89 - 105 m	Clay, grey, with a little calcareous gravel.

It is likely that this sequence is fairly typical of the Project Area, though the various layers can be expected to vary widely in thickness and the depth at which they are found.

It should be mentioned that all the lithological data available relates to areas very close to the Jubba River, whereas the proposed development area (where the proposed settlements will be situated) is located astride the Shabeelle flood plain. Thus it is possible that the alluvial succession there is rather different.

In terms of geomorphology four distinct units have been identified in the region by Lockwood/FAO (1968):

(i) Marine Plain.

(ii) Shabeelle Alluvium.

(iii) Jubba Alluvium.

(iv) Beach Remnants.

The Marine Plain is the most widespread of these. The Shabeelle Alluvium occurs in a wide flood plain with a now mainly abandoned river channel as the present day Shabeelle ends in a swamp upstream of the Project Area, except at times of particularly large floods. The Jubba Alluvium is found in a narrow tract along the present course of the river. The Beach Remnants occur as small isolated, slightly elevated patches of sandy material; these are believed to be remnants of beach ridges and coastal sand dunes.

From the point of view of hydrogeology the geomorphology of the Area may be significant with relation to groundwater salinity. In view of the recent marine history of the region, the best chances of good quality groundwater occurrence are near the present and recent courses of the rivers where the saline marine influence may have been flushed out by seepage from the rivers.

3.3 AQUIFERS

The water table is normally somewhere around five metres below ground level near the Jubba but increases in depth rapidly with distance from the river. In most of the region it is usually at depths of between 15 and 20 metres. It appears that below that depth potentially productive aquifers are found at various levels throughout the Quaternary (? alluvial) profile and are probably also present in the underlying Tertiary sequence.

Dug wells in the Area penetrate about two metres below the water table and usually tap a sandy layer or lens but some may bottom in clay. The productive layer is commonly the sand with calcareous concretion as witnessed by the spoil heaps of newly excavated wells. Water quality evidence suggests that this is a discontinuous series of minor aquifers isolated from each other by clayey material. Nevertheless these aquifers are sufficiently permeable to sustain production by bucket and rope of about 1,000 litres per hour at peak abstraction times. In one case a dug well very close to the river yielded enough water to sustain a pumped discharge of about 5 litres per second (l/s).

Though, as already mentioned, data from deeper, drilled wells is extremely scarce, it appears that further permeable layers of sand and gravel are always found within the top 100 metres or so. Thus all the drilled wells in the region have no problems with sustaining their, admittedly low, production rates. The depths of these wells reportedly vary from some 35 to about 100 metres and the yields are estimated as between 5 and 10 l/s.

Quantitative data on the transmission properties of the aquifers is available at one place only, namely Well No. 20 (see Figure 3.1), where a pumping test has been done. Application of the Logan method to these data gives a transmissivity of 3.3 m^2/hour from a screened section of gravel of 19 metres. This is equivalent to a permeability of about 4.2 m/day, which is more consistent with fine sand than with gravel and suggests that either the aquifer is partially cemented or contains a considerable admixture of very fine material.

Nothing is known about the production capacity of deeper Quaternary and Tertiary aquifers, but they are known to exist.

To summarise it is apparent that potentially productive aquifers occur extensively throughout the profile in the whole region. To obtain discharges of between 5 and 10 l/s, which would certainly satisfy the demands for potable water of individual settlements, drilled depths of well of no more than 100 metres would probably suffice.

3.4 WELLS AND BOREHOLES

All wells and boreholes, that could be found in the region, were visited and all available relevant information from them was collected. The results of this survey are summarised in Table 3.1. The approximate locations of all these wells are given in Figure 3.1.

Eighteen dug wells were inspected. The absolute range of depths is from about 6 to 25 metres, but most of the wells are probably between 17 and 22 metres deep. The penetration below the water table is normally about two metres.

The usual practice is to line the wells with concrete rings about 1.5 m in diameter, though some are left unlined and do not appear to suffer from slumping. The unlined wells are rectangular in cross-section.

In all but two cases, the dug wells are not equipped with any mechanical water lifting devices and water is drawn from them by bucket and rope. The two exceptions are an abandoned well in Jilib, equipped with a broken down windmill pump and a shallow well (6 m) very close to the Jubba river on a banana estate, equipped with a small centrifugal pump, delivering water to an elevated storage tank.

The rates of abstraction by rope and bucket are estimated at no more than 1,000 l/hour at peak and probably less than a tenth of that on average. The well equipped with the centrifugal pump, probably yields about 5 l/s with an operating factor of no more than six hours per day.

3.1 Location of existing wells

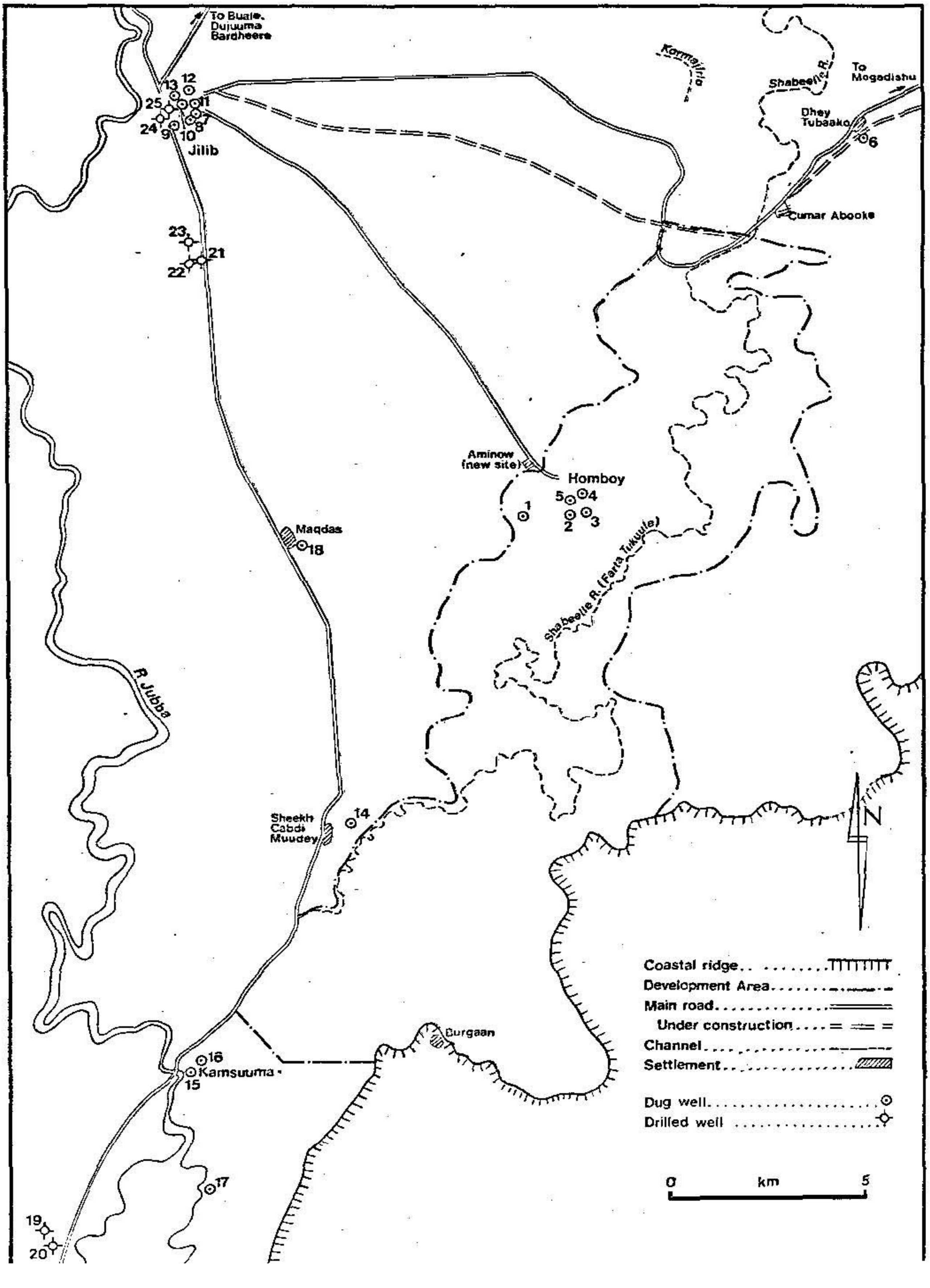


TABLE 3.1 EXISTING WELLS

Well No.	Type	Location	Dia. (m)	Depth (m)	SWL below GL (m)	EC x10^6 @ 25°C	Remarks
1	Dug	Aminow	1.50	?	18.70	1,735	Lined with concrete rings.
2	Dug	Homboy	c.2.00	?	18.45	1,814	Unlined.
3	Dug	Homboy	c.2.00	?	18.45	2,811	Unlined.
4	Dug	Homboy	1.50	?	17.90	1,541	Lined with concrete rings.
5	Dug	Homboy	c.1.50	?	22.20*	4,081	Unlined.
6	Dug	Dhey Tubako	1.50	?	21.44	4,234	Lined with concrete rings. Not used for several years.
7	Dug	Jilib	1.50	?	14.22	2,095	Lined with concrete rings.
8	Dug	Jilib	1.50	?	12.70*	1,571	Lined with concrete rings.
9	Dug	Jilib	1.50	14.20	12.02*	3,115	Lined with concrete rings.
10	Dug	Jilib	1.50	?	12.60*	667	Lined with concrete rings.
11	Dug	Jilib	1.50	-	-	-	Old abandoned well, originally equipped with windmill pump, now filled with rubbish.
12	Dug	Jilib	1.50	?	15.10	30,260	Lined with concrete rings. Newly constructed well - abandoned because of high salinity.
13	Dug	Jilib	1.50	?	10.80*	2,581	Lined with concrete rings.
14	Dug	Sheikh Cabdi Mukdey	c.1.50	?	16.30	8,163	Unlined. Abandoned because of high salinity.
15	Dug	Kamsuma	1.50	?	6.50*	740	Lined with concrete rings.
16	Dug	Kamsuma	1.50	?	6.95	3,401	Lined with concrete rings.
17	Dug	Romana Plantation	1.50	6.00	4.45	833	Lined with concrete rings. Equipped with centrifugal pump.
18	Dug	Maqdas	1.50	21.60	18.22	3,249	Lined with concrete rings.
19	Drilled	Trans-Juba Project Compound	0.20	80.00	7.02	1,584	Equipped with shaft driven turbine and diesel motor.
20	Drilled	Trans Juba Project - near main road	0.20	80.00	6.70	1,224	Equipped with submersible pump and diesel generator.
21	Drilled	Fanoole Project - yard	0.30	26.20	15.90	1,678	Abandoned. Depth was measured but well is open and may be filled with spoil.
22	Drilled	Fanoole Project - yard	0.15	?	?	2,064	Pumped by airlift.
23	Drilled	Fanoole Project - yard	0.30	?	14.78	?	Equipped with pump and motor (Russian), but apparently never used.
24	Drilled	Fanoole Project office compound	?	?	?	1,296	Equipped with submersible pump.
25	Drilled	Jilib	0.15	?56.00	-	-	Disused for some years. Closed with a welded cap.
26	Drilled	Marere - Juba Sugar	?	?	?	952	Equipped with shaft driven turbine and diesel motor.

Source: Field Survey.

* *Water level measured after the well had been in use.*

Most of the dug wells in the region have been installed by the local population themselves but with government assistance; this assistance usually consisted of supplying the concrete lining. Some of the wells were constructed more than 30 years ago. It appears however that recently there has been an upsurge in well construction with about half of the wells inspected being installed within the last two years.

The history of drilled wells in the region is much shorter, being limited to the last 10 years or so.

Eight drilled wells were inspected. In most cases no records of their design and construction could be found, so the information obtained is certainly less than full, but it seems that basically two different designs have been used:

(i) Wells constructed by the Russians; percussion drilled and lined with 12 inches (30 cm) diameter casing. It is not known what type of screen was installed and whether gravel packs were used or not.

(ii) Wells constructed by the Water Development Agency (WDA); rotary drilled and lined with 6 inches (15 cm) or 8 inches (20 cm) diameter casing; drilled diameter was usually 12 inches (30 cm). In the case of those wells for which some records are available, it seems that wire-wound screens and gravel filters were used.

The depths of the Russian constructed wells are reportedly between 35 and 70 metres, though the only well actually sounded during this survey was 26.2 m deep (this was an abandoned well, left open and it may have been partially filled with spoil). The length of screen used per well is not known.

The wells constructed by WDA are up to 100 m deep with about 20 m of screening installed opposite the coarsest strata penetrated.

Five of the drilled wells inspected were in working order. One was pumped by airlift, two by line shaft turbines driven by diesel motors and two by submersible pumps (one connected to the Jilib power supply and one equipped with its own diesel generator). In all cases the yield was estimated at between 5 and 10 l/s. In one case only is there any discharge and drawdown available (Well No. 20). That well was test pumped at 18 and 24 m^3/hour (5 and 6.7 l/s) and gave the same specific capacity, for both discharges, of 0.75 l/s/m drawdown.

3.5. WATER QUALITY

3.5.1 Quality Standards

The most authoritative quality standards for drinking supplies are those established by the World Health Organisation (WHO, 1963). These deal with the physical and chemical as well as biological nature of the water and specify desirable and permissible levels of various constituents and characteristics. The list of these is very extensive, but some of the more important limits are listed in Table 3.2.

Apart from the criteria listed in Table 3.2 bacteriological quality is also subject to acceptability limits. These are specified for both raw and treated water and should be determined by standard sampling and analytical procedures. The limits for potable water are expressed in terms of coliform organisms present in 100 millilitres of water. The permissible level for human consumption is 3 coliform organisms per 100 millilitres.

TABLE 3.2 WHO INTERNATIONAL STANDARDS FOR DRINKING WATER

Substance or Characteristic	Maximum Desirable Level	Maximum Permissible Level
Colour	5 colour units	50 colour units
Odour	Unobjectionable	Unobjectionable
Taste	Unobjectiionable	Unobjectionable
Turbidity	5 turbidity units	25 turbidity units
Total Dissolved Solids	500 ppm	1,500 ppm
pH Range	7.0 - 8.5	6.5 - 9.2
Total Hardness as $CaCO_3$	100 ppm	500 ppm
Boron	1 ppm	1 ppm
Calcium as Ca	75 ppm	200 ppm
Chloride as Cl	200 ppm	600 ppm
Copper as Cu	0.05 ppm	1.5 ppm
Iron (total) as Fe	0.1 ppm	1.0 ppm
Lead as Pb	0	0.1 ppm
Magnesium as Mg	30 ppm	150 ppm
Nitrates and Nitrites as N	0	10 ppm
Sulphate as SO_4	200 ppm	400 ppm
Zinc as Zn	5.0 ppm	15 ppm
Phenol	0.001 ppm	0.002 ppm
Anionic Detergents	0.2 ppm	1.0 ppm
Mineral Oil	0.01 ppm	0.3 ppm

Source: World Health Organisation.

It should be mentioned that the criteria in Table 3.2 are generally observed in the developed countries but many developing countries use potable supplies with one or more characteristics outside the permissible limits. This does not appear to do any great damage to public health.

3.5.2 River Water

It is probable that the Jubba river water is the source of much of the groundwater in the region. Therefore a short discussion of the Jubba water quality is relevant.

The quality of the Jubba is generally good, but it does show considerable seasonal variations. The available chemical analyses are listed in Table 3.3 but these do not represent the full range as there are records of dry season flow with about 1,300 ppm of total dissolved solids (EC x 10^6 of 2,000) (Booker-McConnell, 1970).

TABLE 3.3 CHEMICAL ANALYSES OF JUBBA RIVER WATER (SAMPLES COLLECTED NEAR FANOOLE AND JILIB)

Date	EC $x10^6$ @ 25°C	TDS ppm	PH	Ca ppm	Mg ppm	Na ppm	K ppm	CO_3 ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	Fe ppm	F ppm	Total Hardness ppm	SAR
14/8/75	320	250	8.1	67.1	4.7	4.6	2.3	12.0	213.5	4.8	10.6	-	-	-	0.1
15/9/75	340	210	8.2	66.1	3.5	4.1	1.6	3.0	170.2	10.1	30.1	-	-	-	0.1
23/1/76	410	330	7.4	45.1	9.2	25.3	0.4	0.0	115.9	56.7	40.4	-	-	-	0.9
6/3/76	730	500	7.9	62.1	16.8	65.3	4.3	0.0	132.4	86.5	129.8	-	-	-	1.9
13/3/76	870	588	7.1	72.1	22.9	75.4	4.7	0.0	134.2	127.8	150.0	-	-	-	2.0
20/3/76	990	668	7.2	88.2	25.3	84.6	5.1	0.0	134.2	151.3	174.8	-	-	-	2.0
27/3/76	1,120	768	7.4	88.2	29.3	107.0	5.5	0.0	115.9	177.7	219.8	-	-	-	2.5
10/78	210	110	7.8	30.1	4.5	6.7	2.0	0.0	122.0	4.8	2.8	0.55	0.16	100	0.3
10/78	200	120	7.8	28.1	9.5	5.8	2.0	0.0	109.8	8.6	3.9	1.04	0.13	85	0.2

Source: Booker McConnell and Project Analyses.

As can be seen, provided the overall salinity (TDS) of the water is within the WHO limit, the level of the various constituents is satisfactory as well. This is also likely to be true of groundwater.

3.5.3 Groundwater

Groundwater in the shallow aquifer tapped by dug wells reflects the discontinuous nature of that aquifer by exhibiting extreme variation in salinity. Thus within the town of Jilib the electrical conductivity (EC) of shallow well water varies from some 700 to about 30,000 micromhos/cm. Though the latter of these values is a clear indication of marine influence, presumably during the formation of the Marine Plain, there appears to be no direct relation between the water quality in that aquifer and the geomorphic position. Further, once more than a few metres away from the river, there appears to be no relation between water quality and distance from the Jubba.

All but one of the surveyed dug wells tapping the shallow aquifer, produce water of salinity greater than the WHO desirable limit (TDS of 500 ppm is equivalent to EC x 10^6 of about 780). Most of them (10 out of 18) are also outside the permissible limit (equivalent to EC x 10^6 of about 2,300).

Some full analyses of groundwater from shallow wells in the region are shown in Table 3.4. It may be noticed that the EC values listed are slightly different from those given in Table 3.1. The two sets of samples were collected at different times (about seven months apart).

In the case of drilled wells, all those sampled showed salinities (EC) between the WHO desirable and permissible limits (see Table 3.1). However, all these wells are located within two kilometres of the Jubba River and there is some evidence that the salinity of groundwater in the deeper aquifers increases with distance from the river. Thus, the highest salinities sampled were those from two wells in the Fanoole Project yard about four kilometres south of Jilib; of the wells surveyed these were the furthest from the Jubba. Moreover, some recently constructed tubewells, about 6 km west of the Jubba apparently are all more saline (M. Jones, 1979); reportedly, pronounced water quality stratification is found but all the salinities are well outside the WHO permissible limit, though some of the water is suitable for livestock watering. Finally, according to Technital S.p.A., discussing the general hydrogeology, of the Lower Jubba Plain, the shallower aquifers (up to 50 m depths) normally produce water of very high salinities (TDS of 6,000 to 35,000 ppm), whereas the deeper aquifers yield better water (TDS of 2,500 to 5,500 ppm). All of these salinities are too high for potable supplies.

There are no boreholes in this Project's development area, where the proposed settlements will be located. However, accepting the Jubba as the main source of deeper groundwater in the region, high salinities can be expected in most of the area. The complicating factor is that the development area is located on the Shabeelle flood plain, albeit abandoned. Thus the groundwater quality distribution may also be related to that river, and the occurrence of groundwater of acceptable quality, though unlikely, cannot be completely ruled out.

3.5.4. Conclusions

Water quality is the main problem in attempting to supply the proposed settlements with potable supplies from groundwater sources. Review of available quality data leads to the following major conclusions.

TABLE 3.4 CHEMICAL ANALYSES OF SHALLOW WELL WATER

Well No.	Location	EC x10[6] @ 25°C	TDS ppm	pH	Ca ppm	Mg ppm	Na ppm	K ppm	CO_3 ppm	HCO_3 ppm	SO_4 ppm	Cl ppm	Fe ppm	F ppm	Total Hardness ppm	SAR
4	Homboy	1,370	840	7.6	120.6	50.5	86.7	17.2	0.0	247.8	140.2	177.3	0.34	0.50	475	1.7
6	Dhey Tabako	2,400	1,450	7.7	290.6	50.1	63.5	79.0	0.0	1,189.7	74.4	90.1	0.63	0.20	752	0.9
10	Jilib	600	400	8.1	35.1	16.1	77.5	2.0	0.0	183.0	81.7	56.0	0.33	0.70	145	2.7
16	Kamsuma	4,000	3,560	7.9	237.9	248.7	538.7	24.2	0.0	353.9	2,024.9	269.9	0.76	0.64	1,465	5.8
18	Maqdas	3,050	2,010	8.3	16.0	12.2	753.2	13.7	0.0	616.2	263.2	664.9	0.40	1.00	80	34.5
-	Bandar Salmm	1,390	960	8.7	32.5	8.0	258.75	30.5	0.0	518.6	46.1	150.0	0.46	-	155	10.5
					20	12,3	23	39		61	48	35,5				

Source: Project Analyses.

(i) Potable supplies to the WHO desirable quality standards cannot be obtained from groundwater sources.

(ii) It is most unlikely that shallow dug wells could supply the proposed settlements with water of quality within the permissible WHO limits. However, in view of the highly irregular nature of the shallow aquifer this possibility, though very remote, cannot be completely rejected.

(iii) It is also unlikely that drilled wells could supply the proposed settlements to the permissible WHO standards, but because of the unknown effect of the Shabeelle flood plain on the groundwater system in the area, this option merits further investigation.

3.6 WELL DESIGN AND COSTS

3.6.1 Introduction

Though, as stated above, it is unlikely that potable water of reasonable quality can be supplied to the proposed settlements from groundwater sources, the following brief discussion of well design and costs is given for comparison with alternative water supply schemes. This may assist in deciding whether the groundwater option is worth pursuing further.

The treatment of well design here is necessarily sketchy and highly generalised as the basic data, on which designs are normally based, are not available. Hence an investigatory element is required in any further groundwater work proposed, on which sounder design criteria could be based.

3.6.2 Well Design

Well design is governed largely by economics. The objective of sound well design is to produce a required amount of water, of acceptable quality, over a specified period of time, at the lowest possible cost. This objective is best achieved or at least approached, by adopting design criteria based on generally accepted hydraulic concepts, modified in the light of local practices, observed as having been successful in the past.

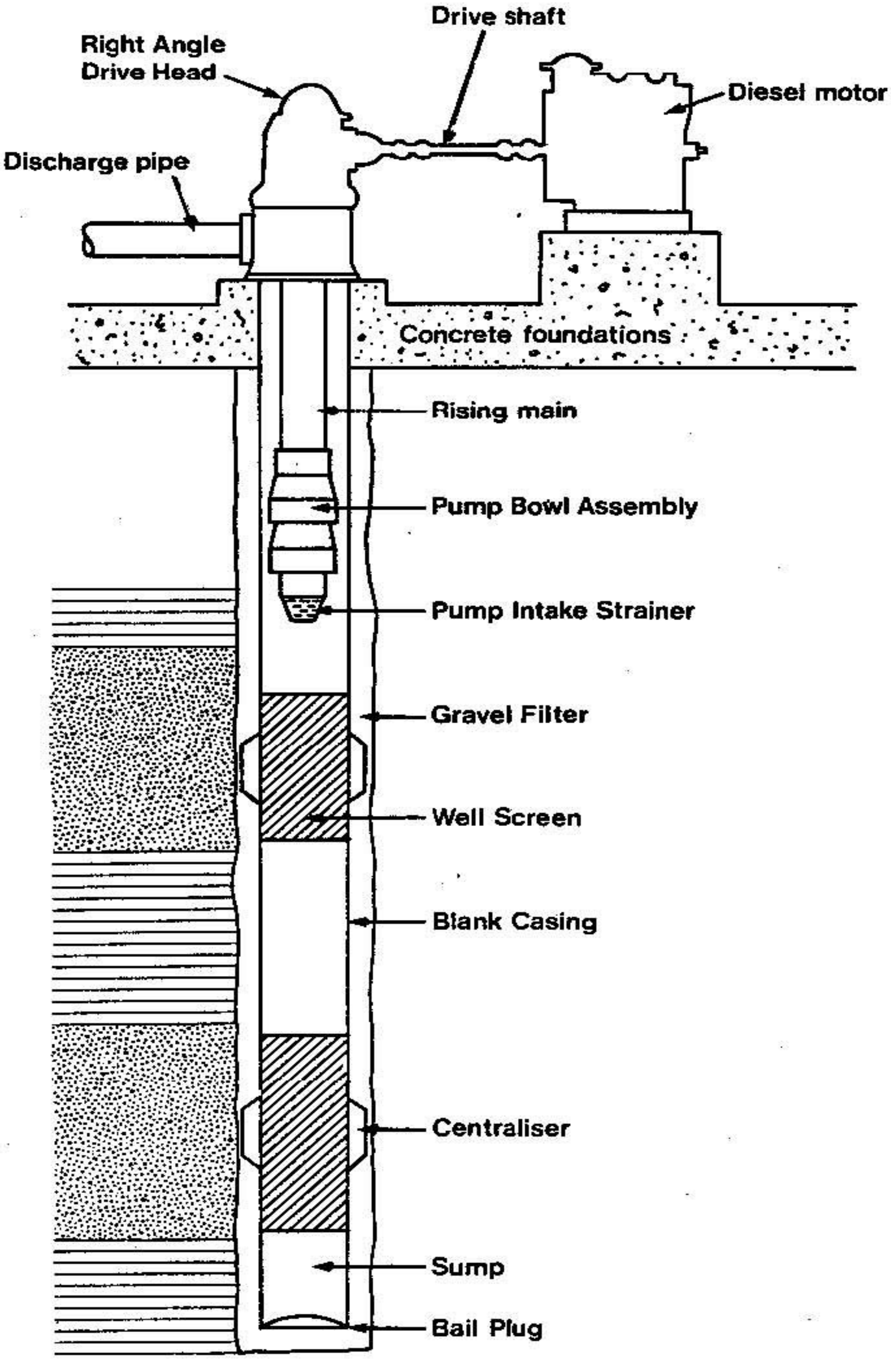
A typical arrangement of a fully equipped well is shown in Figure 3.2, with the various components specified for reference.

Well depth for any required yield depends on the proportion of permeable material in the formation and on the magnitude of the permeability of that material. Thus the effective transmissivity of the producing profile has to be high enough to sustain the required discharge with a reasonable drawdown; further, the amount of screen installed against the productive strata should be long enough to satisfy the screen entrance velocity criterion, which is usually taken as this velocity not exceeding 0.03 m/s.

Screen diameter is partly determined by the same consideration, but it also has to be compatiable with the casing size. The function of the upper part of well casing is ofcourse to accommodate a pump; thus the diameter must be large enough to accept a suitable pump with sufficient annular clearance.

For discharges of 5 to 10 l/s, casing and screen of 0.15 m (6 inches) diameter would

3.2 Typical fully equipped drilled well



be suitable. Judging by the one permeability result available, which is 4.2 m/day for an aquifer described as sand and gravel, some 6 to 12 meters of screen would be required per well for the above discharges and drawdowns not exceeding 20 metres. These dimensions would also satisfy the entrance velocity criterion, provided the area of openings of the screen was greater than 6 per cent.

Thus the drilled depth would be determined by the occurrence of the required thickness of screenable aquifer; it is assumed here that the average depth would be 75 metres. Drilled diameter would have to be large enough to accommodate the casing and screen with a sufficient annular space for an artificial gravel filter, should such be necessary.

In this project, at the present state of knowledge, it would be advisable to plan for wells with gravel packs, as this increases the flexibility of choice regarding which aquifers could be screened in any particular well. A drilled diameter of 0.30 cm (12 inches) would be suitable for 15 cm casing and screen and a reasonable thickness of gravel filter.

With no aquifer grain size analyses available, little useful can be said about the desirable gravel grading and screen slot-size. There appear to be no major problems with sand pumping in any of the existing wells, but it is not known what sizes of slot and gravel were used. It may be that the aquifers are sufficiently well cemented so that the gravel pack grading and screen slot size are not important. However, if a selection has to be made without any additional data becoming available, it is suggested that the gravel should be between 1 and 4 mm and the slot size should be about 1.5 mm.

It seems that mud flush rotary drilling is the quickest and most efficient method of well construction in the area. Installation of casing and screen would be all in one string, followed by gravel pack placement, preferably through tremie pipes. Vigorous development would be required to remove the mudcake formed on the permeable beds during drilling and ensure a good hydraulic connection between the aquifer, gravel and well. This could be achieved by airlifting with strong surging and back-washing.

Assuming static water levels of about 20 metres and drawdowns of similar magnitude, rotary pumps, either turbine or positive displacement (monopump) type would seem the most suitable to obtain the required discharges. Since no electric power is likely to be available, the pumps would probably be powered by diesel motors.

The choice of materials for the various well and pump components is determined largely by the quality of the pumped groundwater. If this quality indicates that corrosion may be a problem then corrosion resistant materials should be used. If no corrosion potential is identified, then cheaper materials such as mild steel may be used. However, corrossivity of water is difficult to evaluate. Thus, often the best indicator for suitable materials is the past history of local wells. Although the history of drilled wells in the region is not very long, no corrosion problems have been reported and it is tentatively concluded that the predominantly mild steel components, used at present, are satisfactory.

3.6.3 Costs

The unit costs of well construction in Somalia are given in Table 3.5. These are based on international contractors estimates, but it is considered that WDA prices would be similar.

TABLE 3.5 UNIT WELL CONSTRUCTION COSTS

Item	Unit	Rate (So.Sh)
Move in and set up all necessary equipment	sum	20,000
Drill 0.3 m dia	lin. m	2,000
Provide & install casing	lin. m	700
Cement casing	lin. m	500
Provide and install screen*	lin. m	800
Provide and place gravel filter	lin. m	50
Develop and test	sum	16,000
Provide and install pump and motor	sum	90,000
Pump house, plinth etc.	sum	30,000

** slotted casing.*
Source: Project Estimates.

These costs apply to the type of well envisaged, that is with casing and screen of 0.15 m diameter and with a pump and motor suitable for delivery of 5 l/s at 40 metres total lift.

Using these unit costs, the capital cost of a fully equipped well, 75 metres deep with 12 metres of screen is estimated at 372,450 So.Sh. Some 70 per cent of this sum would be expensiture in foreign exchange.

In addition to these capital costs of construction, producing the required water supplies would also involve recurrent costs, that is, costs of operation and maintenance (including spares).

Annual cost of spares and maintenance can be taken as 5 per cent of total capital cost, that is 18,622 So.Sh. Fuel costs can be calculated using the following formula.

$$C_f = \frac{3.234 \times 10^{-3} \times Q \times H \times C_D}{E}$$

Where C_f = fuel costs per hour, So.Sh.
Q = discharge rate, l/s
H = total pumping head, metres
E = overall pump and motor efficiency, fraction
C_D = cost of diesel, So.Sh. per litre

Allowing another 15 per cent of this for cost of lubricants and assuming an overall efficiency as 50 per cent, the hourly operating cost, C_o, can be estimated as follows-

$$C_o = 7.438 \times 10^{-3} \times Q \times H \times C_D$$

Thus, taking the cost of diesel as 1.65 So.Sh. per litre, which is the present financial price, the operating cost of a well can be estimated for any discharge and total pumping head. In the case of 5 l/s discharge and 40 metres head, this works out as 2.45 So.Sh. per hour.

The total costs of groundwater abstraction with drilled wells, at various annual operating factors, are summarised in Table 3.6.

TABLE 3.6 COSTS OF GROUNDWATER ABSTRACTION

Well Construction Costs (So.Sh.)	Operating factor (hours/year)	Total Water Pumped (l/year)	Recurrent Costs Maintenance (So.Sh)	Operating (So.Sh.)	Total (So.Sh)
372,450	1,000	18×10^6	18,622	2,450	21,072
-	2,000	36×10^6	18,622	4,900	23,522
-	3,000	54×10^6	18,622	7,350	25,972
-	4,000	72×10^6	18,622	9,800	28,422
-	5,000	90×10^6	18,622	12,250	30,872

Well Depth = 75 m, Discharge = 5 l/s, Total Head = 40 m.

Source: Project Estimates.

3.7 SUMMARY AND RECOMMENDATIONS

The Project Area is located at the confluence of the Jubba and Shabeelle flood plains. The actual area proposed for irrigation development lies wholly on the Shabeelle alluvium.

The whole region is underlain by Tertiary and Quaternary marine and fluviatile strata, which include layers of coarse, clastic, permeable rock. Though little reliable subsurface data are available, it is considered that aquifers, capable of sustaining yields of 5 to 10 l/s, occur within 100 metres of the surface.

There are no boreholes in the proposed development area, but drilled wells are used for water supply to some Government project compounds in the region, particularly those located near the Jubba. In addition there are a number of large diameter, dug wells, which serve as sources of domestic supplies to towns and villages.

Groundwater quality in the region is generally poor to marginal. In terms of WHO drinking water standards, water within the desirable quality limits cannot be obtained from groundwater sources. Further, it is unlikely that even supplies within the much less severe permissible limits can be obtained from wells. However, because of the unknown effect of the Shabeelle flood plain on the groundwater system, it is possible that groundwater quality in the proposed development area departs from the overall regional pattern. Consequently, this problem merits investigation, provided suitable groundwater supplies would be cheaper and easier to obtain than those from surface sources.

With this in mind, the costs of groundwater abstraction by drilled wells were estimated. For a fully equipped well, 75 metres deep, yielding 5 l/s through total lift of 40 metres, the costs would be as follows:

Construction Costs	372,450 So.Sh
Annual Maintenance Costs	18,622 So.Sh
Hourly Operating Costs	2.45 So.Sh.

If these costs compare favourably with those of providing potable supplies from surface sources, then an investigatory drilling programme should be undertaken in the proposed development area. This programme should comprise three exploratory bores, each drilled to 150 metres depth and sampled for water quality.

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