C-5.1 Water qualities of Current water supply system

Report

On

WATER QUALITY ANALYSIS

For

SEVEN TOWNS IN DEBUB REGION

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Introduction

As per request of Japan international co-operation agency (JICA) study team, the laboratory of WRD has conducted water quality analysis for seven target towns in the southern region of the country. These towns are, Debarwa, Mendefera, Adi-Quala, Dekemhare, Segeneiti, Adi-Keyih, and Senafe. The study encompasses chemical, bacteriological and physical assessment of water samples. To accomplish the task, ten sampling points were chosen from each town.

Water source intended for drinking should fulfil requirements which are essential for the well being of the consumer. It should be safe, as well aesthetically acceptable. The basic aspect of water quality which should be examined are:

1. Chemical quality: Chemically, water for public supply should hold optimum concentration of ions and trace metals.
2. Bacteriological quality: It should be free from pathogenic micro-organisms.
3. Physical quality: Aesthetically it should be acceptable to consumers. Meaning, its taste should be palatable, its color and odor acceptable.

The bacteriological and physical examination of water points was carried out in the field, and the technique used for the enumeration of coliforms was membrane filtration. Concerning chemical analysis, water samples were brought to the WRD water laboratory in Asmara and analysed

The analytical results and location of of the sampling points (in UTM coordinates) are annexed within this report.

Evaluation of analytical data

Water for public water supply should be free from any pathogens, chemically safe for human consumption and aesthetically acceptable.

To meet the intended purpose some countries set their own drinking water standards which comply with their own specific conditions. Most countries in the world follow WHO guidelines. Inspite of this, there are no measure differences between standards of some developed countries and that of WHO.
For practical purposes of this report, all references and evaluations of analytical data are given on WHO guidelines.

1. Physio-Chemical characteristics:

A. Electrical conductivity (EC)

EC is a measure of the ability of salts in solution to carry an electric current. The EC value rises with the rise in the degree of mineralisation or salinity.
Potable water should consist optimum concentration of dissolved substances, to serve as feasible source. Consideration of EC value as water quality is mainly due to its effect on taste. WHO has not set a standard for EC value, but the guideline value for TDS(total dissolved solids) which is directly related to EC (TDS = kEC, Where k ranges 0.55 to 0.7 for natural waters) is 1000ppm.
Among the seventy samples analysed from the seven towns, a borehole in Adiquala (AD-06), a well in (SG-09), borehole and a well in Dekemhare (DK-04), (DK-10), have electrical conductivity value greater than 1200 μs/cm to impart disagreeable taste.

B. pH Value

The pH value which is a measure of the concentration of the hydrogen ion is used as indicator of either acidic or basic pollution. The pH value of all the waters in the towns lie within the range of 6.5-8.5 units, which is a recommended limit for drinking.

C. Turbidity

Clarity is an important water quality parameter of water supply. Turbidity in water is caused by suspended matter, such as clay, silt, finely divided organic and inorganic matter, and plankton and other microscopic organisms. If the turbidity exceeds 5NTU, then it is clearly visible in a glass of water and usually rejected by consumer on aesthetic grounds.

Turbidity higher than the recommended value was registered in Segeneyti, Kilowlie(Mendefera),Sememo(Adiquala), and Adi-Keyih dams. This is mainly caused by silt and clay materials transported with the flowing water during raining.
The other sources which are mainly ground water, have value less than 5NTU which meets the standard of WHO.

D. Total Hardness

Total hardness is the sum of calcium and magnesium concentrations, both expressed as calcium carbonate, in milligrams per litre. The hardness or softness of water varies from place to place and reflects the nature of the geology of the area with which the water has been in contact. In general, surface waters are softer than ground waters. Hard waters are associated with chalk and limestone catchment areas, whereas soft waters are associated with impermeable rocks such as grinite.

Very hard water, greater than 350 mg/l as CaCO3, causes scale deposition in pipelines and scum formation in boilers. Soft Waters, less than 75 mg/l as CaCO3 causes leaching of metals and corrosion.
The dams in Adi-Keyih(AK-09), Adi-Quala(AD-01), and Mendefera (Kilowlie)(MN-01) has 62, 54, and 48 mg/l total hardness as Calcium Carbonate, hence classified as soft water. Whereas, nine sampling points which are coded as SN-02, SN-08, AD-06, MN-06, MN-08, DB-06, SG-09, DK-04 and DK-10 has registered hardness value ranging 350 to 743 mg/l as Calcium Carbonate. Therefore, classified as very hard waters.

E. Nitrogenous Compounds

The chemical compounds nitrate, nitrite, and ammonia play a major role in evaluation of water quality. Three of them are interconnected by nitrogen cycle, hence one is a precursor of the other. oxidation of ammonia gives rise to nitrite and further to nitrate. The main concern of nitrate presence in excess is that it is linked to a condition known as blue baby syndrome or infant methaemoglobinemia. Due to its toxicity effect on human body, an upper limit value of 45mg/l has been set.

As the analytical results show, boreholes in Adi-Keyih (AK-10), Adi-Quala (AD-06), and Dubarwa (DB-05), a borehole(DK-04) and a well (DK-10) in Dekemhare, registered 45.2, 89.5, 64.2, 97.4, and 51.8 mg/l nitrate respectively.
Besides, in Senafe at consumer's tap (SN-06), the levels of nitrite was 5.16mg/l . This is exceedingly high in relation to WHO guideline value, which is 3mg/l as nitrite. This could be due to old pipeline system which permits intrusion of contaminants.
The possible source of nitrate contamination is organic matter broken down by bacteria in the soil.

F. Chloride

Chloride is widely distributed in nature in the form of varied salts. Its presence in natural waters can be attributed to dissolution of salt deposits, sewage discharges and sea water intrusion in coastal areas.
The taste threshold for chloride in drinking water is dependent upon the associated cation, but is usually within the range 200-300mg/l. WHO recommends a guideline value of 250mg/l .
Among the seventy samples analysed, with the exception of a bore hole in Dekemhare (DK-04) which was found 260mg/l, all were found to contain less than 250mg/l, hence in the desired limit.

G. Sulphate

High sulphate concentrations in water may contribute to the corrosion of metals in the distribution system. Due to the cathartic effect of sulphate, a guideline value of 400mg/l is set.

The sulphate content of all the analysed samples is far less than the recommended guideline value, therefore there will not be any sulphate related problem with the water supplies.

H. Sodium

The recommended guideline value is 200mg/l which is based on taste thresholds. With the exception of a borehole in Dekemhare (DK-04) which is found to be 215mg/l, all the analysed samples showed a sodium level in the range of acceptable quantity.

I. Iron and Manganese

Both chemical elements are related with staining of laundry and sanitary ware. For this reason a guideline value of 0.3mg/l and 0.1mg/l is set for iron and manganese respectively. For health related reasons a 0.5mg/l guideline value is set for manganese.
Among the analysed samples, a borehole in Senafe (SN-10), a dam in Mendefera (MN-01), and a well in Segeneyti (SG-07) were found to contain 0.39mg/l, 0.41mg/l and 0.61mg/l of iron. The rest samples are free from iron which can cause staining.
Furthermore, four water sources are found to consist 0.2mg/l of manganese. These are, a spring and a hand dug well in Dubarwa (DB-09, DB-10), a well in Segeneyti (SG-07) and a borehole in Dekemhare (DK-05). The rest are found to be free from manganese induced staining problems.

J. Fluoride

Fluoride levels in excess of 1.5mg/l lead to an increase in the occurrence and severity of dental fluorosis (teeth become mottled and brittle). Normally, 1 to 2mg/l fluoride is mentained in public drinking water supplies for the prevention of dental carries in children. All the analysed samples of water showed that the sources contain optimum concentration of fluoride.

K. Copper

As Debarwa was a copper mining site, analysis of water points for copper was done to evaluate the water chemistry of the town.
The guidelines value for copper for health related considerations is 2mg/l.
All the samples analysed contain copper in the limits of the recommended value.

Conclusion Concerning Pysio-Chemical Characteristics

Generally the physio-chemical characteristics of water sources in the seven towns is evaluated as good . The few exceptions being a borehole in Adiquala (AD-06), a well in Segeneyti (SG-09), borehole and a well in Dekemhare (DK-04), (DK-10), which have electrical conductivity value greater than 1200 μs/cm to impart disagreeable taste.

In addition, boreholes in Adi-Keyih (AK-10), Adi-Quala (AD-06), and Dubarwa (DB-05), a borehole(DK-04) and a well (DK-10) in Dekemhare, were found to contain 45.2, 89.5, 64.2, 97.4, and 51.8 mg/l nitrate respectively, which could be potentially health hazard to consumers.

2. Bacteriological Characteristics

The basic requirement for any water source to be considered as an acceptable source for drinking is that it should be freed from bacteria, virus and protozoan.

In evaluation of bacteriological safety of water, routinely testes are done to identify for organisms indicators of pollution. The coliform group of bacteria which are found in sewage, animal and human excrement are the accepted indicators of pathogenic micro-organisms.

WHO standard recommends drinking water must not contain faecal coliform bacteria. Otherwise, it is unsafe for human consumption.

Out of seventy samples analysed from the seven towns, 29 were found to be contaminated with bacteria which are faecal in origin. This shows that the sanitary conditions of the water sources and reservoirs is not well mentained. The most probable source of contamination is human and animal waste which adds up to dams, ground water sources and pipeline systems with run off, percolation and infiltration respectively.

Total coliform bacteria should not occur repeatedly in water samples in regular water quality monitoring programme. Thier presence in a single analysis, as in the case of this study, does not necessarly imply the water sources are unsafe.

Conclusion Concerning Bacteriological Characteristics

As twenty nine of the seventy sampling points were found to be bacteriologically contaminated, it can be concluded that some of the people in these towns is getting unsafe water. However, it is noteworthy to mention that high rate of contamination may be due to unusual rainfall in the area before sampling which may helped to carry/percolate human and animal waste to the sources.

To improve the situation:

- The sanitary condition of the surroundings of the water points should be improved.
- Open wells should be covered with slab and a pump installed.
- Supplies from surface water should be treated before distribution.
- Regular water quality monitoring programme should be introduced.
- Public awareness on hygiene and sanitation should be increased.

Table-1 Water Quality In Debarwa

I.Physical Quality

Date Sampled 29/09/97

Date Analysed 30/09/97

II. Bacteriological Quality

T.C.B = Tatal Coliform Bacteria

F.C.B = Faecal Coliform Bacteria

Well	Description	EC	pH	Temp	Odor	Taste	Turb.	Color	T.C.B	F.C.B	Remarks
Ident		us/cm		°c			NTU		count/100ml,35°c	count/100ml,44.5°c	
DB-01	BH with motor	598	6.7	23.3	agreeable	agreeable	<5	clear	0	0	Safe
DB-02	Main reservoir 15cum	640	6.8	24.2	agreeable	agreeable	<5	clear	0	0	Safe
DB-03	Public tap,Kebabi-edaga	637	6.9	25.7	agreeable	agreeable	<5	clear	0	0	Safe
DB-04	Public tap, Geza-Lamza	630	6.8	25.2	agreeable	agreeable	<5	clear	0	0	Safe
DB-05	Borehole,Catholic Church	935	6.9	25.5	agreeable	agreeable	<5	clear	0	0	Safe
DB-06	BH,Endabenzene,Issak	939	7.0	25.3	agreeable	agreeable	<5	clear	0	0	Safe
DB-07	Consumer's Tap	647	7.1	23.3	agreeable	agreeable	<5	clear	0	0	Safe
DB-08	Consumer's Tap	625	7.0	24.8	agreeable	agreeable	<5	clear	0	0	Safe
DB-09	Spring,Enda Abunestatios	805	7.2	24.0	agreeable	agreeable	<5	clear	6	many	contaminated
DB-10	HDW at Mesfun House	840	7.1	24.6	agreeable	agreeable	<5	clear	13	0	Safe

III.Chemical Quality

Date Sampled 29/09/97

Date Analysed 14/10/97

Well	Description	Ca	Mg	Na	K	Fe	Mn	Cu	HCO3	SO4	Cl	NO3	NO2	N-NH3	F	Hard.
Ident		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	*G.d.h
DB-01	BH with motor	61	26.2	29	4.4	0.07	0.1	0.08	261	17	22	33.2	0.02	0.13	0.07	14.5
DB-02	Main reservoir 15cum	66	24.8	25	1.3	0.01	0.1	0.06	278	20	26	26.6	0.02	0.15	0.08	14.9
DB-03	Public tap,Kebabi-edaga	68	25.3	25	1.8	0.01	0.1	0.04	281	22	32	38.1	0.02	0.21	0.05	15.3
DB-04	Public tap, Geza-Lamza	68	24.3	24	1.3	0.02	0.1	0.10	276	21	16	26.6	0.01	0.12	0.15	15.1
DB-05	Borehole,Catholic Church	90	35	31	1.8	0.03	0.1	0.22	325	31	40	64.2	0.06	0.35	0.10	20.6
DB-06	BH,Endabenzene,Issak	72	42.8	41	1.8	0.02	0.1	0.26	325	44	46	44.3	0.02	0.49	0.05	19.9
DB-07	Consumer's Tap	64	24.3	31	1.7	0.02	0.1	0.12	290	21	24	26.6	0.01	0.12	0.07	14.5
DB-08	Consumer's Tap	62	19.9	25	2.2	0.01	0.1	0.06	271	21	22	23.9	0.01	0.17	0.08	13.3
DB-09	Spring,Enda Abunestatios	70	25.8	34	1.8	0.00	0.2	0.17	400	29	32	21.7	0.23	0.73	0.12	15.8
DB-10	HDW at Mesfun House	76	31.6	35	2.2	0.01	0.2	0.23	407	41	30	22.6	0.06	0.48	0.13	17.9

*G.d.h= German degree of hardness, 1G.d.h= 17.9mg/l hardness as CaCo3

* Note : HDW = Hand Dug Well
BH = Borehole

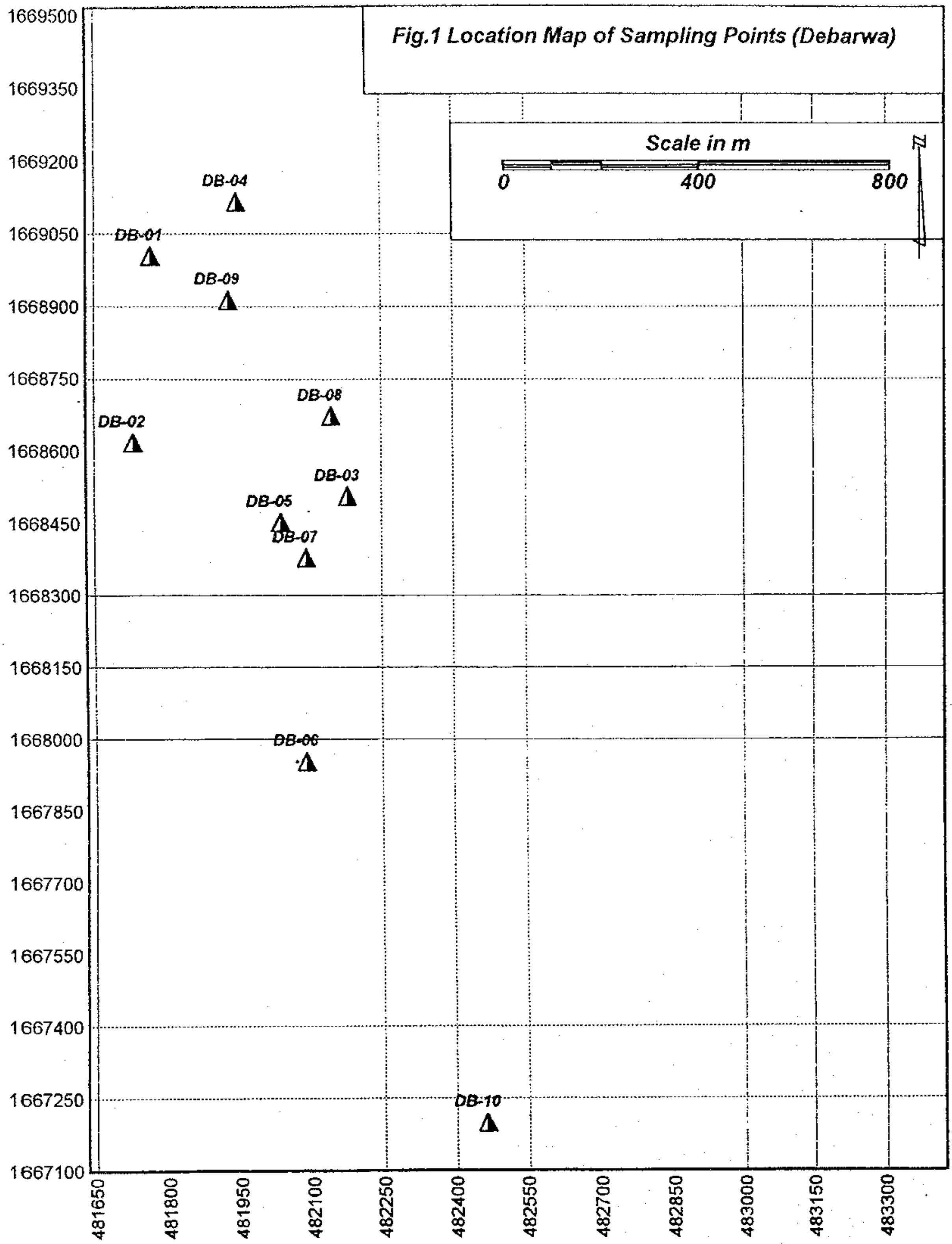
Fig.1 Location Map of Sampling Points (Debarwa)
Scale in m
0
400
800
N
DB-01
DB-02
DB-03
DB-04
DB-05
DB-06
DB-07
DB-08
DB-09
DB-10
1669500
1669350
1669200
1669050
1668900
1668750
1668600
1668450
1668300
1668150
1668000
1667850
1667700
1667550
1667400
1667250
1667100
481650
481800
481950
482100
482250
482400
482550
482700
482850
483000
483150
483300

Report

on

WATER QUALITY ANALYSIS

JICA TESTING BOREHOLES IN DEBUB REGION

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Asmara, Eritrea
Feb. 19, 1998

Water Quality Evaluation of testing boreholes drilled in Debub region of JICA project

1. Mendefera :

Borehole No1 of Adimongoti is of acceptable with respect to chemical and bacteriological quality. Though manganese is present in significant concentration, it has not exceeded the WHO guidelines to cause any staining problems and, as the water is very soft it will be corrosive to pipelines. Besides, the pH is high (8.66) to make the water tastes alkaline.

2. Dubarwa :

This borehole has chemically and bacteriologically acceptable water quality although slightly hard due to calciumbicarbonate.

3. Segeneyti (SEG-01):

The water quality of this borehole is bacteriologically safe and based on the amount of total dissolved solids it is chemically acceptable for drinking. But, the concentration of manganese which is 0.4mg/l exceeds the WHO guidelines of 0.1 mg/l, therefore it will cause staining problem. The amount of ammonia though in the limits of WHO guidelines is considerable to show that there is domestic organic contamination. Furthermore it is slightly hard water which will consume considerable amount of soap for lathering.

4. Segeneyti (SEG-03) :

The source is bacteriologically safe for domestic water supply. Chemically the water quality is fairly good. The electrical conductivity value indicates that the dissolved solids are within the limits of WHO guidelines. Hence good quality with respect to dissolved solids. But, the source is slightly hard water and with manganese concentration exceeding the WHO guideline value to cause staining problem.

5. Adikeyih/ Tekondae (ADK-01):

The source is bacteriologically acceptable for drinking. The amount of dissolved solids indicated by the electrical conductivity value is considerable though in the limits of WHO guidelines.

The amount of ammonia is high showing sewage or organic pollution. Furthermore, the concentration of manganese is higher than WHO guideline value. The degree of clarity of the water is not satisfactory which is measured 5 NTU. Besides, it is very hard water due to calciumbicarbonate.

The source can be used as source of water supply only if no better alternative source is available.

6. Adi-Keyih/ Adiwegera (ADK-02):

The source is bacteriologically acceptable for drinking. Chemically the water quality is fairly good . The dissolved minerals is considerable though in the range of WHO guidelines and the concentration of manganese is high to cause staining in laundry and utensils. The amount of calcium is high to make the source hard water. The amount of ammonia though not exceeding WHO guidelines it indicates occurrence of organic contamination.

*7. **Senafe (SEN-02):***

The borehole is found to contain bacteria indicators of faecal pollution. Therefore the source is bacteriologically unsafe for human consumption. Chemically, the source has good composition except for manganese (0.3mg/l) which is exceeding the WHO guidelines of 0.1mg/l for reasons of aesthetic.

8. Dekemhare : DEK-01 and DEK-02

These sources are found to be free from bacteriological contamination. Therefore bacteriologically safe for drinking. Chemically, though safe from health point of view, there are high concentration of calcium and magnesium to make the sources very hard water.

Table 1. Water Quality of JICA testing wells in Zoba Debub

I. Physical Quality

Date Sampled 05.01.98 - 30.01.98

Date Analysed 13.01.98 - 06.02.98

Well Idnt	Sub-Zoba	EC	pH	Temp	Odor	Taste	Turb	Color
		us/cm		°c			NTU	
MEN-01	Mendefera	468	8.66	22.1	agreeable	agreeable	0	clear
DUB-01	Dubarwa	762	7.46	22.2	agreeable	agreeable	0	clear
SEG-01	Segeneyti	832	6.95	24.0	agreeable	agreeable	0	clear
SEG-03	Segeneyti	791	6.74	22.5	agreeable	agreeable	0	clear
ADK-01	Adi-Keyih	1051	6.85	21.4	agreeable	agreeable	5	muddy
ADK-02	Adi-Keyih	948	6.77	20.7	agreeable	agreeable	0	clear
SEN-01	Senafe	734	6.68	21.5	agreeable	agreeable	0	clear
DEK-01	Dekemhare	1247	7.10	22.7	agreeable	agreeable	0	clear
DEK-02	Dekemhare	1184	6.91	22.6	agreeable	agreeable	0	clear

II. Bacteriological Quality

T.C.B = Total Coliform Bacteria

F.C.B = Faecal Coliform Bacteria

Well Idnt	T.C.B	F.C.B	Remarks
	count/100ml,35°c	count/100ml,44.5°c	
MEN-01	0	0	safe
DUB-01	0	0	safe
SEG-01	0	0	safe
SEG-03	0	0	safe
ADK-01	0	0	safe
ADK-02	0	0	safe
SEN-01	many	30	contaminated
DEK-01	0	0	safe
DEK-02	0	0	safe

III. Chemical Quality

Date Sampled 05.01.98 - 12.02.98

Date Analysed 13.01.98 - 18.02.98

Well Idnt	Sub-Zoba	Ca	Mg	Na	K	Fe	Mn	HCO3	SO4	Cl	NO3	N-NH3	NO2	F	Hardness
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	*G.d.h
MEN-01	Mendefera	2.9	0.7	92.4	0.7	0.02	0.1	122.0	34.0	60.0	4.9	0.01	0.004	0.26	0.56
DUB-01	Dubarwa	86.0	32.8	30.8	0.5	0.04	0.0	427.0	32.0	30.0	10.6	0.02	0.340	0.18	19.55
SEG-01	Segeneyti	96.0	37.7	42.9	7.6	0.05	0.4	420.9	68.0	45.0	1.3	0.54	0.000	1.22	22.06
SEG-03	Segeneyti	102.0	32.8	35.2	0.6	0.07	0.4	555.1	34.0	40.0	7.1	0.26	0.049	0.42	19.83
ADK-01	Adi-Keyih	124.0	47.4	51.2	0.6	0.02	0.2	542.9	135.0	32.5	2.7	1.11	0.009	0.62	28.21
ADK-02	Adi-Keyih	110.0	30.4	56.1	0.4	0.02	0.4	488.0	75.0	50.0	1.8	0.60	0.007	0.38	22.35
SEN-01	Senafe	82.0	7.3	40.7	4.5	0.03	0.3	268.4	39.0	30.0	2.7	0.40	0.013	1.05	13.13
DEK-01	Dekemhare	141.2	27.2	75.0	0.9	0.09	0.1	402.6	70.0	155.0	6.2	0.52	0.007	0.52	25.98
DEK-02	Dekemhare	120.0	24.3	98.0	1.2	0.02	0.1	323.3	75.0	170.0	36.3	0.34	0.290	0.44	22.35

*G.d.h = German degree of hardness, 1G.d.h = 17.9 mg/lhardness as CaCO3

Groundwater monitoring data
DEBARWA　　at 6:00 a.m.

Date	Reading	from G.L
[10:00]3/6	4m98.0	-4.890
1998/3/7	4m98.0	-4.980
1998/3/8	4m98.0	-4.980
1998/3/9	4m98.3	-4.983
1998/3/10	4m98.4	-4.984
1998/3/11	4m98.4	-4.984
1998/3/12	4m98.4	-4.984
1998/3/13	4m98.5	-4.985
1998/3/14	4m98.3	-4.983
1998/3/15	4m98.2	-4.982
1998/3/16	4m98.2	-4.982
1998/3/17	4m98.3	-4.983
1998/3/18	4m98.3	-4.983
1998/3/19	4m98.2	-4.982
1998/3/20	4m98.3	-4.983
1998/3/21	4m98.3	-4.983
1998/3/22	4m98.4	-4.984
1998/3/23	4m98.3	-4.983
1998/3/24	4m98.3	-4.983
1998/3/25	4m98.4	-4.984
1998/3/26	4m98.5	-4.985
1998/3/27	4m98.6	-4.986
1998/3/28	4m98.6	-4.986
1998/3/29	4m98.6	-4.986
1998/3/30	4m98.6	-4.986
1998/3/31	4m98.5	-4.985
1998/4/1	4m98.4	-4.984
1998/4/2	4m98.3	-4.983
1998/4/3	4m98.3	-4.983
1998/4/4	4m98.4	-4.984
1998/4/5	4m98.4	-4.984
1998/4/6	4m98.5	-4.985
1998/4/7	4m98.4	-4.984
1998/4/8	4m98.4	-4.984
1998/4/9	4m98.4	-4.984
1998/4/10	4m98.3	-4.983
1998/4/11	4m98.3	-4.983
1998/4/12	4m98.3	-4.983
1998/4/13	4m98.4	-4.984
1998/4/14	4m98.5	-4.985
1998/4/15	4m98.5	-4.985
1998/4/16	4m98.5	-4.985
1998/4/17	4m98.5	-4.985
1998/4/18	4m98.4	-4.984
1998/4/19	4m98.4	-4.984
1998/4/20	4m98.4	-4.984
1998/4/21	4m98.4	-4.984
1998/4/22	4m98.4	-4.984
1998/4/23	4m98.4	-4.984
1998/4/24	4m98.5	-4.985
1998/4/25	4m98.5	-4.985
1998/4/26	4m98.4	-4.984
1998/4/27	4m98.4	-4.984
1998/4/28	4m98.5	-4.985
1998/4/29	4m98.5	-4.985
1998/4/30	4m98.5	-4.985
1998/5/1	4m98.5	-4.985
1998/5/2	4m98.6	-4.986
1998/5/3	4m98.3	-4.983
1998/5/4	4m98.2	-4.982
1998/5/5	4m98.1	-4.981
1998/5/6	4m98.1	-4.981
1998/5/7	4m98.1	-4.981
1998/5/8	4m98.1	-4.981
1998/5/9	4m98.1	-4.981
1998/5/10	4m98.5	-4.985
1998/5/11	4m98.7	-4.987
1998/5/12	4m98.7	-4.987
1998/5/13	4m98.7	-4.987
1998/5/14	4m98.6	-4.986
1998/5/15	4m98.5	-4.985
1998/5/16	4m98.5	-4.985
1998/5/17	4m98.5	-4.984
1998/5/18	4m98.4	-4.984
1998/5/19	4m98.5	-4.985
1998/5/20	4m98.5	-4.985
1998/5/21	4m98.5	-4.985
1998/5/22	4m98.5	-4.985
1998/5/23	4m98.4	-4.984
1998/5/24	4m98.4	-4.984
1998/5/25	4m98.3	-4.983
1998/5/26	4m98.4	-4.984
1998/5/27	4m98.4	-4.984
1998/5/28	4m98.5	-4.985
1998/5/29	4m98.5	-4.985
1998/5/30	4m98.5	-4.985
1998/5/31	4m98.5	-4.985
1998/6/1	4m98.4	-4.984
1998/6/2	4m98.4	-4.984
1998/6/3	4m98.4	-4.984
1998/6/4	4m98.4	-4.984
1998/6/5	4m98.4	-4.984
1998/6/6	4m98.5	-4.985
1998/6/7	4m98.5	-4.985
1998/6/8	4m98.5	-4.985
1998/6/9	4m98.5	-4.985
1998/6/10	4m98.4	-4.984
1998/6/11	4m98.4	-4.984
(9:15)6/11	4m98.4	-4.984

C-7.1 Well Inventory

Table -.-.1 Well Inventory 1 DEBARWA

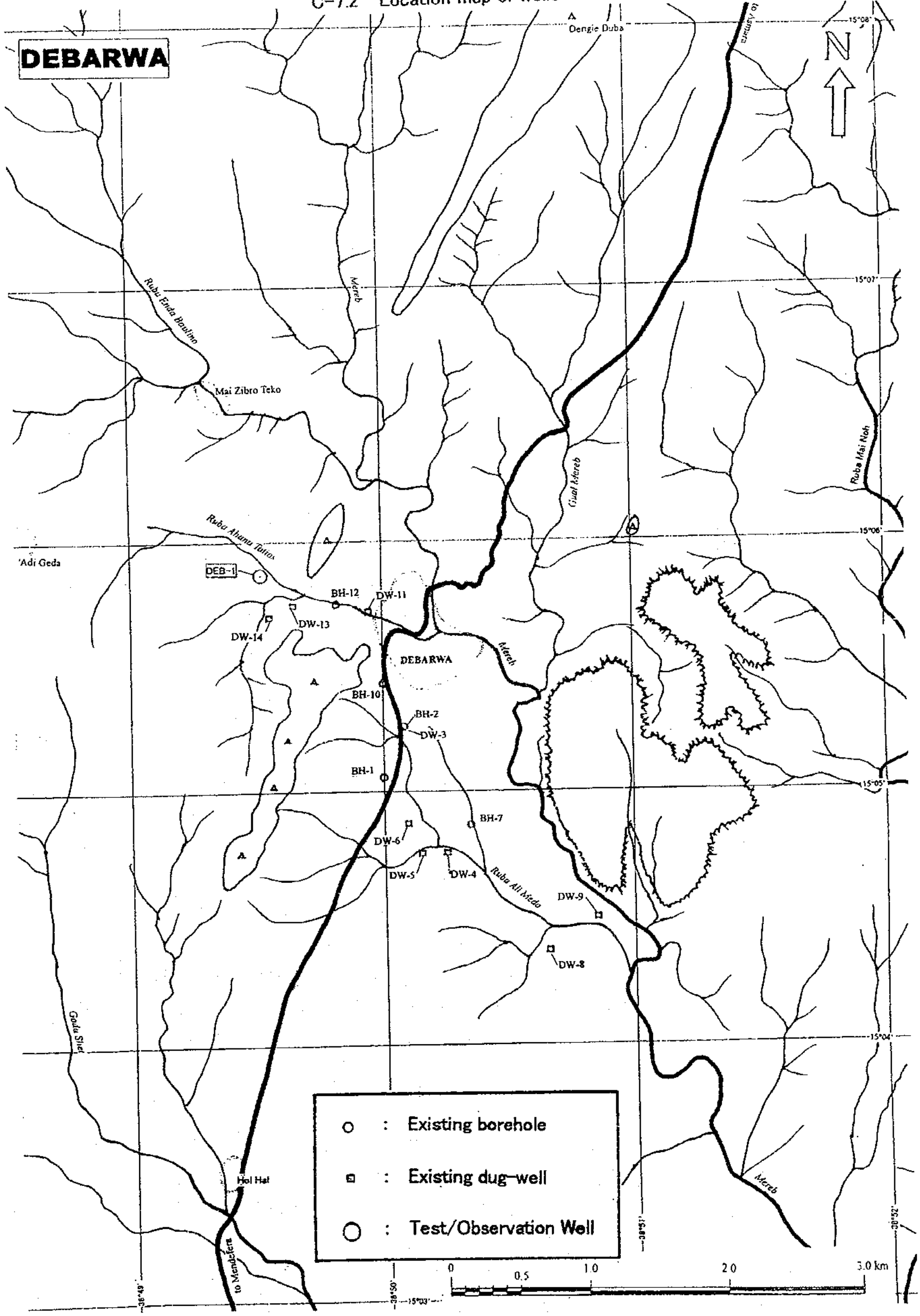
<Well Ident>	<Location>	<Altitute> (m)	<Latitude> deg	min	sec	<Longl.> deg	min	sec	<Wateruse>	<Constr. year>	<Depth> (m)	<Diameter> (m)	<Water level(m)>	<Yield> (l/min)	EC(micro S/cm)	<pH>	<Pump system>	<Pump status>	<Remarks>	<Well ident. of WRD>
BH-1	Mobile Gasolin station	1846	15	5	3	38	50	0	Domestic	1996	30	0.127	8.75		931	7.38	Submersible	Functional		
BH-2	Ghrmai park	1850	15	5	16	38	50	4	Out of use	1988		0.1524					Hand (India Mark II)	Out of use	UNICEF	Water quality problem
DW-3	Ghrmai park	1849	15	5	16	38	50	4	Domestic	1994	6	2.3	3.15		993	7.7	Bucket		Seasonal	
DW-4	Ali Meda	1843	15	4	45	38	50	15	Domestic & irrigation	1979	13	5 x 10	5.2		829	7.23	Motor	Functional	Perennial	
DW-5	Ali Meda	1844	15	4	45	38	50	9	Domestic & irrigation	1987	8	5 x 10	4		878	7.23	Motor	Functional	Seasonal	
DW-6	Ali Meda	1845	15	4	52	38	50	6	Irrigatin	1990	9	3 x 4	6.7		841	8.14	Motor	Functional	Seasonal	
BH-7	Plastic factory	1846	15	4	52	38	50	20	Domestic	1995	46	0.18	3.72	60-72[1]	340	7.27	Submersible	Functional		DB005B01
DW-8	Ali Meda	1842	15	4	22	38	50	39	Irrigatin	1972	7	5 x 8	5.78		779	7.72	Motor	Functional	Perennial	
DW-9	Ali Meda	1840	15	4	30	38	50	51	Irrigatin	1986	4	7 x 7	3		900	7.54	Motor	Functional	Perennial	
BH-10	Kindergarden of Catholic church	1860	15	5	26	38	50	0	Domestic	1994	52	0.127	14	300[1]	945	7.46	Submersible	Functional	3 hrs operation every 3 days	
DW-11[2]	Ruba Abuna Tatios	1857	15	5	43	38	49	57	Public W/S Debarwa			7 x 10	0.65		798	7.48	Bucket		Seasonal	
BH-12	Ruba Abuna Tatios	1859	15	5	45	38	49	49	Public W/S Debarwa		60	0.1524		180[1]	731	7.19	Motor (Lam-bhrdini)	Functional		
DW-13	Ruba Abuna Tatios	1860	15	5	45	38	49	39	Irrigatin			4 x 7	3.87		765	7.61	Motor	Functional	Seasonal	
DW-14	Ruba Abuna Tatios	1861	15	5	42	38	49	33	Irrigatin		5.7	5 x 5	4		791	7.73	Motor	Functional	Seasonal	

Date surveyed : mainly 9 Oct., 1997
Well ident. : BH:Borehole, DW:Dug well, R:Reservoir
Bracket of construction year : year of repair

1) : Drilling data of WRD
Bracket of Wpt. Diameter : inside diameter

2) : Spring-type
Bracket of pump system : pump type and capacity

C-7.2 Location map of wells



Appendix C-8 Technical Specification of Production Well

1. SCOPE OF WORKS

1.1. OBJECTIVES OF WORKS

The objectives of works are to establish production well(s) for one of the water sources of _____ town. The detail of specifications will be mutually adjusted between the Engineer and the Contractor during the course of work.

1.2. CONTENTS OF WORKS

The content of works under this Contract consists of as below:

(1) Mobilization and Demobilization to/from the survey area, inclusive of moving from the Site to Site, and Site preparation.

(2) Production Well Drilling;
Drilling works, inclusive of a drilling, borehole logging, casing installation, gravel-packing, grout-sealing, development, head works, etc.

(3) Pumping Test, composed of Preliminary, Step-drawdown, Constant discharge, and Recovery tests, inclusive of water sampling and water quality analysis.

(4) Reporting, inclusive of daily drilling records, borehole and lithological logs, pumping test records, photographs, sketches, and so forth.

1.3. MEASUREMENT AND PAYMENT

The measurement and payment for the works carried out by the Contractor shall be made in accordance with the quantity actually worked out by the Contractor and confirmed by the Engineer's (Consultant's supervisor) measurement; and the unit or lump sum price specified in the Bill of Quantities, APPENDIX-__ of the Contract.

The unit or lump sum price specified in the Bill of Quantities shall be deemed to involve every costs necessary for the appropriate item of work inclusive of personnel, machinery amortization, consumable and permanently installed materials, overhead, profit, tax, duties and so forth. No extra payment shall be made for the lump sum price in case the quantities of works specified in the Bill of Quantities may be increased or decreased.

2. LOCATION OF WORKS

The works under this Contract are to be carried out in and around the six (6) towns as shown in the Figure-A "Location Map of the Drilling Works" attached.

The exact well drilling sites are to be indicated in-situ to the Contractor by the Engineer prior to the mobilization of drilling equipment.

3. EQUIPMENT, TOOLS, DEVICES AND MATERIALS TO BE EMPLOYED

3.1. GENERAL

The equipment, sampler, tools, measuring devices, and materials to be employed to the works under this Contract shall be provided by the Contractor, excepting water sampler for water quality analysis, and water quality meters for in-situ water quality test which are to be provided by the Study Team.

The Contractor shall submit, prior to the mobilization to the area, a list of equipment, samplers, and major tools, describing the model, type, capacity, specification, quantities to the Engineer for his approval.

3.2. SCREEN AND BLANC CASING

Blank casing pipes for the wells shall be made of PVC with inner-diameter of 6 inches.

Screen pipes to be installed in the wells shall also be made of PVC with 6 inches diameter and of open ratio of more than ten percent (10%).

3.3. CENTRALIZER AND BOTTOM PLUG

Centralizer and bottom plug shall be of the same material and diameter of above mentioned pipes.

4. WORKS

4.1. MOBILIZATION AND DEMOBILIZATION

The Contractor shall mobilize and demobilize the personnel, equipment, tools, devices, and materials necessary for the works under this Contract to/from the work area under the Project from/to the Contractor's base within Eritrea.

The Contractor shall prepare the drilling sites to suite for the erection of equipment, working space, and others.

Further, the Contractor shall make moving the drilling equipment and others from a site to another site.

4.2. DRILLING OF WELLS

4.2.1. DRILLING

(1) Drilling Site

The exact site of well to be drilled is indicated in-situ to the Contractor by the Engineer prior to the mobilization to the area.

Upon the Engineer's indication, the Contractor shall mark out the point by means of wooden or stone stake with the Well Number.

(2) Type of Well

The standard type of well is shown as the Figure-__ "Standard Well Structure", and explained as follows:

The well shall consist of blank casing, slotted screen, and bottom plug of PVC pipes in 150 mm (6 inches) diameter.

The drilling diameters, the bit size, shall be good enough for the casing and gravel-packing, and be not less than 240 mm (9-5/8 inches) except surface casing portion which required to drill by 317 mm (12-1/2 inches) or more larger size bit.

The depth of the well shall be just covering the aquifer portion and as instructed by the Engineer.

(3) Quantities of Drilling Works

The work quantities in the initial plan are as shown in the Table-__ "Summary of the Works" and Table-__ "Drilling Site and Plan" attached. The depth of each well and the total quantities are to be modified on the course of works in accordance with the Engineer's instruction.

The unit and lump sum prices in the related items of the Bill of Quantities (APPENDIX-__ of the Contract) shall never be revised even if the said modification may take place.

(4) Drilling Works

The drilling of well shall be carried out by fluid-circulating direct rotary and/or the down-the-hole method or other method approved by the Engineer. The circulating fluid shall be as thin as possible except under an artesian condition.

The surface casing pipe at the top six (6) meter portion of all wells shall be installed to control sloughing and to ensure good condition to make the grout-sealing.

(5) Sampling

The drill-cut sampling about a half (0.5) kg in weight shall be collected at an interval of every one (1) meter and every change of formation encountered. The sample collected shall be put into a plastic bag together with a tag marked the Well Number and the depth collected.

The sample corrected shall be submitted to the Engineer for his inspection for casing program immediately after the completion of well drilling.

(6) Daily Drilling Record

The Contractor shall provide the daily drilling record in a form approved by the Engineer describing water level before and after the daily drilling work, drilling rate, characteristics of drill-cut, loss or increase of drilling fluid, and so forth. The record shall be submitted to the Engineer upon the completion of drilling of any well.

4.2.2. BOREHOLE LOGGING

Immediately after the completion of well drilling to the designated depth, the Contractor shall make borehole logging.

The logging items shall be of 1) resistivity (long and short) and 2) Spontaneous Potential (SP). The borehole log thus measured shall be submitted to the Engineer, immediately after completion of the logging, for his examination and formulation of the casing program.

4.2.3. INSTALLATION OF CASING AND SCREEN PIPES

On the basis of the results obtained from lithological and borehole logs; and so forth, the casing program shall be finally decided by the Engineer. In accordance with the Engineer's instruction on casing program, the Contractor shall install, in the center of the borehole, bottom plug, screen and blank casing pipes into the drilled hole. The centralizer shall be attached to the said pipes at every twelve (12) meters interval from the bottom or as instructed by the Engineer.

4.2.4. GRAVEL-PCKING AND GROUT-SEALING

(1) Gravel-packing

Immediately after the casing installation is over, gravel-packing shall be carried out into the annular space between the pipes installed and the hole.

The packing gravel shall be composed of siliceous materials and selected gradation, approved by the Engineer prior to the installation work.

The most care shall be paid dropping gravel at equal rate and shaking the pipes to avoid sticking and bridging of gravel at the annular apace and/or the centralizer.

Upon the Engineer's instruction, drill-cut or impervious materials may be packed at the blank casing portion.

(2) Grout-sealing

The Contractor shall seal by means of cement or mortar grouting the annular space between the hole and casing pipes at the upper-most six (6) meters portion of the borehole.

4.2.5. DEVELOPMENT

Immediately after the gravel-packing is over, the borehole shall be developed by means of jetting, surging by water or air, and water lifting by air or other appropriate manners. Borehole development shall be lasted when the lifted water is judged to be free from mud, sand, and other suspensions, and otherwise instructed by the Engineer, but for at least 24 hours.

4.2.6. PUMPING TEST

(1) Equipment and devices

The Contractor shall provide a proper pump and its attachment to be utilized for the pumping test. The type, name, capacity, and its specification shall be noticed to the Engineer for his approval prior to carry it to the site.

For measurement of discharge, the Contractor shall provide a calibrated wear, orifice or venture meter and/or accurate associated piezometer.

Water level in the well shall be measured by electric detective devices.

The pumped water shall be led and released at the position enough far from the teat well, not to disturb the test by re-infiltration, by proper conduit or through other suitable means.

(2) Preliminary Test

After setting of all equipment and devices, the pumping equipment shall be calibrated at various pumping rates in order to ensure that all the equipment are properly functioning and to select the pumping rate for the subsequent step-drawdown test, the drawdown and yield shall be presumed through the test.

The pumping rate shall be modified according to the drawdown at the pumping well, and the preliminary pumping shall be continued at least four (4) hours.

The static water level of both pumping and observatory well (if exist) shall be measured carefully before any pumping, and the tests described below shall be started after the water level recovered to the original water level.

(3) Step-drawdown Test

The borehole shall be pumped continuously at least three (3) increasing and two (2) decreasing discharge rates, maintaining each rate at a water level to be stable, but at least more than 180 minutes.

The pumping rate of each step shall be instructed by the Engineer based on the result of preliminary test.

For each pumping discharge, the water level at the borehole shall be measured and recorded in the manner shown below;

Period	*Interval of recording*
0 – 5 min.	30 sec.
5 – 15 min.	1 min.
15 – 30 min.	5 min.
30 – 90 min.	10 min.
after 360 min.	30 min.

(4) Constant Discharge Test and Recovery Test

Pumping shall be continued at least 48 hours without any interruption. The constant discharge rate shall be instructed by the Engineer.

Water level of the borehole shall be measured and recorded during full pumping and recovery period. The measurement of recovery can be stopped when the recovery attains to the static water level.

The water level shall be measured and recorded as following time interval;

Period	*Interval of recording*
0 – 5 min.	30 sec.
5 – 15 min.	1 min.
15 – 30 min.	5 min.
30 – 180 min.	15 min.
180 – 360 min.	30 min.
360 – 900 min.	60 min.
after 900 min.	120 min.

(5) Test Record

The Contractor shall submit the pumping test records, in a proper forms of hard-printed and floppy-disk-base approved by the Engineer, within three (3) days after the completion of any pumping test to the Engineer.

(6) In-situ Water Quality Analysis

The Contractor shall make a series of in-situ water quality test of water temperature, pH, EC, and so forth, and take water sample for laboratory water quality analysis, during the constant discharge test.

(7) Laboratory Water Quality Analysis

The Contractor shall send water samples to the laboratory of WRD, immediately after the sampling. The items to be analyzed are as follows, and the cost on the analysis shall be born by the Contractor.

Cations: Ca, Mg, Na, K, Fe

Anions: HCO_3, CO_3, SO_4, Cl, NO_3

Others: Mn, NO_2, PO_4, F, B, SiO_2, N-NH_3

Physical Properties: TDS, Hardness, Conductivity, pH

Bacteriologic properties: Total coliform bacteria, Faecal coliform bacteria

4.2.7. HEADWORK

Upon the completion of all the works specified above, the Contractor shall place the concrete pad and well-cap to the wells as the following manners;

(1) Concrete Pad

The dimension of concrete pad for the well shall be 1.00 m of wide, 1.00 m of long, both centered by the drilled well, and 0.50 m of deep, or otherwise instructed by the Engineer. The concrete mix of the Portland cement, fine and coarse aggregates, by volume ratio, shall be of 1:2:4 or as instructed by the Engineer.

(2) Well-cap

All the wells completed shall be covered by cap. The design, dimension, size and type of cap shall be approved by the Engineer prior to actual providing.

(3) Installation of Automatic water-level recorder

The Contractor shall install total ____ of automatic water-level recorders provided by WRD into ___ monitoring wells existing or drilled under this Contract. Details on hook, wire, method to set, etc., shall be proposed by the Contractor for Engineer's approval prior to the installation work.

4.2.8. SITE CLEARANCE

On the completion of all the works in the field, the Contractor shall remove all equipment and materials concerned, clean up the site as almost same as original states before the commencement of the works.

4.2.9. REPORTING

The Contractor shall provide the following reports and records, and on all occasions submit them to the Engineer;

(1) Daily Reports

- Daily drilling record
- Daily work record

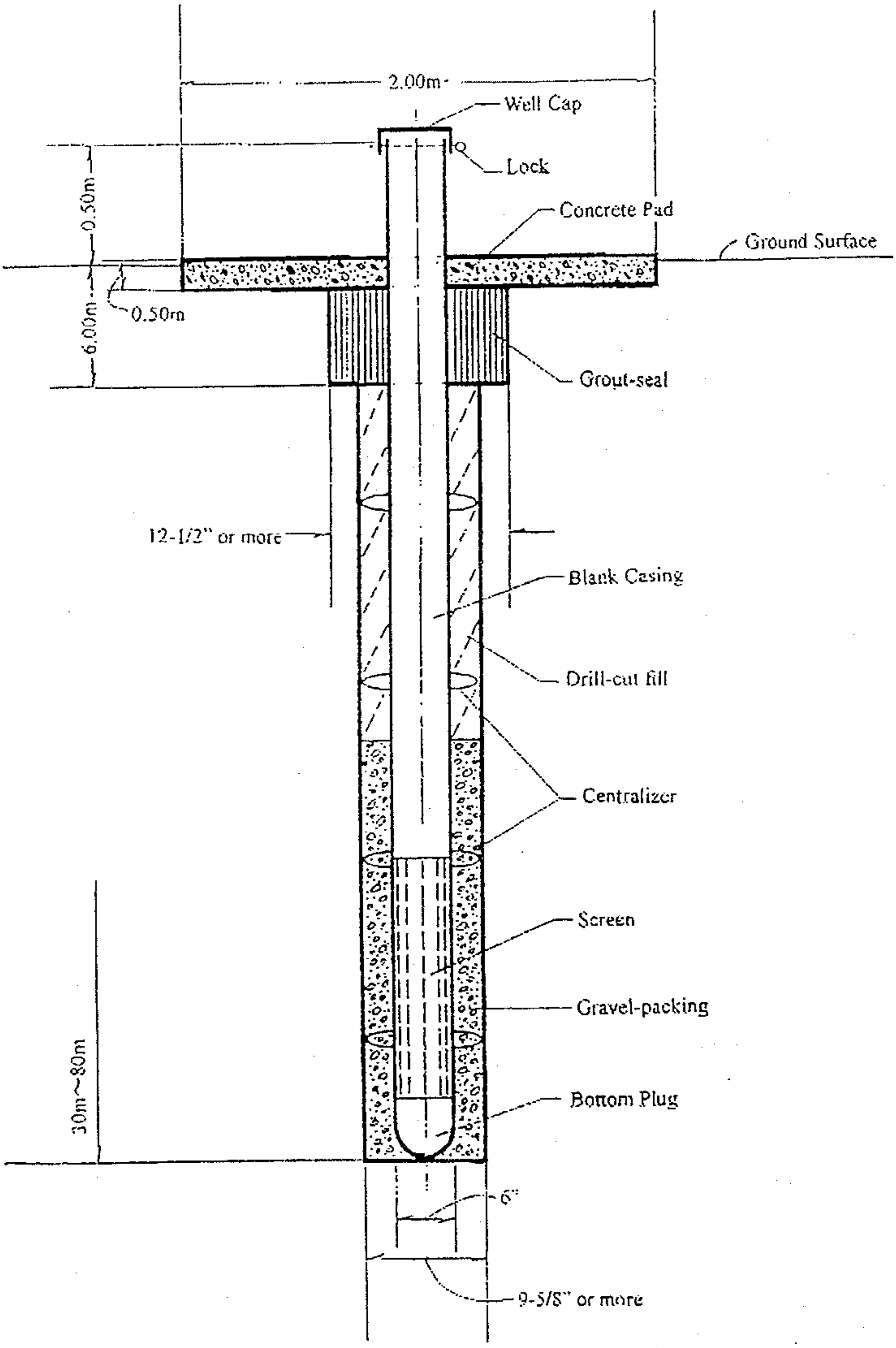
(2) Results

- Drilling logs
- Lithological logs
- Borehole logs
- Pumping tests

(3) Color photograph (or sketch by the instruction)

- Typical work operation
- Site views
- Equipment, measuring devices and materials
- Other related to the execution of the works and indicated by the Engineer.

Appendix C-9 Standard Design of Production Well



APPENDIX D

WATER SUPPLY

TABLE OF CONTENTS

1. Service Population

No.1

Debarwa

Year	1997	2005			2010			2015		
Zone,Village		Total Pop.	%	Supplied	Total Pop.	%	Supplied	Total Pop.	%	Supplied
Zone 1	1,884	3,701	0.90	3,331	5,078	1.00	5,078	6,719	1.00	6,719
Zone 2	1,551	3,047	0.90	2,742	4,180	1.00	4,180	5,532	1.00	5,532
Geza Lamza	1,396	2,742	0.70	1,920	3,762	0.85	3,198	4,979	1.00	4,979
Total	4,831	9,490	0.84	7,993	13,020	0.96	12,456	17,230	1.00	17,230
Projected Pop.		9,490			13,020			17,230		

Mendefera

Year	1997	2005			2010			2015		
Zone,Village		Total Pop.	%	Supplied	Total Pop.	%	Supplied	Total Pop.	%	Supplied
Western zone										
5	1,398	2,227	0.60	1,336	2,857	0.80	2,286	3,629	1.00	3,629
6	2,005	3,194	0.70	2,236	4,097	0.85	3,483	5,204	1.00	5,204
7	4,089	6,513	0.80	5,211	8,356	0.90	7,520	10,614	1.00	10,614
8	2,275	3,624	0.70	2,537	4,650	0.80	3,720	5,906	1.00	5,906
Eastern zone									–	
1	2,743	4,370	0.70	3,059	5,606	0.85	4,765	7,121	1.00	7,121
2	2,934	4,674	0.70	3,272	5,996	0.85	5,096	7,616	1.00	7,616
4	2,192	3,491	0.60	2,095	4,479	0.75	3,359	5,689	1.00	5,689
Adi Bari	1,488	2,370	0.00	0	3,041	1.00	3,041	3,863	1.00	3,863
Adi Wegri	708	1,128	0.00	0	1,447	0.00	0	1,838	1.00	1,838
Adi Hare	539	859	0.00	0	1,101	0.00	0	1,399	1.00	1,399
Total	20,371	32,450	0.61	19,745	41,630	0.80	33,270	52,880	1.00	52,880
Projected Pop.		32,450			41,630			52,880		

Adiquala

Year	1997	2005			2010			2015		
Zone,Village		Total Pop.	%	Supplied	Total Pop.	%	Supplied	Total Pop.	%	Supplied
Adiquala										
Zone 1	1,475	2,399	1.00	2,399	3,004	1.00	3,004	3,685	1.00	3,685
Zone 2	1,818	2,956	1.00	2,956	3,701	1.00	3,701	4,541	1.00	4,541
Zone 3	1,857	3,020	1.00	3,020	3,782	1.00	3,782	4,639	1.00	4,639
Zone 4	2,075	3,374	1.00	3,374	4,224	1.00	4,224	5,182	1.00	5,182
Geza Gebrai	335	545	0.00	0	682	1.00	682	837	1.00	837
Geza Azazi	334	543	0.00	0	680	1.00	680	834	1.00	834
Adi Arbaa	625	1,016	0.00	0	1,273	0.00	0	1,561	1.00	1,561
Geza Atat	87	141	0.00	0	177	1.00	177	217	1.00	217
Tekerakari	117	190	0.00	0	238	1.00	238	292	1.00	292
Adi Hihi	306	498	0.00	0	623	0.00	0	764	1.00	764
Adi Mini	201	327	0.00	0	409	0.00	0	502	1.00	502
Adi Shinfio	258	420	0.00	0	525	0.00	0	644	1.00	644
Total	9,488	15,430	0.76	11,750	19,320	0.85	16,490	23,700	1.00	23,700
Projected Pop.		15,430			19,320			23,700		

Dekemhare

No.2

Year	1997	2005			2010			2015		
Zone,Village		Total Pop.	%	Supplied	Total Pop.	%	Supplied	Total Pop.	%	Supplied
Zone 1										
1	3,163	5,016	0.60	3,009	6,425	0.80	5,140	8,155	1.00	8,155
2	3,168	5,024	0.90	4,522	6,436	1.00	6,436	8,168	1.00	8,168
3	1,746	2,768	0.70	1,938	3,546	0.85	3,015	4,501	1.00	4,501
4	1,024	1,623	0.90	1,461	2,080	1.00	2,080	2,639	1.00	2,639
5	776	1,230	1.00	1,230	1,576	1.00	1,576	2,000	1.00	2,000
Zone 2									–	
6	2,616	4,148	1.00	4,148	5,314	1.00	5,314	6,744	1.00	6,744
7	2,057	3,261	1.00	3,261	4,178	1.00	4,178	5,302	1.00	5,302
8	2,106	3,339	1.00	3,339	4,278	1.00	4,278	5,429	1.00	5,429
9	2,920	4,631	0.80	3,705	5,932	1.00	5,932	7,529	1.00	7,529
Hadamu	1,192	1,890	0.00	0	2,421	0.00	0	3,073	1.00	3,073
Metsalu	314	498	0.00	0	638	0.00	0	810	1.00	810
Amhare	593	940	0.00	0	1,205	0.00	0	1,529	1.00	1,529
Total	21,675	34,370	0.77	26,614	44,030	0.86	37,949	55,880	1.00	55,880
Projected Pop.		34,370			44,030			55,880		

Segeneiti

Year	1997	2005			2010			2015		
Zone,Village		Total Pop.	%	Supplied	Total Pop.	%	Supplied	Total Pop.	%	Supplied
1	2,477	4,304	0.80	3,443	5,513	0.90	4,962	6,851	1.00	6,851
2	3,669	6,376	0.60	3,826	8,167	0.80	6,534	10,149	1.00	10,149
Total	6,146	10,680	0.68	7,269	13,680	0.84	11,495	17,000	1.00	17,000
Projected Pop.		10,680			13,680			17,000		

Adi Keyih

Year	1997	2005			2010			2015		
Zone,Village		Total Pop.	%	Supplied	Total Pop.	%	Supplied	Total Pop.	%	Supplied
Zone 1	7,837	12,212	0.70	8,548	15,057	0.85	12,798	18,293	1.00	18,293
Zone 2	6,378	9,938	0.80	7,951	12,253	1.00	12,253	14,887	1.00	14,887
Total	14,215	22,150	0.74	16,499	27,310	0.92	25,052	33,180	1.00	33,180
Projected Pop.		22,150			27,310			33,180		

Senafe

Year	1997	2005			2010			2015		
Zone,Village		Total Pop.	%	Supplied	Total Pop.	%	Supplied	Total Pop.	%	Supplied
Zone 1										
1	730	1,147	0.90	1,033	1,419	1.00	1,419	1,728	1.00	1,728
2	1,022	1,606	0.80	1,285	1,986	1.00	1,986	2,419	1.00	2,419
3	876	1,377	0.80	1,102	1,703	1.00	1,703	2,073	1.00	2,073
Zone 2									–	
4	3,549	5,578	0.70	3,905	6,898	0.90	6,208	8,398	1.00	8,398
5	1,971	3,099	1.00	3,099	3,832	1.00	3,832	4,666	1.00	4,666
6	2,366	3,719	1.00	3,719	4,598	1.00	4,598	5,599	1.00	5,599
Metera	1,178	1,852	0.80	1,481	2,290	0.90	2,061	2,788	1.00	2,788
Awle	590	927	0.00	0	1,147	0.00	0	1,396	1.00	1,396
Hahahile	0	0	0.00	0	0	0.00	0	0	1.00	0
Tisha	652	1,025	0.00	0	1,267	0.00	0	1,543	1.00	1,543
Afema	0	0	0.00	0	0	0.00	0	0	1.00	0
Total	12,934	20,330	0.77	15,623	25,140	0.87	21,807	30,610	1.00	30,610
Projected Pop.		20,330			25,140			30,610		

Total

Target Year	1997	2005			2010			2015		
		Total Pop.	%	Supplied	Total Pop.	%	Supplied	Total Pop.	%	Supplied
Grand Tatal	89,660	144,900	0.73	105,491	184,130	0.86	158,518	230,480	1.00	230,480

2. Water Demand

Water Demand

Name of Town	Year	Population			Average Water Demand				(m3/d)	Daily Max. (m3/d)	Hourly (m3/h)
		Whole	Supply area	%	Domestic	Industry	Others	Loss	Total		
Debarwa	2005	9,490	7,990	84.2	150		141	51	342	411	25.7
	2010	13,020	12,460	95.7	247	81	206	94	629	754	47.2
	2015	17,230	17,230	100.0	390	271	272	165	1,098	1,318	82.3
Mendefera	2005	32,450	19,750	60.9	456		253	125	834	1,001	62.6
	2010	41,630	33,270	79.9	979	314	324	285	1,902	2,283	142.7
	2015	52,880	52,880	100.0	1,840	413	412	470	3,134	3,761	235.1
Adiquala	2005	15,430	11,750	76.2	241		136	66	443	532	33.2
	2010	19,320	16,490	85.4	389		170	99	658	789	49.3
	2015	23,700	23,700	100.0	728		208	165	1,102	1,322	82.6
Dekemhare	2005	34,370	26,610	77.4	615		320	165	1,100	1,320	82.5
	2010	44,030	37,950	86.2	1,117	210	410	307	2,044	2,452	153.3
	2015	55,880	55,880	100.0	1,945	1,050	520	620	4,135	4,962	310.1
Segeneiti	2005	10,680	7,270	68.1	136		107	43	287	344	21.5
	2010	13,680	11,500	84.1	228		138	65	431	517	32.3
	2015	17,000	17,000	100.0	385		171	98	654	785	49.0
Adi Keyih	2005	22,150	16,500	74.5	381		220	106	707	849	53.0
	2010	27,310	25,050	91.7	737		271	178	1,186	1,424	89.0
	2015	33,180	33,180	100.0	1,155		329	262	1,746	2,095	130.9
Senafe	2005	20,330	15,620	76.8	321		174	87	582	698	43.6
	2010	25,140	21,810	86.8	515		215	129	859	1,030	64.4
	2015	30,610	30,610	100.0	940		261	212	1,414	1,697	106.0
Total	2005	144,900	105,490	72.8	2,301		1,350	644	4,295	5,154	322.1
	2010	184,130	158,530	86.1	4,214	605	1,733	1,156	7,708	9,250	578.1
	2015	230,480	230,480	100.0	7,383	1,734	2,173	1,992	13,283	15,939	996.2

(1) Population

		Debarwa		Mendefera		Adiquala		Dekemhare		Segeneiti		Adi Keyih		Senafe	
Water consumption		%	l/c/d	%	l/c/d	%	l/c/d	%	l/c/d	%	l/c/d	%	l/c/d	%	l/c/d
1997	H.C.	1.25	25	10.94	24.11	13.86	20.45	5.67	25.59	3	28.73	4.95	11.66	7.78	10.3
	Y.C.			6.56	14.95	6.14	12.07	8.67	15.67	5	12.64	10.64	5.94	6.62	6.8
	C.W.P	41.7	8.56	29.2	10.13	63.6	14.31			90.5	16.45	13.94	8.79	83.8	8.04
Average			9.0		14.1		15.2		19.6		16.6		8.2		8.1
Population			4,831		20,371		9,488		21,675		6,146		14,215		12,934
Water Demand			44		287		144		425		102		117		105
2005	H.C.	17	28	29	35	23	29	29	35	17	28	29	35	23	29
	Y.C.	22	22	33	22	33	22	33	22	22	22	33	22	33	22
	C.W.P	61	15	38	15	44	15	38	15	61	15	38	15	44	15
Average			18.8		23.1		20.5		23.1		18.8		23.1		20.5
Population			7,990		19,750		11,750		26,610		7,270		16,500		15,620
Water Demand			150		456		241		615		136		381		321
2010	H.C.	19	30	34	40	27	34	34	40	19	30	34	40	27	34
	Y.C.	24	24	66	24	37	24	66	24	24	24	66	24	37	24
	C.W.P	56	15	0	15	37	15	0	15	56	15	0	15	37	15
Average			19.9		29.4		23.6		29.4		19.9		29.4		23.6
Population			12,460		33,270		16,490		37,950		11,500		25,050		21,810
Water Demand			247		979		389		1,117		228		737		515
2015	H.C.	22	35	39	47	31	39	39	47	22	35	39	47	31	39
	Y.C.	27	27	61	27	69	27	61	27	27	27	61	27	69	27
	C.W.P	51	15	0	15	0	15	0	15	51	15	0	15	0	15
Average			22.6		34.8		30.7		34.8		22.6		34.8		30.7
Population			17,230		52,880		23,700		55,880		17,000		33,180		30,610
Water Demand			390		1,840		728		1,945		385		1,155		940

(2) Industry

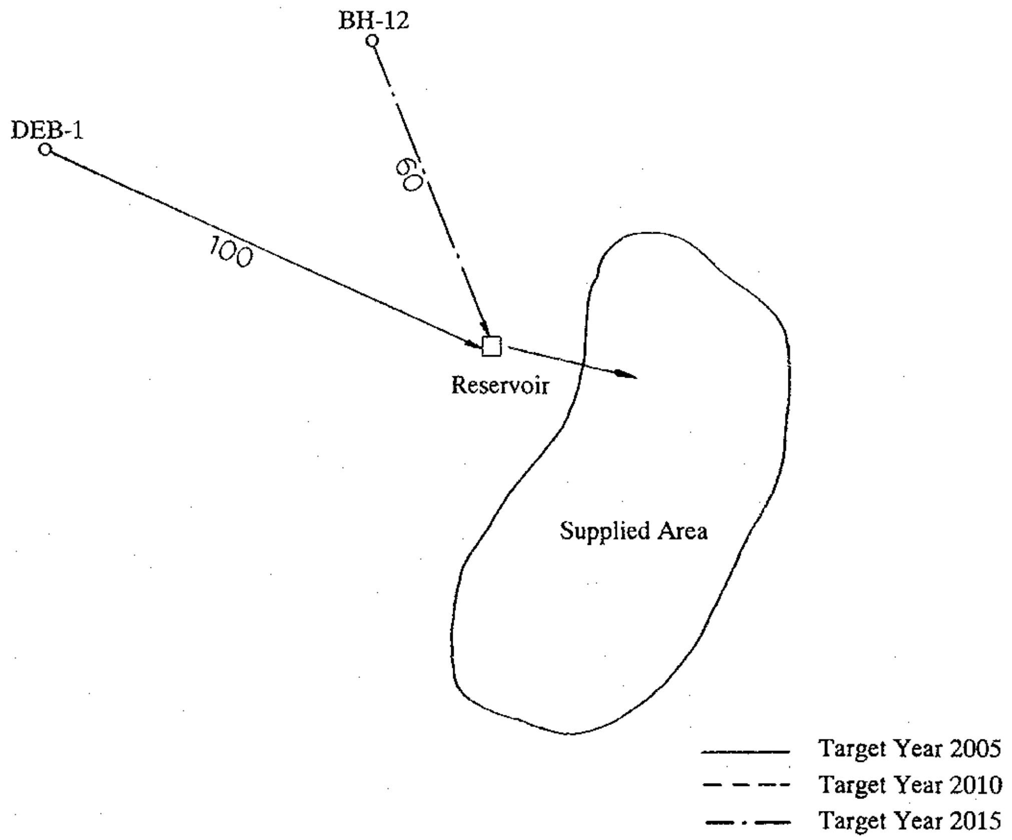
	unit	Water consum.	Debarwa	Mendefera	Adiquala	Dekemhare	Segeneiti	Adi Keyih	Senafe
Industry	ha	15,000	18.09			70			
Light Indus.		5,500		57					
				75					
Total			18.09			70.00			
Water Demand		2005							
		2010	81	314		210			
		2015	271	413		1,050			

(3) Number of Institutions

	unit	Water consum.	Debarwa	Mendefera	Adiquala	Dekemhare	Segeneiti	Adi Keyih	Senafe
School	pupil	5	3,228	15,120	5,901	7,905	3,111	6,233	3,649
Hospital	bed	100	20	30	20	20	35	40	35
Clinic	bed	100	5	5		5	5	5	5
Hotel	shop	210	5	13	7	13	5	17	13
Bar, Tea shop	shop	210	68	79	20	103	16	72	63
Restaurant	shop	210	85	75	60	61	20	45	80
Church	visiter	5	450	1,430	790	2,020	580	1,180	830
Mosque	visiter	5	60	1,220	320	300	70	480	930
Office	person	5	570	1,641	1,005	1,812	690	990	738
Factory	site	1000	19	23	23	102	27	64	43
Water Demand		1997	76	159	83	202	62	141	110
(Others)		2005	141	253	136	320	107	220	174
		2010	206	324	170	410	138	271	215
		2015	272	412	208	520	171	329	261

2.1 Plan of Water Source and Transmission Pipelines

Debarwa



2.2 Hydraulic Calculation of Transmission Pipeline

Hydraulic Calculation of Transmission Line

Debarwa	Target Year		**2005**		**2010**		**2015**			
	Well No.		DEB-1		DEB-1		DEB-1	DEB-1	BH12	
Condition	Symbol	Unit	24hr ope.		24hr ope.		24hr ope.	24hr ope.	24hr ope.	
Elevation of Intake	EL1	m	1850.50		1850.50		1850.50		1850	
Ground water level		m	13.20						10.00	
Elevation of Reservoir	EL2	m	1903.00		1903.00		1903.00		1903.00	
Water level		m	3.00						3.00	
Discharge	Q	m3/d	411		754		754	369	195	
Discharge	Q1	m3/s	0.0048		0.0087		0.0087	0.0043	0.0023	
Pipe Diameter	D	mm	100		100		100	80	60	
Velocity	V	m/s	0.61		1.11		1.11	0.85	0.80	
Velocity Coefficient	C		110		110		110	110	110	
Pipe Length	L	m	690		690		690	690	480	
Loss Head	h2	m	4.61		14.15		14.15	11.19	9.71	
Actual Head	h1	m	68.70		68.70		68.70	68.70	66.00	
Total Head	H	m	73.31		82.85		82.85	79.89	75.71	

- Pumps are operated 24 hours per day.

2.3 Capacity of Reservoir

Capacity of Reservoir

No.1

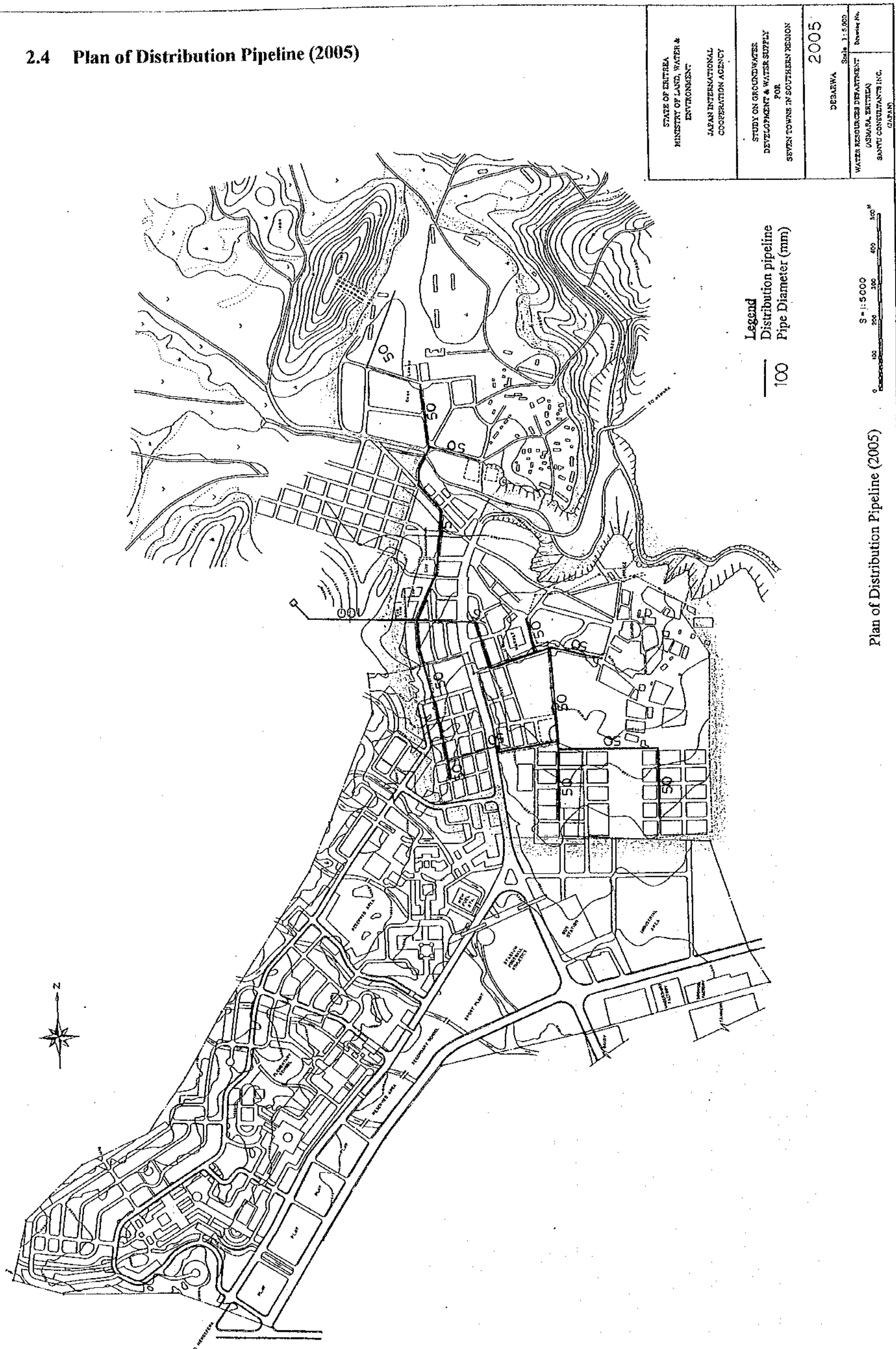
Name of Town	Rsv. No.	Target Year	Max. Daily Consumption (m3/d)	Reservoir Capacity: Necessary (m3)	Reservoir Capacity: Design (m3)	Dimension of Reservoir: Length (m)	Dimension of Reservoir: Width (m)	Dimension of Reservoir: High (m)	Dimension of Reservoir: Actual (m3)	Additional Reservoir: Capacity (m3)	Additional Reservoir: Length (m)	Additional Reservoir: Width (m)	Additional Reservoir: High (m)	Additional Reservoir: Actual (m3)	Remarks
Debarwa	DB-1	2005	411	137	140	7.0	7.0	3.0	147					147	
	DB-1	2010	754	251	260	9.6	9.0	3.0	259	120	5.5	7.0	3.0	116	
	DB-1	2015	1,318	439	440	12.5	12.0	3.0	450	180	9.0	7.0	3.0	189	
Mendefera	MD-1	2005	1,001	334	340	10.0	10.0	3.5	350					350	
	MD-1	2010	2,283	761	770	15.0	15.0	3.5	788	430	12.5	10.0	3.5	438	
(80.0)	MD-1	2015	3,009	1003	1010	17.0	17.0	3.5	1012	240	7.0	10.0	3.5	245	
(13.7)	MD-2	2015	515	172	180	8.5	8.5	2.5	181						
(3.4)	MD-3	2015	128	43	50	4.5	4.5	2.5	51						(Adi Wegri)
(2.9)	MD-4	2015	109	36	40	4.0	4.0	2.5	40						(Adi Hare)
Adiquala	AQ-1	2005	532	177	180	7.5	8.0	3.0	180					180	
(81.0)	AQ-1	2010	639	213	220	8.6	8.6	3.0	222	40	4.0	4.0	3.0	48	
(63.8)	AQ-1	2015	843	281	290	10.0	10.0	3.0	300	70	4.5	5.0	3.0	68	
	AQ-1'	2005	532	22	25	3.5	3.0	2.5	26					26	H=13m, Q=1hr
	AQ-1'	2010	639	27	30	3.5	3.5	2.5	31	5	2.0	2.0	2.0	8	H=13m, Q=1hr
	AQ-1'	2015	843	35	35	4.0	4.0	2.5	40	5	2.0	2.0	2.0	8	H=13m, Q=1hr
(19.0)	AQ-2	2010	150	50	50	4.0	4.5	3.0	54					54	H=13m
(30.5)	AQ-2	2015	403	134	140	7.0	7.0	3.0	147	90	5.5	5.5	3.0	91	H=13m
(5.7)	AQ-3	2015	75	25	30	3.5	3.5	2.5	31						Mini & Shinfio
Dekemhare															
(84.2+15.8)	DK-1	2005	1,320	440	440	8.5	15.0	3.5	446					446	
(88.8+11.2)	DK-1	2010	2,452	817	820	16.0	15.0	3.5	840	380	7.5	15.0	3.5	394	
(86.7+6.0))	DK-1	2015	4,600	1533	1540	30.0	15.0	3.5	1575	720	14.0	15.0	3.5	735	
(15.8)	DK-1'	2005	209	9	10	2.0	3.0	2.0	12					12	H=12m, Q=1hr
(11.2)	DK-1'	2010	275	11	15	3.0	3.0	2.0	18						H=12m, Q=1hr
(6.0)	DK-1'	2015	298	12	15	3.0	3.0	2.0	18						H=12m, Q=1hr
(2.9)	DK-2	2015	144	48	50	4.5	4.5	2.5	51						Hadamu
(1.8)	DK-3	2015	89	30	30	3.5	3.5	2.5	31						Metsalu
(2.6)	DK-4	2015	129	43	50	4.5	4.5	2.5	51						Amhare

Capacity of Reservoir

No.2

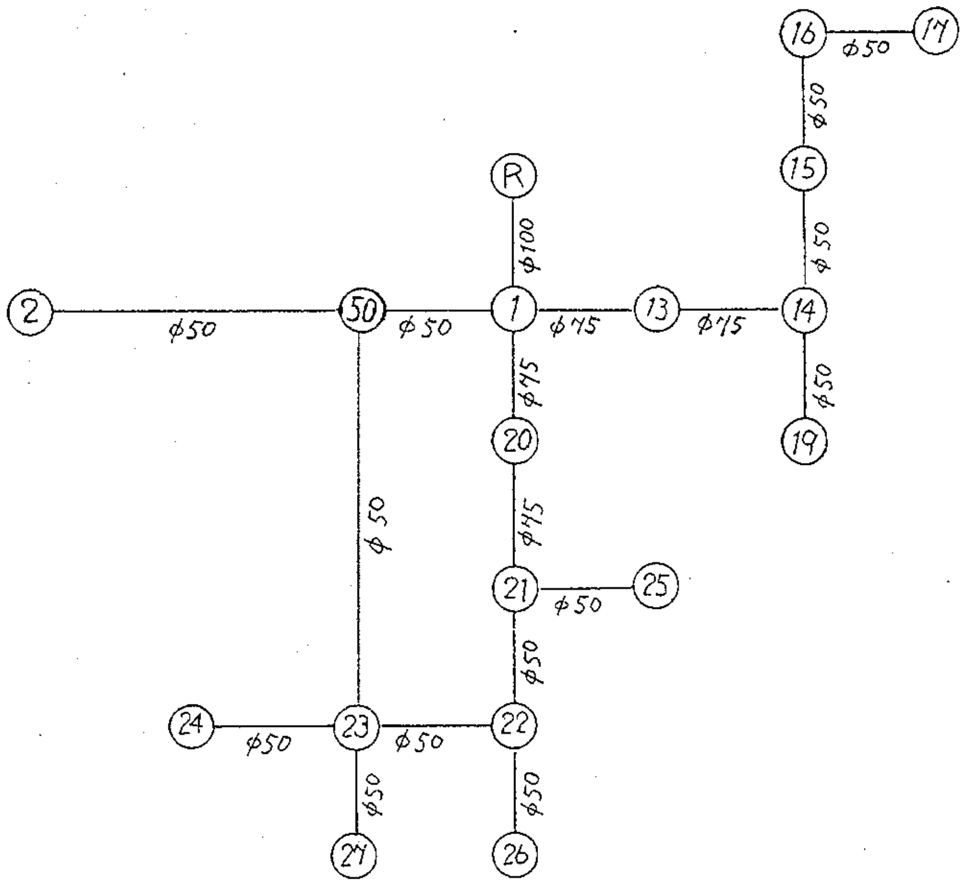
Name of Town	Rsv. No.	Target Year	Max. Daily Consumption (m3/d)	Reservoir Capacity Necessary (m3)	Reservoir Capacity Design (m3)	Dimension of Reservoir Length (m)	Dimension of Reservoir Width (m)	Dimension of Reservoir High (m)	Dimension of Reservoir Actual (m3)	Additional Reservoir Capacity (m3)	Additional Reservoir Length (m)	Additional Reservoir Width (m)	Additional Reservoir High (m)	Additional Reservoir Actual (m3)	Remarks
Segeneiti	SG-1	2005	344	115	120	7.0	7.0	2.5	123					123	
(74.0)	SG-1	2010	383	128	130	7.2	7.2	2.5	130	10	2.0	2.0	2.5	10	
(50.9)	SG-1	2015	400	133	140	7.5	7.5	2.5	141	10	2.0	2.0	2.5	10	
(26.0)	SG-2	2010	134	45	50	4.5	4.5	2.5	51					51	H=12.5m
(49.1)	SG-2	2015	385	128	130	7.2	7.2	2.5	130	80	6.0	6.0	2.5	90	H=12.5m
Aadi Keyih	AD-1	2005	849	283	290	10.0	10.0	3.0	300					300	H=5.5m
	AD-1	2010	1,424	475	480	12.5	13.0	3.0	488	190	6.5	10.0	3.0	195	H=5.5m
	AD-1	2015	2,095	698	700	15.5	15.5	3.0	721	220	7.5	10.0	3.0	225	H=5.5m
Senafe	SN-1	2005	698	233	240				600						Existing
	SN-1	2010	1,030	343	350				600						
(81.4)	SN-1	2015	1,381	460	470				600						
(18.6)	SN-2	2015	316	105	110	6.5	6.5	2.6	110						Afema

2.4 Plan of Distribution Pipeline (2005)



Calculation of Pipe Networks

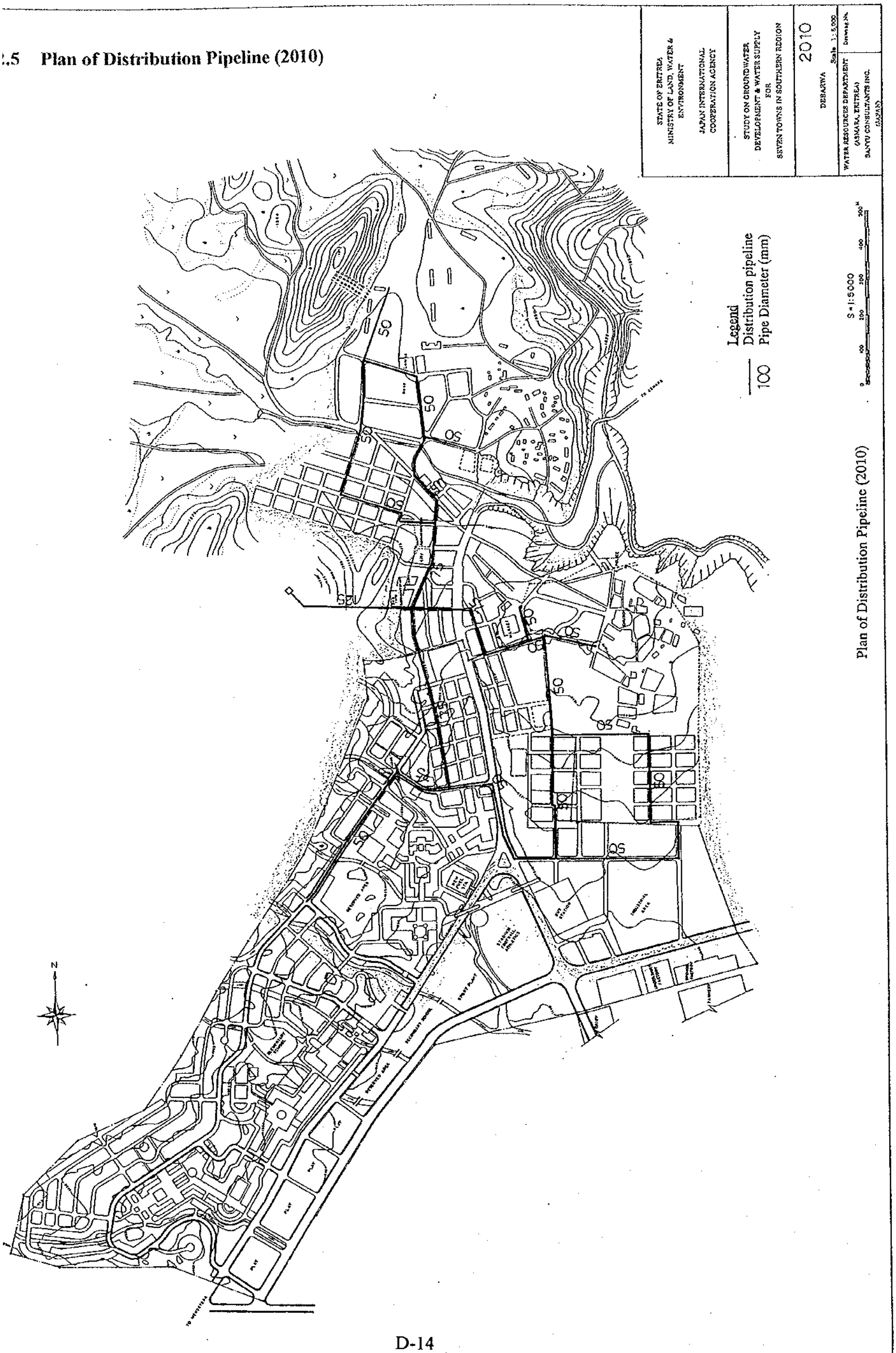
DEBARWA 2005



Node No.	Dynamic (WL.m)	Ground Elevation (EL.m)	Effective Head (m)	Area (ha)	Outflow Quantitiy (L/sec)
0	1903.000	1904.000	-1.000	-102.20	-7.14
1	1897.912	1867.400	30.512	0.00	0.00
13	1895.301	1865.600	29.700	4.70	0.33
14	1893.107	1859.000	34.107	0.00	0.00
15	1887.732	1859.000	28.732	11.50	0.80
16	1886.164	1862.000	24.164	0.00	0.00
17	1882.807	1863.000	19.807	13.90	0.97
50	1891.590	1858.000	33.590	0.00	0.00
23	1889.731	1863.000	26.731	5.90	0.41
22	1891.591	1869.900	21.691	5.00	0.35
21	1893.237	1869.800	23.437	0.00	0.00
20	1896.573	1864.300	32.273	4.70	0.33
24	1888.778	1855.300	33.478	7.90	0.55
27	1887.946	1854.500	33.446	7.60	0.53
26	1888.368	1868.000	20.368	13.60	0.95
25	1892.064	1870.500	21.564	10.20	0.71
19	1891.118	1858.000	33.118	10.10	0.71
2	1891.241	1852.500	38.741	7.10	0.50

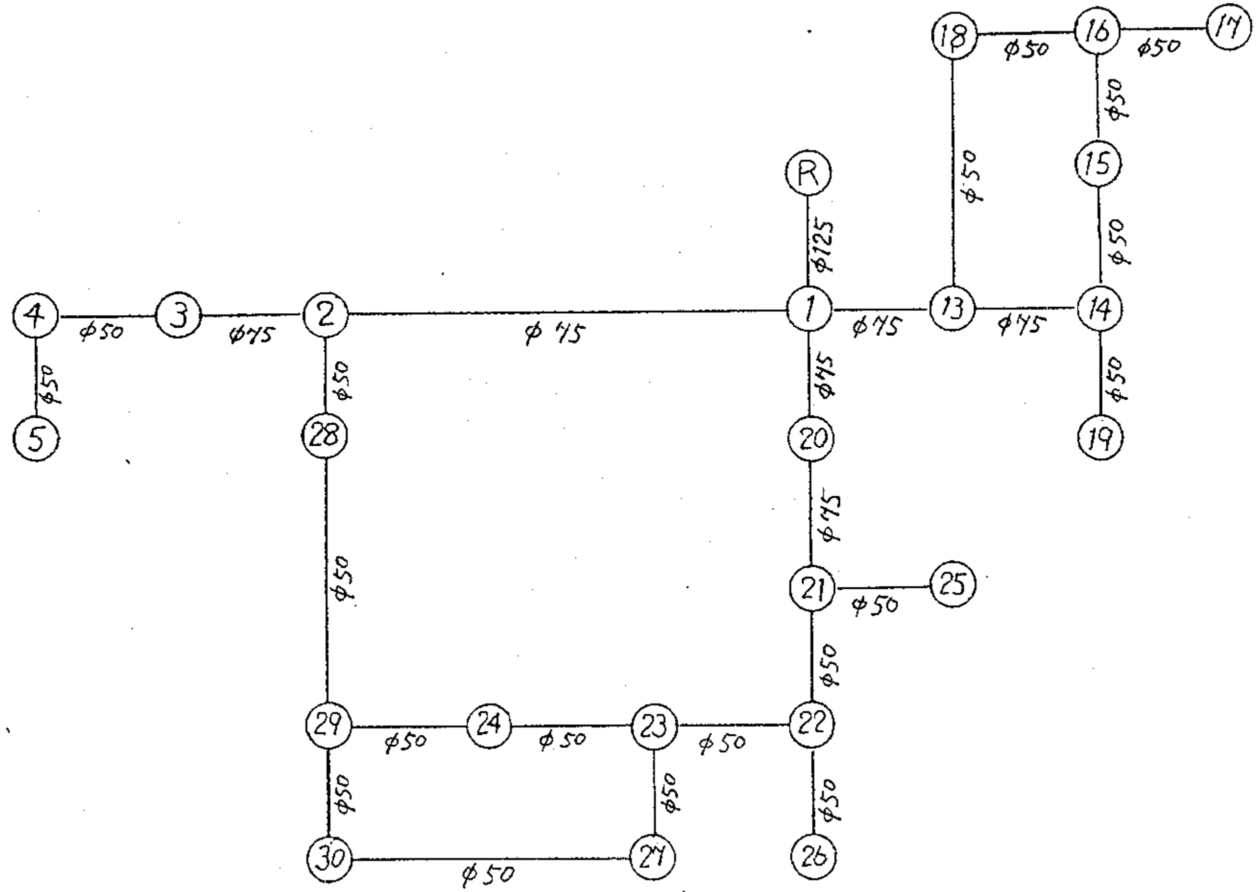
Pipe line No.	Node No. From	Node No. To	Dia. (mm)	Length (m)	Flow Coefficient	Flow (L/sec)	velocity (m/sec)	Loss of Head (m)	Hydraulic Gradient (m/1000m)	Head Loss Coefficient	Hydrostatic Head	Water Hummer Head	Design Pressure (kg/sq.cm)	Pipe Material
1	0	1	100	365.00	110	7.1	0.910	5.088	13.939	0.03299	3.64	1.75	5.39	
2	1	13	75	260.00	110	2.8	0.636	2.612	10.045	0.03649	3.81	1.75	5.56	
3	13	14	75	275.00	110	2.5	0.562	2.194	7.977	0.03717	4.47	1.75	6.22	
4	14	15	50	174.00	110	1.8	0.904	5.375	30.892	0.03707	4.47	1.75	6.22	
5	15	16	50	155.00	110	1.0	0.495	1.568	10.117	0.04053	4.47	1.75	6.22	
6	16	17	50	332.00	110	1.0	0.494	3.356	10.109	0.04053	4.17	1.75	5.92	
7	1	50	50	410.00	110	1.2	0.621	6.323	15.421	0.03918	4.57	1.75	6.32	
8	50	23	50	316.00	110	0.7	0.369	1.859	5.882	0.04233	4.57	1.75	6.32	
9	23	22	50	282.00	110	-0.8	-0.393	-1.860	-6.597	-0.04194	4.07	1.75	5.82	
10	22	21	50	40.00	110	-2.1	-1.055	-1.646	-41.138	-0.03623	3.39	3.39	6.78	
11	21	20	75	338.00	110	-2.8	-0.630	-3.336	-9.871	-0.03655	3.94	1.75	5.69	
12	20	1	75	110.00	110	-3.1	-0.706	-1.339	-12.174	-0.03594	3.94	1.75	5.69	
13	23	24	50	269.00	110	0.6	0.281	0.953	3.543	0.04408	4.84	1.75	6.59	
14	23	27	50	540.00	110	0.5	0.270	1.785	3.306	0.04432	4.92	1.75	6.67	
15	22	26	50	332.00	110	0.9	0.484	3.223	9.708	0.04066	3.57	1.75	5.32	
16	21	25	50	206.00	110	0.7	0.363	1.172	5.691	0.04244	3.39	3.39	6.78	
17	14	19	50	355.00	110	0.7	0.360	1.989	5.604	0.04249	4.57	1.75	6.32	
18	50	2	50	120.00	110	0.5	0.252	0.348	2.901	0.04479	5.12	1.75	6.87	
合計				4879.00										

2.5 Plan of Distribution Pipeline (2010)



Plan of Distribution Pipeline (2010)

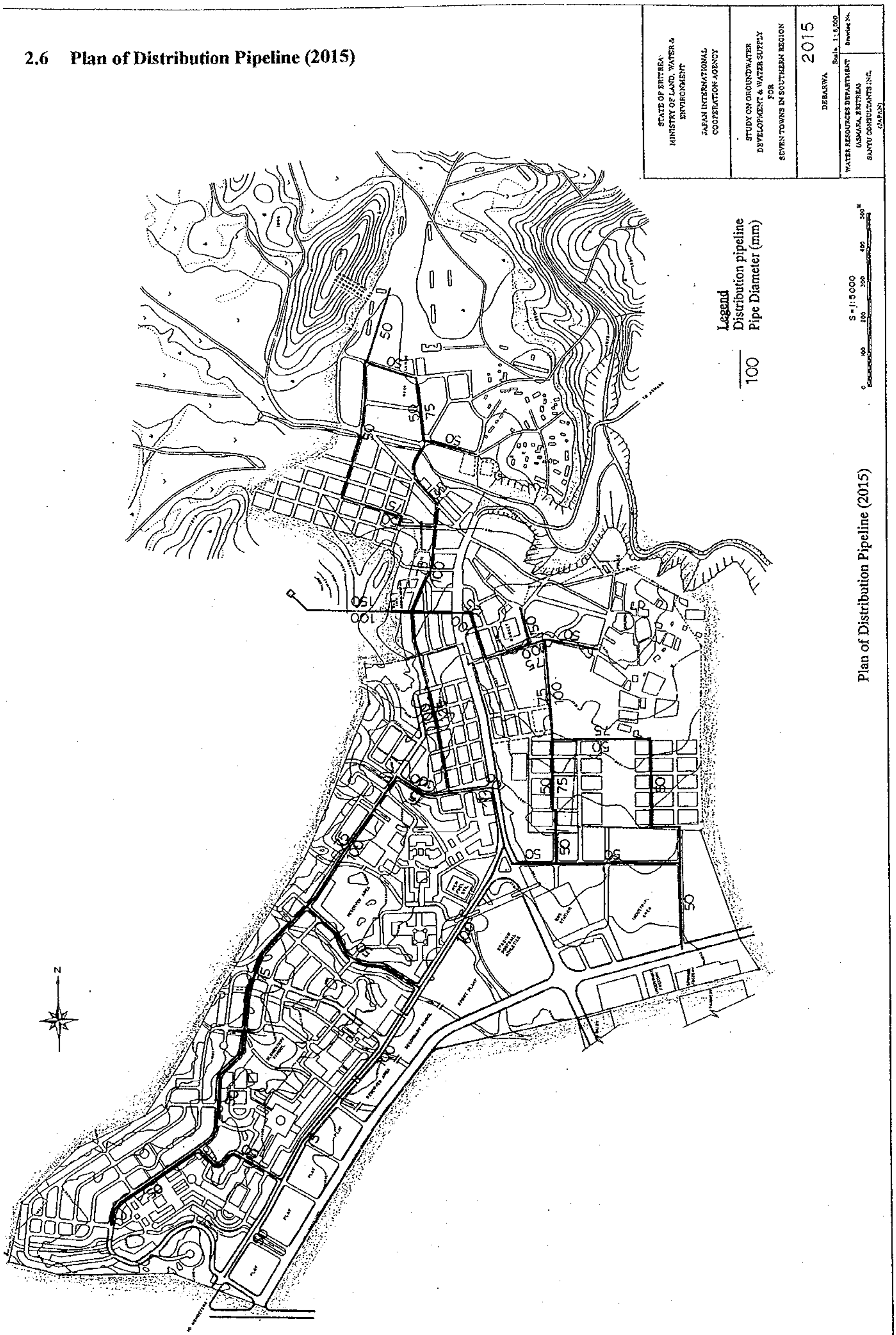
DEBARWA 2010



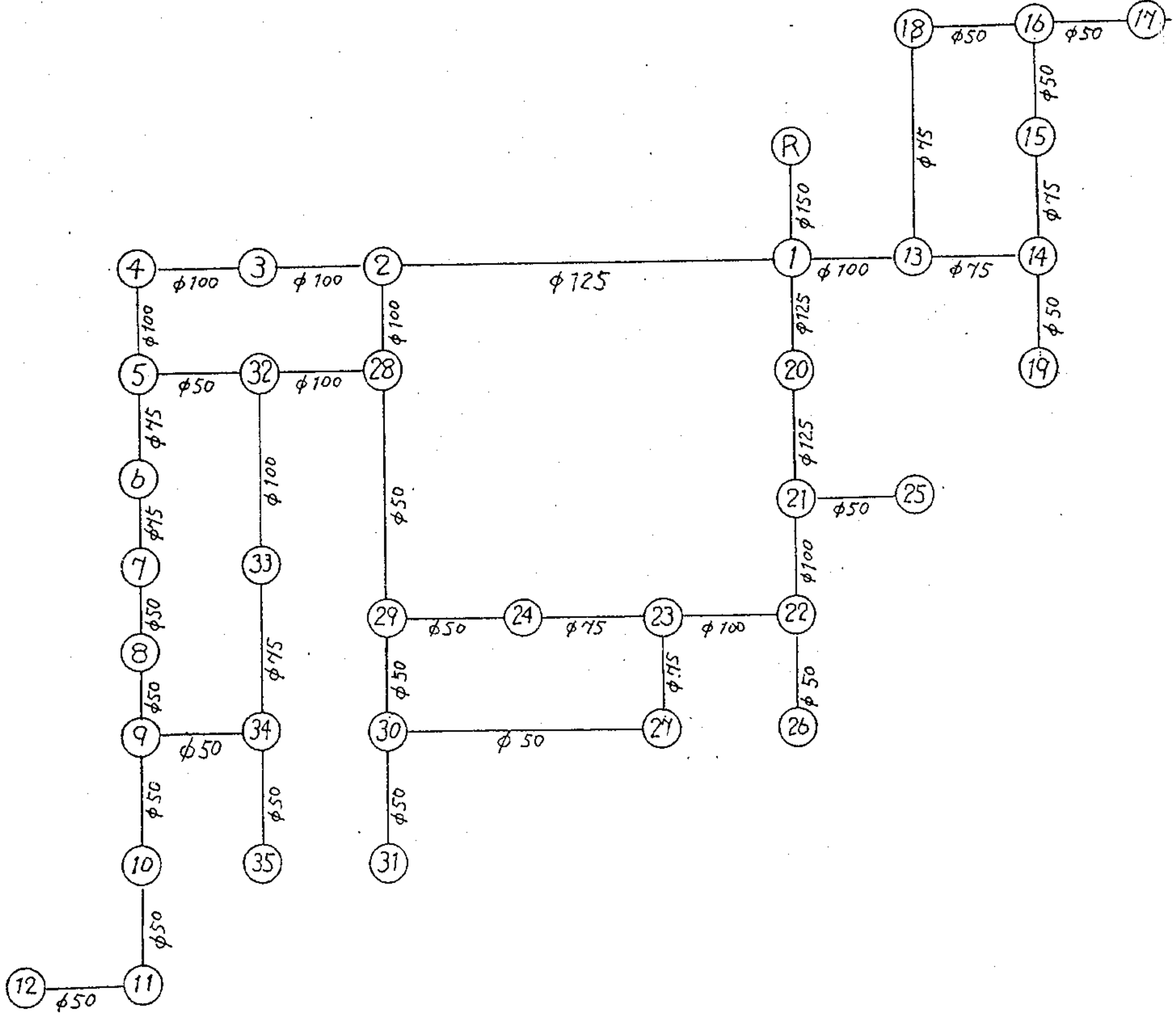
Node No.	Dynamic (WL.m)	Ground Elevation (EL.m)	Effective Head (m)	Area (ha)	Outflow Quantitiy (L/sec)
0	1903.000	1904.000	-1.000	-163.70	-13.11
1	1897.731	1867.400	30.331	0.00	0.00
20	1895.005	1864.300	30.705	4.70	0.38
21	1887.865	1869.800	18.065	0.00	0.00
22	1883.784	1869.900	13.884	5.00	0.40
23	1873.974	1863.000	10.974	5.90	0.47
24	1873.446	1855.300	18.146	7.90	0.63
29	1873.515	1853.100	20.415	0.00	0.00
30	1867.625	1849.500	18.125	20.90	1.67
2	1884.350	1852.500	31.850	7.10	0.57
3	1882.876	1859.000	23.876	8.00	0.64
4	1878.293	1860.800	17.493	8.00	0.64
5	1872.766	1857.700	15.066	16.00	1.28
28	1878.042	1848.000	30.042	0.00	0.00
13	1892.918	1865.600	27.318	4.70	0.38
14	1890.867	1859.000	31.867	0.00	0.00
15	1886.514	1859.000	27.514	11.50	0.92
16	1885.742	1862.000	23.742	0.00	0.00
17	1881.417	1863.000	18.417	13.90	1.11
18	1887.005	1875.000	12.005	8.60	0.69
19	1888.306	1858.000	30.306	10.10	0.81
25	1886.361	1870.500	15.861	10.20	0.82
26	1879.625	1868.000	11.625	13.60	1.09
27	1868.001	1854.500	13.501	7.60	0.61

Pipe line No.	Node No. From	Node No. To	Dia. (mm)	Length (m)	Flow Coefficient	Flow (L/sec)	velocity (m/sec)	Loss of Head (m)	Hydraulic Gradient (m/1000m)	Head Loss Coefficient	Hydrostatic Head	Water Hummer Head	Design Pressure (kg/sq.cm)	Pipe Material
1	0	1	125	365.00	110	13.1	1.067	5.269	14.436	0.03104	3.64	1.75	5.39	
2	1	20	75	110.00	110	4.6	1.036	2.726	24.780	0.03395	3.94	1.75	5.69	
3	20	21	75	338.00	110	4.2	0.950	7.140	21.124	0.03439	3.94	1.75	5.69	
4	21	22	50	40.00	110	3.4	1.723	4.081	102.026	0.03369	3.39	3.39	6.78	
5	22	23	50	282.00	110	1.9	0.964	9.810	34.788	0.03672	4.07	1.75	5.82	
6	23	24	50	269.00	110	0.4	0.204	0.528	1.962	0.04621	4.84	1.75	6.59	
7	24	29	50	98.00	110	-0.2	-0.117	-0.069	-0.700	-0.05018	5.06	1.75	6.81	
8	29	30	50	358.00	110	1.3	0.643	5.890	16.452	0.03898	5.42	1.75	7.17	
9	1	2	75	530.00	110	4.6	1.046	13.381	25.248	0.03390	5.12	1.75	6.87	
10	2	3	75	174.00	110	2.6	0.580	1.474	8.471	0.03700	5.12	1.75	6.87	
11	3	4	50	128.00	110	1.9	0.979	4.583	35.803	0.03663	4.47	1.75	6.22	
12	4	5	50	327.00	110	1.3	0.653	5.527	16.902	0.03890	4.60	1.75	6.35	
13	2	28	50	282.00	110	1.5	0.759	6.308	22.368	0.03804	5.57	1.75	7.32	
14	28	29	50	202.00	110	1.5	0.760	4.527	22.411	0.03803	5.57	1.75	7.32	
15	1	13	75	260.00	110	3.9	0.885	4.813	18.511	0.03475	3.81	1.75	5.56	
16	13	14	75	275.00	110	2.4	0.542	2.052	7.460	0.03737	4.47	1.75	6.22	
17	14	15	50	174.00	110	1.6	0.806	4.353	25.015	0.03770	4.47	1.75	6.22	
18	15	16	50	155.00	110	0.7	0.337	0.772	4.982	0.04289	4.47	1.75	6.22	
19	16	17	50	332.00	110	1.1	0.567	4.325	13.027	0.03972	4.17	1.75	5.92	
20	13	18	50	435.00	110	1.1	0.580	5.913	13.593	0.03958	3.81	1.75	5.56	
21	18	16	50	516.00	110	0.5	0.230	1.263	2.449	0.04540	4.17	1.75	5.92	
22	14	19	50	355.00	110	0.8	0.412	2.561	7.213	0.04164	4.57	1.75	6.32	
23	21	25	50	206.00	110	0.8	0.415	1.505	7.304	0.04160	3.39	3.39	6.78	
24	22	26	50	332.00	110	1.1	0.555	4.159	12.528	0.03984	3.57	1.75	5.32	
25	23	27	50	540.00	110	1.0	0.519	5.973	11.061	0.04024	4.92	1.75	6.67	
26	30	27	50	182.00	110	-0.4	-0.210	-0.376	-2.066	-0.04602	5.42	1.75	7.17	
合計				7265.00										

2.6 Plan of Distribution Pipeline (2015)

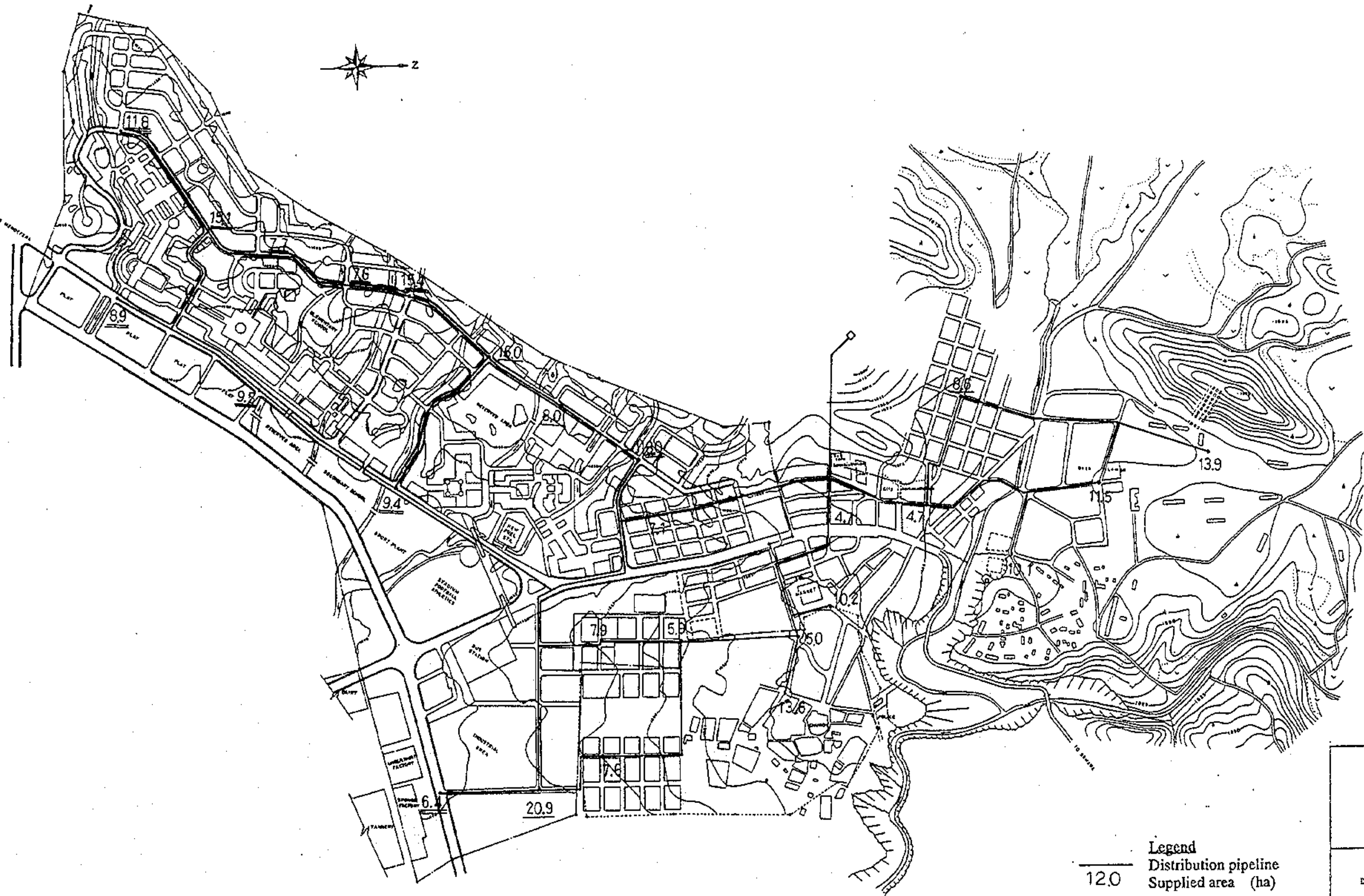


DEBARWA 2015



Node No.	Dynamic (WL.m)	Ground Elevation (EL.m)	Effective Head (m)	Area (ha)	Outflow Quantitiy (L/sec)
0	1903.000	1904.000	-1.000	-255.50	-22.86
1	1897.026	1867.400	29.626	0.00	0.00
2	1891.617	1852.500	39.117	7.10	0.64
3	1889.843	1859.000	30.843	8.00	0.72
4	1888.809	1860.800	28.009	8.00	0.72
5	1886.782	1857.700	29.083	16.00	1.43
6	1882.835	1863.100	19.735	15.40	1.38
7	1881.889	1861.000	20.889	7.60	0.68
8	1876.751	1855.700	21.051	7.70	0.69
9	1875.776	1855.000	20.776	8.40	0.75
10	1869.716	1855.500	14.216	6.70	0.60
11	1868.203	1855.800	12.403	5.60	0.50
12	1867.902	1855.100	12.802	6.20	0.55
13	1895.589	1865.600	29.989	4.70	0.42
14	1893.293	1859.000	34.293	0.00	0.00
15	1892.651	1859.000	33.651	11.50	1.03
16	1891.992	1862.000	29.992	0.00	0.00
17	1886.681	1863.000	23.681	13.90	1.24
18	1894.376	1875.000	19.376	8.60	0.77
19	1890.152	1858.000	32.152	10.10	0.90
20	1896.470	1864.300	32.170	4.70	0.42
21	1894.920	1869.800	25.120	0.00	0.00
22	1894.499	1869.900	24.599	5.00	0.45
23	1892.845	1863.000	29.845	5.90	0.53
24	1891.575	1855.300	36.275	7.90	0.71
25	1893.063	1870.500	22.563	10.20	0.91
26	1889.397	1868.000	21.397	13.60	1.22
27	1889.728	1854.500	35.228	7.60	0.68
28	1890.151	1848.000	42.151	0.00	0.00
29	1890.195	1853.100	37.095	0.00	0.00
30	1886.086	1849.500	36.586	20.90	1.87
31	1885.135	1843.000	42.135	6.40	0.57
32	1887.336	1845.100	42.236	9.40	0.84
33	1886.001	1845.600	40.401	9.50	0.85
34	1883.806	1847.200	36.606	0.00	0.00
35	1881.508	1848.800	32.708	8.90	0.80

Pipe line No.	Node No. From	Node No. To	Dia. (mm)	Length (m)	Flow Coefficient	Flow (L/sec)	velocity (m/sec)	Loss of Head (m)	Hydraulic Gradient (m/1000m)	Head Loss Coefficient	Hydrostatic Head	Water Hummer Head	Design Pressure (kg/sq.cm)	Pipe Material
1	0	1	150	365.00	110	22.6	1.281	5.974	16.367	0.02931	3.64	1.75	5.39	
2	1	2	125	530.00	110	10.9	0.885	5.409	10.205	0.03191	5.13	1.75	6.88	
3	2	3	100	174.00	110	6.0	0.769	1.774	10.196	0.03382	5.12	1.75	6.87	
4	3	4	100	128.00	110	5.3	0.678	1.035	8.083	0.03446	4.47	1.75	6.22	
5	4	5	100	327.00	110	4.6	0.587	2.026	6.196	0.03520	4.61	1.75	6.36	
6	5	6	75	261.00	110	3.5	0.793	3.947	15.124	0.03532	4.60	1.75	6.35	
7	6	7	75	158.00	110	2.1	0.481	0.947	5.991	0.03803	4.27	1.75	6.02	
8	7	8	50	243.00	110	1.4	0.736	5.138	21.144	0.03821	4.80	1.75	6.55	
9	8	9	50	153.00	110	0.8	0.385	0.975	6.370	0.04206	4.87	1.75	6.62	
10	9	10	50	223.00	110	1.7	0.843	6.060	27.175	0.03745	4.87	1.75	6.62	
11	10	11	50	128.00	110	1.1	0.538	1.513	11.820	0.04003	4.82	1.75	6.57	
12	11	12	50	84.00	110	0.6	0.283	0.301	3.587	0.04403	4.86	1.75	6.61	
13	1	13	100	260.00	110	4.3	0.552	1.438	5.529	0.03552	3.81	1.75	5.56	
14	13	14	75	275.00	110	2.5	0.576	2.295	8.346	0.03704	4.47	1.75	6.22	
15	14	15	75	174.00	110	1.6	0.371	0.643	3.694	0.03953	4.47	1.75	6.22	
16	15	16	50	155.00	110	0.6	0.310	0.659	4.251	0.04344	4.47	1.75	6.22	
17	16	17	50	332.00	110	1.2	0.633	5.311	15.997	0.03907	4.17	1.75	5.92	
18	13	18	75	435.00	110	1.4	0.318	1.212	2.787	0.04044	3.81	1.75	5.56	
19	14	19	50	355.00	110	0.9	0.460	3.141	8.848	0.04097	4.57	1.75	6.32	
20	1	20	125	110.00	110	7.4	0.606	0.556	5.054	0.03376	3.95	1.75	5.70	
21	20	21	125	338.00	110	7.1	0.575	1.550	4.587	0.03402	3.95	1.75	5.70	
22	21	22	100	40.00	110	6.1	0.782	0.421	10.529	0.03374	3.39	3.39	6.79	
23	22	23	100	282.00	110	4.5	0.570	1.654	5.865	0.03535	4.07	1.75	5.82	
24	23	24	75	269.00	110	1.9	0.423	1.270	4.720	0.03877	4.84	1.75	6.59	
25	21	25	50	206.00	110	0.9	0.465	1.856	9.012	0.04091	3.39	3.39	6.78	
26	22	26	50	332.00	110	1.2	0.620	5.102	15.366	0.03920	3.57	1.75	5.32	
27	23	27	75	540.00	110	2.1	0.472	3.117	5.772	0.03815	4.92	1.75	6.67	
28	2	28	100	282.00	110	4.2	0.534	1.466	5.199	0.03570	5.57	1.75	7.32	
29	28	29	50	202.00	110	-0.1	-0.062	-0.043	-0.215	-0.05515	5.57	1.75	7.32	
30	29	30	50	358.00	110	1.0	0.529	4.108	11.476	0.04012	5.42	1.75	7.17	
31	30	31	50	250.00	110	0.6	0.292	0.951	3.805	0.04383	6.07	1.75	7.82	
32	28	32	100	499.00	110	4.4	0.558	2.815	5.642	0.03546	5.86	1.75	7.61	
33	32	33	100	402.00	110	3.3	0.419	1.335	3.321	0.03700	5.86	1.75	7.61	
34	33	34	75	283.00	110	2.4	0.553	2.194	7.754	0.03726	5.81	1.75	7.56	
35	34	35	50	328.00	110	0.8	0.406	2.298	7.006	0.04174	5.65	1.75	7.40	
36	18	16	50	516.00	110	0.6	0.324	2.385	4.621	0.04315	4.17	1.75	5.92	
37	24	29	50	98.00	110	1.2	0.591	1.380	14.085	0.03947	5.06	1.75	6.81	
38	5	32	50	416.00	110	-0.3	-0.165	-0.553	-1.330	-0.04767	5.86	1.75	7.61	
39	9	34	50	297.00	110	-1.7	-0.841	-8.030	-27.038	-0.03746	5.65	1.75	7.40	
40	27	30	50	182.00	110	1.4	0.715	3.642	20.010	0.03838	5.42	1.75	7.17	
合計				10990.00										



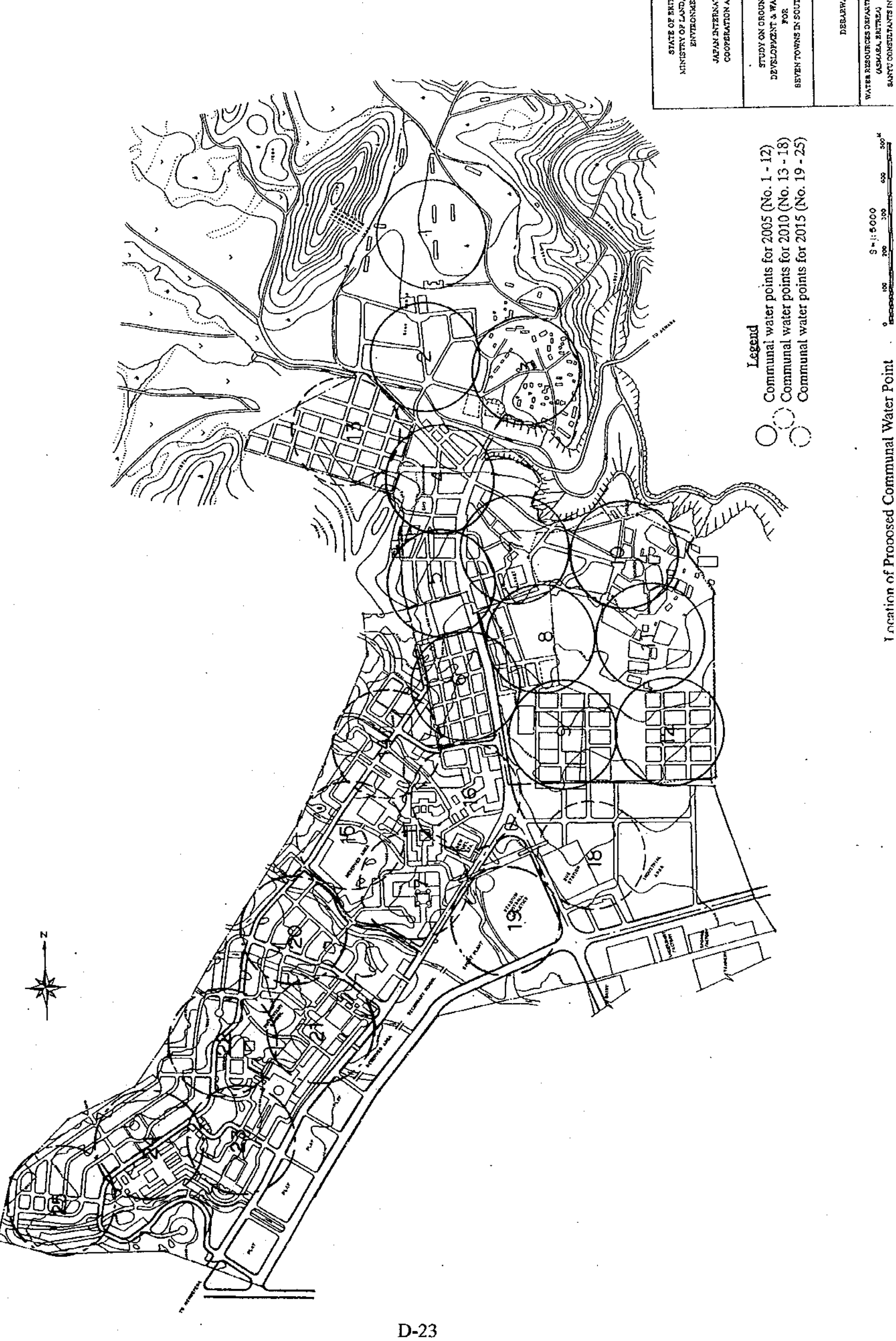
S = 1:5000

0 100 200 300 400 500 M

Supplied Points and Its Area

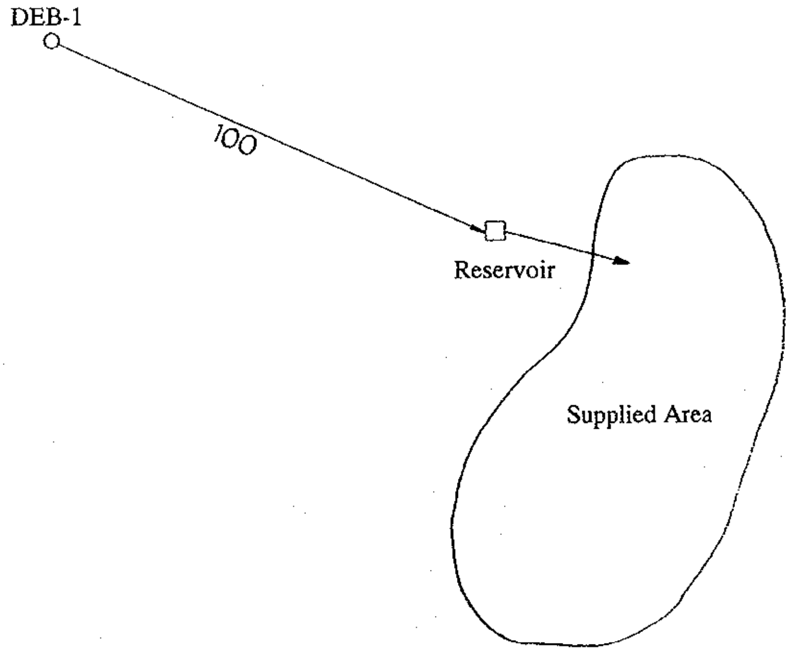
STATE OF ERITREA MINISTRY OF LAND, WATER & ENVIRONMENT JAPAN INTERNATIONAL COOPERATION AGENCY	
STUDY ON GROUNDWATER DEVELOPMENT & WATER SUPPLY FOR SEVEN TOWNS IN SOUTHERN REGION	
DEBARWA Scale 1:5,000	
WATER RESOURCES DEPARTMENT (ASMARA, ERITREA) SANYU CONSULTANTS INC. (JAPAN)	Drawing No.

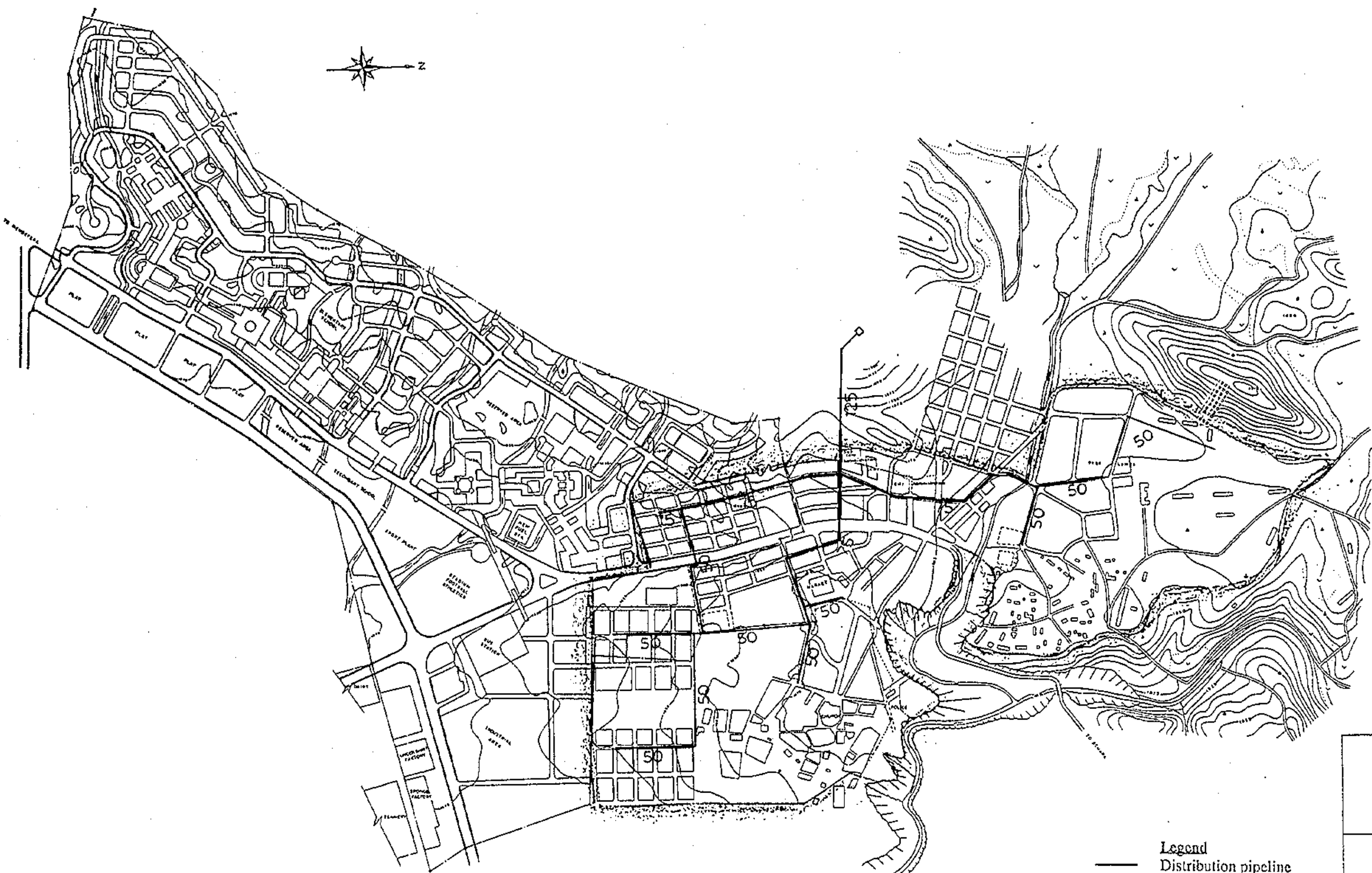
2.7 Location of Proposed Communal Water Point



2.8 Plan of Water Source and Transmission Pipeline (2005)

Debarwa





Legend

———	Distribution pipeline
100	Pipe Diameter (mm)

Plan of Distribution Pipeline (2005)

S = 1:5000

0 100 200 300 400 500 m

STATE OF ERITREA
MINISTRY OF LAND, WATER & ENVIRONMENT

JAPAN INTERNATIONAL COOPERATION AGENCY

STUDY ON GROUNDWATER DEVELOPMENT & WATER SUPPLY FOR SEVEN TOWNS IN SOUTHERN REGION

2005

DEBARWA

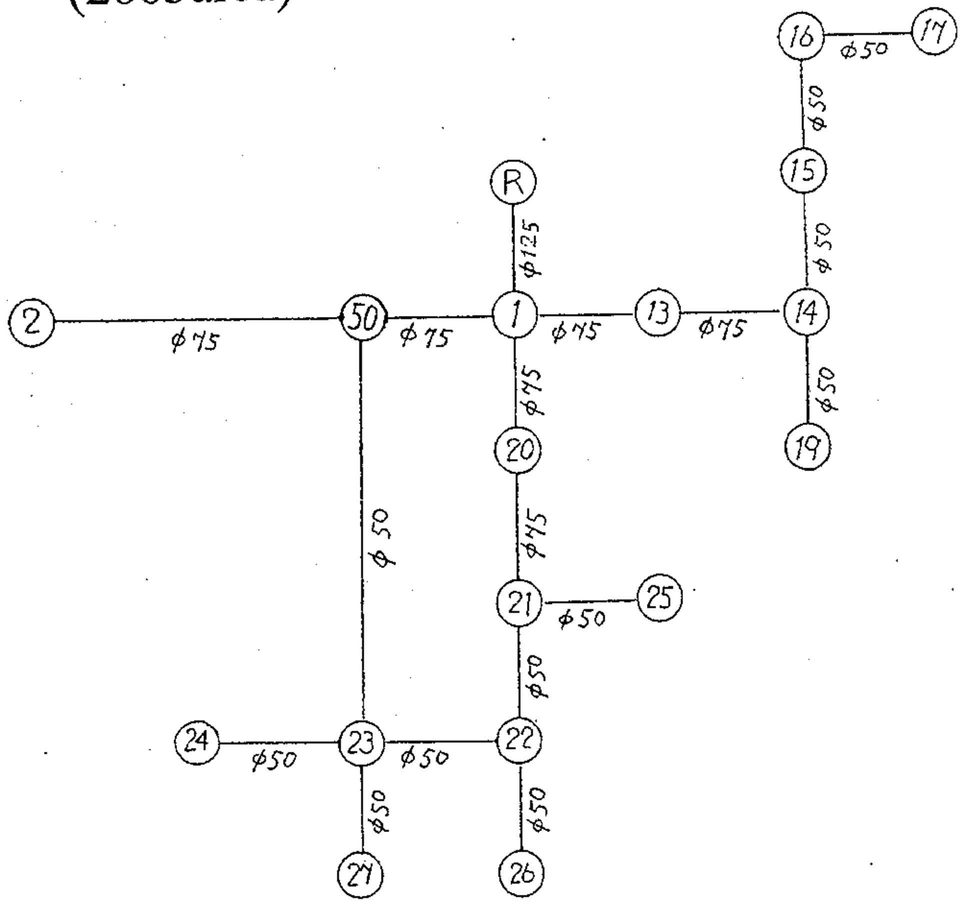
Scale 1:5,000

WATER RESOURCES DEPARTMENT (ASMARA, ERITREA)
SANYU CONSULTANTS INC. (JAPAN)

Drawing No.

Calculation of Pipe Networks

DEBARWA 2010 (2005area)



Node No.	Dynamic (WL.m)	Ground Elevation (EL.m)	Effective Head (m)	Area (ha)	Outflow Quantitiy (L/sec)
0	1903.000	1904.000	-1.000	-102.20	-8.19
1	1900.798	1867.400	33.398	0.00	0.00
13	1897.432	1865.600	31.832	4.70	0.38
14	1894.607	1859.000	35.607	0.00	0.00
15	1887.682	1859.000	28.682	11.50	0.92
16	1885.662	1862.000	23.662	0.00	0.00
17	1881.338	1863.000	18.338	13.90	1.11
50	1898.990	1858.000	40.990	0.00	0.00
23	1893.899	1863.000	30.899	5.90	0.47
22	1894.630	1869.900	24.730	5.00	0.40
21	1896.111	1869.800	26.311	0.00	0.00
20	1899.425	1864.300	35.125	4.70	0.38
24	1892.671	1855.300	37.371	7.90	0.63
27	1891.598	1854.500	37.098	7.60	0.61
26	1890.475	1868.000	22.475	13.60	1.09
25	1894.600	1870.500	24.100	10.20	0.82
19	1892.044	1858.000	34.044	10.10	0.81
2	1898.928	1852.500	46.428	7.10	0.57

Pipe line No.	Node No. From	Node No. To	Dia. (mm)	Length (m)	Flow Coefficient	Flow (L/sec)	velocity (m/sec)	Loss of Head (m)	Hydraulic Gradient (m/1000m)	Head Loss Coefficient	Hydrostatic Head	Water Hummer Head	Design Pressure (kg/sq.cm)	Pipe Material
1	0	1	125	365.00	110	8.2	0.666	2.202	6.034	0.03329	3.64	1.75	5.39	
2	1	13	75	260.00	110	3.2	0.729	3.366	12.945	0.03576	3.81	1.75	5.56	
3	13	14	75	275.00	110	2.8	0.644	2.825	10.273	0.03643	4.47	1.75	6.22	
4	14	15	50	174.00	110	2.0	1.036	6.924	39.795	0.03632	4.47	1.75	6.22	
5	15	16	50	155.00	110	1.1	0.567	2.020	13.034	0.03972	4.47	1.75	6.22	
6	16	17	50	332.00	110	1.1	0.567	4.324	13.023	0.03972	4.17	1.75	5.92	
7	1	50	75	410.00	110	1.8	0.408	1.808	4.409	0.03898	4.57	1.75	6.32	
8	50	23	50	316.00	110	1.2	0.636	5.091	16.110	0.03905	4.57	1.75	6.32	
9	23	22	50	282.00	110	-0.5	-0.237	-0.731	-2.593	-0.04519	4.07	1.75	5.82	
10	22	21	50	40.00	110	-2.0	-0.996	-1.480	-37.012	-0.03653	3.39	3.39	6.78	
11	21	20	75	338.00	110	-2.8	-0.628	-3.314	-9.805	-0.03657	3.94	1.75	5.69	
12	20	1	75	110.00	110	-3.2	-0.715	-1.373	-12.480	-0.03587	3.94	1.75	5.69	
13	23	24	50	269.00	110	0.6	0.322	1.228	4.566	0.04319	4.84	1.75	6.59	
14	23	27	50	540.00	110	0.6	0.310	2.301	4.261	0.04343	4.92	1.75	6.67	
15	22	26	50	332.00	110	1.1	0.555	4.155	12.515	0.03984	3.57	1.75	5.32	
16	21	25	50	206.00	110	0.8	0.416	1.510	7.333	0.04159	3.39	3.39	6.78	
17	14	19	50	355.00	110	0.8	0.412	2.563	7.220	0.04164	4.57	1.75	6.32	
18	50	2	75	120.00	110	0.6	0.128	0.062	0.519	0.04626	5.12	1.75	6.87	
合計				4879.00										

2.9 Target Years for Pipeline

The pipe diameters of the transmission line and main distribution line are enlarged to meet the water demand in the target year. The diameter of the various case and target year calculated and shown in this tables and figures.

1) Transmission Pipeline

The table A was estimated the following conditions.

(a) Pipelines shown in the table are adopted that wells connected this pipelines have enough capacity to cover the future water demand or additional wells are planned to be connected to this pipelines.

(b) Pipe diameter is determined according to the pump operation hour and the water demand of each target year.

(c) Pipe diameter is also selected to consider the minimum velocity and the future water demand.

(d) Life times are 50 years in pipeline and 15 years in pump.

(e) The sum per year consists of the pipeline construction cost, pump installation cost and these operation and maintenance cost.

- Debarwa

The case of pipe diameter of 100mm and 24hr pump operation of the target year 2005 is not cheapest in the target year 2005, but it is the same diameter of the target year 2010 and is economical in the target year 2010. This case must be planned a new pipe at the target year 2015 because the pipe diameter of 100mm can not be enough to cover the water demand of the target year 2015.

- Adiquala

The case of All Ex. & Intake that is pipe diameter of 100mm and 24hr pump operation of the target year 2005 is economical in the target year 2005, and it is the same diameter of the target year 2010 and 2015. The reason is that this case is not necessary of the booster pump.

The case of nADQ-1 that is pipe diameter of 125mm and 24hr pump operation in the target year 2010 is the same mentioned above.

- Dekemhare

Case- II of the target year 2005 is economical in the target year 2005, and it is the same diameter of the target year 2010 and 2015. The difference is only the booster pumps.

- Segeneiti

The case of pipe diameter of 100mm and 24hr pump operation of the target year 2005 is economical in the target year 2005, and it is the same diameter of the target year 2010 and 2015. The difference is only the booster pumps.

- Adi Keyih

  The case of ADI-2 that is pipe diameter of 100mm of the target year 2005 is can be used the water demand of the target year 2010 and 2015.

  Case II of DW-2 and BH-7 of the target year 2005 is not economical in the target year 2005, but it is the same diameter of the target year 2010 and 2015.

As mentioned above, the diameters of the transmission pipeline planned for the water demand of the target year 2010 are economical to use the water demand of the target year 2005 totally.

2) Main Distribution Pipeline

The table B was estimated the following conditions.

(f) Pipe diameter is determined according to the water demand of each target year.

(g) Pipe length is restricted within the are of the target year of 2005.

This table shows that the pipe diameters are enlarged according to the water demand, and its cost is also increased 22.2% in 2010 and 43.5% in 2015 against the target year 2005 on the average.

Therefore, the diameters of the transmission pipeline and main distribution pipeline are planned for the water demand in the target year 2010 under the project. The transmission pipeline and main distribution pipeline in the target year 2015 will be equipped with another one line to meet the water demand in the target year 2015. The reasons to employ these diameters are a) it is difficult to expand the facilities to meet the water demand, b) the facilities covering the water demand in the target year 2010 is nearly 20 % increase from those in 2005, and is cheaper than construction of another one line (refer to Appendix D), c) the facilities covering water demand in the final target year 2015 are nearly 40 % increase from those in 2005, and the final future plan is still unclear at present.

Table A Transmission Pipeline

Name of Town	Well No.	Pipelines Diameter	60	80	100	125	150	200	Total Length	Cost	Cost/Year	Pumps Well Pump		Booster Pump		Cost/Year	O&M cost	Total Cost	
		Unit Price	442.41	521.87	583.63	645.92	661.27	806.43	(m)	(Nkf)	(Nkf)	Cost (Nkf)	(Kw)	Cost (Nkf)	(Kw)	(Nkf)	(Nkf)	(Nkf)	(%)
Debarwa																			
2005	DEB-1	24 ope.	0	690	0	0			690	360,090	7,202	148,693	7.5			9,913	39,420	56,535	100.0
	DEB-1	24 ope.	0	0	690	0			690	402,705	8,054	148,693	7.5			9,913	39,420	57,387	101.5
	DEB-1	18 ope.	0	0	690	0			690	402,705	8,054	149,864	7.5			9,991	39,420	57,465	101.6
2010	DEB-1	Single	0	0	690	0			690	402,705	8,054	151,193	11.0			10,080	57,816	75,950	134.3
	DEB-1	Addition	0	1,380	0	0			1,380	720,181	14,404	285,364	15.0			19,024	78,840	112,268	198.6
	DEB-1	Double	0	1,380	0	0			1,380	720,181	14,404	289,257	15.0			19,284	78,840	112,527	199.0
2015	DEB-1	Single	0	0	0	690			690	445,685	8,914	176,838	15.0			11,789	78,840	99,543	176.1
	DEB-1	Addition	0	0	1,380	0			1,380	805,409	16,108	299,728	15.0			19,982	78,840	114,930	203.3
	DEB-1	Double	0	2,070	0	0			2,070	1,080,271	21,605	433,885	22.5			28,926	118,260	168,791	298.6
Adiquala																			
2005	All Ex.	24 ope.		2,851					2,851	1,487,851	29,757	149,864	7.5	82,104	11.0	15,465	97,236	142,458	100.0
	All Ex.	24 ope.			2,851				2,851	1,663,929	33,279	172,851	11.0			11,523	57,816	102,618	72.0
	All Ex.	18 ope.			2,851				2,851	1,663,929	33,279	151,193	11.0	108,380	11.0	17,305	115,632	166,215	116.7
2010	All Ex.	24 ope.			2,851				2,851	1,663,929	33,279	172,851	11.0			11,523	57,816	102,618	72.0
2015	All Ex.	24 ope.			2,851				2,851	1,663,929	33,279	172,851	11.0			11,523	57,816	102,618	72.0
2010	nADQ-1	24 ope.		5,100					5,100	2,661,537	53,231	100,913	1.5	364,566	44.0	31,032	239,148	323,411	100.0
	nADQ-1	24 ope.		100	5,000	0			5,100	2,970,337	59,407	100,913	1.5	358,053	30.0	30,598	165,564	255,568	79.0
	nADQ-1	18 ope.		5,100					5,100	2,661,537	53,231	144,628	7.5	420,797	60.0	37,695	354,780	445,706	137.8
2015	nADQ-1	24 ope.		100		5,000			5,100	3,261,787	65,636	100,913	1.5	460,302	74.0	37,414	396,828	499,878	154.6
Dekemhare																			
2005	BH-14,DEK-1,DEK-2	Case-1		628	948	2,250	3,941		7,767	4,940,401	98,808	397,811	17.2	177,285	18.5	38,340	187,639	324,787	100.0
	BH-14,DEK-1,DEK-2	Case-2		628	948			6,191	7,767	5,873,624	117,472	360,297	11.4	134,516	15.0	32,988	138,758	289,218	89.0
2010	BH-14,DEK-1,DEK-2			628	948	0	0	6,191	7,767	5,873,624	117,472	390,135	15.2	217,629	30.0	40,518	237,571	395,561	121.8
2015	BH-14,DEK-1,DEK-2			628	948	0	0	6,191	7,767	5,873,624	117,472	390,135	15.2	217,629	30.0	40,518	237,571	395,561	121.8
Segeneiti																			
2005	SEG-2	24 ope.		5,253					5,253	2,741,383	54,828	159,909	7.5	177,138	16.5	22,470	126,144	203,441	100.0
	SEG-2	24 ope.		1,085	4,168				5,253	2,998,799	59,976	159,909	7.5	91,142	11.0	16,737	97,236	173,949	85.5
	SEG-2	18 ope.		1,085	4,168				5,253	2,998,799	59,976	167,297	11.0	186,651	22.0	23,596	173,448	257,020	126.3
2010	SEG-2	24 ope.	0	1,085	4,168				5,253	2,998,799	59,976	152,095	11.0	184,467	18.5	22,437	155,052	237,465	116.7
2015	SEG-2	Single	0	1,085	4,168				5,253	2,998,799	59,976	176,838	11.0	196,341	22.5	24,879	176,076	260,931	128.3
Adi Keyih																			
2005	ADI-2				2,853				2,853	1,665,096	33,302	167,297	11.0	103,123	15.0	18,028	136,656	187,986	100.0
2010	ADI-2	24 ope.			2,853				2,853	1,665,096	33,302	172,851	11.0	103,883	15.0	18,449	136,656	188,407	100.2
2015	ADI-2	24 ope.			2,853				2,853	1,665,096	33,302	172,851	11.0	103,883	15.0	18,449	136,656	188,407	100.2
2005	DW-2,BH-7	Case-1	2,105	928					3,033	1,415,568	28,311	211,795	5.2	82,104	5.5	19,593	56,239	104,144	100.0
		Case-2	343	1,772	918				3,033	1,612,273	32,245	211,748	5.2	82,104	5.5	19,590	56,239	108,075	103.8
2010	DW-2,BH-7		343	1,772	918				3,033	1,612,273	32,245	211,795	5.2	85,997	11.0	19,853	85,147	137,245	131.8
2015	DW-2,BH-7		343	1,772	918				3,033	1,612,273	32,245	211,795	5.2	85,997	11.0	19,853	85,147	137,245	131.8

Table B　　Distribution Pipeline

Pipe Diameter		(mm)	50	75	100	125	150	200	250	300	Total	
Unit Price		(Nkf)	133.75	183.28	229.77	274.61	365.34	625.80	926.50	1,119.32	(Nkf)	(%)
Debarwa												
2005	Length	(m)	3,531	983	365						4,879	
	Cost	(Nkf)	472,271	180,164	83,866	0	0	0	0	0	736,302	100.0
2010	Length	(m)	3,001	1,513		365					4,879	
	Cost	(Nkf)	401,384	277,303	0	100,233	0	0	0	0	778,919	105.8
2015	Length	(m)	1,696	1,258	582	978	365				4,879	
	Cost	(Nkf)	226,840	230,566	133,726	268,569	133,349	0	0	0	993,050	134.9
Mendefera												
2005	Length	(m)	1,510	2,417	510	419	883				5,739	
	Cost	(Nkf)	201,963	442,988	117,183	115,062	322,595	0	0	0	1,199,790	100.0
2010	Length	(m)	389	1,114	454	1,970	832	980			5,739	
	Cost	(Nkf)	52,029	204,174	104,316	540,982	303,963	613,284	0	0	1,818,747	151.6
2015	Length	(m)	291	1,212	172	2,252	832	97	883		5,739	
	Cost	(Nkf)	38,921	222,135	39,520	618,422	303,963	60,703	818,100	0	2,101,764	175.2
Adiquala												
2005	Length	(m)	1,194	1,326	212	15					2,747	
	Cost	(Nkf)	159,698	243,029	48,711	4,119	0	0	0	0	455,557	100.0
2010	Length	(m)	1,194	1,326	212	15					2,747	
	Cost	(Nkf)	159,698	243,029	48,711	4,119	0	0	0	0	455,557	100.0
2015	Length	(m)	1,194	1,326	212	0	15				2,747	
	Cost	(Nkf)	159,698	243,029	48,711	0	5,480	0	0	0	456,918	100.3
Dekemhare												
2005	Length	(m)	1,485	2,901	2,133	630	205	133			7,487	
	Cost	(Nkf)	198,619	531,695	490,099	173,004	74,895	83,231	0	0	1,551,544	100.0
2010	Length	(m)	849	1,275	2,599	1,486	940	205	133		7,487	
	Cost	(Nkf)	113,554	233,682	597,172	408,070	343,420	128,289	123,225	0	1,947,412	125.5
2015	Length	(m)	647	1,191	1,447	774	1,884	1,206	134	204	7,487	
	Cost	(Nkf)	86,536	218,286	332,477	212,548	688,301	754,715	124,151	228,341	2,645,356	170.5
Segeneiti												
2005	Length	(m)	2,008	1,186		531					3,725	
	Cost	(Nkf)	268,570	217,370	0	145,818	0	0	0	0	631,758	100.0
2010	Length	(m)	2,008	954	232	531					3,725	
	Cost	(Nkf)	268,570	174,849	53,307	145,818	0	0	0	0	642,544	101.7
2015	Length	(m)	2,008	954	232	531					3,725	
	Cost	(Nkf)	268,570	174,849	53,307	145,818	0	0	0	0	642,544	101.7
Adi Keyih												
2005	Length	(m)		1,134	983	584	859				3,560	
	Cost	(Nkf)	0	207,840	225,864	160,372	313,827	0	0	0	907,903	100.0
2010	Length	(m)	0	776	844	1,081	216	643			3,560	
	Cost	(Nkf)	0	142,225	193,926	296,853	78,913	402,389	0	0	1,114,307	122.7
2015	Length	(m)	0	776	486	1,439	216	643			3,560	
	Cost	(Nkf)	0	142,225	111,668	395,164	78,913	402,389	0	0	1,130,360	124.5
Senafe												
2005	Length	(m)	1,216	1,356	632	198	120				3,522	
	Cost	(Nkf)	162,640	248,528	145,215	54,373	43,841	0	0	0	654,596	100.0
2010	Length	(m)	906	774	1,270	254	318				3,522	
	Cost	(Nkf)	121,178	141,859	291,808	69,751	116,178	0	0	0	740,773	113.2
2015	Length	(m)	616	747	1,105	586	348	120			3,522	
	Cost	(Nkf)	82,390	136,910	253,896	160,921	127,138	75,096	0	0	836,352	127.8
Total Length		(m)	25,743	26,499	14,682	14,639	8,033	4,027	1,150	204	94,977	
Tatao Cost	2005	(Nkf)									6,137,449	100.0
	2010	(Nkf)									7,498,259	122.2
	2015	(Nkf)									8,806,343	143.5