CHAPTER 4 CURRENT SITUATION

4.1 Natural Condition

4.1.1 Topography, Geology and Hydrogeology

(1) Topography

Figure 4.1.1 shows a topography near around Adi Keyih town. The topo-map is extracted from the topo sheet made by USSR in 1977, and the aerial photos of the base of the mapping is farther old as said as in 40s. Although the topo-map does not show the extension of the town because of its age, the town area extends widely on the top of high and very flat plateau now a day. Elevation of the town area is around 2,400m (by the topo-map), the highest among the 7 towns of the study target.

Characteristic of the area, in the topographical feature, is N-S trending several rows of plateaux with quite flat surface. Originally it must be a vast flat plateau but dissected by several streams and separated into several individual blocks. Thus, those plateaux are surrounded by quite steep, almost vertical escarpments, and the streams are carving deep gorges in between those plateaux. While, a top of each plateau is usually flat or very gently undulated. Among the dissecting streams, ones flow north or east are finally pouring into the Red Sea, and the ones flow south or west are the tributaries of the Mereb.

(2) Geology

Geological map of the site is presented as Figure 4.1.2. As shown in the figure, the Adigrat sandstone forms the roofs of the plateaux. Most part of Adi Keyih town is also underlain by the sandstone. The thickness of the sandstone is several 10s of meter in the surroundings of the town. While Precambrian metamorphic rocks, mainly phyllites and chlorite schists, occur in the valleys in between the plateaux. Structural lines in N-S or NNE-SSW direction are recognized along Ruba Bur. On far south of the area, a large rock mass consisted of trachytic volcanics, intruded by some alkaline intrusives, exists showing characteristic mountain features.

Alluvial sediments may accumulate to a depth of several meters along the 2 streams of Ruba Bur and Ruba Adi Wegera. Then, at the southeast of the town, fairly wide alluvial plain called as Tekonda is extending along the tributary of Ruba Bur, showing a landscape of beautiful grassland. The alluvial sediments are derived from the metamorphic rocks, the sandstone and chlorite schists.

In and around the town, several boreholes were drilled (refer to the Well Inventory) but no lithological information can be obtained up to now concerning these boreholes.

(3) Hydrogeology

Hydrogeological situation of Adi Keyih site was arranged and presented as Hydrogeological Map, attached in the Report (Appendix-C).

Figure 4.1.1 Topographic Map -Adi Keyih-

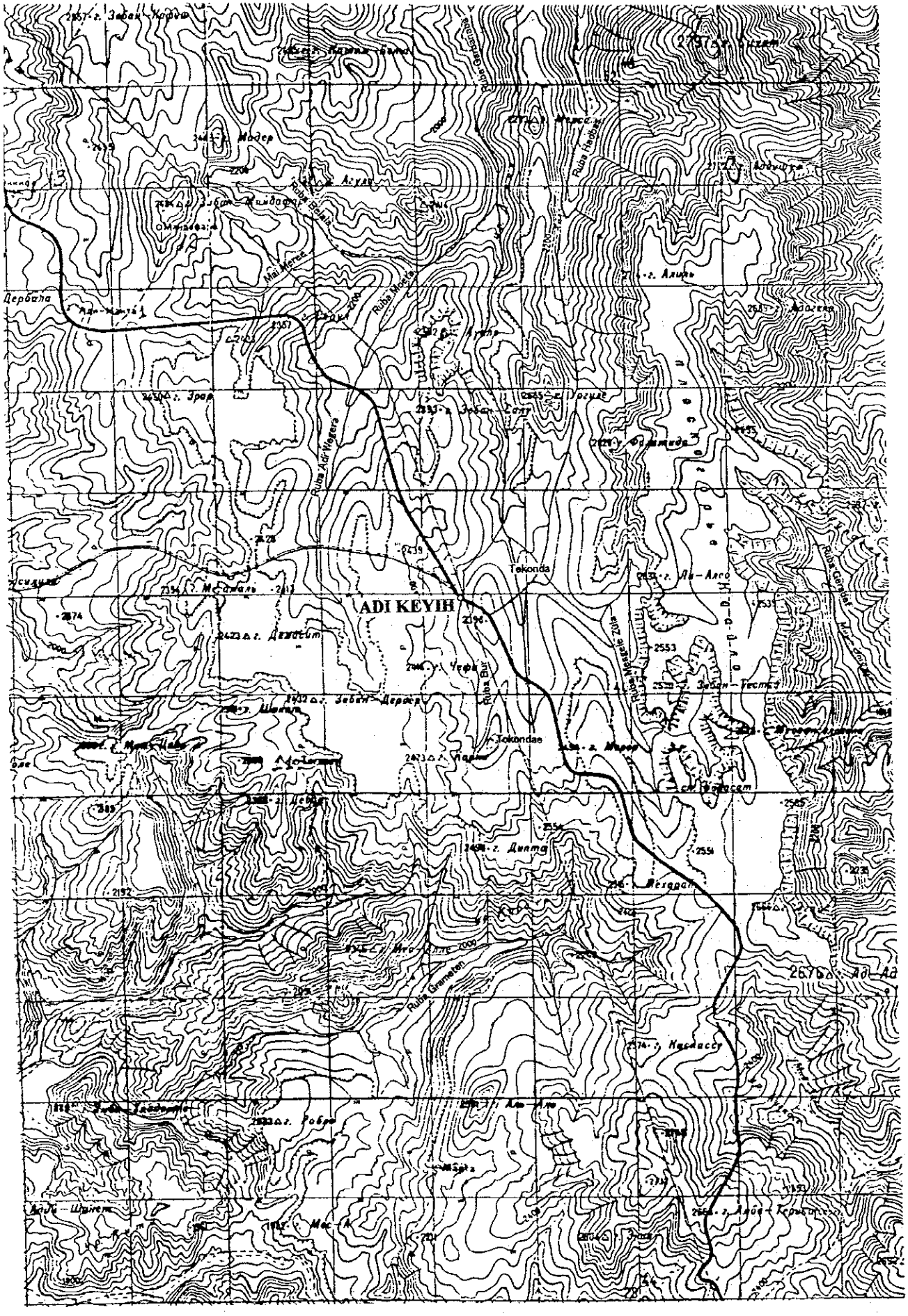
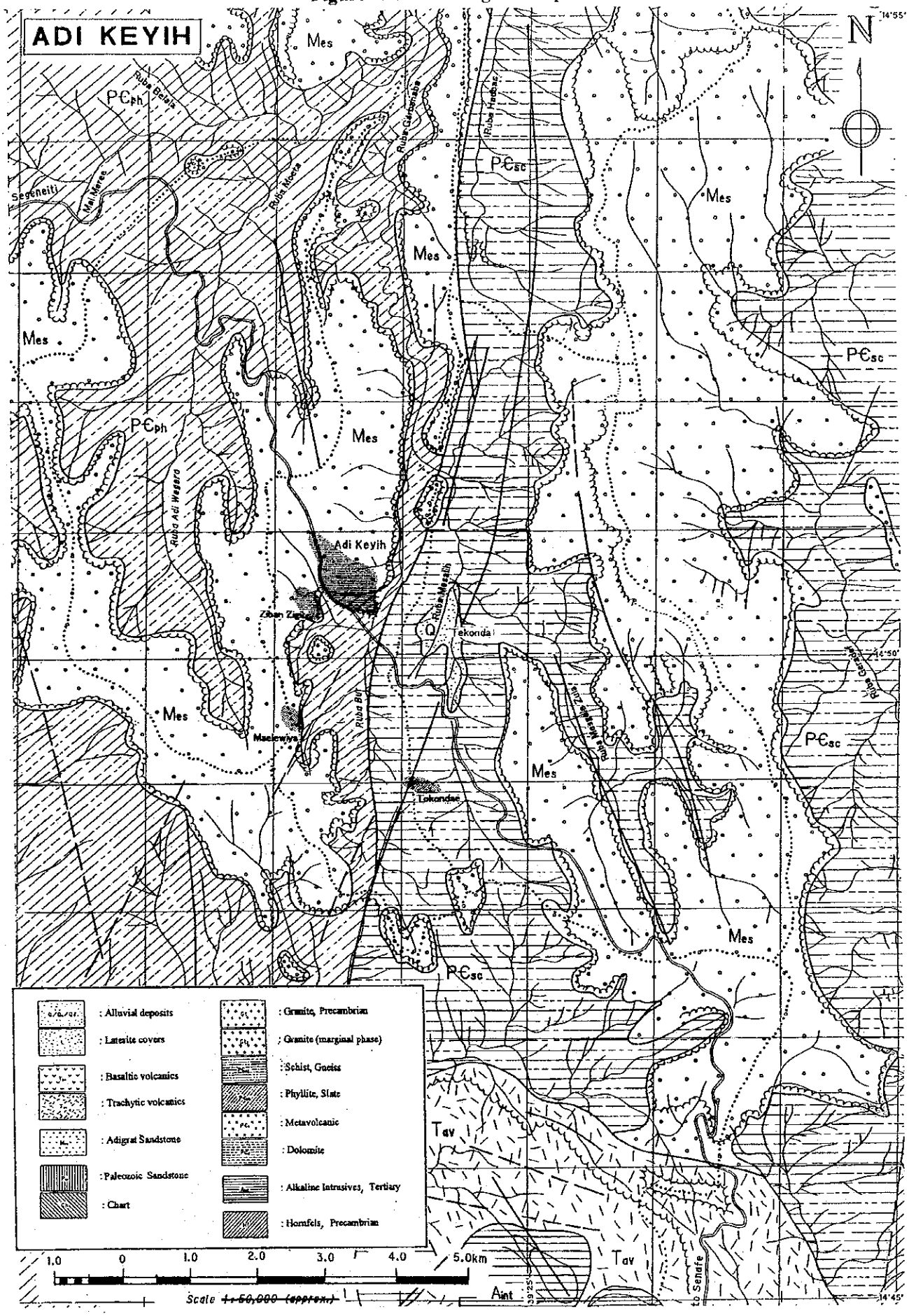


Figure 4.1.2 Geological Map



Flat tops of the plateaux in the area are forming a watershed in between the Red Sea and the Mereb catchment areas. Most of the stream dissecting the plateaux run toward north (to the Red Sea), so the main watershed passes along the southern edge of the plateaux in general. Then, every N-S tending plateaux makes a sub-watershed of each tributaries running to north. The major part of the area, including the town area, is belonging to the Red Sea catchment, while, southwestern one-third of the area belongs to the Mereb catchment from a macro view.

Almost all of the area, excepting far south of the area, is underlain by Metamorphic Basement, locally overlain by Adigrat sandstone. That means, a major aquifer in the area is to be a fissured aquifer type of the metamorphic basement, classified into a-ii, associated with a fissured aquifer of sedimentary rocks, Adigrat sandstone type: b-i. Aquifer of alluvial deposit type (d-i) is recognizable only at Tekonda but it may be combined aquifer with the basement type aquifer. As mentioned above, there is a trachytic rock mass on far south of the area, and this is, as well as the alkaline intrusives associated, categorized into an aquitard or aquiclude: AqC.

Fissured aquifer in the metamorphic basement is reported to have low groundwater productivity. However, the existing boreholes of BH-3, 4 and 5 (as the code names in the Inventory) show 1.0 to 2.0 lit/sec of yield, and the newly drilled Test Well (ADI-2) indicates more than 8.0 lit/sec of yield. Thus, the metamorphic basement aquifer in this area has a moderate water productivity in general, and rather high productivity locally. While, the fissured aquifer in Adigrat sandstone is said to have a moderate productivity ranging 2.0 - 3.0 lit/sec. However, among 5 boreholes drilled in Adigrat sandstone near around the town, 4 boreholes yield less than 1.0 lit/sec. And the fact may mean, Adigrat sandstone has a good water contain property but actual yield shall be depend upon the geological structure and recharge condition.

4.1.2 Meteorology and Hydrology

(1) Meteorology

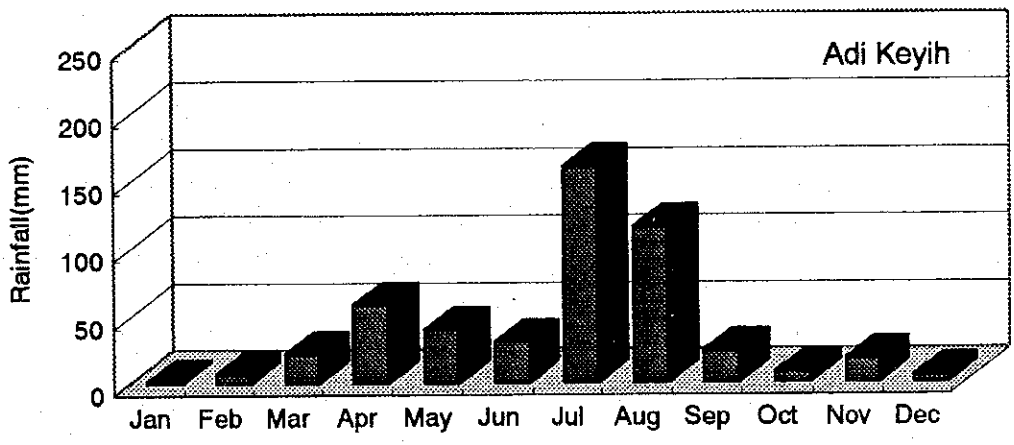
Rainfall and temperature data are collected by MOA and WRD. The annual average temperature varies between 10 and 20°C. According to the data of Mendefera, evaporation is higher in April, 7.5mm/day and low in August, about 4.6mm/day. Annual average rainfall is about 494mm and as in the other sub-regions, most of them occur during the months of July and August. The monthly rainfalls of these months are 243mm and 211mm respectively. In October 1997, an unusual pattern of rainfall was observed. The monthly total was recorded as 91.0mm, whereas, the past highest is recorded as 40mm. Average monthly values of meteorological parameters are presented in Table 4.1.1. The pattern of monthly rainfall is presented in Figure 4.1.3.

Table 4.1.1 Meteorological Data

Month	Temperature (°C)	R.H. (%)	Windspeed (m/sec)	Pan Evapo. (mm/day)	Sunshine (hr/day)	Rainfall (mm)
Jan	16.3	75	1.5	5.4	10.8	1.6
Feb	17.6	68	1.6	6.7	10.4	7.6
Mar	15.9	59	1.7	7.0	10.7	22.4
Apr	19.4	70	1.8	7.5	11.1	58.6
May	20.1	65	2.0	6.0	12.3	40.0
Jun	19.4	64	1.9	5.4	11.2	30.8
Jul	16.7	98	1.8	5.6	8.8	161.1
Aug	17.5	95	1.8	4.6	7.2	115.7
Sep	18.2	78	1.7	5.1	9.7	24.2
Oct	17.7	86	2.1	6.3	11.4	8.0
Nov	16.4	89	1.4	5.5	10.6	17.9
Dec	15.7	83	1.3	5.5	10.7	5.8
					Total	493.7

Data source: Sector Study Report (ref. FAO), MoA and WRD

Figure 4.1.3 Monthly Rainfall Pattern



(2) Hydrology

Adi Keyih does not have prominent rivers except Ruba Bur. There are about 11 micro dams in this sub-region. Among them, Ruba Bur is in the vicinity of the town and acts as very good artificial recharge source for the wells downstream of it. Tekonda is also another small dam not far from the town but only used for livestock purpose. There is another medium class dam named Hawatsu is located quite far from the town still serving as a reliable source of surface water for multipurpose uses. Nevertheless most of the micro dams are subject to dry up almost every year. A list of the existing micro dams is presented in Table 4.1.2.

Table 4.1.2 A List of Existing Micro Dams

Sl. No.	Name	Const. Year	Agency	Capacity (cum)	Remarks
1	Ruba-Bur	1986	Cath. Sec.	236,570	Silted
2	Tekonda	1985	Cath. Sec.	102,000	Silted
3	Hawatsu	1986	LWF	350,000	Silted
4	Adi Wegera	1986	MOA	220,000	DM.
5	Ma Arda	1984	MOA	68,840	H.S.
6	Dera	1992	MOA	11,325	RGC
7	Samdy	1992	MOA	20,900	Silted
8	Hadish Adi	1992	MOA	13,460	Silted
9	Halai	1994	MOA	18,370	Silted
10	Ziban Zigib	1992	MOA	150,000	DM
11	One Cab	1996	MOA	205,000	DM

Source: MOA,
H.S.: Highly silted, RGC: Relatively good condition, DM: Damaged,
LWF: Lutherian World Federation

4.1.3 Hydrogeological Investigation and Groundwater Monitoring

(1) Hydrogeological investigation

To identify the water resources available for each target township, to evaluate the potential of those water resources, and to obtain basic data needed to formulate a water resources development plan, a series of hydrogeological surveys were conducted. To minimize the survey period and to maximize the outputs of the survey, the hydrogeological survey must be conducted systematically, from the wider area to the local; extensive to intensive; and general to special. Thus, the hydrogeological surveys in this Study flew as follows:

1) Regional geological study:

To grasp the geological conditions/structures of the area and to select the following geophysical prospecting site(s), through a review of existing data/information, aerial-photo interpretation, and an actual field reconnaissance survey.

2) Geophysical prospecting:

To analyze the resistivity structure of the ground and interpret the geological/hydrogeological relations, to select the most suitable drilling point for test or observation well(s), through VLF-EM, horizontal geoelectric sounding (HS), and/or vertical geoelectric sounding (VES).

3) Test well drilling:

To obtain exact geological/hydrogeological information of the site and to know the aquifer potential through well drilling, borehole logging, pumping test, and water quality analysis. Further, to get data on time-series groundwater level fluctuations through setting automatic water level recorders into the wells.

4) Total analysis:

To analyze the geological and hydrogeological conditions of the target areas, to identify the

available and suitable water resources, and to evaluate their resource potential for long-term development, through comprehensive analysis, examination and consideration of the results of the above mentioned field surveys.

The details and results of each investigation work were already reported as "Field Investigation Report", as a separated volume of the Interim Report, and quite roughly but the work volumes and results of them are summarized and presented in Appendix-C, excepting the parts explained in the following clauses.

(2) Groundwater monitoring

After completion of the Test Well drillings, an automatic water level recorder was installed in ADI-2. The measurement of water level in the wells was commenced on March 8, but the measurements were disturbed soon, through a trouble of mechanical parts. A spool axle was broken, supposedly by high temperature, so that the chart was not winded. The malfunction was found out recently, and the spool axle was repaired temporary. Thus, it is functioning now but the data since the beginning up to the time were not available.

4.1.4 Water Resources

(1) Existing water resources

Many boreholes and dug wells exist on the top of Adi Keyih plateau and along Ruba Bur. All of existing wells, both boreholes and dug-wells, were checked and arranged into Well Inventory associated with their location map. These are attached in Appendix-C, and only a copy of the location map is presented here as Figure 4.1.4. As the Inventory said, and as shown in the figure, there are 10 wells in total, 2 of dug-wells and 8 of boreholes.

Current public water sources of the town are those: one of dug-wells (DW-2) and three boreholes of BH-3, 4 and 7. Among those, the dug-well and two boreholes (BH-3 and 4) are located along Ruba Bur, and the last one (BH-7) situates on the top of plateau, inside of the town. Groundwater in those sources are utilized through a mechanical pump, some are submersible and some are borehole pump.

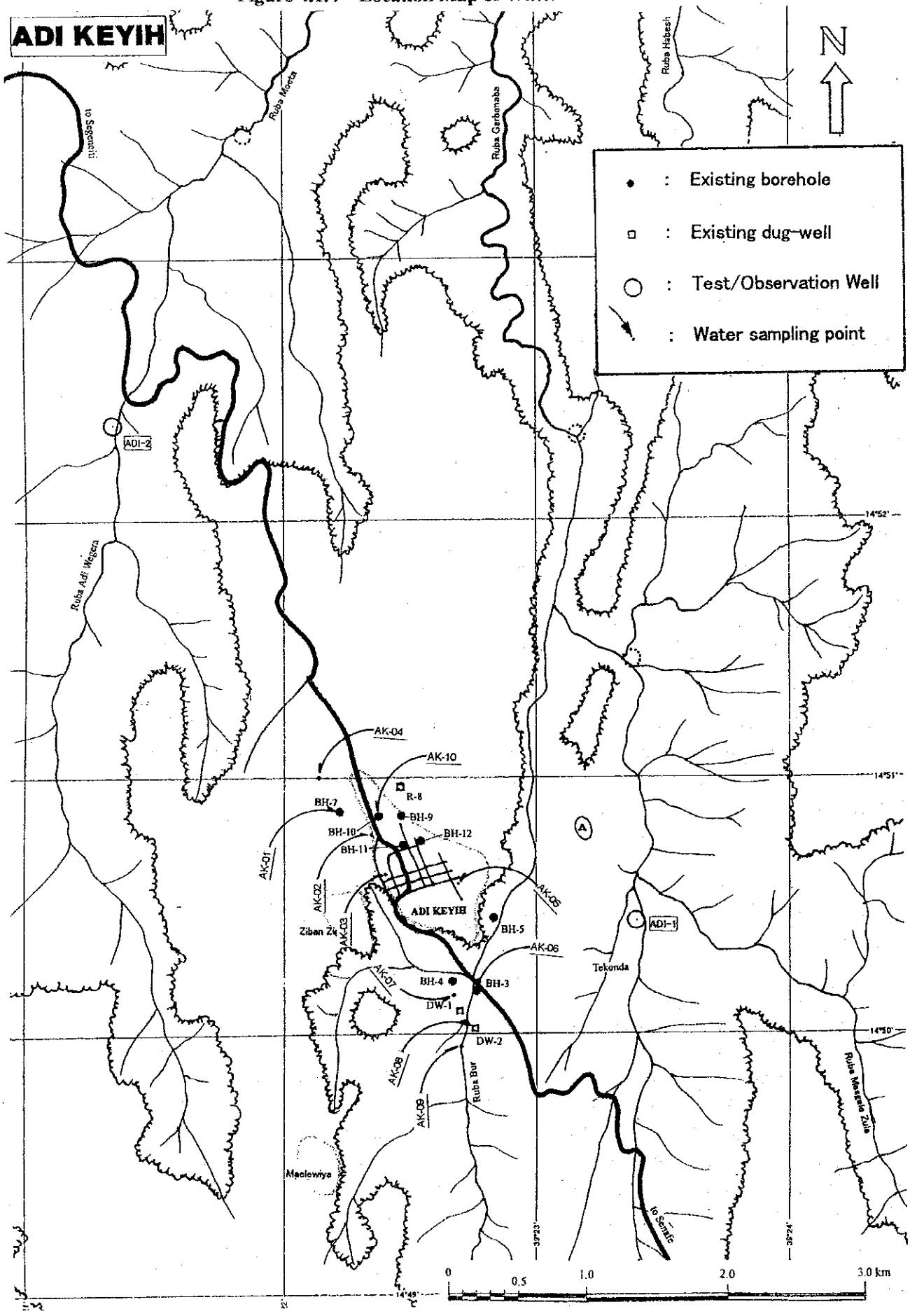
Besides those current public water sources, one dug-well (DW-1) is out of use now, and one borehole (BH-5) is capped. This borehole was de-capped and pump-tested to know the yield under the Study. Remaining 4 boreholes (BH-9 to 12) are equipped with a hand-pump and utilized for mainly domestic water use.

(2) Test wells

For Adi Keyih town, two Test Wells were drilled, named ADI-1 and ADI-2.

ADI-1 was drilled in the grassland called as Tekonda, around 1.0km west of the town. While, ADI-2 was drilled at Adi Wegera valley, fairly far from the town area around 3.5km in northern direction (referred to Figure 4.1.4). They were planned to drill up to 60m depth but resulted depths were 30 and 40m for ADI-1 and 2, respectively. Total results of the drilling are presented in Appendix, and lithological conditions of them are roughly explained bellow:

Figure 4.1.4 Location Map of Water Resources



ADI-1

0 – 5.0m	Top soil, clayey, including fine to coarse gravel, brown.
5.0 – 8.0m	Pelitic Schist, weathered, including Qz grain, light brown.
8.0 – 11.0m	Pelitic Schist, heavily weathered into coarse sand like, including Qz fragments, dark brown.
11.0 – 14.0m	Pelitic Schist, slightly weathered, crack rich, Qz fragments included, dark gray.
14.0 – 30.0m	Graphite Schist, coarse matrix, crack rich, including thin Qz veins, locally sheared, black.

ADI-2

0 – 2.0m	Top soil, clayey, light brown.
2.0 – 5.0m	Sand, residual coarse sands weathered from schist, brown.
5.0 – 17.0m	Siliceous Schist, weekly weathered, coarse matrix, crack rich but hard, brownish gray.
17.0 – 18.0m	Quartz vein, white.
18.0 – 36.0m	Siliceous Schist, weekly weathered to fresh, hard, gray to bluish gray.
36.0 – 40.0m	Alternation of Siliceous Schist and Qz Veins, white and gray.

ADI-1 was drilled at extremely low resistivity zone from mainly geological and mineralogical interests (please refer to Field Investigation Report associated in Interim Report), and the drilling revealed such quite low resistivity material was Graphite Schist. In the same time, the drilling fetched not much but meaningful amount of fresh groundwater yield (1.0 lit/sec), nevertheless such low resistivity. In this borehole, groundwater was contained mainly in the upper weathered pelitic schist, so that the screen was installed at the span from 9.0 to 21.0m. A series of pumping was conducted and the constant discharge test under 1.2 lit/sec of pumping rate indicated around 26.9 m^2/day of Transmissivity.

In the borehole of ADI-2, groundwater table was detected at very shallow depth of only 1.0m. Then, the groundwater yield was gradually increased through the drilling progress, and a significant yield of 4.0 lit/sec was obtained at the depth of 15.0m. Lower span than the depth also contained some water, therefore, the screen was set from 10.0 to 25.0m in depth. Through the step draw-down test, the maximum yield of 16.0 lit/sec was obtained, however, the optimum rate for long period pumping was decided as 7.0 lit/sec. Continuously, the constant discharge test at the pumping rate of 7.0 lit/sec was conducted for 48 hours, and the test showed its transmissivity of 77.2 m^2/day.

One of the existing boreholes, BH-5 was drilled but kept capped since 1991. Under the Study, a series of pumping test was conducted in this well, to know the yield of the well and aquifer condition here, as a supplemental field survey. Through the test, around 1 lit/sec of yield and rather small 6 m^2/day of transmissivity were obtained.

4.1.5 Water Quality

In order to know the water quality of current water supply system, samples from ten points were collected, and their physical, chemical and bacteriological qualities were analyzed in the laboratory of WRD. The samples include the main source of water, vicinity of the main source, dug-well, public fountain, house connections, etc. The location of the sampling points is presented in Figure 4.1.4, together with all water sources.

It was reported that the water quality, in particular chemical properties, of this sub-region is generally good. However, the results of the analyses show that more than half of the samples inclusive of water sources, reservoir, and consumer's taps were found contaminated with *faecal coliform bacteria*. In this connection, it is noteworthy to mention that the findings of such a higher number of contaminated samples may be due to inflows of rainwater from the surrounding areas to the sample sources at/or before the time of sample collection. The results of the analysis are presented as Table 4.1.3, and arranged as Piper Diagram as shown below (Figure 4.1.5).

4.2 Socioeconomic, Water Supply and Sanitation Conditions

4.2.1 Socio-economy and Gender Issue

(1) History and population

Adi Keyih is located in the southern part of Debub Region some 2,300m above sea level. It is an ancient town and prior to Italian colonialism it used to serve as a trading center for merchants that travel as far as the hinterland of Ethiopia. It is divided into two zones the first encompassing the original village and the second made up of the rather modern part with old and dilapidated buildings. A master plan has been completed and approved and presently many buildings are being erected forcing the already inadequate town utilities to be over-stretched.

The population figure for Adi Keyih for 1997 is around 14,000 comprising of 44.0% males and 56.0% females. Data on age structure reveal that 47.3% of the population are below 14 years of age and those over 65 years only 5.4%, the remaining 47.36% are of working age group. In terms of ethnic composition, 64.0% are of Tigrigna ethnic group while that of Saho is 16.6%. An estimated 63.3% of the inhabitants profess Christianity while about 19.7% are followers of Islam.

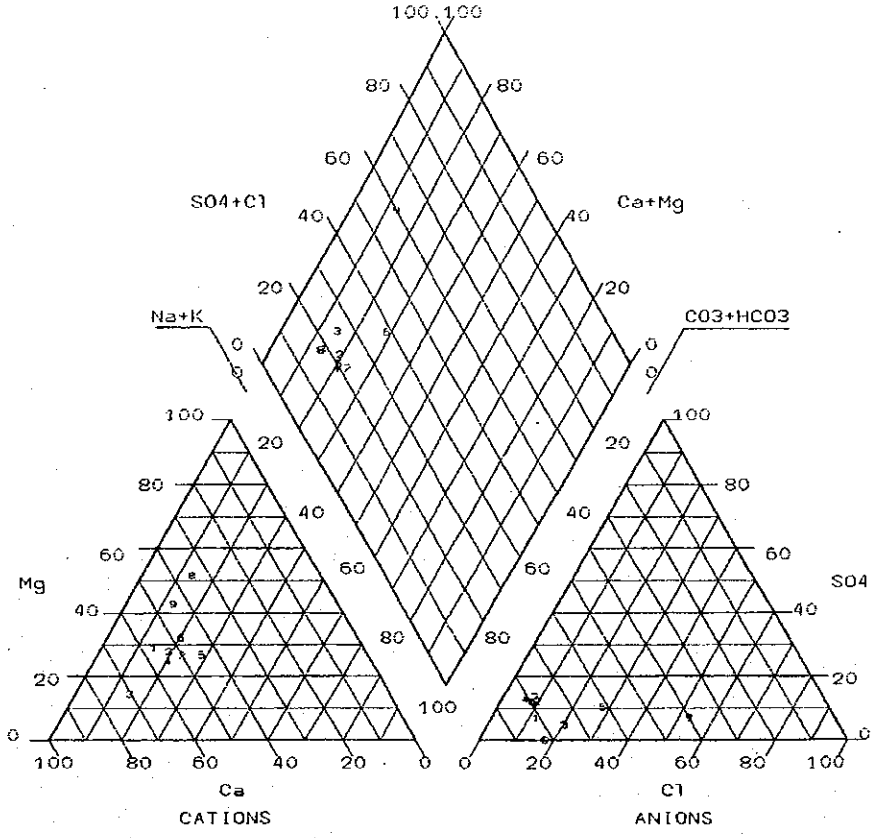
(2) Economic conditions

According to the figures provided from the town administration, the town dwellers could be classified as: 31% laborers, 14% traders and shop owners, 45.2% other workers engaged in all sorts occupation like masonry, stone quarrying, sand vendors, etc. The farming community are the original inhabitants of the town. The traders and shop owners include those who reside in the town and not those ones that live in the surrounding villages and other towns but who have shops in the town. Adi Keyih has 536 licensed micro and small-scale enterprises classified into manufacturing (64); trade and distribution (340); hotels, restaurants, tea rooms, etc. (89); service establishments (42); and others (1). Most of these are one man establishments. Market day is every Saturday and more than 30 villages (about 10,000 people) come to the market. More are reportedly coming during harvest period and holidays to sell their livestock and buy necessities. In the town, there are 18 line ministry offices and 2 non-government offices.

An estimated 52.7% of the inhabitants of the town are illiterate, and those who can read, write and have completed primary school and above are 5.1%, 2.7% and 39.2% respectively.

There are 10 educational institutions (2 kindergarten, 4 primary, 3 junior and one senior secondary school) enrolling a total of 6312 students with 121 teachers. The percentage distribution of enrollment in these levels of education amounts to 3.4%, 59.4%, 20.2% and 17.0% respectively.

Figure 4.1.5. Water Quality of Adi Keyih Area



Label	Seq.No	Sample Identification
1	1	AK-1
2	2	AK-2
3	3	AK-3
4	4	AK-4
5	5	AK-5
6	6	AK-6
7	7	AK-7
8	8	AK-8
9	9	AK-9
A	10	AK-10

I. Physical Quality

Date Sampled 27/10/97

Date Analysed 28/10/97

II. Bacteriological Quality

T.C.B = Total 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		
AK-01	BH in town,with pump	389	6.5	18.7	agreeable	agreeable	<5	clear		0		0	Safe
AK-02	Reservoir,100cu.m	225	7.2	22.3	agreeable	agreeable	<5	clear		0		0	Safe
AK-03	Public Tap in Town	367	6.2	20.4	agreeable	agreeable	<5	clear		0		0	Safe
AK-04	Consumer's Tap	379	7.0	18.3	agreeable	agreeable	<5	clear		140		89	contaminated
AK-05	Consumer's Tap	444	7.2	18.8	agreeable	agreeable	<5	clear		many		many	contaminated
AK-06	BH Near Reservoir	639	6.5	26.4	agreeable	agreeable	<5	clear		0		0	Safe
AK-07	Reservoir 360 cu.m	449	7.3	20.1	agreeable	agreeable	<5	clear		many		many	contaminated
AK-08	Shallow Well	437	6.9	24.1	agreeable	agreeable	<5	clear		many		many	contaminated
AK-09	Dam	103	7.5	22.9	agreeable	disagree	32	muddy		many		many	contaminated
AK-10	BH, Sec School	484	5.8	19.8	agreeable	agreeable	<5	clear		many		many	contaminated

III.Chemical Quality

Date Sampled 27/10/97

Date Analysed 07/11/97

Well	Description	Ca	Mg	Na	K	Fe	Mn	HCO3	SO4	Cl	NO3	N-NH3	NO2	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	*G.d.h
AK-01	BH in town,with pump	54	17	15	1.3	0.06	0.1	185	13	16	18.2	0.28	0.99	0.24	11.4
AK-02	Reservoir,100cu.m	59	19	24	1.3	0.01	0.0	215	27	16	9.7	0.03	0.00	0.39	12.7
AK-03	Public Tap in Town	64	8	15	1.3	0.02	0.0	176	9	28	17.3	0.03	0.01	0.11	10.7
AK-04	Consumer's Tap	43	21	14	1.3	0.02	0.0	171	3	28	17.3	0.00	0.06	0.18	10.9
AK-05	Consumer's Tap	62	17	26	1.3	0.02	0.1	264	34	12	5.8	0.04	0.00	0.49	12.5
AK-06	BH Near Reservoir	55	20	40	1.4	0.10	0.1	195	26	52	4.0	0.24	0.01	0.63	12.3
AK-07	Reservoir 360 cu.m	56	23	27	1.3	0.01	0.0	259	31	16	6.2	0.11	0.01	0.48	13.2
AK-08	Shallow Well	59	19	30	3.1	0.01	0.0	254	35	16	5.3	0.20	0.01	0.37	12.7
AK-09	Dam	10	9	3	2.6	0.05	0.1	63	0	8	3.5	0.12	0.01	0.12	3.5
AK-10	BH, Sec School	46	27	14	2.6	0.00	0.0	93	13	72	45.2	0.09	0.70	0.05	12.7

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

* Note:HDW = Hand dug well

BH = Borehole

(3) Social and gender issues: Analysis of the result of the survey

a) Household characteristics

The average household size for the town of the population of Adi Keyih is 5.72. Relative to the other towns, it has the highest female head of households, comprising of about 48%. The Tigrigna ethnic group and adherents of the Christian faith make up 83% of the sampled households. In terms of ethnic composition, 84% are from the Tigrina ethnic group, while 15% are Saho. The latter are mostly followers of Islam and the former Christians (Appendix A, Table 4.1).

b) Occupation

According to the survey, more than one third (35%) reported that they are unemployed. Those engaged in trade and commerce are 32%, in Government 12% and the rest in other occupation. Of the women respondents, 60% said they have no jobs and only 27% of them are employed in commerce. Those women respondents that are employed in Government offices are only 6% as compared to men who are 18%. Like the residents of the other towns, agriculture is not a main stay for the good majority of the residents of Adi Keyih (Appendix A, Table 4.2).

c) Agriculture and land

Only a small percentage of the respondent households own land for agriculture with an average size of a little less than one hectare. Overall, production of crop is minimum and except for sorghum, which they sell about 50% of production, the rest is used for personal consumption (Appendix A, Table 4.3). With regards to livestock only 7% of the respondents own livestock. On the average, a sampled household owns 4 cows/ox, 2 sheep/goats and 5 chicken (Appendix A, Table 4.4).

d) Household income and expenditure

The average income for a sample household in Adi Keyih is Nfa 877 per month. Women's income is reported to be Nfa 675. In terms of occupation by religion and ethnic background, the Saho ethnic group who comprise 15% of the population earn slightly higher income than the majority Christian Tigrigna group. The disaggregated income by occupation also indicates that commerce is the highest earner followed by others and Government. The jobless earn substantial income higher than the major economic sectors (Appendix A, Table 4.5).

The composition of the town's sample households by income group and the major items of household expenditures reveals that only less than 5% of the households earn less than Nfa 299 per month. Another 41% and 39% earn between Nfa 300-599 and 600-999 in a month. Those that reportedly earn more than Nfa 3000 per month are about 4%, a figure much higher than any of the seven towns. In terms of their expenditure pattern, the survey shows that 50% of an average household's expenditure is spent on food and beverage which when compared with the figure for the other towns is high. Monthly expenditure on water is low, but the residents' expenditure pattern on travel and culture and clothes and footwear follow a similar pattern as in the other towns (Appendix A, Table 4.6).

e) Household level of education

The education status of respondents reveal that 100% of the children in the sample households go to

school. Literacy rate stands at 64%. The education status of heads of households shows that 44% have completed primary school, 18% junior and 24% senior secondary school. Those who claim to have reached college and above level of education are 4% (Appendix A, Table 4.7).

f) Women status and participation in communal activities

It is reported that on the average, one women per household participates in women's organizations or groups. Almost all women in the sampled households are engaged in house keeping, about 24% in trade, 9% in cottage industry and only 3% in Government jobs. Of the young girls, 62% attend school and 53% also assist their mothers in house keeping. Those percentage of young girls that are engaged in commerce are only 3% (Appendix A, Table 4.8).

The participation of women in educational sessions of social services looks better in Adi Keyih than in the other towns. Firstly, there fewer respondents who said that they do not participate in such sessions. Secondly, participation in most of the activities seems much higher for water use, sanitation childcare and family planning. There is also literacy session with 11% participants (Appendix A, Table 4.9).

In similar manner to that of other towns, residents of Adi Keyih do not participate in management of communal water points and toilets. This is again surprising because of the large number of CWP and CT in the town, but again stressing the need for a strong community organization and management intervention. Most women participate in community organizations of socio-cultural type (55%), savings associations (17%) and formal national organizations like PFDJ and NUEW (92%) (Appendix A, Table 4.10 and 11).

g) Water related and other problems

Households' response to the type of problem they face seems to be mostly confined to shortage of income and water for which the percentages are 55 and 29 respectively. Of the female respondents 41% said that water is of primary problem as compared to 18% for men. Otherwise, the respondents seem to be satisfied with the existing utilities and facilities (Appendix A, Table 4.12).

When existing problems related with the present water supply facility are analyzed, stoppage of water (61%), bad quality (34%), expensive water tariff (30%) and long queuing (17%) are prominent (Appendix A, Table 4.13).

h) Affordability for water and sanitation facilities

In general many of all the income group responded that they can afford to pay Nfa 5-9 per month for water supplied by the town administration. Another 24% reported that they are willing to pay Nfa 10-14. Very few of the lower income group of less than Nfa 299 responded that they can afford. Even the high income group seem to afford from Nfa 5-9 per month (Appendix A, Table 4.15).

With regards to payment for communal toilets, the affordability and the willingness to pay is very low. Like in the other towns, it is the middle income group who are willing and can afford to pay for communal toilets. This again, reasserts the earlier conclusion that these income group would be willing to even construct their own toilet if given some credit facilities to do so (Appendix A, Table 4.16).

i) Communal water points

Those households respondents of the town that travel less than 90m and from 100-199m to the nearest communal water point account for only 8% each. Those who travel 200-300m are the majority and account for 62%. As many as 23% travel more than 400m suggesting that these water points are not well located in terms of easy reach to the clients. Unlike other towns, men fetching water 14.0 times a week which is more than that of women who travel 13.9 times weekly only. In like manner, boys and girls equally share the burden of fetching water. Of the 92% unsatisfied household respondents, 50% prefer yard connection and 42% community water points. A surprisingly small percentage of 8% favor house connection (Appendix A, Table 4.17).

4.2.2 Water Supply Conditions

Though limited in scope, Adi Keyih has a piped water facility. The socio-economic survey result shows that the population covered by house connection, yard connection and communal water point is 5%, 11% and 14% respectively with daily per capital consumption rate of about 29, 13 and 16 liters respectively (Appendix E, Table 4.2).

The existing distribution pipelines are very old and being steel have lots of perforations, hence the water is liable to contamination while being conveyed. Moreover, the Municipality water is neither disinfected for a safeguard measure nor the reservoir ever been cleaned.

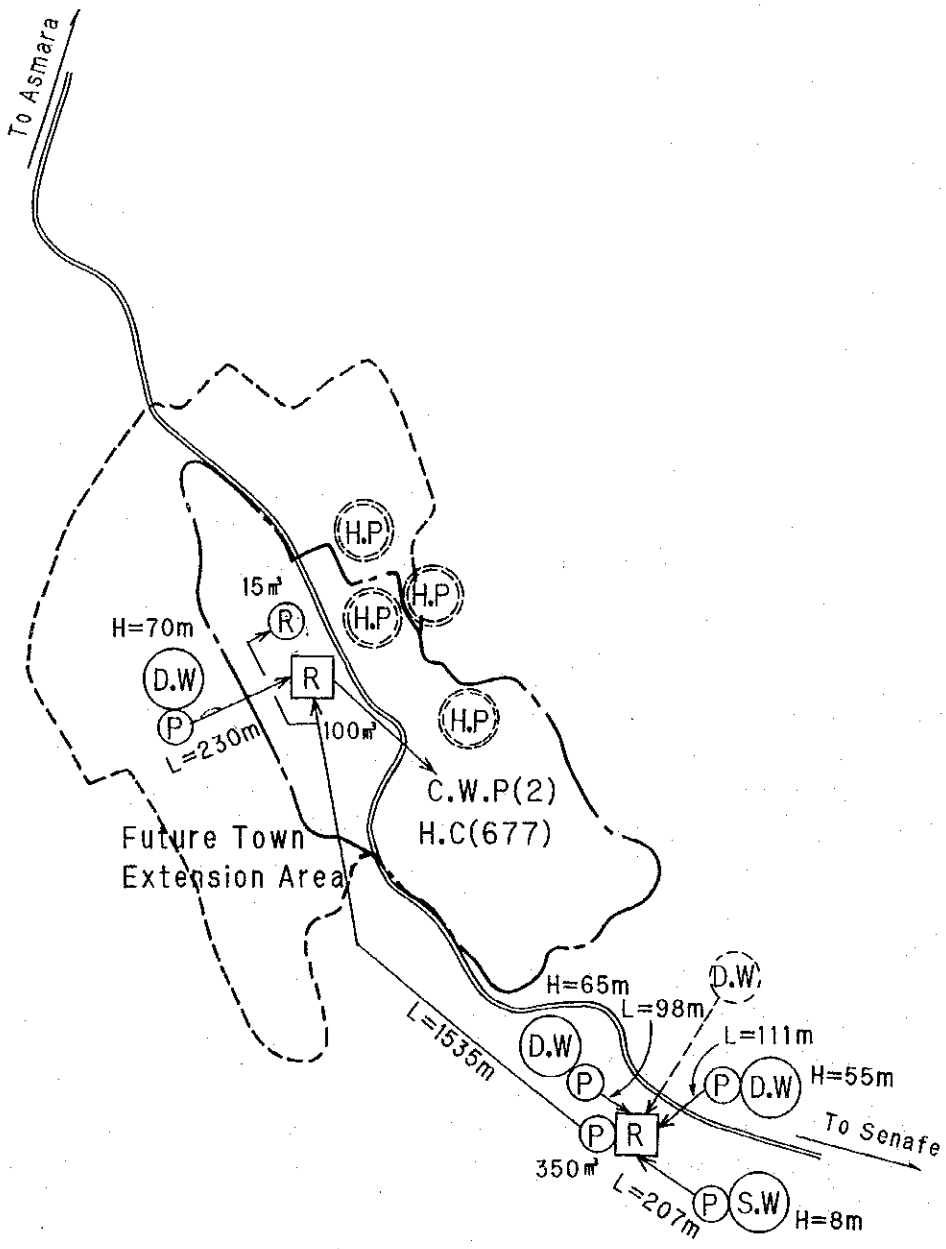
From the community water point users about 44% are to travel more than 400m to fetch water and about 50% of those who fetch from river travel more than 1000m (Appendix E, Table 4.3). 92% of the community water point users are not satisfied with the service they are getting. 8% of those say their affordable preferences are house connection and 50% say they afford yard connection. The remaining households though not satisfied they reported that they can afford only community water point. The river water consumers say they use the water as supplementary source for washing purpose only.

At present there are no community based management system for the communal water points. All community water points are under the management of WSS. In the survey the community were asked about this matter and about 99% of the population said they favor the community based management system for the communal water points.

The proportion of water supply by pipes is estimated nearly 30 percent and the remaining proportion is almost covered by water vender. There are two communal water points and 677 house connections served by pipes.

There is a reservoir (350 m^3 in capacity) and a booster pump on the top of hill in the southern outskirts of the town. Main water sources of the town are three boreholes. Though one of them is out of order, the pumped water is collected to this reservoir and transmitted to the two reservoirs located in the center of the town by a booster pump. The booster pump is operated 7 - 8 hours per day. One reservoir in the town is a ground type of 100 m3 in capacity and another is an elevated type of 15 m^3 in capacity. Water of the two small reservoirs in the town is also fed from the deep well located in the west at 230m far from the two reservoirs. Both reservoirs cover two communal water points and 677 house connections. Outline of water supply system in the town is illustrated as Figure 4.2.1.

Figure 4.2.1 Outline of Water Supply Facility



LEGEND

D.W:Deep well
S.W:Shallow well
H.P:Hand pump
P :Submersible/boosting pump
R :Reservoir
C.W.P:Communal water point
H.C:House connection
W.T:Water tanker
○ :Existing facility
◎ :Private facility
□ :Square reservoir
⊂⊃ :Out of use
⊏⊐ :Dam
— :Boundary of the town
— :Boundary for future town extension

There are two water tankers, but one is out of order at present, and four private hand pumps in the town. Water of the water tankers is taken from the 350 m^3 reservoir.

Major problems of the water supply facilities are small capacity of the reservoirs, obsolete pumps, leakage from the distribution pipes, etc.

4.2.3 Sanitary and Health Condition

(1) Public sanitation

The town has no sewerage system, but there is an old storm drainage system from Italian colony. With regard to refuse disposal, the town administration provides a dump truck which goes round in the city each day to collect garbage directly from the houses.

The Municipality of the town has a sanitary section whose duty is to strictly follow the implementation of the Municipality's sanitation regulations. Among its duties, this section deploys inspectors who check, penalize and report monthly to the administration as to the cleanliness of bars, restaurants, hotels etc. with regard to their service areas, staff, latrines etc. For breaking the regulations, the first step is warning, followed by penalties of Birr 20 and above, depending on the supervisor's judgment. These regulations have been strictly imposed since 1996, during which about 10 shops were closed. This section also has 7 staff whose responsibility is to clean the town. Moreover, two inspectors go round the town during the night and day to check the implementation of the regulations (urinating, defecation and throwing garbage in public places are not permitted). The penalties for not following the regulations vary from 2 Birr to 5 Birr. A public cleaning campaign is conducted every three months. Generally, with the strict implementation of the regulations, the town is relatively cleaner.

There are two public latrines. One of the latrines was constructed in 1989 which is used for urinal and the second one was constructed in 1987 which is used for defecation. Both have attendants who clean and watch guard. So far no fee has been introduced for public latrines in order to encourage people to use latrine. The latrines, up to now, are in good condition. Public small and big enterprises such as bars, restaurants etc. have latrines. The Town administration in its new regulation now is obliging the owners to provide latrine.

(2) Household sanitation

With respect to the private latrines, a study has been conducted and 53% of households do not have such facility. The kind of private latrines exist n town are flush (septic tank) and dry pit latrine.

From the socio-economic survey result some of the residents who use open field to relieve them selves seems to be not aware to the need for the private latrine. Though 50% of the household are not satisfied with the existing latrine and say their affordable preferences are flush type, dry pit and community latrine. Surprisingly only 14% of the population are favoring the credit system if introduced. The average repayment of the loan of those who favor the credit system is 76Nfa per month (Appendix E, Table 4.4).

With respect to newly constructed houses, the design cannot be approved without latrine provisions. However, in the construction phase, often the owners build part of the house or room and leave the rest because of running out of budget. Municipality is now checking all houses and for those who do not

have a latrine, a deadline for their complete construction is given. About 60% of the houses have been checked so far, out of which 40% are building latrines. Two types of latrines are constructed. The first is the pit latrine with dry masonry for soak-away and the second type where the ground formation is black cotton soil a water-tight wall and a concrete floor is compulsory.

With regard to sanitation behaviors the type of materials normally used for anal cleansing are stone, water and paper at 13%, 14% and 87%. The residents for more than 84% use the Town administrations refuse truck for waste disposal, wastewater is disposed by 80% of the society in their surrounding and animal waste by more than 88% is used as fuel or manure (Appendix E, Table 4.4 and 4.5).

(3) School sanitation

There are five schools in Ad Keyih. One of the schools never had water supply and three schools either never had latrine or the latrine they had is out of use due to blockage. Some of the reasons for not having proper sanitation facility are (1) lack of water, (2) there are no attendants who clean and control misusing students (3) lack of education or briefings to students as to how to use latrine specially to those who are not acquainted to latrines. For details of the schools sanitation condition see Appendix E, Table 4.6.

(4) Hygiene/health condition

In Adi Keyih, a mini-hospital exists with 120 beds, a pharmacy, an ambulance , 7 physicians, 13 nurses, 9 dressers and a pharmacist which gives service to the town and the surrounding rural towns as a referral center. According to the hospital data, water and poor sanitation related diseases are common and at high levels in the town. For more than 1000 people get sick annually from diarrhea, amebic dysentery bacillary dysentery and giadiasis Appendix E, Table 4.7. The socio-economic survey result also reflect the occurrences of water and poor sanitation related diseases. It is reported that an average of 20, 16, and 15 persons per household are affected by diarrhea, dysentery and warms respectively in six months period from the time of survey and an average of 1.4 infants die in10 years (Appendix E, Table 4.8).

Most of the people (97%) are aware of child immunization programs. On the other hand their knowledge on ORS preparation is low (72%). About 77% of the residents though are said attended health and hygiene education sessions. The peoples participation on community sanitation work is very high (96%) and areas of participation are by cash, material and labor (Appendix E, Table 4.11).

With regard to hygienic practices, hand washing habit with soap after defecation, before cooking, before eating, after disposal of children stool and after handling of animal dung is only 40%, 5%, 2% , 68% and 75% (Appendix E, Table 4.9). Food handling habit relatively is better. About 93% of the households cover leftover food and all of them wash vegetables (Appendix E, Table 4.10).

4.2.4 Financial Condition of WSS

Water Supply Service (WSS) of Adi Keyih earned 43,056 Nfa in August, 1997, while the expenditures incurred amounted to 18,133 Nfa, or a profit ratio of 57.9%. Throughout 1996 a similar extent of profit ratio was achieved. This ratio is considered an excellent financial performance.

Water sales by cash and meter accounted for 39.9% and 34.9% of incomes respectively, totaling 74.8%.

Salaries and fuel occupied 52.6% and 43.8% of expenditures, respectively, totaling 96.4%.

Numbers of water supply facilities are 677 for house connections, 2 for communal water points, 1 for the water tanker and 4 for private wells.

Water tariffs per cubic meter are 3-3.5 Nfa for house connection users, 5 Nfa for communal water point users and 10 Nfa for users of water from the water tanker. Water tariff for house connection users is considered high as compared to the other 7 towns.

WSS has 14 workers. Each worker earns an income of 7,586 Nfa, which is low among the 7 towns. The average monthly salary per worker is calculated at 679 Nfa.

The per capita per day consumption of water is 10.0 liters according to the results of the socio-economic survey. This per capita consumption is low.

(1) Population in 1997: 14,215

(2) Financial performance in Aug., 1997

Unit: Nfa

Revenues		Expenditures	
Item	Amount	Item	Amount
Water sales by meter	15,008	Salaries	9,535
Water sales by cash	17,198	Per diem	236
Rental charge of meters	1,469	Electricity	43
Service charge	179	Fuel	7,934
Others	9,202	Supply materials	193
Total	43,056	Repairs	22
		Office supply	12
		Others	358
		Total	18,133

(3) Water tariffs

Unit: Nfa/m^3

House connection	Communal water point	Water tanker	Water vendor	Public well
3-3.5*	5	10	-	-

Note: *3.5 Nfa/m^3 is for establishments/institutions.

(4) Number of water supply facilities

House connection	Communal water point	Water tanker	Public well	Private well
677	2	1	0	4

(5) Number of personnel

Division	Functions	Male	Female	Total	Perm.*	C./T.**	Total
Head		1		1	1		1
Administrative	Guard	2		2		2	2
	Driver	1		1	1		1
Financial	Head	1		1	1		1
	Cashier		1	1	1		1
	Meter reader	1		1		1	1
	Water seller	2		2	2		2
Technical	Motor operator	3		3	3		3
	Plumber	2		2	2		2
	Total	13	1	14	11	3	14

Note: *=Permanent, **=Contract/Temporary

(6) Production and consumption of water in 1996 (m^3): 78,845 and 63,076.

(7) Average monthly salary: 679 Nfa.

(8) Per capita per day water consumption: 10.0 liters

CHAPTER 5 STRATEGY ON PLANNING

5.1 Basic Strategy on the Planning

(1) Target year

The project for water resource development, water supply and sanitation improvement is to be formulated as a phased plan to the year 2015. A preliminary assumption would be that the project would comprise 3 phases, with phase horizons of 2005, 2010, and 2015, respectively. Although the 2010~2015 period would comprise mid~long term planning, the subject project formulation would include preliminary facility design and funding plan for this stage as well. With regard to the first phase (priority project with a target date of around 2005) of the project, facility design and costing would be to the feasibility study level.

(2) Water resources development plan

The water resources development plan would focus primarily on groundwater and underflow. This would include study of the feasibility of tapping shallow groundwater in the Quaternary formation and weathered rock zone in and around the target towns, and deep groundwater in rock formations.
Although the water source development plan will focus primarily on groundwater, discharge measurement will be carried out for Mereb river as a candidate, long term water source for Mendefera.

(3) Water use

Water supply would give priority to domestic water, however, industrial water use would also be considered with special attention to future demand trend in this regard in the case of towns such as Debarwa and Dekemhare which are pursuing programs to attract industrial enterprises.

(4) Water supply and sanitation plan

Water supply and sanitation plan would comprise a) facility plan with appropriate attention to natural and socio-economic condition, b) project cost estimation, c) O&M plan for sustainability of facilities, d) institutional strengthening plan, e) examination of the financial feasibility of the project and f) project implementation schedule.

(5) Sustainability of the project

Water supply project for rural towns lies with the municipal government of the concerned town with the aim to achieve budgetary independence. Specific recommendations on an operating structure for water supply systems which is sustainable under independent budget will be done. This would include an examination of factors such as O&M costs, replacement of main equipment after depreciation, etc. Also, in cases where the capacity of beneficiaries to pay water fees is too low to achieve independent budget viability, specific recommendations are to be made with regard to ways to compensate for this gap.

5.2 Population Projection

5.2.1 Population as of 1997

According to figures made available from the Ministry of Local Government, the total population of the seven towns as of 1997 amounts to 89,660 of which 53% are females and 47% males (see Table 5.2.1 below). The figures include the population of the surrounding villages which were incorporated within the town administrations by the MoLG. The population of the surrounding villages amounts to about 11%.

Table 5.2.1 Present Population and Household Size of the Seven Towns

Town	Population
Debarwa	4,831
Mendefera	20,371
Adiquala	9,488
Dekemhare	21,675
Segeneiti	6,146
Adi Keyih	14,215
Senafe	12,934
Total	89,660

Source: Ministry of Local Government,
Town Administration Department, 1997

5.2.2 Basic Assumptions Adopted for Population Projection

Base population data (1997) for all towns is taken from the data provided by the Town Planning Department of the Ministry of Local Government.

It is assumed that during the development plan period, the population of these seven towns will grow very rapidly due to the following reasons:

- the fact that the climate in all these areas is conducive for human settlement,
- that present demand for urban land is quite high as attested by the number of applications received by the town administrations,
- due to the high influx of rural people in search of better employment opportunities, and in search of better public amenities like schooling, health, water, etc.
- the fact that these towns are market centers which attract potential investors in trade and other service and manufacturing activities
- the various infrastructure (road, electricity, telephone, market places, et.) planned to be implemented by the government in the very near future.

5.2.3 Projected Population

Despite the fact that there will be rapid population growth rates in the coming years, it cannot be assumed that all the seven towns will experience uniform growth rate. Therefore, for the present planning

purpose, the seven towns have been categorized into two: those that will likely experience very rapid population growth and those that are likely to have lower growth rates. Following is elaboration on this:

(1) Category One: Mendefera, Dekemhare and Debarwa

These towns are envisaged to undergo a rather fast population growth rate due to the planned economic development program envisaged to be under-taken by the government and the expected private sector investment to follow in, in and around these towns.

Thus, the growth rate for these towns will be:

- at 5% per annum from the years 1998 – 2005, and
- from the year 2006 until the year 2015 they will experience a slower growth rate of 4.5% due to the general expectation of declining population growth.

The number of returnees assumed to settle in these towns is assumed to increase up to the year 2010 and slightly decrease from the year 2011 onwards.

Therefore, the number of returnees assumed to inflow to these towns are:

- from 1997 to 2000 a total inflow of 900,
- from 2001 to 2005 a total inflow of 1200,
- from 2006 to 2010 a total inflow of 1200, and
- from 2011 to 2015 a total inflow of 1000.

(2) Category Two: Adiquala, Segeneity, Adi Keyih and Senafe

The growth rate adopted for these towns is 4.5% up to the year 2005 and a slightly lower one of 3.5% until the year 2015.

The number of returnees assumed to settle in these towns is assumed to increase up to the year 2010 and slightly decrease from the year 2011 onwards.

Therefore, the number of returnees assumed to inflow to these towns are:

- from 1997 to 2000 a total inflow of 750,
- from 2001 to 2005 a total inflow of 1000,
- from 2006 to 2010 a total inflow of 1000, and
- from 2011 to 2015 a total inflow of 750.

5.3 Water Demand Projection

5.3.1 Present Domestic Water Consumption

According to the social economic survey report, present water consumption is expected as follows;

There are many water supply modes in the towns. Main modes are individual connection like house

connection and yard connection, communal water point, water wagon and water vender by donkey. Present supply mode and its water consumption is shown in Table 5.3.1.

This table shows that the house connection is the highest consumption and it is more than 20 l/s/d in five towns. Water wagon supply is the second and its consumption is about 15 – 16 l/s/d. Communal water point is lowest consumption. It means that water wagon supply is very important in seven towns at present.

The average consumption of each mode of service for seven towns is estimated 20.8 l/s/d in house connection, 11.3 l/s/d in yard connection, 11.0 l/s/d in communal water point and 14.1 l/s/d in water wagon.

5.3.2 Approach on Domestic Water Demand

The average domestic water demand and percentage of consumers for each mode of service for the seven towns is estimated based on the following consideration:

(1) Hygiene

The hygienic behaviors are influenced by the availability of adequate water. Hence the estimated water demand need to be adequate enough to keep personal and household hygiene.

(2) Available infrastructure

The infrastructures taken into account are availability of sewerage systems, cistern flush and pour flush latrines, shower and kitchen sink which have great effect on domestic water demand. At present Mendefera, Dekemhare and Adiquala have sewerage system. The town administrations of these towns realized the need and developed plans to rehabilitate and expand the system. In each town the only constraint to its implementation is budget. Moreover, with the implementation of the prospective water supply development project, lack of proper sewerage system will be aggravated.

With regard to present household latrine availability, Dekemhare, Mendefera and Adi Keyih are categorized #1, with 60%, 54% and 47.5% coverage respectively. Senafe and Adiquala are categorized #2, with coverage of 40% and 36.7% respectively, and Segeneiti and Debarwa are categorized # 3 with only 25.4% and 11.1% respectively.

(3) Economic potential

The present economic potential of the people has a direct implication with the available infrastructures. The future economic development growth is difficult to tell but with the development of water supply system it is envisaged that other economic activities will also accelerate accordingly. Hence the present situation is taken into consideration in this approach.

(4) Water resources potential

The water resources potential in these towns are limited in general. Therefore, demand on water supply may also be conditioned in accordance with the water resources potential, if there is no other choice.

Table 5.3.1 Present Supply Mode and Water Consumption

Name of Town	Mode of Supply	Consumers Percentage	Consumption (l/s/d)	Remarks
Debarwa	H.C.	1.25	25.0	
	Y.C.	-	-	
	C.W.	41.7	8.56	
	W.W.	27.8	15.61	
Mendefera	H.C.	10.94	24.11	
	Y.C.	6.56	14.95	
	C.W.	29.2	10.13	
	W.W.	53.3	16.39	
Adiquala	H.C.	13.86	20.45	
	Y.C.	6.14	12.07	
	C.W.	63.6	14.31	
	W.W.	-	-	
Dekemhare	H.C.	5.67	25.59	
	Y.C.	8.67	15.67	
	C.W.	-	-	
	W.W.	78.1	16.51	
Segeneity	H.C.	3.0	11.66	
	Y.C.	5.0	5.94	
	C.W.	90.5	8.79	
	W.W.	-	5.59	
Adi Keyih	H.C.	4.95	28.73	
	Y.C.	10.64	12.64	
	C.W.	13.94	16.45	
	W.W.	78.86	-	
Senafe	H.C.	7.78	10.3	
	Y.C.	6.62	6.8	
	C.W.	83.8	8.04	
	W.W.	1.82	16.49	
Total / Average	H.C.	7.5	20.8	
	Y.C.	7.2	11.3	
	C.W.	36.1	11.0	
	W.W.	45.3	14.1	

- "H.C." means house connection.
- "Y.C." means yard connection.
- "C.W." means communal water point.
- "W.W." means water wagon including water vender by donkey.
- The sums of consumers are not 100% because of multiple answers and neglected other sources.

(5) The government policy

The government policy do not favor subsidy for the services. While determining the water tariff, all expenses including the cost of investment on the system, production cost, and expansion cost are believed to be covered by the consumers. Hence, it is inevitable that people's affordability will limit them from consuming more water.

(6) Population

Population has great impact on water supply and sanitation. With the increase in the population the environment caused by sanitation loses its absorbing capacity and the economic development of the town accordingly increases. Hence development of infrastructures is a pressing demand of the town. At present Adi Keyih, Mendefera and Dekemhare having high populations are categorized #1, Senafe in second level and Segeneiti, Adiquala and Debarwa are placed third level.

(7) Current water demand trend

In all towns the water demand trend for water supplied home is high and for human transported water is vise versa.

Therefore, the towns based on the above listed factor are categorized, and basic factors for water demand are estimated based on the present water supply condition, as follows (refer to Table 5.3.2).

- Category 1 - Mendefera, Dekemhare and Adi Keyih
  - Consumers % of population (in 2000) => HC:YC:CW= 25:30:45
  - Demand rate in 2000 => 30, 20, 15 lcd for HC, YC, and CW
  - Annual growth rate of supply modes => 3% (HC), 2% (YC, only 2005)
  - Annual growth rate of demand by mode => 3% (HC), 2% (YC)
- Category 2 - Senafe and Adiquala
  - Consumers % of population (in 2000) => HC:YC:CW= 20:30:50
  - Demand in 2000 => 25, 20, 15 lcd for HC, YC, and CW
  - Annual growth rate of supply modes => 3% (HC), 2% (YC, to 2010)
  - Annual growth rate of demand by mode => 3% (HC), 2% (YC)
- Category 3 - Debarwa and Segeneiti
  - Consumers % of population => HC:YC:CW= 15:20:65
  - Demand in 2000 => 25, 20, 15 lcd for HC, YC, and CW
  - Annual growth rate of consumers => 3% (HC), 2% (YC, to 2010)
  - Annual growth rate of demand by mode => 2% (HC), 2% (YC)

Note) HC: House Connection, YC: Yard Connection, CW: Communal Water point.

Average domestic water demand based on Table 5.3.2 is shown in Table 5.3.3.

Table 5.3.2 Water Consumption

Name of town	Present water consumption pattern			Expected water demand											
	Mode of supply	Consumption l/c/d	Consumers % of household 1)	Year 2000-2005				Year 2005-2010				Year 2010-2015			
				Consumers (% of hld)		Ave. Consumption (l/c/d)		Consumers (% of hld)		Ave. Consumption (l/c/d)		Consumers (% of hld)		Ave. Consumption (l/c/d)	
				2000	**2005**	2000	**2005**	2005	**2010**	2005	**2010**	2010	**2015**	2010	**2015**
Debarwa	House connection	25	1. 25	15	17	25	28	17	19	28	30	19	22	30	35
	Yard connection	–	–	20	22	20	22	22	24	22	24	24	27	24	27
	Communal water point	8. 56	41. 7	65	61	15	15	61	56	15	15	56	51	15	15
	Water tanker	15. 61	27. 8												
Mendefera	House connection	24. 11	10. 94	25	29	30	35	29	34	35	40	34	39	40	47
	Yard connection	14. 95	6. 56	30	33	20	22	33	66	22	24	66	61	24	27
	Communal water point	10. 13	29. 2	45	38	15	15	38	0	15	15	0	0	15	15
	Water tanker	16. 39	53. 3												
Adiquala	House connection	20. 45	13. 86	20	23	25	29	23	27	29	34	27	31	34	39
	Yard connection	12. 07	6. 14	30	33	20	22	33	37	22	24	37	69	24	27
	Communal water point	14. 31	63. 6	50	44	15	15	44	37	15	15	37	0	15	15
	Water tanker	–	–												
Dekemhare	House connection	25. 59	5. 67	25	29	30	35	29	34	35	40	34	39	40	47
	Yard connection	15. 67	8. 67	30	33	20	22	33	66	22	24	66	61	24	27
	Communal water point	–	–	45	38	15	15	38	0	15	15	0	0	15	15
	Water tanker	16. 51	78. 1												
Segeneiti	House connection	11. 66	3	15	17	25	28	17	19	28	30	19	22	30	35
	Yard connection	5. 94	5	20	22	20	22	22	24	22	24	24	27	24	27
	Communal water point	8. 79	90. 5	65	61	15	15	61	56	15	15	56	51	15	15
	Water tanker	5. 59	–												
Adi Keyih	House connection	28. 73	4. 95	25	29	30	35	29	34	35	40	34	39	40	47
	Yard connection	12. 64	10. 64	30	33	20	22	33	66	22	24	66	61	24	27
	Communal water point	16. 45	13. 94	45	38	15	15	38	0	15	15	0	0	15	15
	Water tanker	–	78. 86												
Senafe	House connection	10. 3	7. 78	20	23	25	29	23	27	29	34	27	31	34	39
	Yard connection	6. 8	6. 62	30	33	20	22	33	37	22	24	37	69	24	27
	Communal water point	8. 04	83. 8	50	44	15	15	44	37	15	15	37	0	15	15
	Water tanker	16. 49	1. 82												

1): The sums aren't necessarily 100% because of multiple answers and neglected other sources.

Table 5.3.3 Domestic Water Demand

(l/c/d)

Name of the Town	In 2005	In 2010	In 2015
Debarwa	18.8	19.9	22.6
Mendefera	23.1	29.4	34.8
Adiquala	20.5	23.6	30.7
Dekemhare	23.1	29.4	34.8
Segeneity	18.8	19.9	22.6
Adi Keyih	23.1	29.4	34.8
Senafe	20.5	23.6	30.7

5.3.3 Other Water Demand

Total water demand consists of the domestic water demand and non-domestic water demands such as governmental, institutional, commercial and industrial demands. There are no standard figures of these non-domestic water consumption in Eritrea.

As a result of the field survey, the following non-domestic water consumption is obtained.

Table 5.3.4 Non-domestic Water Consumption by Field Survey

Item	Number	Water consumption	
		m^3/d	l/shop/d
Hotel	12	2.65	221
Restaurant	12	2.51	209
Shop	12	2.41	201
Factory	12	11.95	996

On the other hand, there are standard figures of these demands in the similar country, as follows.

School	5 lit/pupil
Hospital, Clinic	100 lit/bed
Hotel	100 lit/bed
Bar, Tea shop, Restaurant	200 lit/shop
Church, Mosque	5 lit/visitor
Office	5 lit/person
Industry (dry)	5,500 lit/ha
Industry (wet)	22,000 lit/ha

Water consumption of 5 lit/person as shown above is considered the basic figure for drinking only. As for water consumption of industry, it is planned for industry area in Debarwa, Mendefera and Dekemhare. Light industry is planned in Mendefera but it is unclear what kind of industry is planned in the remaining two towns.

Finally, non domestic water demand adopted is as follows, based on the field survey, discussion with engineers concerned in Water Resources Department and the standard figures of the similar countries.

Table 5.3.5 Non-Domestic Water Demand

Item	Water Demand
School	5 l/pupil
Hospital, Clinic	100 l/bed
Hotel, Bar, Tea shop, Restaurant	210 l/shop
Church, Mosque	5 l/visitor
Office	5 l/person
Factory	1,000 l/factory
Light industry	5,500 l/ha
Other Industry	15,000 l/ha

Non-domestic water demand except for light industry and other industry is assumed to increase in a geometric ratio of population growth rate. Water demands of light industry and other industry planned for future extension are separated and estimated per hectare based on the town planning data. Therefore, non-domestic water demands in each target year employed the same figure as above, and added the following population growth rate.

Table 5.3.6 Increasing Rate per Year for Non-domestic Water Demand

Unit: %

Name of Town	1997-2005	2006-2010	2011-2015
Debarwa	8.80	7.93	7.32
Mendefera	5.99	5.65	5.44
Adiquala	6.27	5.62	5.22
Dekemhare	5.93	5.60	5.40
Segeneiti	7.15	6.35	5.81
Adi Keyih	5.70	5.15	4.82
Senafe	5.81	5.25	4.90

5.3.4 Loss and Peak Demand

(1) Physical loss

Physical losses caused by water leakage and waste from pipes, reservoirs and taps, illicit connections, etc., are put at 15 %, assuming that the new facilities will be constructed by the target year.

(2) Max. daily and peak hour water demand

Fluctuations of the maximum daily water demand and weekly or daily variations for peak hour water demand due to seasonal or monthly climatic conditions, are taken into consideration. It is found by the field survey that water consumption in rainy season is higher by 22 % than that in dry season. Rainwater is very important source during the rainy season for washing (95%) and drinking (5%).

It is very difficult to investigate the peak hour water demand because of insufficient water source and

obsolete water supply facilities. Well pumps are operated 3~12 hours daily to meet the reservoir capacity, and communal water points are used 2~3 times per day at present. However, water supply condition will be developed under this project, and as a result, communal water points will be decreased, while individual connections (house connections and yard connections) will be increased in future.

These factors, for example, employed for Keren-city Water Supply Project for an approx. 70,000 population are 1.2 for max. daily water demand and 1.5 for peak hourly water demand.

Finally, max. daily water demand and peak hourly water demand are worked out by assuming the following coefficient based on the field survey and the standard figures in Eritrea.

Max. daily water demand = C1 x Average daily water demand
Peak hour water demand = C2 x Max. daily water demand
Coefficient of C1 = 1.2
Coefficient of C2 = 1.5

5.4 Water Supply System

5.4.1 Water Supply System

Existing water sources of six towns except Segeneity are located far from and/or lower than the town. Therefore, water is transmitted from the water sources to the reservoir by pumps and is distributed from the reservoir to customers by gravity. Well pumps are operated daily for 2.5 hours in Debarwa, 4.0 hours in Senafe and 7 - 12 hours in the remaining towns at present. In case water source is far form the town such as Mendefera and Dekemhare, water is directly supplied to the customers by water wagons.

The project plan for the water supply system employs the same system with the existing one as a rule. Water sources are to be groundwater because it is the cheapest source and the water can directly used for drinking without treatment. In case groundwater is insufficient to satisfy the demand and/or located extremely far from the town, surface water will be planned. New water sources and the existing water sources to be used in the project are connected to the reservoir by pipelines, not by water wagons. The reasons are a) there are a few water wagons and these wagons have frequent breakdowns, and b) pipeline systems are more safe and steady than the water wagons. Water of the transmission line from water source to reservoir is supplied by pump and the distribution line from reservoir to water taps is by gravity. The transmission line has no direct connection to the distribution line.

5.4.2 Water Supplied Area

Seven towns under the project have each administrative district and the administrative district consists of sub zones in the town and/or some villages. There are schools, hospitals, shops, hotels, churches, mosques, etc., in the sub zones and villages. The center of the town is divided into some sub zones and many inhabitants are living in these sub zones at present.

Each town has their future town plan and future town extension area beside the center of the town. Almost all villages are close and/or near to the town center and are included in the future town extension areas. However, a few villages are far from the town center and there is no future town plan for such

villages at present.

Under the circumstances, water service areas are divided into following three areas under the project in accordance with the present town and water supply conditions, population, future town plan, topographical features and so on. Finally, the administrative districts including all villages are planned for the water supply facilities under the project.

a) Water service area in the project target year 2005 : the areas are center of the town and essential for rehabilitation and improvement of the existing water supply facilities,

b) Water service area in the project target year 2010 : the areas are close to the town center of. These areas are for the future town extension plan, and water of these areas are supplied by water wagons or water venders at present.

c) Water service area in the project target year 2015 : the areas are far from the town center but in the administration district.

5.4.3 Facility Plan

(1) General

Existing water supply facilities are mostly replaced under the project because of following reasons. However, the existing wells counted as the water sources in the project will be used continuously, and only well pumps will be replaced after developing the existing wells. Reservoirs having enough capacity will be used after rehabilitation.

a) Yield from wells is insufficient to cover the future water demand,

b) Well pumps are obsolete and have breakdowns,

c) Reservoirs have small capacity and insufficient water level,

d) Pipelines are also obsolete, insufficient diameter to distribute the future water demand, not standable to the future increasing pressure, unknown position, etc., and

e) Communal water points are damaged.

(2) Target years for pipeline

Water supply facilities have two types, namely, one is pipeline type which is difficult to expand the system to meet the future water demand such like transmission pipeline and main distribution pipeline, while another is easy to expand such like wells pumps, reservoirs, etc.

The facilities for easy expansion are constructed and enlarged to meet the water demand in the target year. However, in case that expanded capacity is as small as $10m^3$ or less and not economical for construction, the facilities are to be constructed to meet the future demand.

The pipe diameters of the transmission line and main distribution line are enlarged to meet the water demand in the target year; for example, the pipe diameter of 100mm in 2005 is replaced by 125mm in 2010 and by 150mm in 2015 in the same line. Therefore, construction of these pipelines shall consider the future water demand.

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.

(3) Pipe material

Water pressure, soil characteristics and topographical configuration are very important to select pipe material for the transmission pipeline and the distribution pipeline.

Water pressure depends on given topographical configuration and total length of the pipelines, especially for transmission pipelines. Some transmission pipelines are expected durable to more than 100m of dynamic water head, while the distribution pipelines are expected to less than 75m. Soil characteristics in the project areas vary in one town to another. The ground bed of each town consists of the following lithologies and it will be difficult to select different pipe material to meet the lithologies.

Debarwa:	unconsolidated soil and weathered laterite,
Mendefera:	soil and weathered crack rich basalt,
Adiquala:	soil and mostly hard fresh basalt including rock fragments,
Dekemhare:	alluvial deposits
Segeneity:	soil and heavily weathered granite,
Adi Keyih:	clayey soil including fine to coarse gravel,
Senafe:	soil and coarse sand including sand stone gravel.

Under these circumstances, following pipe materials are recommendable.

Ductile cast iron pipe for transmission pipeline:
the transmission line is very important and the maximum pressure of the line including water hammer is nearly 1961 kPa (20kgf/cm^2),

PVC pipe for distribution pipeline:
the maximum pressure of the distribution line including water hammer is less than 981 kPa (10 kgf/cm^2).

(4) Power supply

There are main diesel power plants at Mendefera, Dekemhare and Adi Keyih in Debub Region. Electricity in six towns except Debarwa is supplied by these diesel power plants at present.

There is a network plan to connect these diesel power plants with Asmara power plant, and Debarwa will be supplied with electricity by 2000. Therefore, power supply for new water supply facilities in all seven towns will served by these diesel power plant through the network.

(5) Major water supply facility

The following major water supply facilities are planned in the project.

- Intake facility: deep well, shallow well, well pump,
- Transmission facility: transmission pipeline, booster pump, pump pit,
- Distribution facility: reservoir, distribution pipeline,
- Water service facility: individual connection, communal water point,
- Electricity facility: power supply, generator,
- Others: pump house, valves, flow meter.

Basic items of new water supply facilities are planned below.

a) Well

- Diameters of well casing are 150 mm (6 inches) for the yield capacity of 10 lit/s or less, and 200 mm (8 inches) for the capacity exceeding 10 lit/s.
- Material for casing and screen are both PVC pipe.
- Existing wells to be used in the project will be developed.

b) Well pump

- Well pump operation 24 hours daily.
- Type of well pumps are submersible.
- Well pumps for the existing wells for use in the project to be newly replaced.
- One stand-by pump provided in the town.

c) Transmission pipeline

- Pipeline for new installation
- Diameters of pipe in the target year 2005 will be for max. daily water demand in the target year 2010.
- Additional line will be constructed for the water demand in the target year 2015
- Material is ductile cast iron pipe.

d) Booster pump

- Booster pump at less than 130 m head.
- Stand-by pump not planned in the project.
- Type of booster pump is centrifugal.

e) Pump pit

- Pump pit in suction pit for boosting pump.
- Capacity is 30-minutes pumping capacity.
- Min. capacity of the pit as $15m^3$.
- Tank is of reinforced concrete made.

f) Reservoir

- Capacity for grand type is 8-hour max. daily water demand, while that for elevated type is 1-hour demand.

- The reservoirs are reinforced concrete made for ground type and fiberglass reinforced plastics (FRP) made for elevated type.

g) Distribution pipeline
- Pipeline for new installation.
- Diameters of pipe in the target year in 2005 for the max. daily water demand in the target year of 2010.
- An additional line will be installed for the water demand in the target year 2015
- Min. pressure is 7 m.
- Material is PVC pipe.
- Minimum diameter of pipe is 50 mm.

h) Individual connection
- Diameter of pipe is 13 mm.
- Material is polyethylene pipe.
- Flow meter is equipped.

i) Communal water point
- There are 8 taps per communal water point.
- Communal water points for coverage of a radius of 150 m
- Communal water point is made of concrete.

j) Power supply
- Electricity is a main power source for pumps
- No generator planed under the project.

k) Pump house
- Pump house planned for pump panels, the booster pump and generator.
- Pump house is brick made.

l) Others
- Valves (stop valve, air valve, wash out valve, pressure reducing valve, etc.) are installed at the proper position.
- The chlorinating facility is installed on the reservoir.
- Flow meters are installed at the outlet of pumps and reservoirs and at inlet of communal water points and individual connections.

5.5 Sanitation Improvement

5.5.1 Objective and Scope of the Program

The main objective of the Sanitation improvement program is to reduce the water and poor sanitation related diseases and create a healthy and productive society. Ultimately a healthy and productive society will have self sustained economy and a happy family.

This program particularly focus on public and private sanitation facilities improvement and hygienic practices. Hence the scope of the study includes the following areas of sanitation improvement:

- improve public sanitation facilities such as:
  - provision of wastewater and soil waste disposal system
  - provision of solid waste disposal system
  - provision of public and community toilets
  - improve schools, hospitals etc. sanitation facilities
- improve private toilets
- develop sanitation/hygiene educational program
- develop a management structure for sanitation improvement program

5.5.2 General Approach

The general approach of this study on sanitation improvement formulation program is based on the following steps.

a) The first step for the sanitation improvement program formulation is getting a clear picture of the current sanitation and health condition of the town with regard to facilities and practices. Therefore all pertinent information from the grass root to higher official level was gathered by approaching relevant people, referring documents and from socio-economic survey. The type of information collected are on the existing public and private sanitation facilities, economic condition of the town in general and household in particular, sanitation practices and behaviors of the community are assessed.

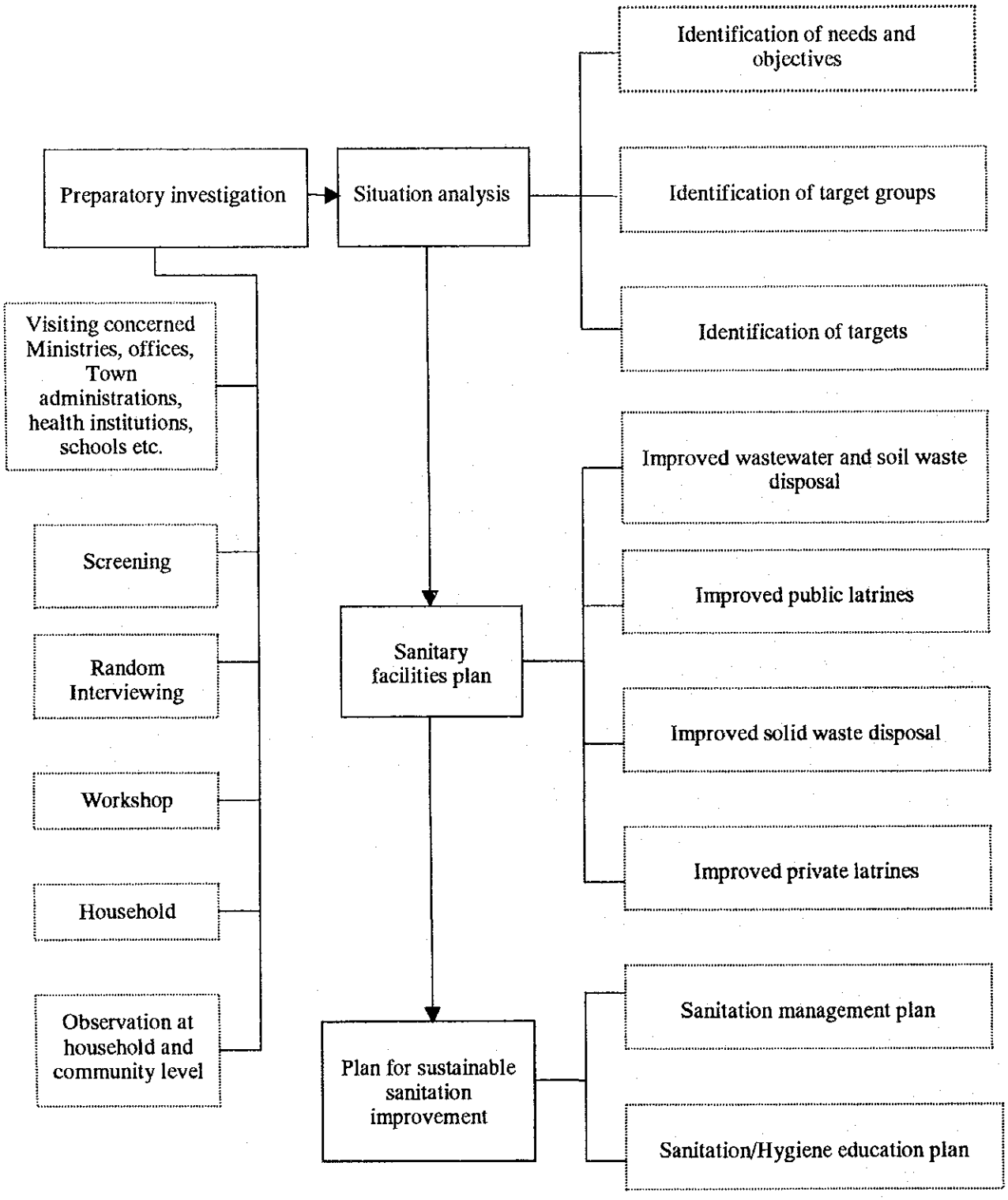
b) Following to the information collection process the situation is analyzed and needs and objectives, the specific targets and the specific target groups are identified.

c) Having a clear picture of the current condition on sanitation, social, cultural, economic etc. aspects the potential developments are foreseen and future plans for improved sanitation facilities program are formulated for three consecutive phases (year 2000-2005, year 2005-2010, and year 2010-2015).

d) Further in this study management and educational plans for effective and sustainable improved sanitation program is proposed.

For details of flow of the study approach please refer Figure 5.5.1.

Figure 5.5.1 Details of the Sanitation Improvement Program Formulation Approach



5.5.3 Areas of Focus and Basic Considerations

The needs and objectives, specific targets of the study and target groups for the sanitation development program are greatly influenced by socio-economic condition of the town and anticipated water demand. Hence the socio-economic study, water demand projections and water supply plans of this study are background for the sanitation improvement program formulation.

Moreover, explicit studies are carried out in areas of:

- Public, institutional and private sanitary facilities with respect to availability, coverage and conditions.
- Communities practice in using sanitary facilities.
- Social, economic, religious and cultural influences on sanitation facilities and usage.
- Availability of common water-born diseases, range of cases of sickness and death.
- Treatment practices for water-born disease.
- Sanitation behaviors in hand washing, utensil keeping, food and water storage, water drawing, infant excreta handling etc.
- Educational programs on sanitation, hygiene and health.
- Community management experiences.
- Community attitude on sanitation improvement programs and willingness to participate
- Government policy and programs on sanitation improvement.
- Existing management structure on sanitation.

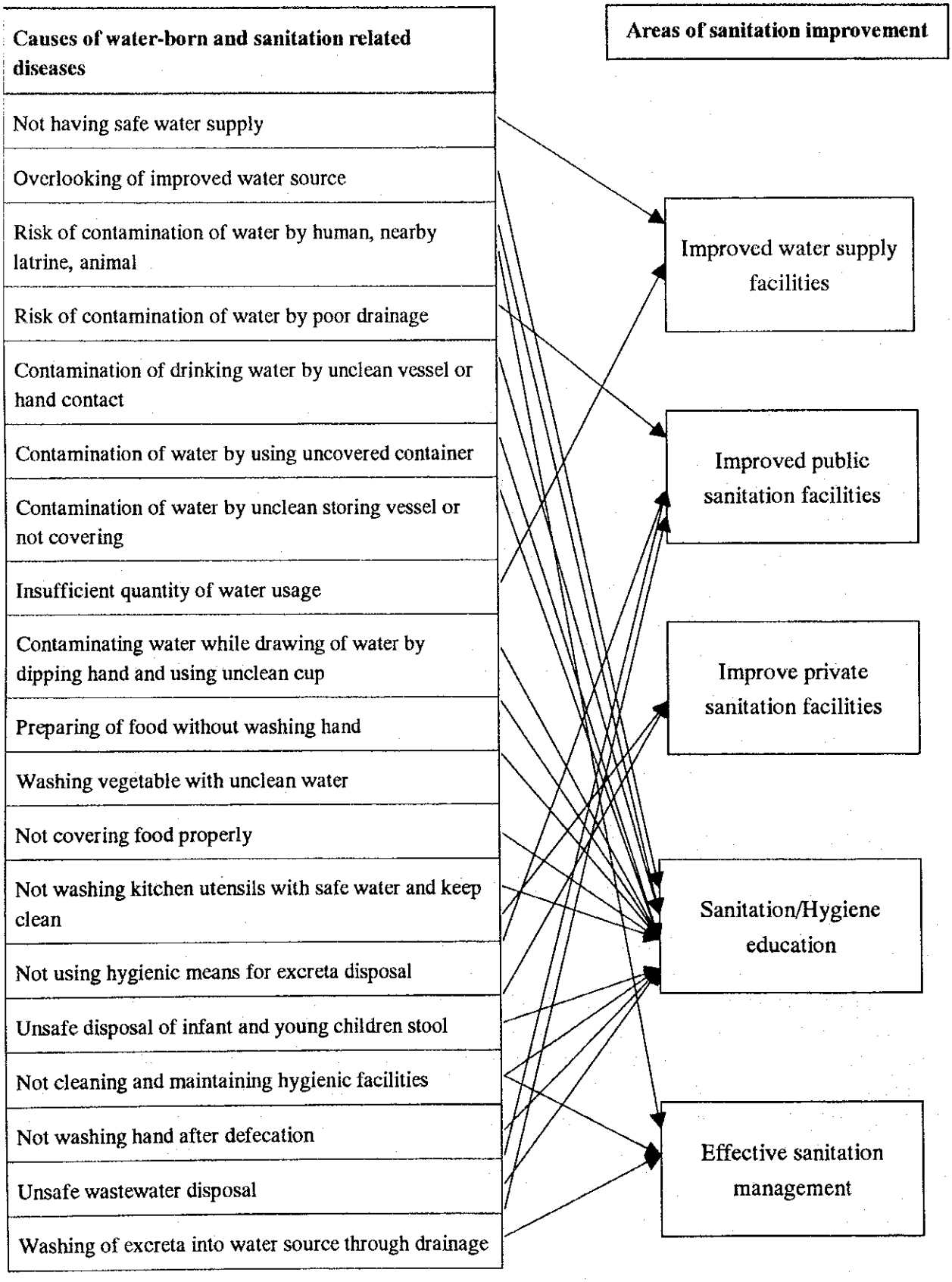
The sanitation facilities plans are developed ensuring the economic and technical feasibility and social and cultural appropriateness in the society. The basic factors considered are:

- make life easier and solve felt problems.
- functionally appropriate, easy to operate and maintain.
- affordable and materials easily available;
- in line with the cultural value and behavioral of the users;

The management plan formulated effectively address the operation and maintenance, staff strengthening, evaluation and monitoring aspect of the solid waste, wastewater and soil waste disposal, public and private latrines and sanitation/hygiene educational management.

To maximize the potential benefits of water supply and sanitation improvement programs on health, facilities need to be used and related behavioral risks reduced. Therefore, the sanitation improvement program is coupled with sanitation/hygiene education programs with the objective of establishing links between water and sanitation facilities on one hand and human practices on the other hand, especially with regard to the use, care, and maintenance of the facilities; the preservation of water safety and its use in sufficient quantities; and the safe disposal of wastewater , human and other solid waste.

Figure 5.5.2 Causes of Water-born and Sanitation Related Diseases and Areas of Sanitation Improvement



5.6 Financial and Economic Analysis

5.6.1 Water Prices and Revenues

(1) Determination of water prices

Water prices will be determined by category of customers and by target year based on:

a) Average monthly household income.

b) Distribution of household income by category of customers.

c) Willingness-to-pay for water.

d) The World Bank's recommendation of 4% of household income as the maximum limit of the payment for water.

e) The richer you are, the more you pay per unit volume of water: unit price for water point users < that for yard connection users < that for house connection owners and commerce/industry/institutions.

f) The more you consume, the more you pay per unit volume of water: the same as immediately above.

g) Future growth of household income.

h) Financial sustainability of water supply facilities to be constructed, i.e. sufficient revenues from water charge to cover the O & M and depreciation costs of the facilities.

(2) Projection of revenues

Revenue from water charges will be projected from:

a) No. of households by year and by category of customers

b) Annual water consumption per household by year and by category of customers

c) Water price by year and by category of customers

d) Bill collection rate, of which 95% is proposed

Another revenue source is the revenue from technical service charge. This revenue will be added on the purchase and transportation cost of connections.

The third revenue source is the revenue from meter rent.

Other revenues are the revenues from the sales of materials, contract fee, connection fee, fines, etc. These revenues were not taken into account as they are of minor importance, irregular and unpredictable.

5.6.2 Financial Analysis

Before financial analysis is carried out, the values will be determined based on the following factors (figures in parenthesis are proposed):

a) Project life (20 years for F/S projects; 30 years for M/P projects)

b) Discount rate (10%)

c) Financing conditions for the initial cost, i.e. subsidy or loan (subsidy)

d) Cost bearing by town people, i.e. the type(s) of cost to be borne by them:

i) O & M cost (yes)

ii) Replacement cost of all equipment and facilities (yes)

e) Durable life of equipment and facilities:

i) Pumps and other electro-mechanical equipment (15 years)

ii) Facilities including boreholes, reservoirs, pipes, communal water points,

iii) pumping stations and treatment plants (50 years)

f) Corporate income tax (free)

The initial cost, O&M cost and revenues will be estimated over a period of years, taking into account the above information and conditions.

Financial analysis comprises two forms of criteria: projection of financial statements and estimation of financial criteria.

(1) Projection of financial statements

Income statement, fund statement and balance sheet will be projected annually up to the last year of project life.

At the same time, major financial indicators such as cost revenue ratio, net profit ratio, the ratio of working capital to revenues and the ratio of net profits to total assets will be calculated based on those financial statements.

Financial feasibility of the project will also be evaluated based on the above statements and indicators.

(2) Estimation of financial criteria

Using cost benefit (revenue) streams, financial criteria including NPV, B/C and FIRR will be estimated.

Evaluation based on the values of the above criteria will be made regarding financial feasibility of the project.

5.6.3 Economic Analysis

(1) Estimation of benefits

a) Economic value of water

The major benefits accruing from the implementation of the Project are the reduction of water related diseases and general improvement of the town people on one hand, and the saving of water fetching time on the other.

Such benefits can be reflected in the price of water. Generally, water charge is controlled by the government to the level by far below the real economic value of water. The real economic value of water is usually clarified by the price at which the public is forced to buy water during its extreme scarcity. People in the 7 towns are forced to buy water from the water tank when there is no other alternative. Water cost is at 10 Nfa per cubic meter, which is 2 to 5 times higher than the water directly secured from the individual connection or the communal water point. In case even this alternative is not available, they buy water from the vendor at an exorbitant rate. In Debarwa, where water situation is more acute than in other towns concerned, such water is bought at 16 to 40 Nfa per cubic meter.

From the foregoing, it will be assumed that the level of the real economic value of water is at least 20 Nfa per cubic meter.

b) lcd and population growth in the "without" the project

Population in a town is projected to grow at the average annual rate of 5 percent. This projection has been made possible on the assumption that enough water will be available in future to cater for the rapidly growing population. Supposing water situation were as severe as at present in future, the growth of population would be much less.

It will be assumed in the "without project" case that the per capita per day consumption of water will not improve in the future and also that the growth rate of population will be half compared with the "with project" case.

(2) Economic cost

To carry out economic analysis of the Project, cost at the market prices shall be converted into economic terms.

The standard conversion factor will be assumed as 0.9, which will be applied to the local components of the capital cost.

(3) Economic analysis

Taking the above-mentioned matters into consideration, economic analysis will be performed for the Project in each town after preparing cost benefit streams for the project life period.

Through the economic analysis, the economic parameters such as NPV. B/C and EIRR will be calculated. In starting such analysis the preconditions adopted in the financial analysis will also be applied.

CHAPTER 6 DEVELOPMENT PROGRAM

Based on the strategy on planning mentioned the previous chapter, development programs are formulated as a phased plan to the year 2015, with target years of 2005, 2010, and 2015.

6.1 Population and Water Demand Projection

Based on the population in 1997, informed by the Ministry of Local Government, the population in each target year are projected as marked in Table 6.1.1.

Administration of Adi Keyih has only two sub zones and the future town extension area is the northern part of the town. The western part of zone 2 is under extension at present. Therefore, water supplied area until the target year 2015 is planned as follows (refer to Figure 6.2.1).

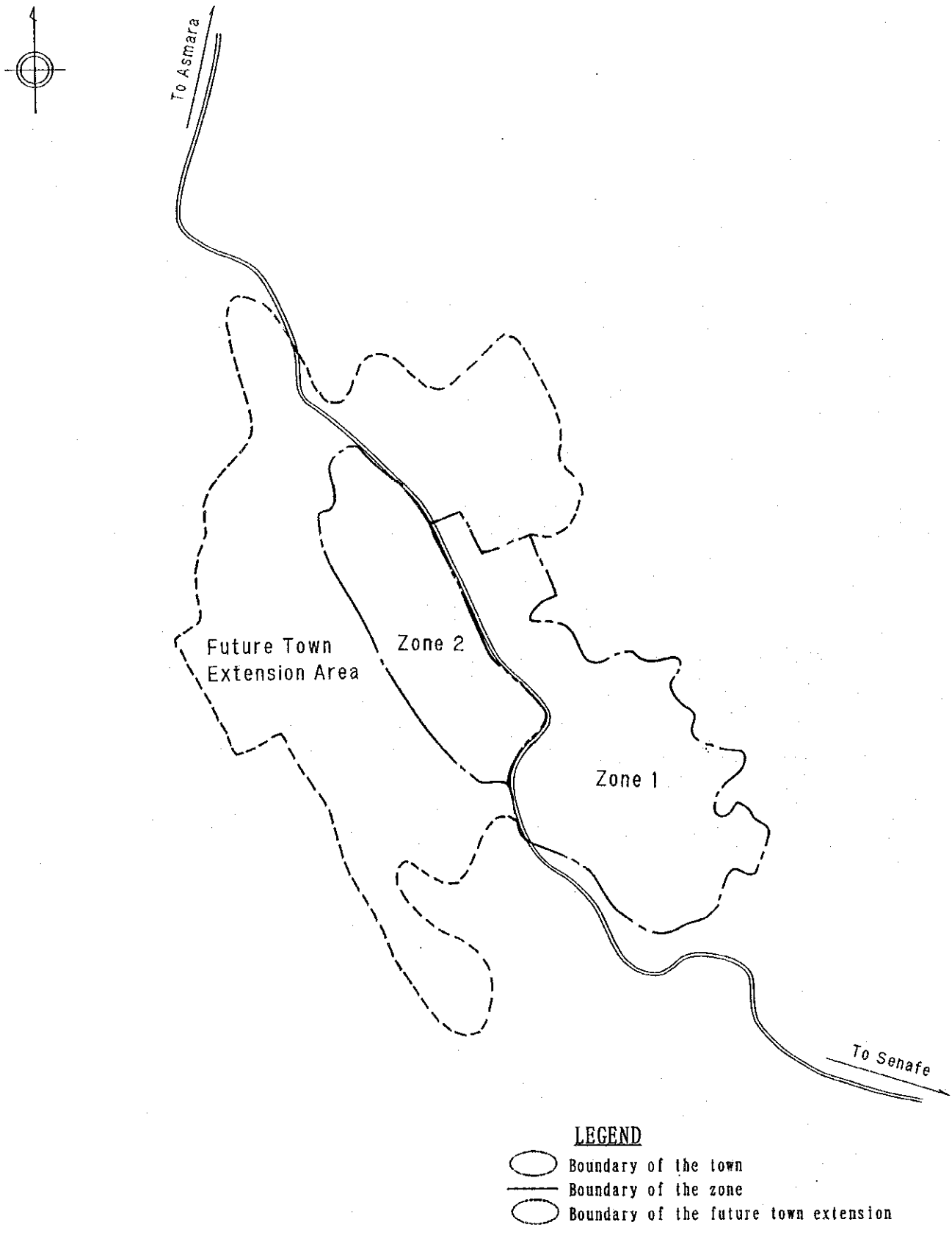
- Target year 2005: zone 1 and eastern part of zone 2,
- Target year 2010: western part of zone 2, and
- Target year 2015: future town extension area.

Water demands are estimated to meet the projected population of the water service area and other factors (refer to Section 5.3.4.). Detailed estimation is shown in Appendix D.

Table 6.1.1 Population and Water Demand

Target Year	2005	2010	2015
Population Projection	22,150	27,310	33,180
Supplied Population	16,500	25,500	33,180
Service ratio (%)	74.5	91.7	100.0
Average Water Consumption (l/c/d)	42.9	47.4	52.6
Average Daily Demand (m^3/d)	707	1,186	1,746
Max daily demand (m^3/d)	849	1,424	2,095
Peak hour demand (m^3/hour)	53.0	89.0	130.9

Figure 6.1.1 Outline of the Service Area



6.2 Water Resources Development Plan

6.2.1 Current Water Resources

The public water sources of the town are separated into two groups. A main water resources group is located at the southern end of the town, downstream of the Ruba Bur Dam, consisted of one dug-well (DW-2) and a borehole (BH-4) associated with a reservoir and booster pump. And a supplemental water source, which is a borehole (BH-7) installed with a submersible pump, is located in the town near the reservoir tank. Besides the said public water sources, four boreholes with a hand-pump are functioning for domestic water sources.

Besides the groundwater resources, there are about 11 micro dams in this area. Among them, Ruba Bur is in the vicinity of the town and acts as very good artificial recharge source for the wells downstream of it. Tekonda is also another small dam not far from the town but only used for livestock purpose.

6.2.2 Potential of Water Resources

(1) Introduction

In general, to evaluate a potential for water resources development, especially for groundwater resources, on a certain area is quite difficult except for the area where has complete hydrological data such as rainfall, surface runoff, groundwater hydrograph, evaporation, etc., recorded for long enough period. Besides those, the properties of controlling aquifer of the area, such as thickness, extension, transmissivity, storage coefficient, etc. shall be required to evaluate the groundwater potential on a certain groundwater basin. Conversely, a water resources potential of an area can be estimated substantially, if such hydrological/hydrogeological data on the area were available. In this case, many water balance equations can be utilized, and a simulation study which is the most reliable way to estimate a water resources development potential can be applied.

Unfortunately, most of such data on around the town are not available at the moment, except for rainfall data. Measurements on surface runoff (at the Mereb River) and groundwater level at Test Well (ADI-2) are already started. Pan Evaporation has been measuring at the Mendefera Station. Thus, the circumstances to evaluate a water resources potential, in detail, shall be established in near future. Right now, however, the water potential must be evaluated based on several suppositions.

(2) Potential of water resources

Basically, an origin of all water in a certain basin is rainfall. Considerable part of rainwater evaporates out before surface runoff or percolating through ground. And a part of remaining rainwater flows out through a river, then, only the last remaining part can percolate through ground recharging a groundwater. The maximum groundwater development potential, steadily available as water resources, is to be the volume of yearly recharging. Thus, the groundwater resources potential, the surface water potential as well, can be estimated as follows:

a) Rainfall – (effective) Evapotranspiration = Effective rain (mm)

b) Effective rain x catchment area = Total water source (m^3)

c) Total water source – Surface runoff = Groundwater recharge (m^3)

For Adi Keyih, monthly mean rainfalls are available (refer to section 4.1.2). Usually, there is no evapo-transpiration data because of difficulty of direct measurement. Evapotranspiration value used to be converted from Pan Evaporation value, as its 60 to 80%. In this Study, 70% of the converting rate from Pan Evaporation to Evapotranspiration is to be adopted as an average. Normally, a rainfall minus 70% of evaporation shall be an effective rain, and thus, only July and August have an effective rain. However, the river flow of the Mereb starts from June and lasts in October in most of the year, so 10% or 20% of monthly rainfalls at the beginning and the ending of a rainy season are intentionally counted as an effective rainfall.

Then, the effective rainwater must be shared between a surface runoff and a groundwater recharging. In Debub region, there is quite a few runoff observation data; those are only one month measuring data on the Mereb at Debarwa Bridge. Although the data indicated that the runoff coefficient of the Mereb was less than 8%, the monthly rainfall for the data (1997) was almost a half of the mean monthly volume. Runoff coefficient varies in accordance with a rainfall, and so about 16% of mean annual runoff coefficient is supposed for the area. In this case, the final effective rainwater is to be shared between runoff and percolation by 6:4, and the ratio shall be adopted at all of the target areas. Thus, the yearly groundwater recharge amount, that means the maximum available groundwater potential, is estimated as shown in Table 6.2.1.

Table 6.2.1 Estimation of Groundwater Recharge

Adi Keyih	Jun	Jul	Aug	Sep	Oct	Annual (mm)	(%)
Rainfall (mm/m)	30.8	161.1	115.7	24.2	8.0	493.7	100.0%
P.E (mm/d)	5.4	5.6	4.6	5.1	5.0	2,107.9	100.0%
E. Evapotr.(-"-)	117.2	121.5	99.8	110.7	108.5	1,503.8	70.0%
E. Rain (mm/m)	3.1	39.6	15.9	4.8	0.8	64.2	13.0%
Runoff (-"-)	1.8	23.7	9.5	2.9	0.5	38.5	7.8%
Recharge (-"-)	1.2	15.8	6.4	1.9	0.3	25.7	5.2%
Act. E.T. (-"-)	27.7	121.5	99.8	19.4	7.2	429.5	87.0%

Note 1) P.E: Pan Evaporation, E.: Effective, E.T.: Evapotranspiration
Note 2) There are no effective rain during Nov.~May.

As shown in the table, the averaged yearly groundwater recharge is estimated as small as 25.7 mm/a, which is only about 5.2 % of the total rainfall.

The area near around the town is divided into some small sub-basins. Eastern half of so-called Adi Keyih plateau including the town area belongs to the Ruba Bur sub-basin. While, western half of the plateau is included in the Ruba Adi Wegera sub-basin, in where the Test Well ADI-2 is located. On the east of Adi Keyih town, there is a small alluvial plain, at where the Test Well ADI-1 was drilled, and the plain is included in so-called Tekonda sub-basin. Further east of the area belongs to the vast catchment area of drainage system pouring into Red Sea. The areas of such sub-basins are 16.1, 16.9, and 35.0 km^2 for the Adi Keyih, Ruba Adi Wegera, and Tekonda sub-basins, respectively (refer to the Figure 6.2.1). Those areas are measured on the 1:50,000 aerial map. Each sub-basin area is extending to downstream more, in an exact saying, but cut short into the meaningful area from a view point of actual groundwater development, e.g. the Ruba Adi Wegera sub-basin is enclosed at the bridge of national road crossing the stream. Based on the area and effective rain, the yearly groundwater recharge on each sub-basin is calculated as 0.41, 0.43, and 0.90 MCM/a, for the said basins respectively.

Finally, a safety groundwater development volume must be considered, because such ground-water recharge occurs during rainy season, mostly within only two months, but water demand continues throughout a year in almost same level. The situation usually prevents a full-use of the maximum water resources potential, in particular in the area where groundwater flows out easily. In the region where has clear rainy and dry seasons, from one-third to one-tenth of the yearly recharge volume shall be taken as a criterion on the maximum groundwater development, depending upon the local condition though. For Adi Keyih area, the main aquifer is the fissured aquifer type of the basement metamorphic rocks, usually showing fair to good yield. And the secondary aquifer is the fissured type aquifer of Adigrat sandstone overlying the basement. There is no actual record on groundwater level here, but it can be supposed that the groundwater flow is not so smooth from the results of groundwater monitoring in the other sites. Such local condition can mitigate the limitation of safety groundwater development somewhat.

(3) Water quality

Water qualities of ten samples taken from the existing water supply system, inclusive of some water sources, were analyzed in the laboratory of WRD. It was reported that the water quality, in particular chemical properties, of this sub-region is generally good. However, the results of the analyses show that more than half of the samples inclusive of water sources, reservoir, and consumer's taps were found contaminated with *faecal coliform bacteria*. Although the report noted that such contamination might be occurred by unusual rainfall and flooding, checking of the water quality must be repeated periodically.

For the new water sources, groundwater extracted from the Test Wells ADI-1 and 2 were analyzed in the same laboratory. The result of analysis is attached in Appendix and shown as Figure 6.2.2. The data indicate that the water qualities of those boreholes are almost good for potable water, not contaminated by bacteria but having rather high EC values.

6.2.3 Water Resources Development Plan

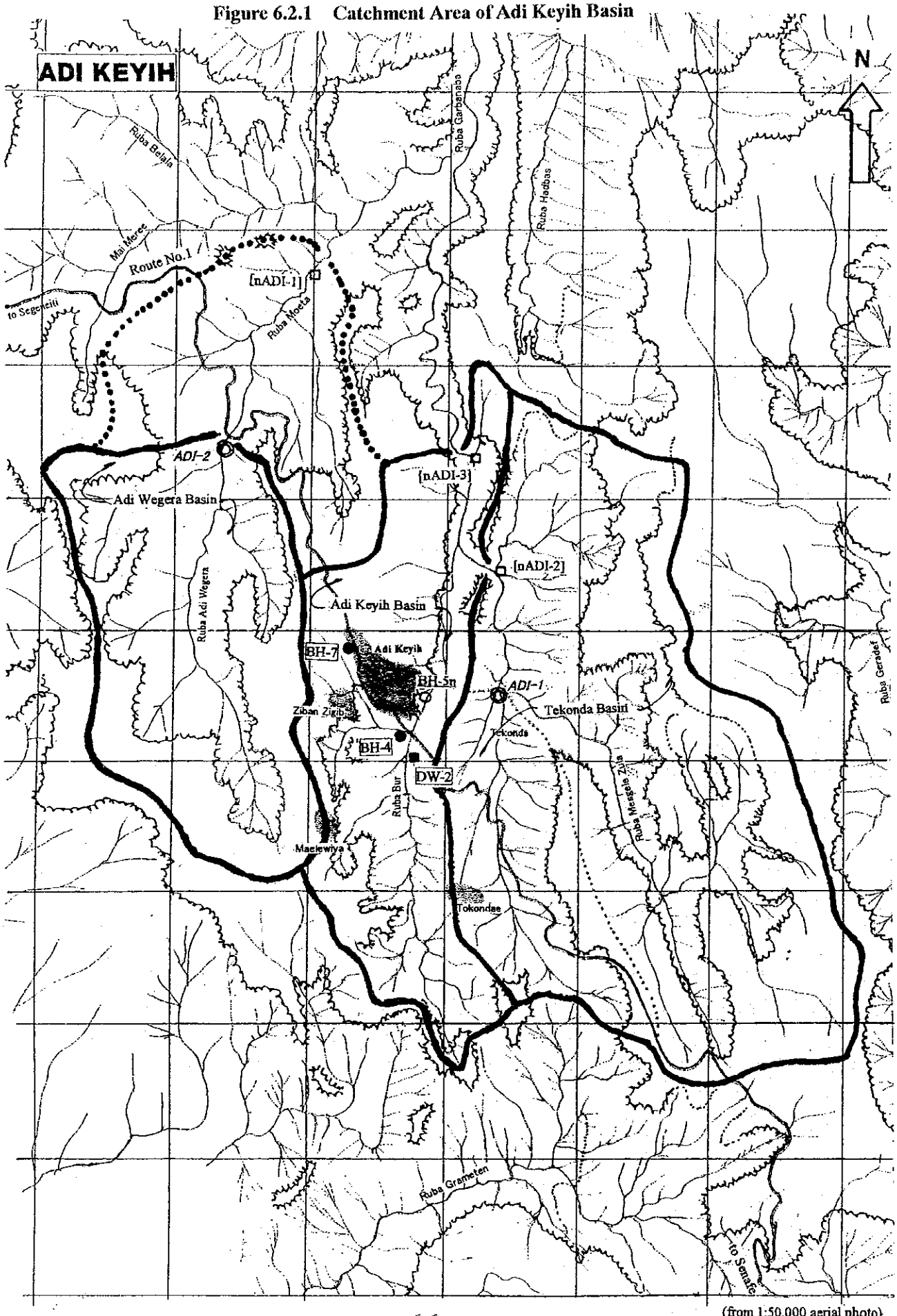
(1) Increasing of water demand

Water demand projection was already discussed in the previous section (6.1). And the Study projected out the increasing water demands of Adi Keyih as 849, 1424, and 2095 m^3/day in the year of 2005, 2010, and 2015, respectively. Increasing ratio of the water demand is rather high in comparison with the other target towns. The situation of such increasing water demand is illustrated in Figure 6.2.3, together with actual water resources development plan explaining in this section.

(2) Water resources development plan

The existing water sources have a total yield of around 553 m^3/day, but the yield of newly drilled ADI-2 and 1 are estimated as around 553.0 and 86.4 m^3/day, as a safety yield. Then, existing BH-5 which is capped now has also 86.4 m^3/day of yield. However, the total of all existing or confirmed yields can cover the water demand in 2005 but 2010. Any other water sources must be developed to cover the demands after 2010.

Figure 6.2.1 Catchment Area of Adi Keyih Basin



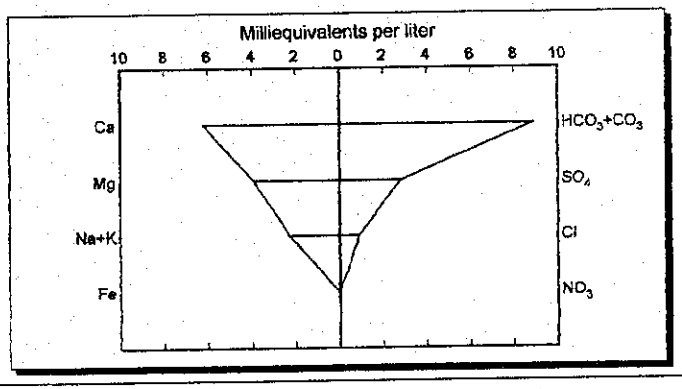
(from 1:50,000 aerial photo)

Figure 6.2.2 Water Quality of ADI-1 and 2

STIFF Diagram

Well Ident ADI-1

Description At Tekonda



Cations	Ca	Mg	Na	K	Fe
Milliequivalents per liter	6.1876	3.8991	2.2272	0.01534	0.0011
Milligrams per liter	124.00	47.40	51.20	0.60	0.02

Anions	HCO3	CO3	SO4	Cl	NO3
Milliequivalents per liter	8.89813		2.81070	0.91683	0.04355
Milligrams per liter	542.90		135.00	32.50	2.70

Mn	NO2	PO4	F	B	SiO2
0.0073	0.02413		0.0326		
TDS	Hardness	Alkalinity	Conductivity	pH	SAR
	28.2		1051.00	6.85	0.9917

Water Type **Calcium Bicarbonate**

Cations (epm) 12.3

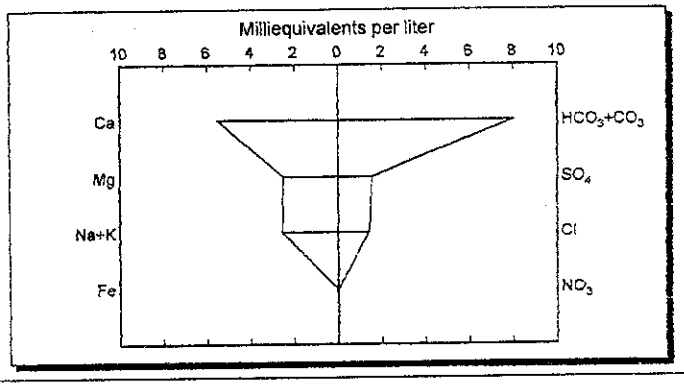
Anions (epm) 12.7

Error Balance 1.45

STIFF Diagram

Well Ident ADI-2

Description Adi Wegela



Cations	Ca	Mg	Na	K	Fe
Milliequivalents per liter	5.4890	2.5007	2.4404	0.10228	0.0011
Milligrams per liter	110.00	30.40	56.10	4.00	0.02

Anions	HCO3	CO3	SO4	Cl	NO3
Milliequivalents per liter	7.99832		1.56150	1.41050	0.02903
Milligrams per liter	488.00		75.00	50.00	1.80

Mn	NO2	PO4	F	B	SiO2
0.0146	0.01304		0.0200		
TDS	Hardness	Alkalinity	Conductivity	pH	SAR
	22.4		948.00	6.77	1.2210

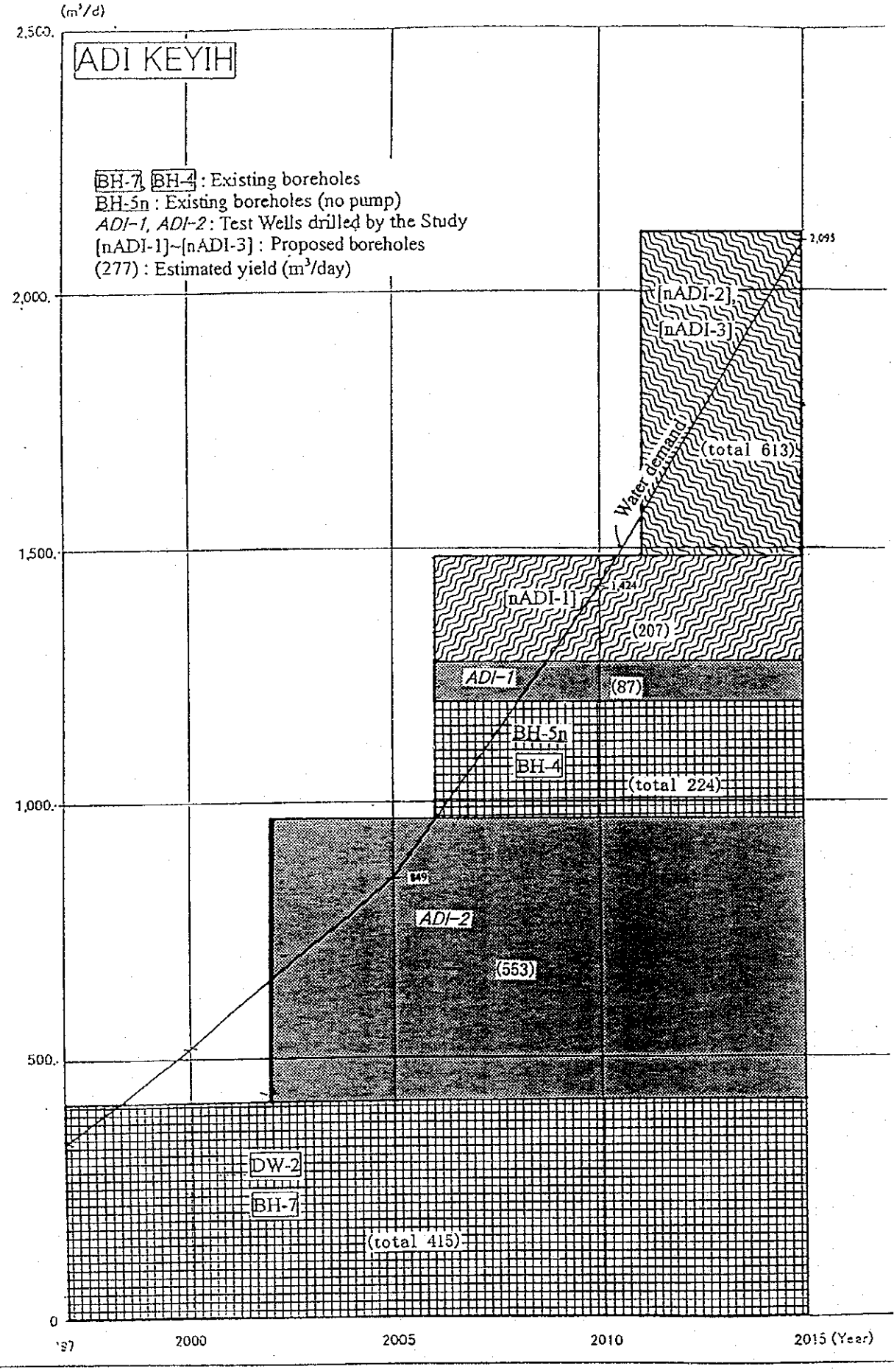
Water Type **Calcium Bicarbonate**

Cations (epm) 10.5

Anions (epm) 11.0

Error Balance 2.19

Figure 6.2.3. WATER DEMAND AND RESOURCES PLAN



Concerning to the water demand in 2005, there are some choices on the combination of water sources, but no water source can cover the demand alone. In this case, to make a simple water supply line, two of existing water sources of DW-2 and BH-7 and a newly drilled ADI-2 are to be involved into the basic water supply system. Because, ADI-2 has the largest water yield, BH-7 has the second large yield and locates near the planned reservoir tank, and DW-2 is one of the current water sources, locates at the southern end of the town, which can make a basic supply line extendable in the future. In this plan, the groundwater development volume in each basin is around 50% and 36% of the yearly recharging volume in Adi Wegera and Ruba Bur basin respectively.

To satisfy the water demand for 2010, not only remaining existing water sources but new water source shall be required. Total yield of the other existing sources, from BH-4, ADI-1, and BH-5, is only 311 m^3/day, and the maximum yield of above mentioned basic water sources is 967.7 m^3/day, thus, more than 145 m^3/day of water shall be short in this target year. To cover the shortage, a new production well shall be drilled. The new well, named as nADI-1, is proposed to drill at the downstream of Ruba Adi Wegera (refer to Figure 4.1.4 in the previous chapter), where is one of quite favorable groundwater basin to be developed. In the case, the groundwater development volume in Ruba Adi Wegera basin shall be of around 41% of the total potential, because the catchment area increases to 26.5 km^2. For the Ruba Bur and Tekonda sub-basins, the development volume becomes to around 20%, because the total area of them is 51.1 km^2.

For the final target year of 2015, more than 600 m^3/day of new water source must be developed in addition to the above mentioned water sources. To cover the shortage, some additional production wells shall be drilled, in the Tekonda sub-basin because it still has an excess groundwater development potential. The proposed new well site is at the downstream end of the Tekonda valley, and if it is not enough to cover the shortage, another well shall be drilled at the downstream end of the Ruba Bur valley. In this stage, total 7 of production wells yielding total 1356.8 m^3/day are allocated in the Ruba Bur and Tekonda sub-basins, and the ratio of the groundwater development to the total groundwater recharge is around 37.7 %, almost allowable ratio considering from the total situations of the area. Finally, it must be noted that the last two wells drilled in the downstream of those valleys need a severe flood protection works, because the downstream of Tekonda valley is usually flushed by floods, several times in a rainy season.

The recommended sites for the new production wells, both for the years of 2010 and 2015, are presented in Figure 6.2.1 together with the locations of Test Wells and existing water sources, however, further systematic siting works to identify the exact drilling points shall be required in each implementation stages.

6.3 Water Supply and Sanitary Facility Plan

6.3.1 Water Supply Facility Plan

(1) General

Water supplied area is at around 2370m to 2340m of elevation and the slopes gently incline from north to south and from west to east. The existing town consisted of zone 1 and eastern part of zone 2 is slightly lower than the western part of zone 2 and the future extension area.

Capacity of all the existing water supply facilities is not enough. In addition to this, the existing facilities except boreholes can not be used because of following conditions of the existing facilities.

- Well pumps are obsolete and have breakdowns,
- Reservoir is obsolete and insufficient pressure,
- Pipelines is also obsolete with insufficient diameter to cover the future demand, unknown location and diameter, etc., and
- Communal water points are damaged.

Therefore, all water supply facilities except the existing wells are newly planned under the project.

(2) Facility plan

Water supply facilities of this project consist of intake facilities (borehole and well pump), Transmission facilities (transmission pipeline, pump pit and booster pump), distribution facilities (reservoir and distribution pipeline), service facilities (individual connections and communal water points) and others (power supply and control house). These facilities are planned and summarized herein, and detailed calculations of each facilities are shown in Appendix D.

a) Intake facilities

As mentioned in "6.1.3 Water Resources Development Plan", new boreholes are drilled to meet the water demand for each target year.

Number of borehole and specifications of well pumps in each target year are as follows:

Target year 2005: Test borehole of ADI-2 and two existing boreholes of DW-2 and BH-7 to be planned.
Spec. of pump at ADI-2: Q=0.300m^3/m, H=102.6m
Spec. of pump at DW-2: Q=0.096m^3/m, H=101.0m
Spec. of pump at BH-7: Q=0.192m^3/m, H=13.1m

Target year 2010: Test borehole of ADI-1, two existing boreholes of BH-4 and BH-5 and one new borehole to be added. Well pumps to be replaced to meet water demand.
Spec. of pump at ADI-1: Q=0.060m^3/m, H=37.5m
Spec. of pump at ADI-2: Q=0.384m^3/m, H=111.7m
Spec. of pump at DW-2: Q=0.096m^3/m, H=113.5m
Spec. of pump at BH-4: Q=0.096m^3/m, H=108.7m
Spec. of pump at BH-5: Q=0.060m^3/m, H=18.6m
Spec. of pump at nADI-1: Q=0.114m^3/m, H=95.1m

Target year 2015: Two new boreholes to be added
Spec. of pump at nADI-2: Q=0.246m^3/m, H=77.1m
Spec. of pump at nADI-3: Q=0.192m^3/m, H=39.2m

b) Transmission facilities

Four new transmission pipelines are planned and extended to meet the water demand. Booster pumps shall be planned because of the long distance and difference of elevations. The transmission

facility plan for each target year is as follows:

Target year 2005: New pipeline from ADI-2 to new reservoir to be planned and another new pipeline from DW-2 and BH-7 to new reservoir to be replaced.
Diameter and total length of the pipe:
D=100mm to 60mm, L=5,886m
Spec. of new booster pump at BP1: Q=0.300m^3/m, H=112.1m
Spec. of new booster pump at BP2: Q=0.288m^3/m, H=48.2m
Number and capacity of pump pit for booster pump:
15m^3 2sets

Target year 2010: New pipeline from ADI-1 and BH-5 to new reservoir, and another new pipeline from nADI-1 to new reservoir to be added. Booster pumps to be replaced to meet water demand.
Diameter and total length of the pipe:
D=125mm to 60mm, L=9,660m
Spec. of new booster pump at BP1: Q=0.384m^3/m, H=115.0m
Spec. of new booster pump at BP2: Q=0.384m^3/m, H=52.6m
Spec. of new two booster pump at BP3: Q=0.120m^3/m, H=83.4m
Spec. of new booster pumps at BP4: Q=0.144m^3/m, H=105.5m
Spec. of new booster pumps at BP4': Q=0.144m^3/m, H=95.1m
Number and capacity of pump pit for booster pump:
15m^3 4sets

Target year 2015: One new pipeline from nADI-2 and nADI-3 to the pump pit of BP4 to be added.
Diameter and total length of the pipe
D=100 to 80mm, L=5,000m
Spec. of new booster pump at BP5: Q=0.483m^3/m, H=123.0m
Spec. of new booster pump at BP6: Q=0.582m^3/m, H=107.7m
Number and capacity of pump pit for booster pump:
15m^3 and 20m^3, each 1set

c) Distribution facilities

A new reservoir is planned at the highest location around 2390m-elevation in the west of the town A new ground type reservoir can cover the necessary pressure of the service areas. The reservoir will be expanded to meet the water demand for each target year.

Distribution pipeline is also newly laid and extended to meet the water demand in each target year. The distribution facility plan for each target year is as follows:

Target year 2005: Capacity and type of new reservoir
V=290m^3, H=5.5m ground type
Diameter and total length of the pipe
D=200 to 50mm, L=19,393m

Target year 2010: Capacity and type of additional reservoir
V=190m^3, H=5.5m ground type
Diameter and total length of expansile pipe

D=125 to 50mm, L=12,811m

Target year 2015: Capacity and type of one additional reservoir
V=220m^3, H=5.5m ground type
Diameter and total length of expansile pipe
D=150 to 50mm, L=10,065m

d) Service facilities

Number of individual connections is estimated from the percentage of consumers in each target year. Communal water points are planned close to the area of low income houses and the vicinity. Communal water points are arranged to cover up the area by circles of 150m-radius. Service facility plan for each target year is as follows:

Target year 2005:	Number of individual connections	1,730 sets
	Number of communal water points	9 sets
Target year 2010:	Number of additional individual connections	771 sets
	Number of additional communal water points	7 sets
Target year 2015:	Number of additional individual connections	984 sets
	Number of additional communal water points	5 sets

e) Others

Power supply for pumps is planed to use the network from diesel power plant in the region. Control houses are planed for the panel for pump, booster pump, generator for future plan, etc. Type A and B of the control house are for well pump, and type C and D are for booster pump. There is a generator room in the Type B and D. Number of control house is as follows:

Target year 2005: Number and type of control house
Type A: 1set, Type B: 2sets, Type C: 1set, Type D: 1set,

Target year 2010: Number and type of additional control house
Type A: 3sets, Type B: 1set, Type C: 3sets, Type D: 1set,

Target year 2015: Number and type of additional control house
Type A: 1set, Type B: 1set, Type C: 1set, Type D: 1set

Table 6.3.1 Number of Facilities

Item		Unit	Year		
Facility	Description		2005	2010	2015
Intake Facility	New borehole	sets		1	
	Existing borehole	sets	2	2	2
	Observation borehole	sets	1	1	
	Dam	sets			
	(Sub-total)	sets	3	4	2
Well Pump Facility	Submersible pump		DW-2, 0.096m3/min 101.0m, 1set	ADI-1, 0.060m3/min 37.5m, 1set	nADI-3, 0.192m3/min 39.2m, 1set
			BH-7, 0.192m3/min 13.1m, 1set	BH-5, 0.060m3/min 18.6m, 1set	nADI-2, 0.246m3/min 77.1m, 1set
			ADI-2, 0.300m3/min 102.6m, 1set	DW-2, 0.096m3/min 113.5m, 1set	
				BH-4, 0.096m3/min 108.7m, 1set	
				nADI-1, 0.114m3/min 95.1m, 1set	
				ADI-2, 0.384m3/min 111.7m, 1set	
	(Sub-total)	sets	3	6	2
Transmission Pipeline	DCIP 125mm	m		800.0	
	ditto 100mm	m	3,771.0		2,700.0
	ditto 80mm	m	1,772.0	4,800.0	2,300.0
	ditto 60mm	m	343.0	3,960.0	
	(Sub-total)	m	5,886.0	9,560.0	5,000.0
Booster Pump Facility	Centrifugal pump		BP.2, 0.288m3/min 48.2m, 1set	BP.3, 0.120m3/min 83.4m, 2set	BP.5, 0.438m3/min 123.0m, 1set
			BP.1, 0.300m3/min 112.1m, 1set	BP.4', 0.144m3/min 95.1m, 1set	BP.6, 0.582m3/min 107.7m, 1set
				BP.4, 0.144m3/min 105.5m, 1set	
				BP.1, 0.384m3/min 115.0m, 1set	
				BP.2, 0.384m3/min 52.6m, 1set	
	(Sub-total)	sets	2	6	2
Pump Pit	Made of RC		15m3, 2set	15m3, 4set	15m3 20m3
	(Sub-total)	sets	2	4	2
Reservoir	Made of RC		290m3, h=5.5m	190m3, h=5.5m	220m3, h=5.5m
	Made of F R P				
	Existing				
	(Sub-total)	sets	1	1	1
Distrbution Pipeline	P V C 200mm	m	643.0		
	ditto 150mm	m	216.0		310.0
	ditto 125mm	m	1,081.0	159.0	152.0
	ditto 100mm	m	844.0	668.0	1,049.0
	ditto 75mm	m	776.0	653.0	1,979.0
	ditto 50mm	m	15,833.0	11,331.0	6,575.0
	(Sub-total)	m	19,393.0	12,811.0	10,065.0
Control House		sets	5	8	4
Communal Water Point		sets	9	7	5
Individual Connection		sets	1,730	771	984
Tempolaty Road	Width 3.0m	m	3,000	6,500	7,000