To execute the civil works, the procurement of equipment (water well rigs and accessories) and material supply (Casing, Screen and Hand Pumps) will be made according to specifications of the local and foreign materials for the Project.

4-2. Project Formulation

4-2-1. Basic Concept

The current total population of the Project Area is 501,000. The total number of usable boreholes is 367, therefore, the population per borehole of 1,365. Taking into consideration the distance from a borehole, the current total population receiving the water supply from boreholes is estimated approximately at 154,000 or only 30.6 percent of the total population (418 persons per borehole in this case), while the rest 347,000 or 69.4 percent are obliged to use rivers or small swamps for their domestic water. Even the people using a borehole may sometimes go back and forth over a 5 - 6 km distance for a few times a day with a bucket on head.

Under such circumstances, the basic concept in planning the Rural water supply in the Project Area is to provide the number of boreholes enough to stably supply domestic water even in a drought year with a view to the possible future population increase.

The various factors relating to the basic concept are as follows.

- o The annual population increase rate shall be estimated at 3.6 percent, which is released from the Ministry of Water Resources and Development.

- o The total population receiving water supply per borehole in the planned target year shall be 250 as recommended by WHO.

- The distance to a borehole for the inhabitants shall be at most 1.0 km.

- The priority of constructing the boreholes shall be in the order of business center, schools, and village where no borehole exists at present. Also priority is given to Miscellaneous group over Main River group.

- A complete dependence on the boreholes for feeding water to livestock requires quite a number of boreholes to be constructed, which is a very hard work. This project shall set the primary purpose in the supply of domestic water to the inhabitants, and assume that the water supply to the livestock be effected by pumping up additional water from boreholes only for a drought period.

4-2-2. Selection of Most Suitable Plan

(1) Alternative Plans

National census of October, 1982 estimates that the current total population of 501,000 in the Project Area will increase at an annual rate of 3.6 percent, thus reaching the estimated population of 1,053,000 or twice the current population in two decades.

Aiming at supplying the water to 250 persons per borehole over the entire Project Area in this period, the comparative study was made to determine how many years are required to best realize the objective from technical and economical viewpoints.

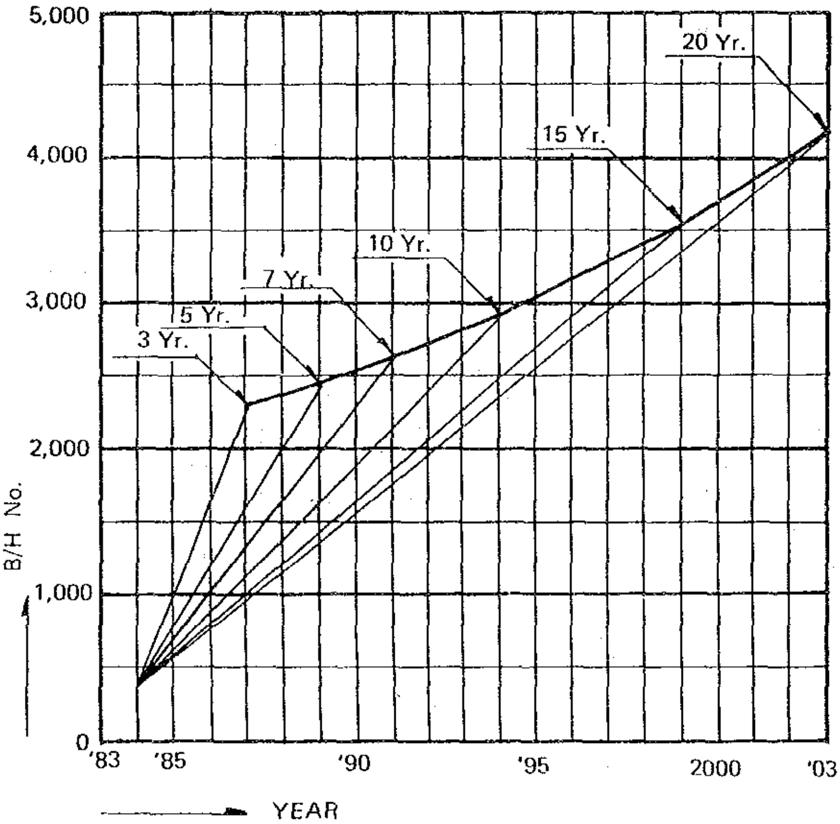
The target years set for this comparative study includes six alternatives 20, 15, 10, 7, 5 and 3 years. Table 4-2-1 shows the number of boreholes required and the corresponding number of persons per borehole. The asterisk (*) represents the year reaching the objective of water supply to 250 persons per borehole. Fig. 4-2-1 illustrates the six alternative plans in a graph form.

Table 4-2-1 Estimated No. of Boreholes for Alternative Plans

Alternative (Target Years)	No. of New Boreholes per Year	Year	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
		Population	518,990	537,670	557,030	577,080	597,850	619,370	641,670	664,770	688,700	713,490	739,180	765,790	793,360	821,920	851,510	882,160	913,920	946,820	980,910	1,016,220	1,052,800
20 yrs.	192	B/H No.	367	559	751	944	1136	1328	1520	1712	1305	2097	2289	2481	2673	2866	3058	3250	3442	3634	3827	4019	4211
		PR B/H	1414	962	742	611	526	466	422	388	362	340	323	309	277	287	278	271	266	261	256	253	* 250
15 yrs.	211	B/H No.	367	578	789	999	1210	1421	1632	1843	2053	2264	2475	2688	2897	3107	3318	3529	3656	3787	3924	4064	4211
		PR B/H	1414	930	706	578	494	436	393	361	335	315	299	285	255	265	257	* 250	250	250	250	250	250
10 yrs.	259	B/H No.	367	626	885	1144	1403	1662	1921	2180	2439	2698	2957	3063	3173	3288	3406	3529	3656	3787	3924	4064	4211
		PR B/H	1414	859	629	504	426	373	334	305	282	264	* 250	250	250	250	250	250	250	250	250	250	250
7 yrs.	327	B/H No.	367	694	1022	1349	1677	2004	2332	2659	2755	2854	2957	3063	3173	3288	3406	3529	3656	3787	3924	4064	4211
		PR B/H	1414	775	545	428	356	309	275	*250	250	250	250	250	250	250	250	250	250	250	250	250	250
5 yrs.	422	B/H No.	367	789	1211	1633	2055	2477	2567	2660	2755	2854	2957	3063	3173	3288	3406	3529	3656	3787	3924	4064	4211
		PR B/H	1414	681	460	356	291	* 250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250
3 yrs.	647	B/H No.	367	1014	1661	2308	2391	2477	2567	2660	2755	2854	2957	3063	3173	3288	3406	3529	3656	3787	3924	4064	4211
		PR B/H	1414	530	335	*250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250

NOTES : B/H No. : Borehole Number
PR B/H : Persons per Borehole
* : Target Year (250 Persons per Borehole)

Fig. 4-2-I No. of Boreholes Attained in 6 Alternative Plans



Note: For detail see Table 4-2-1

(2) Economic Study

Based on the six (6) alternative plans used for comparative economic study, the construction cost was also compared, in which the unit price as of January, 1983 in Zimbabwe is applied with 16 percent average annual price increase estimated from the building materials price index for 1974 through 1982 in Monthly Digest of Statistics, November 1982. For the drilling method, judging from the strata in the Project Area this comparison is based on the air hammer method which is more beneficial technically and economically than the conventional manual percussion method (Refer to Division 4-3). The constructing costs calculated are for boreholes of 45 m depth on average, composed of drilling cost by using high speed rig, material and installation costs of casing and screen as well as hand pump cost.

To find the most suitable drilling programme from the economical viewpoint, six alternatives have been studied with varying number of water well rigs and varying yearly outputs. Table 4-2-2 and Fig. 4-2-2 shows such alternatives as to target period in years, annual output and number of rigs required.

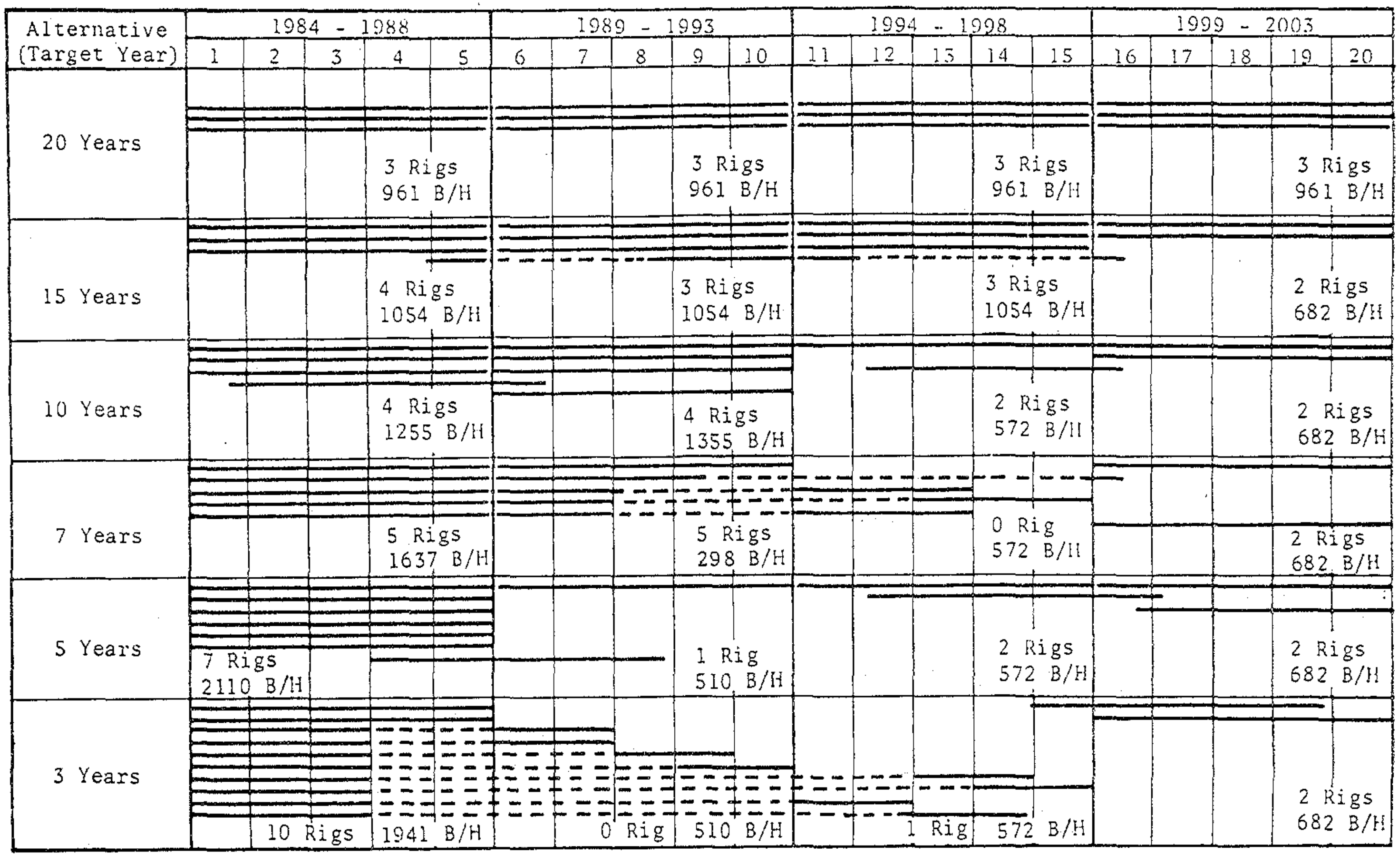
Table 4-2-2 Construction Costs for Alternative Plans

(Unit: '000 Z$)

Alternative (Target Year)	Description	1984/88	1989/93	1994/98	1999/2003	Total
20 yrs.	B/H No.	961	961	961	961	3,844
	5 yr. Cost	8,750	18,350	38,560	81,030	146,690
	Cost/BH	9.1	19.1	40.1	84.3	38.2
15 yrs.	B/H No.	1,054	1,054	1,054	682	3,844
	5 yr. Cost	10,380	20,820	44,070	57,590	132,860
	Cost/BH	9.8	19.8	41.8	84.4	34.6
10 yrs.	B/H No.	1,295	1,295	572	682	3,844
	5 yr. Cost	11,790	24,760	24,080	57,590	118,220
	Cost/BH	9.1	19.1	42.1	84.4	30.8
7 yrs.	B/H No.	1,637	953	572	682	3,844
	5 yr. Cost	14,860	21,850	22,700	57,590	117,000
	Cost/BH	9.1	22.9	39.7	84.4	30.4
5 yrs.	B/H No.	2,110	480	572	682	3,844
	5 yr. Cost	19,720	8,730	24,080	57,590	110,120
	Cost/BH	9.3	18.2	42.1	84.4	28.6
3 yrs.	B/H No.	2,110	480	572	682	3,844
	5 yr. Cost	21,420	14,490	25,800	57,590	119,300
	Cost/BH	10.0	30.2	45.1	84.4	31.0

Note : B/H No.; No. of new boreholes for 5 year period.
Cost/BH; Unit cost per borehole including price escalation.

Fig. 4-2-2 Alternative Plans with Drilling Rig Working Schedule



—— Operating

---- Idling

Note : Life time of a rig is 5 years.

(3) Selected Plan

The construction cost per borehole is lower for the 20-, 10- and 7-year plans in terms of the average over the first five (5) years than other plans. The target of 20 years is too long for a borehole construction plan requiring urgent action.

However, the 7-year planning may require too much capital investment in the Project Area as compared with those in the other areas.

Therefore, the 10-year plan, the intermediate plan among all other alternatives would be the most recommendable for the planned target year in this Project Area.

The 10-year plan requires the construction of 259 boreholes per annum and 2,590 boreholes in total over the projected decade. By the end of the target year the work completed insures the water supply to 250 persons per borehole throughout the Project Area. Henceafter, the number of boreholes should be increased as the population increases.

4-2-3. Rural Water Supply Programme

The ten-year programme is adopted as the most suitable plan based on the study mentioned in Section 4-4-2. Number of the proposed boreholes totals 2,590 or 259 per year on average.

The distribution of social infrastructures for each water resource in the Communal Lands is shown in Table 4-2-4. There are six (6) District Service Centers which have or will have water supply projects financed by the Government or ADB. They are, therefore, excluded from this rural water supply programme. Number of social infrastructres in the Area is shown in Table 3-1-2, and this table shows that boreholes are provided at about 45 percent of Business centers, and 35 percent of schools. Most of them are served by only one borehole each, and thus they also require additional borehole(s) due to shortage of water.

Population, number of existing boreholes and total number of boreholes required in the target year are shown in Table below.

Table 4-2-3. Proposed Borehole Number by 1993

Communal Lands	Population 1983	%	Exist BH/No 1983	Target 1993	Proposed New BH/No 1993
Chilimanzi	43,670	8.4	20	248	228
Shurugwi	43,230	8.3	10	245	235
Runde	38,760	7.5	26	222	196
Mazvihwa	18,470	3.6	6	106	100
Mberengwa	156,210	30.1	115	890	775
Chibi	142,670	27.5	111	813	702
Matibi No.1	41,280	8.0	45	237	192
Maranda	34,700	6.6	34	196	162
Total	518,990	100	367	2,957	2,590

Notes:
(1) Total target number of 2,957 is given in Table 4-2-1.
(2) Target 1993 = 2,957 x percentage of population of each C.L.
(3) Proposed New BH/No.= Target - existing BH/No.

4-2-4. Priority of Programme

In compliance with the 10 year plan, the projected boreholes in the Project Area should be constructed according to the priority mentioned below. Table 4-2-4 shows the number of social infrastructres at three water sources and priority scoring points. In consideration of the actual degree of distress, priority scoring point for providing the borehole is proposed at first for the miscellaneous group, secondly for the main river group and thirdly for the existing borehole group as 3, 2 and 1 respectively. The priority scoring point for each social infrastructure is then given in the order of Service Center (S/C), Business Center (B/C), School (Sch), Hospital/clinic (H/C), village Type-A (V/A), Village Type-B (V/B) and HUT as 7, 6, 5, 4, 3, 2 and 1 respectively. The resultant priority is then expressed in the brackets as the product of these two scoring points. For example school (5) in miscellaneous group (3) has the resultant priority of (5)x(3) = (15). The larger the points are, the larger is the priority.

In the first round of implementation the whole Project Area shall be covered by circular areas with 2 km in radius. The area of one circle is 12.6 km^2. This means that if one borehole each is supplied within one circle area, the total number of boreholes required to cover the whole Project Area (12,400 km^2) is abut 980. Together with the 367 existing boreholes, about 610 new boreholes would cover the whole Project Area. Actually, the total number of boreholes required becomes smaller since more than 10 percent of the Area is non-inhabited area such as mountains. At the end of this round, however, the average number of users per borehole is about 600 and it corresponds to 40 percent of the target programme. In the following round, boreholes shall be added considering the density of population so that the site of high population density will have additional borehole(s) constructed to reach gradually the target density of 250 persons per borehole. For the groups of huts, target density of one borehole per 250 persons is also aimed at and gradually realized according to the priority.

4-2-5. Programme of Each Communal Land

Number of proposed boreholes in each Communal Land is shown in Table 4-2-5. The construction order is in accordance with the priority point given in Table 4-2-4. About 23 percent or 610 boreholes out of total proposed 2,590 boreholes will cover the whole Project Area as described in Section 4-2-4. Water supply programme shall be decided based on the implementation programme described in Chapter V. Programme for each Communal Land is shown in Tables 4-2-5, 4-2-6 and DAW No.10 and DAW No.11 according to the implementation programme and priority points mentioned above.

Table 4-2-6 shows the implementation programme for the first three years. The programme covers Village Type-B (V/B) which has four priority points. After that, borehole construction might be shifted to Business Centers, and Schools which already have boreholes or to groups of huts covered by Miscellaneous Water Sources.

Table 4-2-4 Social Infrastructures and Priority Scoring Points

COMMUNAL LANDS	Boreholes (1) B/H No.	(7) S/C	(6) B/C	(5) SCH	(4) H/C	(3) V/A	(2) V/B	(1) HUT
Chilimanzi	20	5	4	11	2	4	4	2,085
		(7)	(6)	(5)	(4)	(3)	(2)	(1)
Shurugwi	11	6	3	8	6	2	2	1,152
		(7)	(6)	(5)	(4)	(3)	(2)	(1)
Runde	26	3	3	11	1	0	0	1,237
		(7)	(6)	(5)	(4)	(3)	(2)	(1)
Mazvihwa	6	3	0	3	0	0	0	398
		(7)	(6)	(5)	(4)	(3)	(2)	(1)
Mberengwa	114	14	28	27	15	7	5	3,245
		(7)	(6)	(5)	(4)	(3)	(2)	(1)
Chibi	111	6	22	29	5	2	3	2,515
		(7)	(6)	(5)	(4)	(3)	(2)	(1)
Matibi No.1	45	4	9	17	2	1	3	1,661
		(7)	(6)	(5)	(4)	(3)	(2)	(1)
Maranda	34	2	7	13	6	0	0	948
		(7)	(6)	(5)	(4)	(3)	(2)	(1)
Total	367	43	76	119	37	16	17	13,241

COMMUNAL LANDS	Main Rivers (2) (6) B/C	(5) SCH	(4) H/C	(3) V/A	(2) V/B	(1) HUT
Chilimanzi	0	3	-	0	0	251
	(12)	(10)	(8)	(6)	(4)	(2)
Shurugwi	1	0	-	0	0	0
	(12)	(10)	(8)	(6)	(4)	(2)
Runde	0	3	-	0	0	751
	(12)	(10)	(8)	(6)	(4)	(2)
Mazvihwa	0	0	-	0	0	578
	(12)	(10)	(8)	(6)	(4)	(2)
Mberengwa	1	5	-	1	4	1,851
	(12)	(10)	(8)	(6)	(4)	(2)
Chibi	2	4	-	0	1	1,565
	(12)	(10)	(8)	(6)	(4)	(2)
Matibi No.1	2	2	-	0	0	349
	(12)	(10)	(8)	(6)	(4)	(2)
Maranda	0	6	-	0	0	270
	(12)	(10)	(8)	(6)	(4)	(2)
Total	6	23	-	1	5	5,615

COMMUNAL LANDS	Miscellaneous (3) (6) B/C	(5) SCH	(4) H/C	(3) V/A	(2) V/B	(1) HUT
Chilimanzi	2	19	-	1	3	3,414
	(18)	(15)	(12)	(9)	(6)	(3)
Shurugwi	10	18	-	0	3	5,459
	(18)	(15)	(12)	(9)	(6)	(3)
Runde	3	13	-	1	0	2,071
	(18)	(15)	(12)	(9)	(6)	(3)
Mazvihwa	2	3	-	1	1	964
	(18)	(15)	(12)	(9)	(6)	(3)
Mberengwa	26	57	-	5	0	9,576
	(18)	(15)	(12)	(9)	(6)	(3)
Chibi	27	44	-	1	4	8,671
	(18)	(15)	(12)	(9)	(6)	(3)
Matibi No.1	6	5	-	1	0	1,628
	(18)	(15)	(12)	(9)	(6)	(3)
Maranda	9	13	-	0	0	1,932
	(18)	(15)	(12)	(9)	(6)	(3)
Total	85	172	-	10	11	33,715

Notes:
1. B/H: Borehole, MWR & D
2. S/C: Service Center
3. B/C: Business Center
4. SCH: School
5. H/C: Hospital or Clinic
6. V/A: Village Type-A, more than/equal to 10 block houses.
7. V/B: Village Type-B, less than 10 block houses.
8. HUT: Hut Nos.
9. ( ): The Figures in Parentheses give the Priority Scoring Points.

Source: 1 to 5 are from the District Administrators.

6 to 8 are from the Topo-maps 1/50,000 (1979).

Table 4-2-5 Proposed Drilling Programme by 1993/94 (Target Year)

(Unit: Borehole Number)

Year / C.L.	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	Total
Chilimanzi	13	25	25	26	23	23	23	23	23	24	228
Shurugwi	13	29	24	27	24	23	24	23	24	23	234
Runde	12	18	22	23	20	20	21	20	20	20	196
Mazvihwa	6	7	11	12	11	10	11	10	11	11	100
Mberengwa	46	92	88	88	76	78	77	78	76	77	776
Chibi	43	74	81	80	71	71	70	71	71	70	702
Matibi No.1	12	21	24	21	19	19	19	19	19	19	192
Maranda	10	27	19	17	15	15	14	15	15	15	162
Total	155	293	294	294	259	259	259	259	259	259	2,590

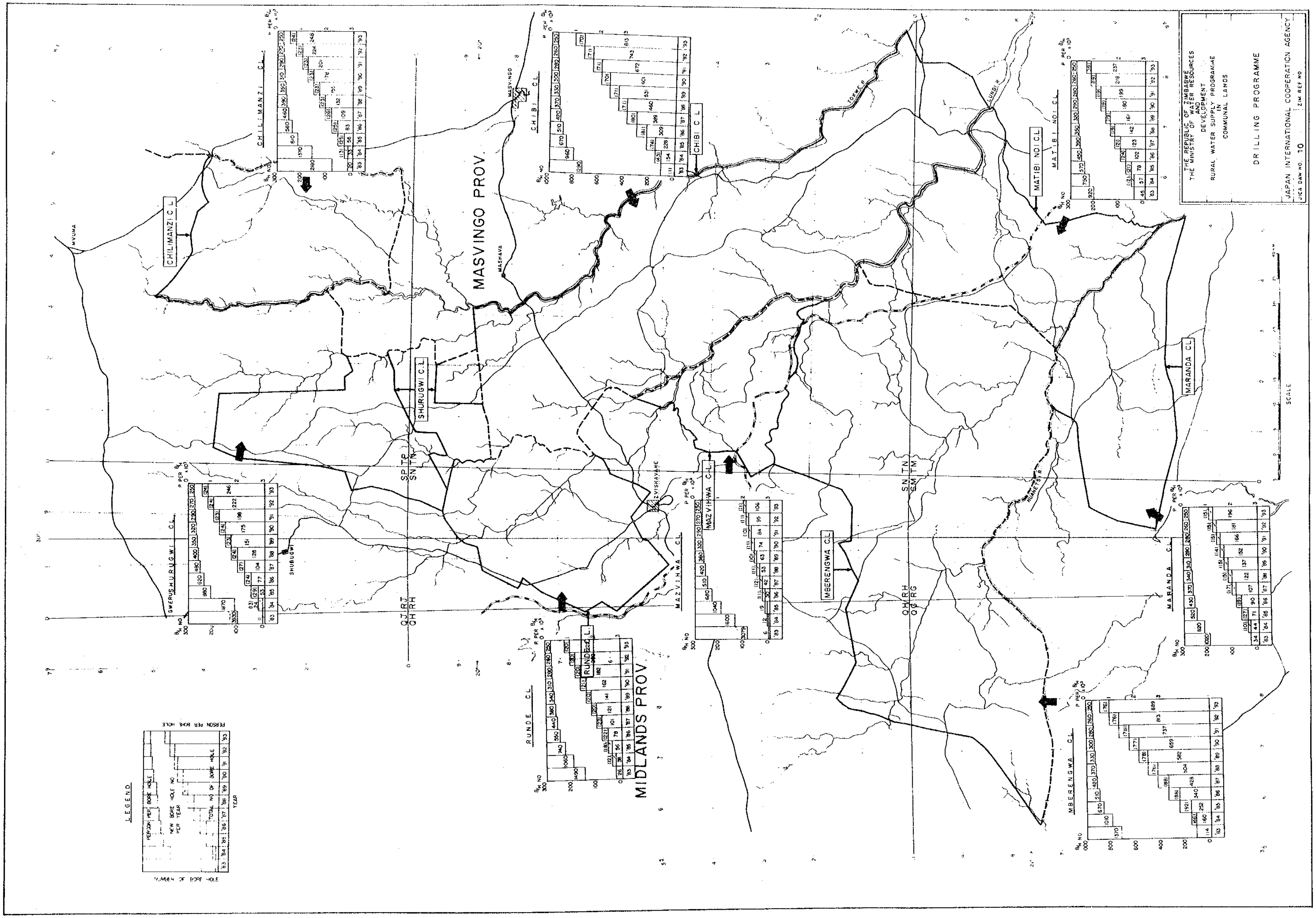
Note : Detail Programme for first three years 1984 to 1986 is shown in Table 4-2-6.

Table 4-2-6 Proposed Drilling Programme in First Three Years

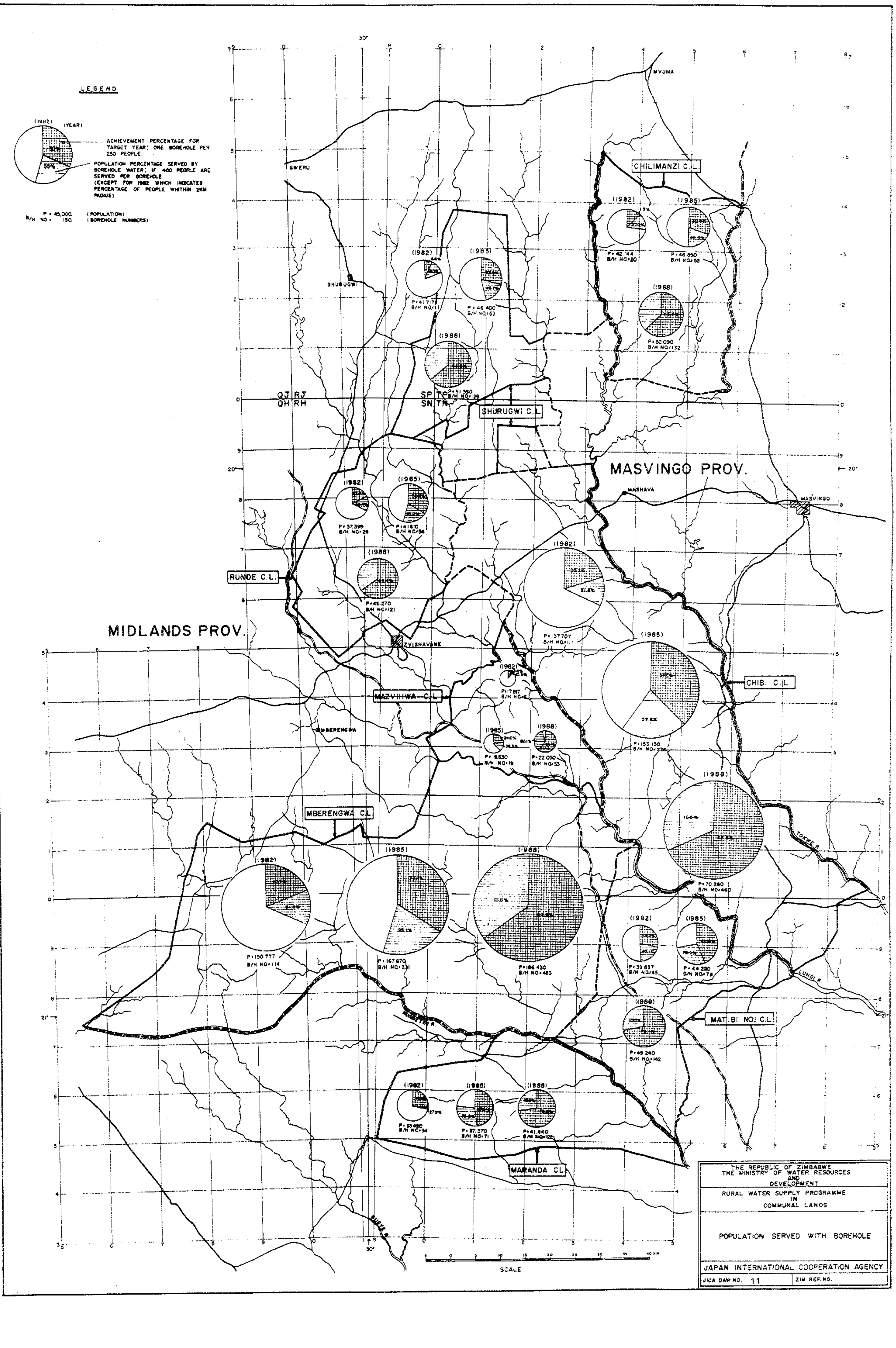
(Unit: Borehole Numbers)

Year / Point / Name of C.L.	1984/85		1985/86							1986/87			Total
	18 pt	15 pt	15 pt	12 pt	10 pt	9 pt	7 pt	6 pt	5 pt	5 pt	4 pt	3 pt	
Chilimanzi	2	11	8	0	3	1	6	7	0	11	2	12	63
Shurugwi	12	1	17	1	0	0	5	6	0	8	6	10	66
Runde	5	7	6	1	3	1	1	3	3	8	1	13	52
Mazvihwa	5	1	2	0	0	1	0	1	3	0	0	11	24
Mberengwa	31	15	42	2	5	5	9	29	0	27	15	46	226
Chibi	29	14	30	2	4	1	5	26	6	23	5	53	198
Matibi No.1	8	4	1	2	2	1	3	9	3	14	2	8	57
Maranda	9	1	12	0	6	0	2	7	0	13	6	0	56
Sub-total	101	54	118	8	23	10	31	88	15	104	37	153	742
Total	155		293							294			742

Note : Pt; Priority scoring points shown in Table 4-2-4.



THE REPUBLIC OF ZIMBABWE
THE MINISTRY OF WATER RESOURCES AND DEVELOPMENT
RURAL WATER SUPPLY PROGRAMME IN COMMUNAL LANDS
DRILLING PROGRAMME
JAPAN INTERNATIONAL COOPERATION AGENCY
JICA DAW NO. 10
MASVINGO PROV.
MIDLANDS PROV.
CHILIMANZI C.L.
CHIBI C.L.
MATIBI NO.I C.L.
MARANDA C.L.
SHURUGWI C.L.
MAZVIHWA C.L.
MBERENGWA C.L.
RUNDE C.L.
GWERU SHURUGWI C.L.
MASVINGO
MASHAVA
ZVISHAVANE
SHURUGWI
MVUMA
LEGEND
PERSON PER BORE HOLE
NEW BORE HOLE NO PER YEAR
TOTAL NO OF BORE HOLE
NUMBER OF BORE HOLE
YEAR
SCALE



LEGEND
(1982) (YEAR)
ACHIEVEMENT PERCENTAGE FOR TARGET YEAR: ONE BOREHOLE PER 250 PEOPLE.
POPULATION PERCENTAGE SERVED BY BOREHOLE WATER: IF 400 PEOPLE ARE SERVED PER BOREHOLE (EXCEPT FOR 1982 WHICH INDICATES PERCENTAGE OF PEOPLE WITHIN 2KM RADIUS)
P = 45,000. (POPULATION)
B/H NO = 150. (BOREHOLE NUMBERS)
MIDLANDS PROV.
MASVINGO PROV.
CHILIMANZI C.L.
SHURUGWI C.L.
RUNDE C.L.
MAZVIHWA C.L.
CHIBI C.L.
MBERENGWA C.L.
MATIBI NO.1 C.L.
MARANDA C.L.
MVUMA
GWERU
SHURUGWI
MASHAVA
MASVINGO
ZVISHAVANE
MBERENGWA
TOKWE R.
LUNDI R.
MWENEZI R.
BUBYE R.
SCALE
THE REPUBLIC OF ZIMBABWE
THE MINISTRY OF WATER RESOURCES AND DEVELOPMENT
RURAL WATER SUPPLY PROGRAMME IN COMMUNAL LANDS
POPULATION SERVED WITH BOREHOLE
JAPAN INTERNATIONAL COOPERATION AGENCY
JICA DAW NO. 11
ZIM REF. NO.

4-2-6. Standards

(1) Water Demand

In general, water demand depends on service level to be provided. Which system to be selected or how to combine each system is decided respectively according to social condition of each country. In this Project a service level by borehole is adopted for Communal Lands. In this case, a distance of transportation between water source and each hut is an important factor that determines water demand. In respect of this point, an international standard is already reported by the International Red Cross Society in 1981 as Table below.

Table 4-2-7. Average Daily Water Demand for Domestic Use in Developing Countries

Water Supply System		Daily Water Demand	
Type of Water Service	Distance from Water Sources(m)	Average(lcd)	Range(lcd)
Well/public tap	more than 1,000 m	7	5 - 10
	500 to 1,000 m	12	10 - 15
Well	less than 250 m	20	15 - 25
Public tap	less than 250 m	30	20 - 50
Yard connection		40	20 - 50
House connection	single tap	50	30 - 50
	multiple tap	150	70 -250

Notes: 1. taken from E.G. WAGNER and U.N. LEROIX (1981), "Water Supply for Rural Areas and Small Communities".

2. lcd = liter per capita per day

In the present report water demand was estimated based on the standard of the International Red Cross Society. A distance of transportation to be planned in this Project varies from 300 m to 700 m. Applying this figure to the standard, average daily water demand per capita is 15 lcd or more and the range is between approximately 12 and 18 lcd.

As population per one borehole will be 250 people, and planned water demand is presumed 15 lcd, and the required daily water volume per one borehole is calculated as follows:

15 lcd x 250 persons = 3,750 l/day

The required pumping duration for the daily water demand is calculated next. Supposing that the capacity of hand pump to be adopted is as follows:

Pumping capacity: 15 l/min
Pumping efficiency: 70%

Then,

$$\frac{3{,}750 \text{ lit}}{15 \text{ lit/min} \times 70\%} = 357 \text{ min} \doteqdot 6 \text{ hrs.}$$

The required pumping duration is about six hours. This figure is considered acceptable if people operate the hand pump for two hours three times a day.

(2) Water Quality

i) Water quality standard in Zimbabwe

The water quality analysis and judgement for drinking water are carried out by Government Analyst Laboratory and according to WHO's International Standards for Drinking Water.

WHO's standard is divided into two parts; one is a standard for taste and the other one is a standard for health.

Maximum permissible level in Table 4-2-8 is adopted as a standard for taste in Zimbabwe. Actually, some allowance is given in the application of this standard, in case there is no other water sources. And the water quality is not harmful to human health, it is permitted to use that water source as drinking water even if several items of water quality exceed the standard value.

On the other hand, Upper Limit of Concentration in Table 4-2-9 is adopted as a standard for health.

ii) Water quality standard in this Project

The water quality standard of WHO has been adopted as an international standard throughout the world. But, recently some relaxation of standard has been required for economic reason in developing countries. WHO is, therefore, trying to revise the present standard and establish a guideline, which indicates a desirable water quality for drinking. When the desirable value is exceeded, this does not mean that the water is unsuitable, but a certain measure for improvement is required.

Taking account of this international trend and of the water quality standard in Zimbabwe, a water quality standard in this Project is summarized as follows:

The maximum permissible level in "International Standards for Drinking Water" (3rd edition) of WHO is recommended. In this case, it is necessary to take account of the surrounding environment and judge the water to be acceptable or not.

° Standard for health

Arsenic (AS), Cadmium (Cd), Cyanide (CN), Lead (Pb), Mercury (Hg), Selenium (Se)

Taking account of harm to health, WHO's standard should apply to these items.

° Nitrate Nitrogen

Nitrate Nitrogen in drinking water cause methaemoglobinaemia to children. According to WHO's standard, Nitrate (as No_3) concentration should be less than 45 mg/l.

This value is converted into Nitrate Nitrogen of about 10 mg/l. There is a case where methaemoglobinaemia does not occur even if Nitrate Nitrogen concentration is more than 10 mg/l, but in consideration of safety especially for children, standard value should be less than 10 mg/l which is the same as WHO's standard.

° Fluorides

Fluorides in drinking water causes decayed teeth. WHO's standard, classifies six degrees of values by annual average of maximum daily air temperature in each region. Applying this classification to Zimbabwe, upper limit of Fluorides is 1,0 mg/l. But, standard value of Fluorides should be decided taking account of life condition, especially eating habit and water consumption. Therefore, a standard value of this Project is estimated from 1,2 to 1.5 mg/l.

° Bacteria

It is necessary to establish a standard and an examination system for bacteria in drinking water because of non-availability of water quality standard in Zimbabwe and WHO.

Although a water quality standard for the Project is specified as mentioned above, it is important for Zimbabwe Government to establish monitoring system of water quality to effectively promote the Project.

Table 4-2-8. Water Quality Standard for Taste 1/

	Water Quality Standards	
Substance	Highest Desirable Level	Maximum Permissble Level
Colour	5 units	50 units
Odour	Unobjectionable	Unobjectionable
Taste	Unobjectionable	Unobjectionable
Suspended matter	5 units	25 units
Total solids	500 mg/l	1,500 mg/l
pH ranges	7.0 to 8.5	6.5 to 9.2
Total hardness	100 mg/l $CaCO_3$	500 mg/l $CaCO_3$
Calcium (as Ca)	75 mg/l	200 mg/l
Magnesium (as Mg)	30 mg/l 2/ 150 mg/l	150 mg/l
Chloride (as Cl)	200 mg/l	600 mg/l
Copper (as Cu)	0.05 mg/l	1.5 mg/l
Iron (total as Fe)	0.1 mg/l	1.0 mg/l
Manganese (as Mn)	0.05 mg/l	0.5 mg/l
Sulfate (as SO_4)	200 mg/l	400 mg/l
Zinc (as Zn)	5.0 mg/l	15 mg/l

Notes: 1/ Taken from substances and characteristics affecting the acceptability of water for domestic case in WHO's water quality standard.

2/ Not more than 30 mg/l if there are 250 mg/l of sulfate; if there is less sulfate. Magnesium up to 150 mg/l may be allowed.

Table 4-2-9. Water Quality Standard for Health

Substance	Water Quality Standard Upper Limit of Concentration
Arsenic (as As)	0.05 mg/l
Cadmium (as Cd)	0.01 mg/l
Cyanide (as CN)	0.05 mg/l
Lead (as Pb)	0.1 mg/l
Mercury (as Hg)	0.001 mg/l
Selenium (as Se)	0.01 mg/l
Nitrate Nitrogen	10 mg/l
Fluoride (as F)	0.8 - 1.7 mg/l

Note: Taken from Tentative Limits for toxic substance in drinking water, Nitrate Nitrogen and Fluorides in WHO's water quality standard.

4-3. Facilities Planning

The groundwater supply facilities consist of borehole, pumping equipment and other appurtenant facilities. The planning of facilities take into account both hydrogeological conditions and the current water supply facilities in Zimbabwe.

4-3-1. Borehole

(1) General Description

This Section describes the study on the drilling method, borehole specification and drilling equipment, which are the most important aspects of the facilities.

This paragraph discusses the drilling method with a view to current boreholes. With respect to the groundwater in this Project, the boreholes is planned for deep groundwater, taking into account the water quantity, stable supply, and hygiene.

It is necessary to employ a drilling method that allows the hard rock formation to be drilled efficiently, and yet prevents any small fissure or breakages from being clogged.

The drilling equipment can be classified into the percussion system to crush rocks by applying an impact force, and the rotary system to crush rocks by cutting, scooping and forcefully impressing a bit blade head. In order to increase the drilling speed, the percussion system increases the bit load to be applied and drop speed and impact frequency per hour, whereas the rotary system increases the revolution and bit load to be applied. Based on these drilling systems, a classification of drilling equipment and drills is given in Table below.

Table 4-3-1 Classification of Drilling Equipment

- Percussion drilling rig
  - (a) Cable tool type drilling rig
  - (b) Rod tool type drilling rig

- Rotary drilling rig
  - (a) Spindle type drilling rig
  - (b) Turn table type drilling rig
  - (c) Top head drive type drilling rig

- Top head drive drill (dyna-drill, turbo-drill, electro-drill, etc.)

- Air percussion drill (or down-the-hole percussion drill = DTH drill)

The drilling fluid to be applied can be classified into liquid and gas in terms of form. The purpose of applying a drilling fluid lies in (1) removal of cutting chips, (2) cooling and lubrication of bit head, (3) prevention of well wall caving, (4) prevention of confined ground water overflowing, (5) source for top head drive or DTH drill, and so forth. For items (3) and (4) above gas cannot be used. A classification of drilling fluids is given in Table below.

Table 4-3-2 Classification of Drilling Fluids

- Use of gas
  - (a) Dry Method: Air drilling
    Natural gas drilling
  - (b) Wet method: Mist drilling
    Foam drilling

- Use of liquid
  - (a) Water drilling
  - (b) Mud drilling (including oil-base mud)

There are various drilling methods depending on the drilling equipment/drills and the drilling fluids applied. Each method is discussed below.

(2) Percussion Method

In this method, a heavy bit is connected at the end of a rope which is mechanically winched up to a certain height, then, dropped down with its own gravity. This is repeated to crush and drill the ground strata by the impact force generated by the bit drop. All cutting chips created at the drilling bottom are discharged out via the bailer. The percussion method has the impact frequency of 100 to 120 times/min at maximum. Generally mud water is used as the drilling fluid in this method, but only fresh water is used for the purpose in Zimbabwe. This method is suitable in a non-solid layer, but uneconomical in a solid layer, as the drilling speed is slow. The drilling rig consists of bit striking system, bit and bailer winching system.

(3) Rotary Method

In this method, a bit is connected at the end of a drill pipe which is rotated to turn the bit, thus crushing and cutting the strata. A 3-cutter rock roller bit is to be used in a solid rock. As for drilling ways, there are the direct and reverse circulation ways with use of a liquid, and the air rotary way with use of a gas. The drilling rig consists of rotary system, winching system, pressure supply system, and rig. For a circulation unit of drilling fluid applied, a mud pump or high pressure compressor is to be used. Based on the difference in the rotary and pressure supply systems, this drilling rig can be classified into the spindle, turn table, and top head drive types. For the water well drilling, the direct circulation way or air rotary way is mainly applied with use of spindle or top head drive type down to about 100 m in depth, and with use of turn table type for a further depth. As the spindle type can drill a small diameter at a high revolution, this is mainly applied for surveying the application of a diamond bit. Either top head drive type or turn table type has the revolution of 120 to 150 r.p.m., which is applicable to the 3-cutter rock roller bit to be used for a large diameter and full cross-section drilling.

(4) Top Head Drive Drill Method

This method applies the rotary drilling rig on the ground to turn the bit to cut the strata through the pressure and flow generated by turning a turbine or rotor shaft directly connected to the bit in the mud water. There is also a drill to turn by directly connecting a submergible motor to the bit. During drilling, there is no need of turning the drilling pipe, but just supplying a pressure will suffice.

(5) Air Percussion Drill (DTH Drill) Method

Using the rotary drilling rig, a bit and an air hammer are connected to a drilling pipe and laid on the bottom hole to give the impact force to the bit through the compressed air pressure or hammer's self-gravity for crushing and drilling the rocks. During drilling, the drilling pipe is turned at 20 to 40 r.p.m. so that the bit will not hit only one spot. The striking frequency is 950 to 1,250 times/min. or higher. Comparing with other drilling methods, this drilling speed is remarkably fast. As for the disadvantage, this method is not applicable in a layer with soft surface soil in a heavily weathered area and with a low elastic coefficient. This is because no sufficient impact force can be obtained by the bit striking, thus making the drilling impossible. Use of a top head drive type with a long stroke in the pressure supply system gives a good workability of the rotary drilling rig.

For the high pressure supply system, the pressure of 12 - 20 kg/cm^2 and the air flow of 12.6 - 21.0 m^3/min are applied, but the higher the pressure, the better the drilling efficiency and the longer the bit life.

(6) Selection of Drilling Method

Comparison of the three drilling methods is shown in Table 4-3-3.

Table 4-3-3. Comparison of Drilling Methods

Drilling Method	Air-percussion	Percussion	Rotary
I. Conditions			
(1) No. of B/H per year	259 nos	259 nos	259 nos
(2) B/H depth on aver.	45 m	45 m	45 m
(3) Casing length on average	29 m	29 m	29 m
II. Drilling Ability			
(1) Drilling period/BH	1.6 days	12.9 days	7.5 days
(2) B/H completion period	4 days	16 days	10 days
(3) No. of B/H per year per rig 1/	65 nos	16 nos	19 nos
(4) No. of drilling rig required	4 rigs	17 rigs	14 rigs
(5) No. of staff per rig	4 men	5 men	5 men
(6) Total man-day per B/H	16 man-day	80 man-day	50 man-day
III. Price of Rig with Standard Accessories			
(1) Price of rig 2/	348,250 (Z$)	86,400 (Z$)	188,000 (Z$)
IV. Drilling Cost per B/H			
(1) Personnel expenses	307 (Z$)	1,535 (Z$)	959 (Z$)
(2) Material consumption	478	445	500
(3) Fuel	351	198	186
(4) Depreciation	1,072	285	1,799
Total	2,208 (Z$) 3/	2,463 (Z$) 4/	3,444 (Z$) 4/
Ratio	100	110	130

Notes: 1/: Working day per year is assumed at 280 days. As the ratio of unsuccessful B/H is assumed ten percent, actual drilling number is 72, 18, and 21, respectively.

2/: 22 percent of overhead is included in the drilling cost.

3/: Zimbabwean cost is applied for personnel expenses

4/: The drilling cost of percussion method is estimated based on unit drilling cost of Z$40 per meter (Jan. 1983) obtained at MWR&D plus 10 percent of overhead and 10 percent of unsuccessful B/H cost.

Among various drilling methods that take into account the number of drilling days, drilling cost, protection of water source strata, and so forth, a drilling method recommendable for the Project is a combination of air percussion method as the main one with the air rotary method at a soft layer (mainly at the surface soil), including the application of air drill type (DTH drill) and foam drill type, depending upon the groundwater spring condition. The advantages of air percussion and air rotary methods are listed below.

- o Especially with the air percussion drill, the drilling speed is fast enough to allow the well to be drilled vertically.

- o The air rotary drill has a better drilling rate than the conventional mud water circulation drilling method. There is also no drilling interference such as a lost circulation in a bore hole at an abundant fault or breakage layer, and a less clogging in the breakages.

- o The drilling rate is good, and the bit life is longer as no rock is re-cut.

- o The process can be reduced due to a decrease in the round-trip frequency.

- o Because less working water is required, this is quite convenient if water is hardly available in a dry region.

On the contrary, the disadvantage lies in the fact that these methods are weak against the plenty of overflowing water or strata caving.

(7) Borehole Specifications

i) Selection of drilling sites and borehole depth

The drilling points will be determined, in principle, through both the ground survey and geophysical prospecting survey. It is, however, preferable to select a convenient location of water supply as much as possible. The drilling depth shall also be determined through the geophysical prospecting survey. The borehole depth was designed in consideration of the average depth of 42.8 m in the existing boreholes. However, the scheduled drilling depth was 52.0 m, based on the results from the existing geophysical prospecting survey by the MWR&D. Considering all these, the plan of borehole depth is expected to be 40 to 50 m with the average of 45 m.

ii) Casing and borehole diameters

The casing diameter is determined by the type of pumping equipment to be used, while the drilling diameter by the size of casing to be put in.

The casing diameter is 125 to 150 mm for the existing boreholes. The pumping equipment is of a manual type. A conductor pipe is first placed to prevent any weathered top layer from caving, and later replaced by first step casing. The second and third step casings are placed into the rock down to the end of caving depth. The borehole will be left bare without the second and/or third casing, if no caving happens during drilling after placing the first step casing.

Table 4-3-4 Casing and Drilling Diameters

Step	Drilling method	Drilling diameter(mm)	Casing diameter(mm)	Remarks
1st	Air rotary	269.9	225	Casing drawn & collected later
2nd	Air percussion	219	150	
3rd	Air percussion	150	100	Some without casing

The third step casing is placed in a 100 x 150 mm bell collar, and the length overlapping with the second step casing is two to three meters. The third step casing is slotted over all length, while the second step casing requires slotting depending upon the insertion depth.

iii) Type of casing and strainer

As for the casing materials, there are two kinds of pipes, i.e., steel pipes, and FRP (fiberglass reinforced plastic) pipes. This pipework must meet the following conditions.

- To have a certain degree of physical strength capable of bearing impact from the transportation and placement.
- To be resistant to chemicals as some areas in this project have a high salinity content.
- To be resistant to degradation and deformation, as they may be exposed to direct sunshine and/or high temperatures.
- The slotting cost, price and freight cost to be inexpensive.
- The conductor pipes to especially require a physical strength as their insertion and withdrawal is repeated.

In view of all the above, the casing materials and specifications to be applied in each step are given in Table below.

Table 4-3-5. Casing Materials and Specifications

Step	Marterial	Dimensions (mm) OD	ID	t	Connecting System
1st	Steel pipe for oil well	231.9	224	7.9	Threaded screw
2nd	Steel pipe	165.2	155.2	5.0	Electric welding Partly slotted
3rd	FRP pipe	108	100	4.0	Pinning & bonding Stotted

The casing inside diameter (ID) depends especially upon the next step bit or the pump suction diameter, so that the second step casing requires a diameter of more than 155 mm.

iv) Hygienic preservation

In order to maintain the water quality of boreholes, it is necessary to prevent any contaminated water on the ground surface from entering the boreholes. For this purpose, cement mortar is filled between GL 0 - 2 m around the second step casing. A metal pedal basket is used at the 2 m position, whereby holding the cement mortar. Because of necessity to protect the wall of borehole, the second step casing shall be put into a depth of at least more than 15.5 m.

v) Type of borehole

In designing the boreholes, the plan is made in three (3) types in terms of the drilling diameter, casing insertion depth, and borehole structure. The features of each borehole type are shown in Table below.

Table 4-3-6 Type of Borehole

Type	Type - 1	Type - 2	Type - 3
Application	To apply to B/H without caving	To apply to B/H with caving down to the middle depth	To apply to B/H with caving down to the bottom depth
Lower limit of casing insert.	15.5 m	21 - 32 m	40 - 50 m
Expected Percentage of Occurrence	20%	60%	20%

The expected percentage of occurrence of each borehole type is determined based on the analysis of 139 boreholes data on the casing insertion depths. The following discusses the results of analysis. The classification per casing insertion depth is shown in Table below.

Table 4-3-7 Classification by Casing Length of Existing Boreholes

	Casing Length			
Name of C.L.	less than 15.5 m	15.6 m - 32 m	more than 32 m	Total
Chilimanzi	5	8	1	14
Shurugwi	5	5	0	10
Runde	2	4	2	8
Mazvihwa	0	1	0	1
Mberengwa	6	10	5	21
Chibi	8	23	9	40
Matibi No.1	12	7	0	19
Maranda	15	9	2	26
Total BH/No.	53	67	19	139
Percentage (%)	38.0	48.4	13.6	100
Type of Borehole Planned	Type-1	Type-2	Type-3	

The existing data are classified into the planned three (3) types, TYPE-1 (38 percent); TYPE-2 (48.4 percent); and TYPE-3 (13.6 percent). The local distribution of all existing boreholes is not proportional to the population distribution, but the planning is made to distribute the boreholes in proportion to the population, so that a correction needed is made. The corrected result is in Table below.

Table 4-3-8 Casing Length to be Installed for Borehole

		Existing Boreholes				Project Boreholes			
	Pop.	Type-1	Type-2	Type-3	Total	Type-1	Type-2	Type-3	Total
C.L.	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Chilimanzi	8.4	35.7	57.2	7.1	100	3.0	4.8	0.6	8.4
Shurugwi	8.3	50.0	50.0	0.0	100	4.1	4.2	0.0	8.3
Runde	7.5	25.0	50.0	25.0	100	1.9	3.7	1.9	7.5
Mazvihwa	3.6	0.0	100.0	0.0	100	0.0	3.6	0.0	3.6
Mberengwa	30.1	23.8	52.4	23.8	100	7.2	15.8	7.1	30.1
Chibi	27.4	20.0	57.5	22.5	100	5.4	15.8	6.2	27.4
Matibi No.1	8.0	63.2	36.8	0.0	100	5.1	2.9	0.0	8.0
Maranda	6.7	57.7	34.6	7.7	100	3.9	2.3	0.5	6.7
Total	100.0	38.0	48.8	13.6	100	30.6	53.1	16.3	100.0

Notes: Casing length of Type-1 is less than 15.5 m
Casing length of Type-2 is 15.6 to 32 m
Casing length of Type-3 is more than 32 m

(8) Drilling Equipment

The drilling equipment shall be of truck or trailer mounted type having a manoeuverability while it is in operation, because it is necessary to drill new boreholes in as short a period as possible. The top head drive type drilling rig with a good operating efficiency is the best, as it can be applied to either air percussion or air rotary method. The major equipment and materials to be used are listed in Table 4-3-9.

Table 4-3-9. Drilling Equipment

Nomenclature	Specification and Capacity
Drilling rig	Truck mounted top head drive type, 150 mm x 100 mm
Compressor	Trailer mounted screw compressor 12 kg/cm^2 x 21 m^3/min
Air hammer	Drilling diameter: 6", 8 5/8"
Drilling pipe	4-3/4" drilling pipe, 5" drill collar and stabilizer
Casing tools	Elevator, spider and snatch block
Fishing tools	Tap, band, hydraulic jack, fishing magnet, knocking block, drive and hammer assembly
Fluid circulation line	Delivery hose, swivel, air hose, etc.
Truck	All wheel drive truck with UNIC for movement of drilling equipment and materials

4-3-2. Pumping Equipment

Most of the pumping equipment in Zimbabwe is the hand pump with a very few exceptions of the power driven pumps. This is chiefly attributable to the facts that the boreholes do not have enough yield capacity for electric pumping, and that there are few locations where the population is concentrated. Considering the scattering population and the operation and maintenance of the pumping equipment, the hand pump will be used for the Project.

(1) Type of Hand Pump

The type of hand pump to be used would be of deep well type head pump, as the average static water level is 12.6 m. The hand pump for the Project must meet the following conditions.

- To be capable of pumping up water, even if the water level is lowered to about 30 to 40 m depth.

- To have a pumping capacity of at least 15 l/min.

- To be of easy and safe handling type, as women and children are the main users of the hand pumps.

- To be free from troubles and to require less maintenance or to be easy to repair when a trouble happens.

- The aggregate cost of purchase and maintenance to be inexpensive, with a longer durability period.

The type of high head pump conceivable for the Project is (1) bush pump (plunger type) currently in operation in Zimbabwe, (2) hydro-pump Vergnet (diaphragmatic type) of French make relatively popular in West Africa, or (3) bellows pump (bellows type) of Japanese make. These three (3) types of hand pumps are discussed below, and the summary is given in Tables 4-3-10 and 4-3-11.

i) Pumping capacity

The total head allowing an adult to pump by type of pump is as follows.

- Bush pump (Zimbabwe): 25 m
- Vergnet pump (France): 60 m
- Bellows pump (Japan): 50 m

The total head of the bush pump is limited to 25 m, if it is operated by one person. If the water level is further lowered, two to three persons are required for the handling operation. In the pumping test conducted by the Survey Team, three (3) adult persons were required for pumping at the water level of about 30 m. As the handling becomes heavy at a deeper water level, also, the operating frequency becomes lesser, so that the pumping is limited only to about 5 l/min at the water level of 30 m. Furthermore, because of the heavy handling operation, an overload is imposed on the handle fulcrum, foundation, rod, and so on, causing a trouble or reducing the durability period. The Vergnet and bellows pumps facilitate an easy operation even by women or children with the total pumping capacity of 15 l/min or more.

ii) Price

WHO calculates the hand pump price for comparison from the following formulae, viz:

Total annual cost (C) = Annual capital cost (R)
+ Annual operation and maintenance cost (M)............(1)

Annual capital cost (R) = Capital cost (P)
$x\ i\ (1 + i)^n / \ (1 + i)^n - 1$...(2)

where: n = number of durability years
i = Cost

Substituting in the foregoing formulae for each pump condition, the total annual cost ratio becomes 1.6 for the Vergnet pump and 0.9 for the bellows pump, if the bush pump is indexed 1.0.

Table 4-3-10. Comparison of Hand Pumps (1)

Name of Hand Pump	Bush Pump	Bellows Pump	Vergnet Pump
I. Specifications			
(1) Pump Type	Plunger	Bellows	Diaphragmatic
(2) Power Transmission	Rod drive	Cable drive	Hydraulic drive
(3) Operation	by hand	by hand	by foot
(4) Cylinder Dia.	75 mm	89 mm	92 mm
(5) Minimum B/H Dia.	4"	4"	4"
(6) Discharge Pipe	Steel pipe 50 mm	Steel pipe 32 mm	Polyethylene hose, 26 mm x 2
II. Cost Evaluation			
(1) Capital Cost (ratio)	1.0	1.7	2.9
(2) Annual Cost 1/ (ratio)	1.0	0.9	1.6
III. Operation and Maintenance			
(1) Operation	heavy	easy	easy
(2) Maintenance	large	small	small
IV. Country of Origin	Zimbabwe	Japan	France

Note: 1/: Detail is given in Table 4-3-11.

Table 4-3-11 Comparison of Hand Pumps (2)

Description	Bush Pump	Bellows Pump	Vergnet Pump
P: Capital Cost(ratio)1/	100	174	291
(n) Life Span(years)2/	5	8	8
(i) Prime Rate(%)	18	8	16
M: O/M Cost(ratio)1/	17.7	14.2	14.2

Note: 1/ The above figures in (P) and (M) are calculated assuming the capital cost of Bush Pump as 100

2/ (n) is estimated according to the materials, quality, and the mechanism of each pump

Result(Ratio of total annual cost)

	ratio of (R)		ratio of (M)		ration of (C)
Bush Pump:	100 x 0.320	+	17.7	≒	49.7(1.0)
Bellow Pump:	174 x 0.174	+	14.2	=	44.5(0.9)
Vergnet Pump:	292 x 0.230	+	14.2	=	81.1(1.6)

(2) Selection of Hand Pump

As a result of the comparative study, given the conditions in Zimbabwe, and on the specifications, annual cost, and O/M with a long-time view, the bellow pump can be considered the best and, therefore, is used as the pumping equipment for this Project.

4-3-3. Appurtenant Facilities

The existing appurtenant water supply facilities are not uniform, differing in the style for each borehole. For this Project consideration is given to the population per borehole, health and hygiene, easy operation, water feeding to domestic animals during a drought, and so forth in studying the appurtenant facilities. The following facilities are planned.

- Laundry space
- Trough for livestock
- Bathing space
- Drain ditch
- Fence

In designing each appurtenant water supply facility, consideration is given to the following.

(1) Laundry Space

A space is to be provided for the dual purposes of water scooping and laundry, making an integral part with the hand pump bench in hygienic view.

Water is often spilt over outside the scooping and laundry space, so that concrete floor is made all around in one meter width at the same level with the ground in view of hygiene and easy use.

Leading water from the hand pump to the trough for livestock makes good use of the elevation differential (500 mm) between the pumping outlet and the trough inlet. Switching between the scooping and laundry spaces can be done via a 3-way valve (pole valve) with little trouble.

The water supply piping is, in principle, not buried under the ground, but exposed to open air.

(2) Trough for Livestock

The trough size may vary depending upon the pumping capacity and the number of livestock to be fed with water. The water supply is basically available only for people, and the livestock should drink river water. The water supply to the trough for livestock is done only when there is an allowance in the pumping capacity and at the time of a drought.

The trough size is designed to meet the hourly capacity (15 l/min.) of the hand pump installed.

In order to prevent a space around the trough from mudding due to water spread, concreting is provided at the same level with the ground in view of hygiene.

In view of hygiene, the laundry or bathing space is possibly built far apart from the trough for livestock.

(3) Bathing Space

The bathing space is provided separately for males and females. No piping is made between the borehole and the bathing space.

The bath is made by stacking up the concrete blocks without roof. It is designed to accommodate four to five persons with 1 m^2 per person both for the male and female.

(4) Drain ditch

The drain ditch is to be constructed for the purpose of preventing any water from ponding around the facilities and also preventing such water, if any, from permeating into the ground and from entering the borehole.

Water is drained toward the possible lowest topography. If necessary, the drain may be extended by digging a further ditch in the ground.

(5) Fence

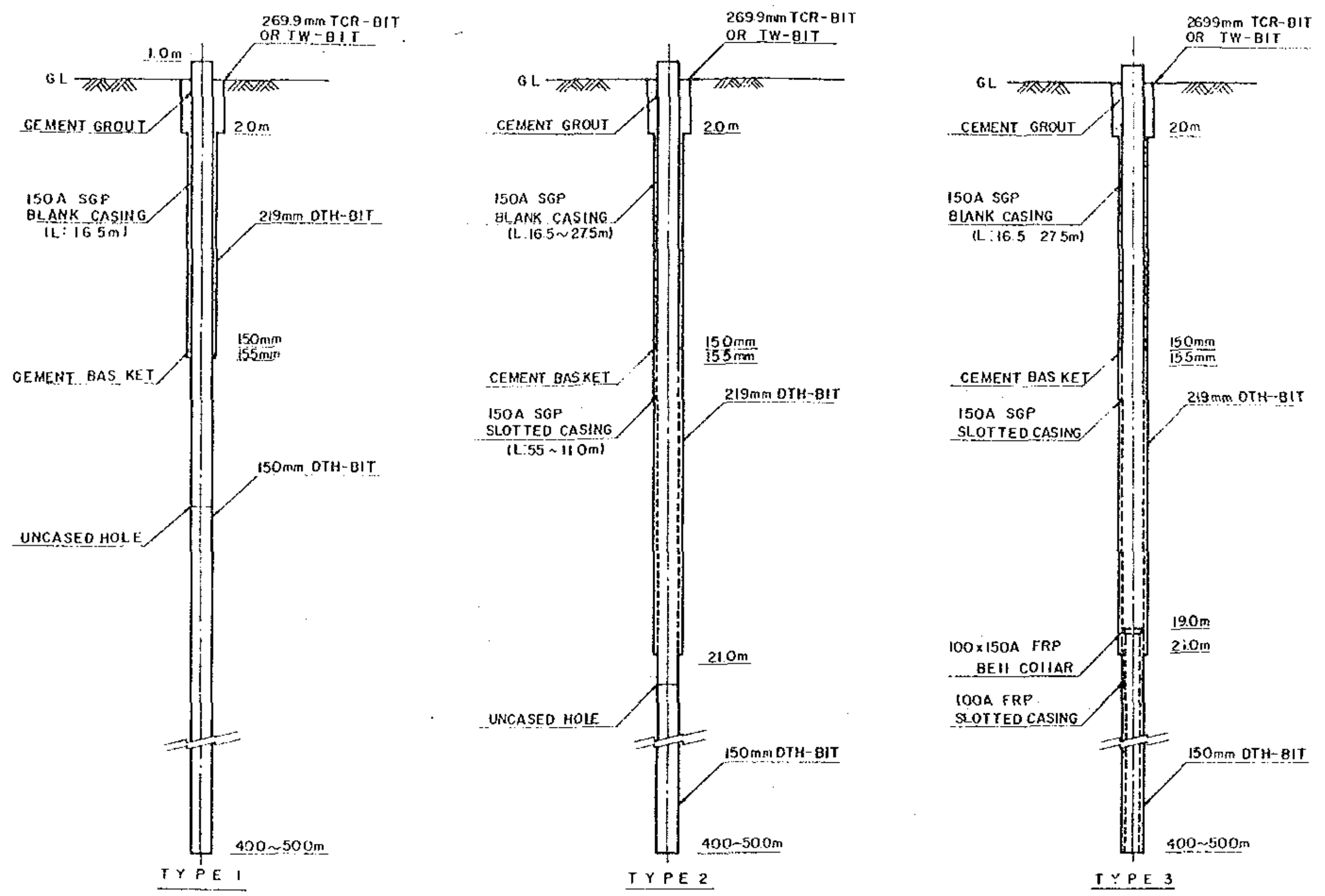
A fence is erected around the laundry and bathing spaces so as not to allow any livestock to enter. A similar facility is provided to the entrance in view of hygiene.

The fence is made of barbed wires and wooden posts.

4-4. Preliminary Design and Cost Estimation

4-4-1. Preliminary Design

The preliminary design of water supply facilities for the Project is carried out based on the study of Division 4-3 "Facilities Planning". Further, the project cost is estimated according to the Project components and preliminary design of the Project. The preliminary design of the facilities is made for borehole and water supply facilities such as hand pump, bathing space, laundry space, etc. Type of boreholes and appurtenant facilities are shown in the drawings of DAW No.12 and DAW No.13.



TYPE OF BORE HOLES

Note

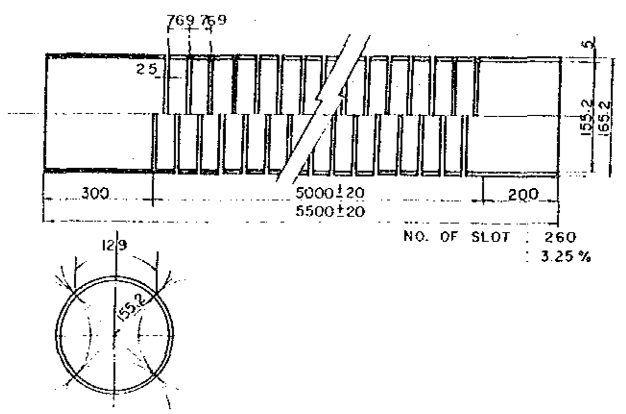
TCR–BIT : THREE CUTTER ROCK ROLLER BIT

TW–BIT : THREE WING BIT

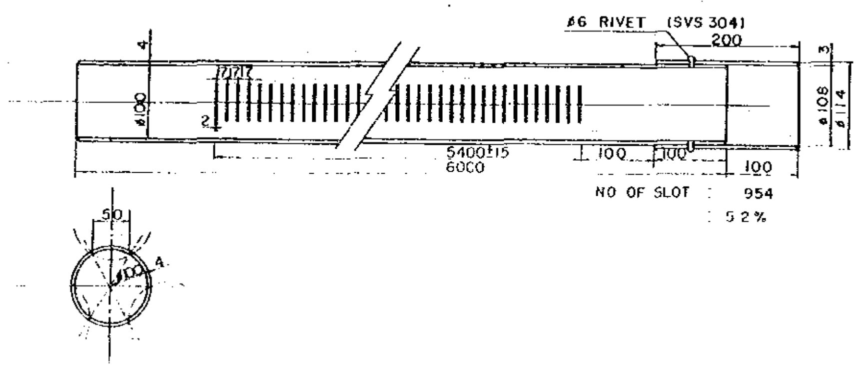
DTH–BIT : DOWN THE HOLE HAMMER BIT

SGP : STEEL GALVANIZED PIPE

FRP : FIBERGLASS REINFORCED PLASTICPIPE



150A SGP SLOTTED CASING



100A FRP SLOTTED CASING

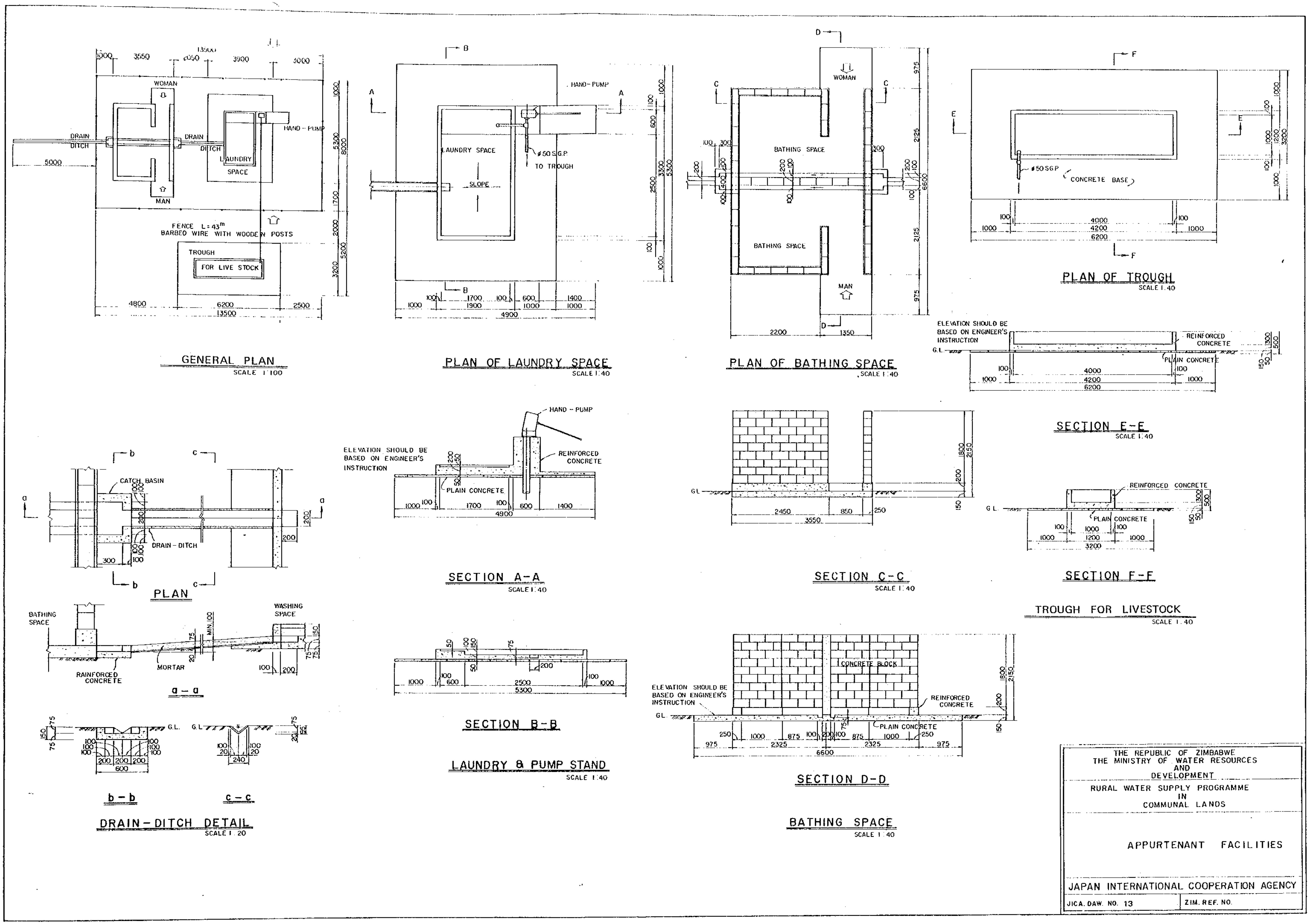
THE REPUBLIC OF ZIMBABWE
THE MINISTRY OF WATER RESOURCES AND DEVELOPMENT

RURAL WATER SUPPLY PROGRAMME IN COMMUNAL LANDS

TYPES OF BOREHOLES

JAPAN INTERNATIONAL COOPERATION AGENCY

JICA DAW. NO. 12	ZIM. REF NO.


GENERAL PLAN
SCALE 1:100
PLAN OF LAUNDRY SPACE
SCALE 1:40
PLAN OF BATHING SPACE
SCALE 1:40
PLAN OF TROUGH
SCALE 1:40
SECTION E-E
SCALE 1:40
PLAN
a – a
b – b
c – c
DRAIN-DITCH DETAIL
SCALE 1:20
SECTION A-A
SCALE 1:40
SECTION B-B
LAUNDRY & PUMP STAND
SCALE 1:40
SECTION C-C
SCALE 1:40
SECTION D-D
BATHING SPACE
SCALE 1:40
SECTION F-F
TROUGH FOR LIVESTOCK
SCALE 1:40
FENCE L=43m
BARBED WIRE WITH WOODEN POSTS
TROUGH FOR LIVE STOCK
HAND-PUMP
LAUNDRY SPACE
WOMAN
MAN
BATHING SPACE
ELEVATION SHOULD BE BASED ON ENGINEER'S INSTRUCTION
REINFORCED CONCRETE
PLAIN CONCRETE
CONCRETE BLOCK
CATCH BASIN
DRAIN-DITCH
THE REPUBLIC OF ZIMBABWE
THE MINISTRY OF WATER RESOURCES AND DEVELOPMENT
RURAL WATER SUPPLY PROGRAMME IN COMMUNAL LANDS
APPURTENANT FACILITIES
JAPAN INTERNATIONAL COOPERATION AGENCY
JICA. DAW. NO. 13
ZIM. REF. NO.

(1) Borehole

The three types of borehole are designed for the Project in consideration of hydrogeological conditions. The specifications of each type of borehole are shown in Table below.

Table 4-4-1 Specifications of Borehole

Type of B/H	Type - 1	Type - 2	Type - 3
B/H depth (Aver.)	40-50 m	40-50 m	40-50 m
Depth of cement grout	2 m	2 m	2 m
Drilling depth by 8 5/8"	15.5 m	21 m	21 m
Casing length, 6" steel pipe	15.5 m	15.5 m	15.5 m
Perforated casing length, 6" steel pipe	0	5.5 m	5.5 m
Drilling depth by 6" DTH bit	24.5-34.5 m	19-29 m	19-29 m
Perforated casing length, 4" FRP pipe	0	0	12-30 m
Application	No caving or only upper caving	Caving upto middle depth	Caving upto lower brackish water
Assumed Ratio	20%	60%	20%

The drilling work will be carried out using the truck mounted top head drive type drilling rig combined with air percussion method and/or air-rotary drilling method depending on the hydrogeological condition.

(2) Appurtenant Facilities

The minimum facilities for water supply are only borehole and pumping equipment. In consideration of improvement of inhabitant's living standard, sanitary environment, and water supply for livestock in case of a drought year, the facilities such as laundry space, trough for livestock and bathing space will be required in addition to the minimum facilities. The water supply facility at one site consists of the above mentioned facilities, fence and drain in the preliminary design.

The basic layout of facilities and the detail design of each facility are shown in the drawings of borehole and appurtenant facilities.

The area required for construction of the facilities is about 130 m^2 at a site. The practical layout of facility for each site will take into account the topographical features. The hand pump equipment will be basically set at the comparatively high position in the site to drain waste water with gravity.

4-4-2. Project Cost Estimation

(1) Project cost

Total Project cost is estimated at 53,100,000 Zimbabwe dollars. The unit prices were extracted form the price list of the MWR&D in January, 1983. The annual price escalation rate of 16%, which is the average value for civil works in the last ten years. The whole Project period is divided into three stages. The total construction costs were summed for each stage in Table below and in Table 4-4-3.

Table 4-4-2 Project Cost

Unit:Z$1,000

Descriptions	1st Stage	2nd Stage	3rd Stage	Total
	BH/No.			
	1,036	777	777	2,590
1. Civil Works	5,243	3,933	3,933	13,109
2. Procurement & Equipment	1,393	1,393	-	2,786
3. Operation & Maintenance	126	363	580	1,069
4. Administrative Exp.	307	233	222	762
5. Consulting Fee	1,019	759	719	2,497
6. Contingency	810	669	546	2,025
7. Price Escalation	3,635	10,279	16,917	30,831
Total	12,533	17,629	22,917	53,079

Note: For detail see Table 4-4-3.

Table 4-4-3 Breakdown of Project Cost

(Unit: Z$ '000)

Description	Project Cost 9.5 Years B/H No.2590			I Stage 3.5 Years B/H No.1036			II Stage 3 Years B/H No.777			III Stage 3 Years B/H No.777		
	Total	Foreign Currency	Local Currency	Total	Foreign Currency	Local Currency	Total	Foreign Currency	Local Currency	Total	Foreign Currency	Local Currency
I Civil Work												
(1) Drilling	2,941	1,931	1,010	1,177	773	404	882	579	303	882	579	303
(2) Casing, Screen Pump & Others	7,138	1,278	5,860	2,854	510	2,344	2,142	384	1,758	2,142	384	1,758
(3) Miscellaneous	3,030	609	2,421	1,212	243	969	909	183	726	909	183	726
Sub-total	13,109	3,818	9,291	5,243	1,526	3,717	3,933	1,146	2,787	3,933	1,146	2,787
II Procurement of Equipment												
Drilling Rig	2,786	2,508	278	1,393	1,254	139	1,393	1,254	139	-	-	-
Sub-total (I + II)	15,895	6,326	9,569	6,636	2,780	3,856	5,326	2,400	2,926	3,933	1,146	2,787
III Operation & Maintenance	1,069	86	983	126	10	116	363	30	333	580	46	534
IV Administrative Expenditure	762	-	762	307	-	307	233	-	233	222	-	222
V Consulting Fee	2,497	1,778	719	1,019	724	295	759	542	217	719	512	207
Sub-total (I to V)	20,223	8,190	12,033	8,088	3,514	4,574	6,681	2,972	3,709	5,454	1,704	3,750
VI Contingency	2,025	821	1,204	810	352	458	669	298	371	546	171	375
Sub-total (I to VI)	22,248	9,011	13,237	8,898	3,866	5,032	7,350	3,270	4,080	6,000	1,875	4,125
VII Price Escalation	30,831	10,850	19,981	3,635	1,169	2,466	10,279	4,421	5,858	16,917	5,260	11,657
Grand Total	53,079	19,861	33,218	12,533	5,035	7,498	17,629	7,691	9,938	22,917	7,135	15,782

Note: For further detail see Tables A, 4-4-2-2- to A, 4-4-2-7 of Appendix (Vol.II)

(2) Civil Works Cost

The total civil works cost is Z$ 13,109,000 and the unit cost per borehole is Z$ 5,100(which does not include hire charge for machinery). It consists of direct cost, indirect cost and administrative expenditure. The direct cost includes costs for drilling works, electric logging, casing and screen installation, pumping test, core sampling, water quality test, installation of hand pump, construction of laundry space, bathing space, trough for livestock and fencing, etc. The indirect cost includes common temporary facilities and site management costs, etc.

Costs of drilling and installation of casing and screen differ according to the types of boreholes. Unit costs of these items are calculated by first estimating the ratio of these types and then figuring out the cost through weighted average. Also a fixed rate of ten percent for hitting dry boreholes is included in the cost estimation.

(3) Procurement of Drilling Rig

The total cost of procurement is Z$ 2,786,000 and the unit cost of a drilling rig is Z$348,250. The unit cost includes the truck mounted drilling rig equipped with standard accessories, and a high-pressure compressor. The cost comprises CIF at Durban, unloading and inland transportation. The number to be procured is four units each for both the first and second stages. The construction cost including the hire charge for the drilling rig, in other words total cost of 1. and 2. in Table 4-4-2, is Z$15,895,000 in total and the unit cost is Z$6,100 per borehole.

(4) Operation and Maintenance Cost

Total O/M cost is Z$1,069,000. This is based on the repair cost of Z$93.44 per borehole once a year, which is assumed to be the average annual cost including operation, maintenance and repair costs.

(5) Administrative Expenditure

Total administrative expenditure is Z$762,000. This cost is for the salaries of the Government staff, offices, furniture, office necessities, etc. The amount is estimated at 8 percent of the local portion of the construction cost (item 1, and 2 of Table 4-4-2).

(6) Consulting Fee

The consulting fee is Z$2,497,000. Unit cost per borehole is Z$964. Consulting services comprise geophysical and geological survey, selection of borehole site, detail design, approval of manufactured machinery, supervision of construction works, approval of the whole Project works, etc. The cost is based on the man-months of expatriate and local staff shown in Fig. 5-4-1. It includes salaries, travel and other expenses.

(7) Contingencies

The amount of Z$2,025,000 is allocated to accommodate the differences in quantities, unforeseen circumstances. It is estimated at 10 percent of the item 1. Civil works and 2. Procurement of Equipment of Table 4-4-2.

(8) Price Escalation

The total amount of price escalation is Z$30,831,000. The price escalation rate of 16 percent is adopted, which is the average value for construction works given for years from 1974 to 1982 in the November 1982 issue of "Monthly Digest of Statistics" by Central Statistical Office of Zimbabwe.

(9) Unit Cost

The unit prices for materials, fuels and personnel are the prices used by the MWR&D in January, 1983. The exchange rate between US$ and Japanese Yen is US$ 1.00 = 240 Yen which is the average for 13th, 14th, and 17th of January 1983. The exchange rate between US$ and Z$ is Z$ 1.00 = US$ 1.09 on 15th January, 1983. Therefore, the exchange rate between Z$ and Yen is Z$1.00 = 250 Yen

(10) Foreign and local currency portions

The total Project Cost(before adding price escalation) is estimated to be divided into 40 percent of foreign currency portion and 60 percent of local currency portion. The proportion for each individual component of the Project is as follows:

Description	Foreign Component (%)	Local Component
Drilling Equipment	90	10
Fuel and oil	90	10
Other construction materials	20	80

CHAPTER V IMPLEMENTATION PROGRAMME AND OPERATION & MAINTENANCE

CHAPTER V. IMPLEMENTATION PROGRAMME AND OPERATION & MAINTENANCE

5-1. Executive Agency

The Rural Water Supply Programme under this plan includes borehole drilling and construction of appurtenant facilities. The following is considered for executing these works.

i) Direct operation under the Ministry of Water Resources and Development
ii) Work contracting system in renting the equipment and machines
iii) Lump-sum work contracting system

The direct operation under the Ministry of Water Resources and Development in item i) above is a system to execute all works involved by using the equipment and materials owned or newly purchased for this purpose by the MWR&D. The number of drilling rigs owned by the MWR&D is limited. As MWR&D performs the similar work on a nation-wide basis, assigning the substantial number of drilling rigs (requiring about 17 units of the percussion drilling rig for this implementation programme of 259 boreholes per year) only to this Project is quite difficult. If new drilling rigs are to be purchased, it is necessary to train a number of skilled workers in meeting such new rigs, together with the increased need for supervisors. For this reason, the burden of the MWR&D increases, making the system impracticable.

The work contracting system in item ii) above is a system to have a contractor undertake the work by renting the equipment and machinery owned or newly purchased by the MWR&D. This system requires less number of employees of the MWR&D to be involved in this Project, and the construction cost may turn out to be low, if the MWR&D owns enough equipment and machines available to rent.

It is therefore recommended that MWR&D procure new equipment and machinery under the loan agreement. This system (item ii) is most practicable.

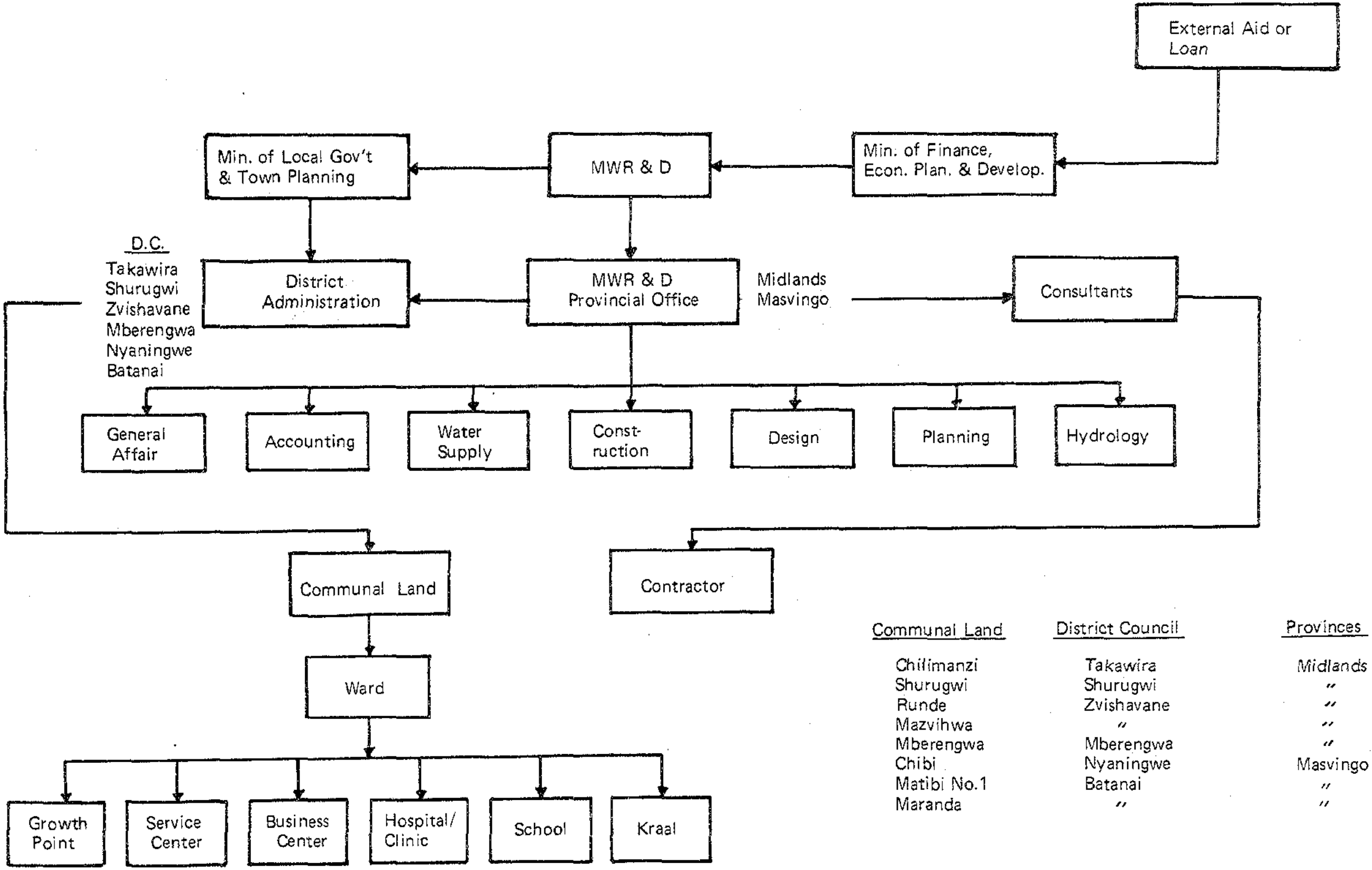
The lump-sum work contracting system in item iii) is a system to have a contractor undertake all the works involved in this Project on a lump-sum basis. Suppose that the MWR&D employs consultants for the design, supervision of the construction works, the direct burden of the MWR&D can be greatly reduced (like in the case of item ii)). On the other hand, there is a disadvantage that the larger the uncertainty in the work execution, the higher the contract amount (this is also the case in item ii)).

In conclusion, the Project will be carried out with the method of item ii. However, the contractor to be selected for this Project preferably should possess not only enough knowhow and technology for the borehole construction works, but also past experience of performing similar projects.

The local offices of the MWR&D is responsible for the administrative matters arising from and related to the construction works.

The organization chart for Project implementation and operation and maintenance is shown in Fig.5-1-1.

Fig. 5 - 1 - 1. Schematic Diagram for Implementation Programme



Communal Land	District Council	Provinces
Chilimanzi	Takawira	Midlands
Shurugwi	Shurugwi	〃
Runde	Zvishavane	〃
Mazvihwa	〃	〃
Mberengwa	Mberengwa	〃
Chibi	Nyaningwe	Masvingo
Matibi No.1	Batanai	〃
Maranda	〃	〃

5-2. Implementation Programme

The 10-year plan of the Rural Water Supply Programme is scheduled in the three (3) stages of 4 years, 3 years and 3 years.

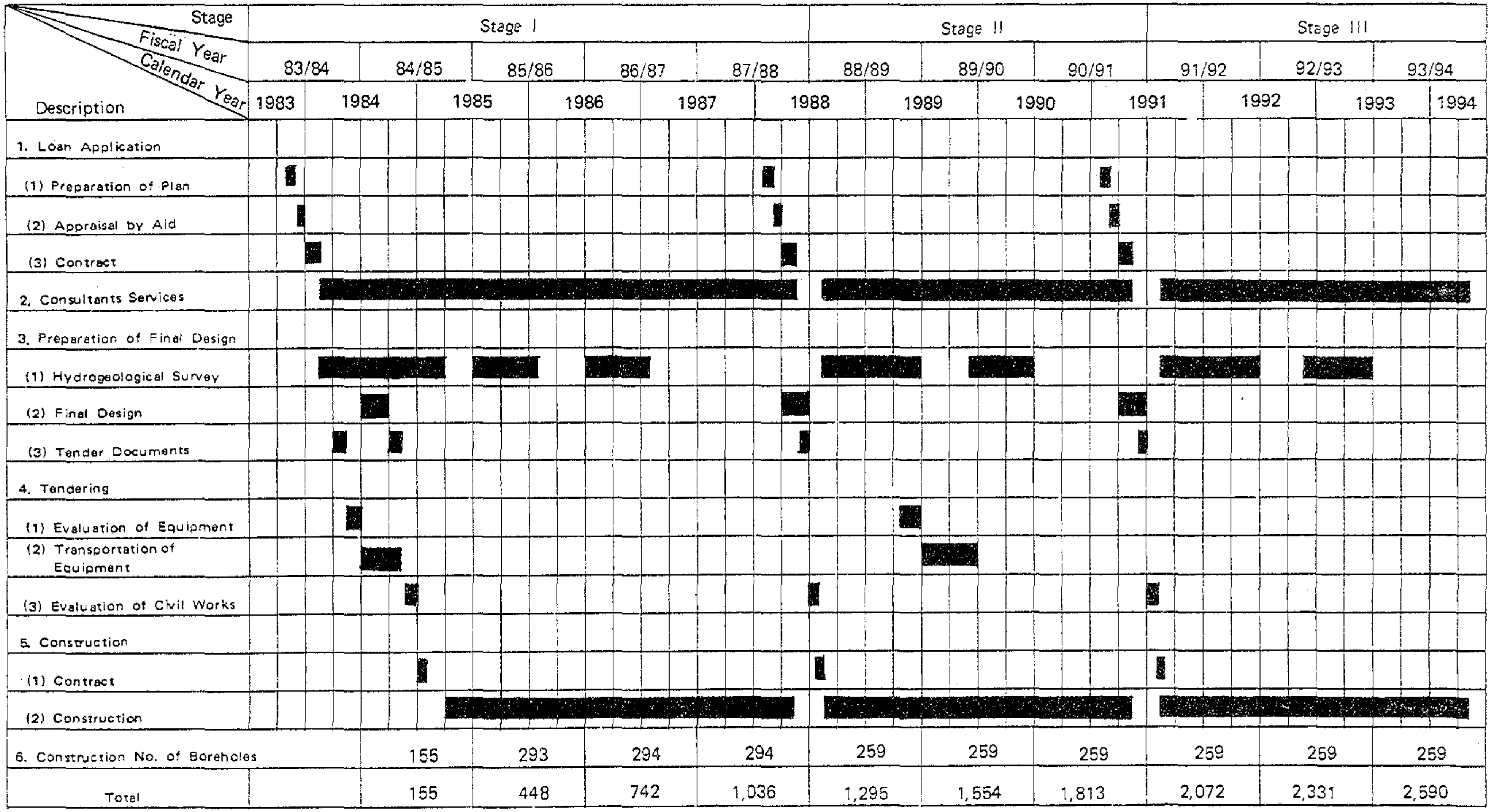
At the beginning of each stage, a loan agreement is to be concluded with an appropriate bank, based on this implementation programme. Following this agreement, the MWR&D makes an agreement with consultants, specifying the scope of works and role of consulting services in the Project. The consultants will conduct the hydrogeological survey where the boreholes are to be actually drilled, and after analyzing the survey results, will prepare the final designs. In parallel with the foregoing, the consultants will prepare all documents necessary for the tender.

The tendering will be conducted in two stages. First the tender will be made public through newspapers and the tenderers wishing to apply to the tender invitation will be examined in advance through pre-qualification. Thus the qualified tenderers are selected. Then the qualified terderers will submit their tender for the Project.

Disputes or differences arising out of or in connection with the work contract between the contractor and the MWR&D will be settled by the consultants according to the stipulations of the conditions of contract.

Figure 5-2-1 shows the implementation programme in graph form.

Fig. 5–2–1 Implementation Programme



5-3. Operation and Maintenance

5-3-1. Organization

Water supply facilities of the Project will be taken over and operated by each District Administration Office after construction of the facilities. The Project Area is divided into six District Administration areas which control eight Communal Lands. Each Communal Land consists of several wards in which scattered are service centers, business centers, hospitals, schools, kraals and so on.

Inhabitants, who will utilize these boreholes, should form a water committee which will lay down the rules for operation and maintenance of the water facilities. This committee should be closely connected with the District Council.

5-3-2. Operation and Maintenance

The annual cost of operation and maintenance is estimated at about Z$107,000(Z$1,069,000/10 years). The activities of water supply operation usually include management, operation and maintenance of the existing facilities as well as enlargement of the facilities to cope with the future increase in water demand. From the financial point of view the operation should be able to stand on the income arising from the water fee to cover the cost of operation and maintenance.

As the beneficiary inhabitants of the Project Area have practically no means of income themselves, it is presently impossible to charge any water fee. Therefore, the whole cost of construction and O/M cost will be borne by the funds coming from the state or the foreign sources. The beneficiary inhabitants will contribute to the operation and maintenance by way of labour through the water committee.

The following goals are to be set of the operation and maintenance. A water committee is to be established for each Communal Land. Their activities should consist of setting rules for utilization and operation of water use, repairing, education of the people on the benefits of having clean and safe water, conducting various services concerning water use, and when the water fee is introduced in future, reading the water meters and collecting the fees. The ultimate amount of this fee will be on the order of five percent of the household expenses.

The Provincial Offices of the MWR&D have a water section which is staffed with various experts to render assistance to the water conservation of the Communal Lands. Such experts manage civil, mechanical, and electrical works, and conduct water and hydrogeological survey. These staff are to be gradually enlarged as the needs grow. The MWR&D will compile and analyse various data collected in the fields.

5-4. Consulting Services

The services by the consultants are divided into four categories, i.e., site investigation, final design, tendering procedure and construction supervision. The present Project is divided into three stages during the whole period (1983/84 to 1993/94) and separate contract is to be concluded for each stage. Brief description of each stage of consultants services and specialists to be appointed is given below. The assignment periods of consultants are illustrated in Figure 5-4-1.

(1) Site Investigation

Hydrogeological investigations are conducted under this title. As the construction works continue for a long period, it is recommendable to mobilize a suitable number of engineers at the site and to finish the investigation in accordance with the construction schedule. Three hydrogeologists including two locals and a civil design engineer will be engaged.

The socio-economic data and plan of approach to the Project are already available from the present report. Therefore, the collection of data and hydrogeological survey for final design will be conducted by the hydrogeologists and the civil design engineer.

(2) Final Design

The final design and the detailed design will be made using the results obtained from the site investigation, including preparation of tender documents, such as conditions of contract, specificatons, and bills of quantities. A civil design engineer will be assigned to this task.

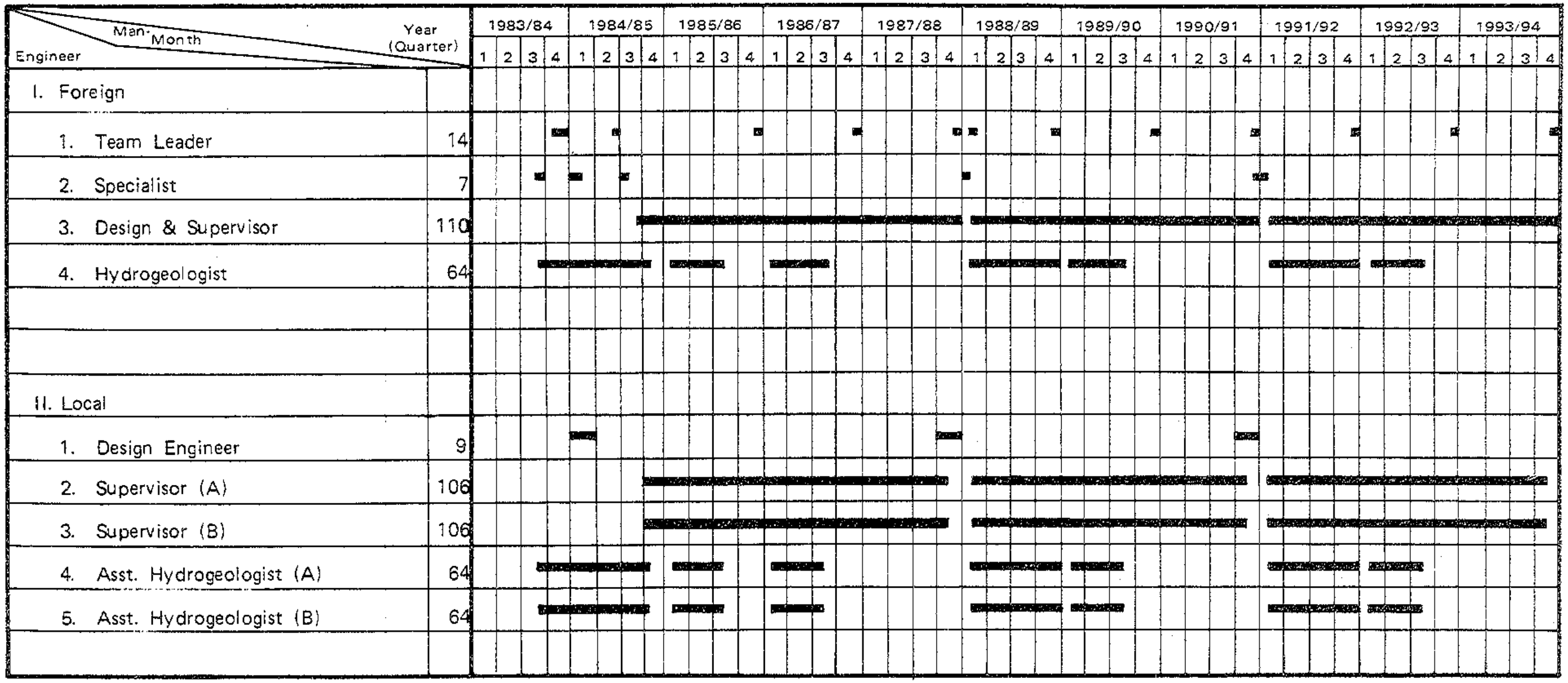
(3) Tendering

Tendering services consist of tender procedure for evaluation of the procurement of equipment and materials and civil works. Team leader and a tender specialist will take charge of the responsibility.

(4) Construction Supervision

For smooth and correct performance of the construction works, one construction supervisor and two local construction supervisors will be engaged. Their responsibilities include minor designing based on the concept of the basic design, such as deciding on the depth of borehole, length of screen, etc. and issuing instruction letters to the contractor, accordingly.

Fig. 5–4–1 Manning Schedule of Consulting Services



CHAPTER VI PROJECT EVALUATION

CHAPTER VI. PROJECT EVALUATION

6-1. General

Severe water shortage has become a serious social problem in the Project Area as well as in the whole country. The aim of this Project is to secure safe groundwater supply for domestic purpose and livestock use by constructing boreholes for more areas.

By supplying groundwater to the inhabitants various benefits can be drawn, such as safe water supply, decrease in water related diseases, saving in water fetching time, upgrading quality of rural life, etc. Thus welfare of the people is enhanced, and the difference in standard of living of various regions can be gradually leveled, which is the national aim.

Financial analysis is the evaluation of the Project from the financial viewpoint. The direct benefit of this Project is the stable supply of hygienic domestic water by constructing boreholes. The Project aims to satisfy so-called BHN (Basic Human Needs). From the inhabitants' financial conditions that even self-sufficient agriculture is precarious, it is not possible to charge the water fee to them. It is therefore very difficult to express the benefit in monetary terms. Financial analysis is conducted by tabulating the yearly loan and repayment schedule.

6-2. Financial Analysis

As shown in Table 4-4-3 in CHAPTER IV, the Project cost is estimated at Z$53,079,000. It is broken down into foreign currency and domestic currency portions which amount to Z$19,861,000 and Z$33,218,000, respectively. Since the Project is planned to satisfy BHN and recovering the costs from the beneficiaries cannot be expected, it is impossible to conceive a self-paying basis for the

Project. The Project cost is, therefore, to be financed by the Zimbabwe Government and by overseas loans.

Tables 6-2-1 and 6-2-2 show such overseas loans in yearly loan and repayment schedule on the assumption that the grace period is 5 years, yearly interest, 1.0 or 3.0 percent and the repayment period, 20 years. They indicate that the loan is extracted for 11 years from 1983/84 to 1993/94 and the repayment period is 30 years from 1988/89 to 2018/19. The yearly loans are the annual foreign currency Portions Worked out in Table A.4-4-2-2 of Appendix.

Table 6-2-1 Annual Loan & Repayment Schedule(1)

Conditions of Loan

Interest ... 1.00%

Grace Period ... 5 years

Repayment Period ... 20 years

(Unit: Z$ 1,000)

Fisical	External Loan	Interest	Total Loan	Amount of Repayment
1983/84	1,477	15	1,492	-
1984/85	506	20	2,018	-
1985/86	896	29	2,943	-
1986/87	1,048	39	4,031	-
1987/88	1,108	51	5,190	-
1988/89	4,337	95	9,536	86
1989/90	1,721	113	11,255	115
1990/91	1,633	129	12,850	167
1991/92	2,194	150	14,966	228
1992/93	2,295	173	17,141	293
1993/94	2,646	198	19,439	546
1994/95	-	194	18,987	646
1995/96	-	190	18,436	741
1996/97	-	184	17,751	869
1997/98	-	178	16,926	1,003
1998/99	-	169	15,938	1,157
1999/2000	-	159	14,940	1,157
2000/01	-	149	13,932	1,157
2001/02	-	139	12,914	1,157
2002/03	-	129	11,886	1,157
2003/04	-	119	10,848	1,157
2004/05	-	108	9,799	1,157
2005/06	-	98	8,740	1,157
2006/07	-	87	7,670	1,157
2007/08	-	77	6,590	1,157
2008/09	-	66	5,585	1,071
2009/10	-	56	4,599	1,042
2010/11	-	46	3,655	990
2011/12	-	37	2,763	929
2012/13	-	28	1,927	864
2013/14	-	19	1,335	611
2014/15	-	13	837	511
2015/16	-	8	429	416
2016/17	-	4	152	288
2017/18	-	1	0	154

Table 6-2-2 Annual Loan & Repayment Schedule(2)

Conditions of Loan

Interest ... 3.00%

Grace Period ... 5 years

Repayment Period ... 20 years

(Unit: Z$ 1,000)

Fisical	External Loan	Interest	Total Loan	Amount of Repayment
1983/84	1,477	44	1,521	-
1984/85	506	61	2,088	-
1985/86	896	90	3,074	-
1986/87	1,048	124	4,246	-
1987/89	1,108	161	5,515	-
1988/89	4,337	296	10,033	115
1989/90	1,721	353	11,953	154
1990/91	1,633	408	13,770	224
1991/92	2,194	479	16,137	306
1992/93	2,295	553	18,593	392
1993/94	2,646	637	21,146	730
1994/95	-	634	20,916	864
1995/96	-	627	20,552	991
1996/97	-	617	20,007	1,162
1997/98	-	600	19,266	1,341
1998/99	-	578	18,297	1,547
1999/2000	-	549	17,299	1,547
2000/01	-	519	16,217	1,547
2001/02	-	488	15,212	1,547
2002/03	-	456	14,121	1,547
2003/04	-	424	12,998	1,547
2004/05	-	390	11,841	1,547
2005/06	-	355	10,649	1,547
2006/07	-	319	9,421	1,547
2007/08	-	283	8,157	1,547
2008/09	-	245	6,970	1,432
2009/10	-	209	5,786	1,393
2010/11	-	174	4,637	1,323
2011/12	-	139	3,535	1,241
2012/13	-	106	2,486	1,155
2013/14	-	75	1,744	817
2014/15	-	52	1,113	683
2015/16	-	33	568	556
2016/17	-	18	200	385
2017/18	-	6	0	206

6-3. Social Impact

Although the direct benefits cannot be measured, several indirect benefits in the form of positive social impact can be listed. Major ones are (1) Decrease in water-related diseases (2) useful application of saved hauling time (3) Improvement of rural life quality (4) Better provision of community services prompted by evenfual grouping of villagers around the boreholes. Following are the descriptive accounts of such benefits.

(1) Decrease of water-related diseases

The incidence of the water-related diseases such as schistosomiasis, diarrhoeal disorders, etc. will be reduced by improving sanitary conditions through supply of clean water for domestic use. Economic implications of the disease are that sick persons and those who care for the sick are not able to contribute to economically productive activities. On the other hand smaller incidence of disease due to improved sanitary conditions reduces the extent of medical attendance and expenditures, which is also an economic gain.

(2) Utilization of saved time

Much time and heavy labor are being sacrificed by women (mostly housewives) for fetching domestic water for a long distance. By reducing this heavy duty womenfolk would be able to spend more time for the care of their children and for the welfare of the family. she may also be able to convert the time saved for some economically productive or culturally useful activities.

(3) Improvement of rural life quality

Provision of borehole water not only means that unsuitable water is replaced by clean hygienic water, but also it is inevitable that the present consumption of 5 to 8 lcd should increase as villagers become more conscious of hygienic and sanitary conditions of their life. It would be the first basic step for improving their life style and raising the standard of life.

(4) Better community service

Availability of clean and safe water source may encourage people in the periphery to move towards near the borehole and form a loose grouping of sub-communal entity. When this occurs, several socially advantageous phenomena may result in addition to the shortening of hauling distance. Such advantages are:

- It gives incentives to the private sector to start various establishments, such as convenience and service stores, public transportation depots, processing factories for various agricultural products, etc. It may also lead to easy formation of cooperatives.

- It facilitates and induces the central and regional government authorities in providing offices of public services, such as registrar's office, telephone and post office, police station, etc. Supply of better infrastructure, such as construction of roads, schools, clinics would follow.