CHAPTER 7 PILOT PROJECTS

7.1 Water Supply

7.1.1 Hand Pump Installation (Refer to Appendix 7.1 for details)

(1) Objective

There are over 3,000 wells installed in Chitungwiza Municipality. Water from these wells is mostly withdrawn by a bucket with rope hoisting, which is quite inefficient and insanitary. Prevalence of cholera and typhoid in 2012 in the municipality was suspected to be brought about by utilization of water from shallow wells. Improvement of the inefficient and insanitary condition by installation of hand pumps was planned in the Pilot Project.

(2) Proposed area

The selected area is Unit 'L' as shown in Figure 7.1.1, where tap water is supplied only several hours a week, in addition, there are many wells with a various yield capacity between several hundred litter /day and over 20 m^3/day.

Figure 7.1.1 Location of Selected Area

The Number of selected wells is 10, and these were selected as shown in Figure 7.1.2 with the conditions listed below:

1) The yield capacity is relatively large; this was confirmed by interview survey in the neighbourhood.
2) The residents including the surrounding area are using the well.

(3) Hand pump

The team considered that the hand pump prevailing in the municipality should be selected from local products. “Elephant Pump” shown in Photo 7.1.1 was found in several housings in the municipality.

The mechanism of the pump is shown in Figure 7.1.3, which is very simple and economical, costing just 250US$ with installation.

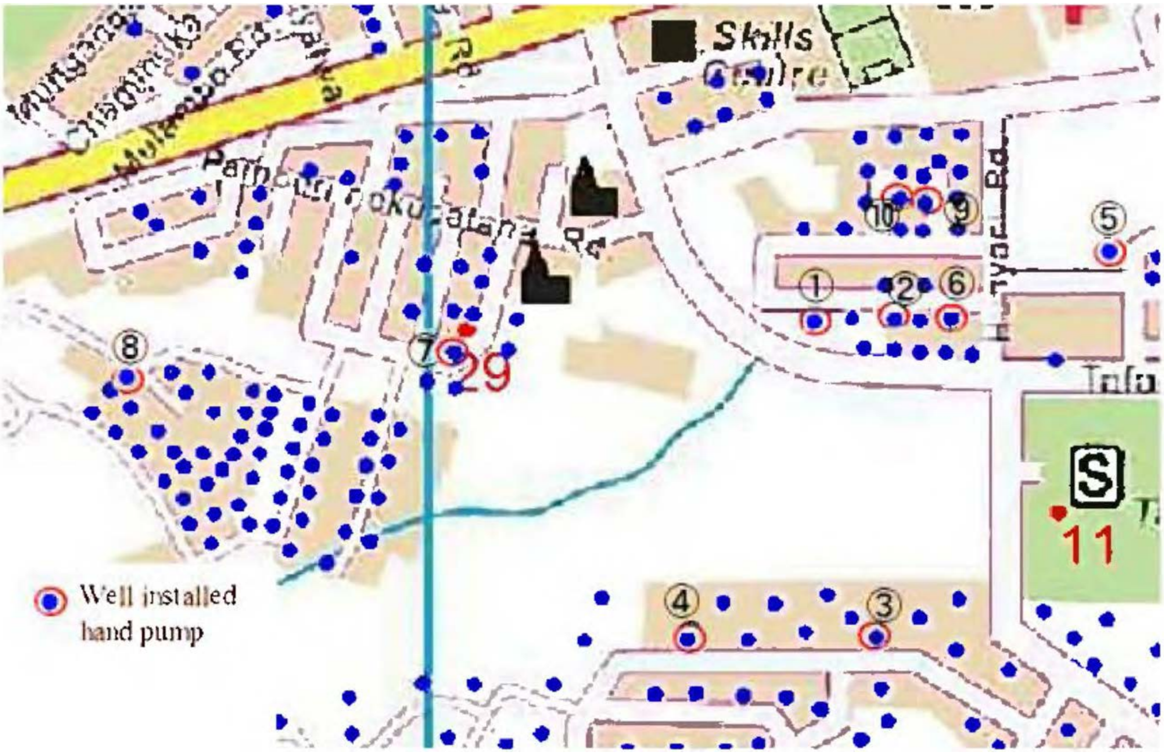


Figure 7.1.2 Location of Hand Pumps Installed

Photo 7.1.1 Elephant Pump

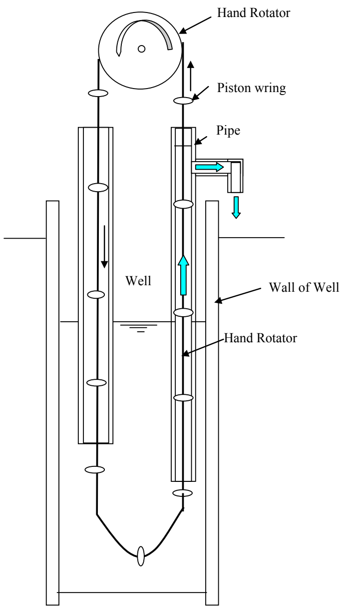


Figure 7.1.3 Mechanism of Elephant Pump

This pump withdraws water by rising rings in a pipe with capacity of around 10 litter/min, which is similar to that of a normal faucet. The rings are fixed to a string, and continuously raised by rotating wheel.

(4) Hand pump installation and survey

Hands pumps were installed on the beginning of November, and before the installation a basic survey was carried out to obtain information on the housings' water utilization target from wells. When wells were installed, a leaflet was distributed to housing units utilizing these wells for awareness on hygiene improvement when utilizing wells. The number of housing units surveyed for target wells was decided to be 1/3 of all the housing units utilizing wells.

FOR THE PEOPLE USING HAND PUMP

Caution: This well's water is not safe for drinking

Water Quality taken from a well located Unit L

Item	WHO Standards	Analysis results
Bacteria	100	300
Coliform	Nil	20

As shown in the above table , the bacteria exceeded WHO guideline three times, in addition ,the number of coliform is detected, which should not be detected. Therefore, **the water** taken from wells **should be safe by boiling or inputting aqua tablets before drinking** no matter how clean or pure it may look like.

Manner for using well and the Water

1. Use the hand pump properly and orderly
2. Be careful for hygiene manner: wash hands before using the well and clean the buckets
3. Should boil water or input aqua tablets before drinking
4. Always keep your buckets tightly sealed with a lid when storing water
5. Do not wash clothes near the well

(5) Survey results

Survey results were analysed numerically, and are shown in Table 7.1.1. As shown in the table, features of families utilizing target wells are summarized below:

1) The number of families utilizing each well range from 7-30 (average 16.4),
2) The number of sample families selected was 68 out of 164, 41.4%,
3) Average number of people in surveyed families was 8.7,
4) Average consumption (intake) of well water was 284 litters/day,
5) Average spending time of water taken from wells is 55.4 minutes, and
6) For the hygiene and safety of drinking water, 57% of people use tablets, which can be purchased from the local market and/or distributed for free by donor organizations.

Table 7.1.1 Summarized Survey Results

No.	Using Families	Sample no.	Average Living Number	Consumption (L/d)		Rate (times)	Spending Time(min.)		Rate (times)	Use Tablet	
				Before	After		Before	After		Before	After
1	15	10	9.3	285	308	1.08	56	15.3	0.27	5	7
2	20	7	7.4	307	308	1.00	58	32.0	0.55	6	6
3	15	6	8.7	258	296	1.15	65	18.0	0.28	2	2
4	20	8	9.1	347	359	1.03	47	19.0	0.40	4	4
5	20	10	7.6	210	243	1.16	54	12.0	0.22	3	3
6	12	4	11.0	156	188	1.21	46	4.3	0.09	3	3
7	30	10	9.2	385	495	1.29	65	31.0	0.48	7	7
8	10	5	7.2	295	315	1.07	46	30.0	0.65	3	3
9	7	3	6.7	258	342	1.33	50	20.0	0.40	3	3
10	15	5	10.4	335	480	1.43	67	14.8	0.22	3	3
Total	164	68	---	---	---	---	---	---	---	39	41
Average	16.4	6.8	8.7	284	333	1.17	55.4	19.6	0.36	3.9	4.1

After installation of hand pumps, some utilizing manner changes listed below were observed:

1) Water consumption was slightly increased by 1.17 times (333/284).
2) Spending time was drastically decreased by 0.36 times (19.6/55.4).
3) The rate of using tablets was not marginally changed even though the instructions on distributed leaflets.
4) Some families complained about the poor quality of hand pumps, but after modification of these by the manufacturer under the requirement of the Team, these complaints had ceased.

(6) Conclusion

Installation of hand pumps is one of the predominant methods to improve the inefficiency and insanitary conditions. From the results of this pilot project, efficiency was found to be drastically improved, and the hygiene condition was also improved because people don't need to touch well water when using the pump.

Accordingly, the installation should be progressed considering the procedures listed below:

1) Since water quality of shallow wells is not suitable for direct drinking, strong instruction to boil or use tablets is necessary.
2) The quality of installed hand pumps was low with uneven/poor quality parts and poor installation skills, and then a standardization of design, parts and installation procedures is necessary.

7.1.2 Water Leakage Survey and Flow Measurement (Refer to Appendix 7.2)

(1) Purpose

1) Water leakage measurement

Water leakage ratio was determined by the difference between water supply and inflow to STP (Sewage Treatment Plant). Additionally, night time measurements of two areas were carried out in this pilot project. During the night time, since water consumption by people is little, water flow in a certain area is assumed to be the water leakage.

2) Flow measurement of branch pipes

In the water supply system of Chitungwiza Municipality, only one flow meter is installed in PE-WTP, which was repaired on July 2012. The flow meter measures the transmission flow form City of Harare to the municipality. Other meters had been installed at the outlet pipe from the elevated tank and outflow pipe from lift pumps, by which water is transmitted to the elevated tank, but both of the flow meters are now out of order.

Since the information of flow balance of branch pipes was needed for the maintenance as shown in Figure 7.1.4, flow measurement of branch pipes was therefore conducted.

(2) Measurement condition

Originally, two ultra-sonic flow meters were planned to be used, but unfortunately one of them which was brought from Japan could not be used to measure pipe flow, only one flow meter was then used by a local specialist.

The location of measurement points is shown in Figure 7.1.4, however due to the low flow rate of water to the municipality in the week when the Team measured the flow rate, measurement points for water leakage were changed. Originally, two (2) points a/b and c/d were planed to be measured, but they were changed to points “e” and “f” due to the availability of one flow meter. In addition, since the water flow cannot reach point 9 and the ground reservoirs because of the low water flow rate, the flow at points 6, 7 and 10 cannot be measured.

The target areas of leakage survey are shown in Figure 7.1.4 and Figure 7.1.5 (1) and (2). Area “e” is composed of a housing complex as shown in Figure 7.1.5 (1), which was constructed late 1980s and the area has always been distributed compared to the intermittent distribution in other areas. This is due to the fact that the branch valve to regulate the distribution flow to this area broke down under the open condition. However since it was repaired in August 2012, it has been closed by the municipality if necessary.

Area “f” is composed of the largest hospital in the municipality and a housing complex as shown in Figure 7.1.5 (2). Because this area was the first priority area for the municipality to provide a sustainable water supply, Valve ⑤ never fully closes. The pipe installation year of Area “e” is late 1980s, and that of Area “f” is 1976. On the measurement of “e” and “f”, daily water flow is determined by average water flow of a two hours interval of measurement, and a continuous measurement was made for a 12 hour period.

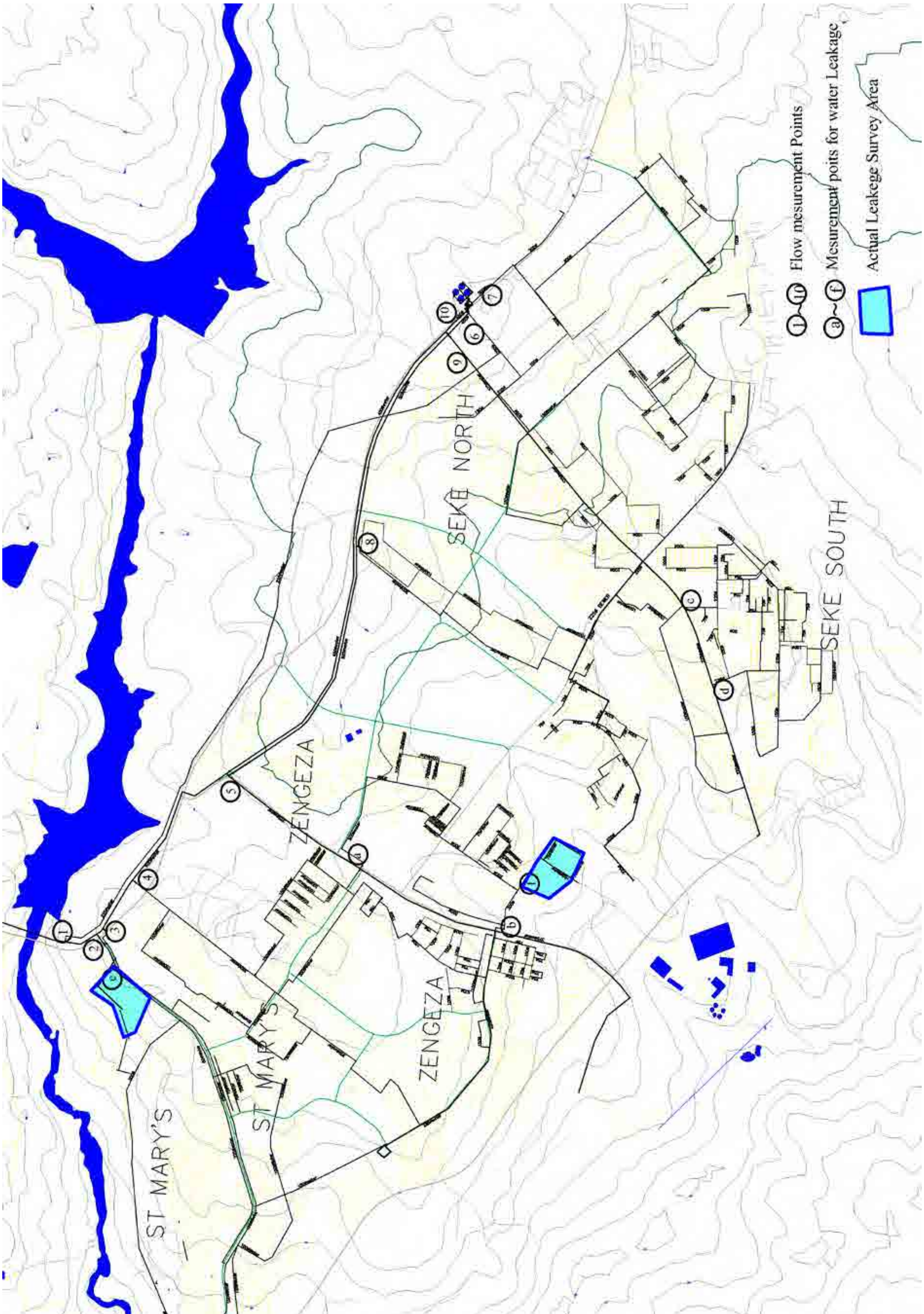


Figure 7.1.4 Location of Flow Measurement Points

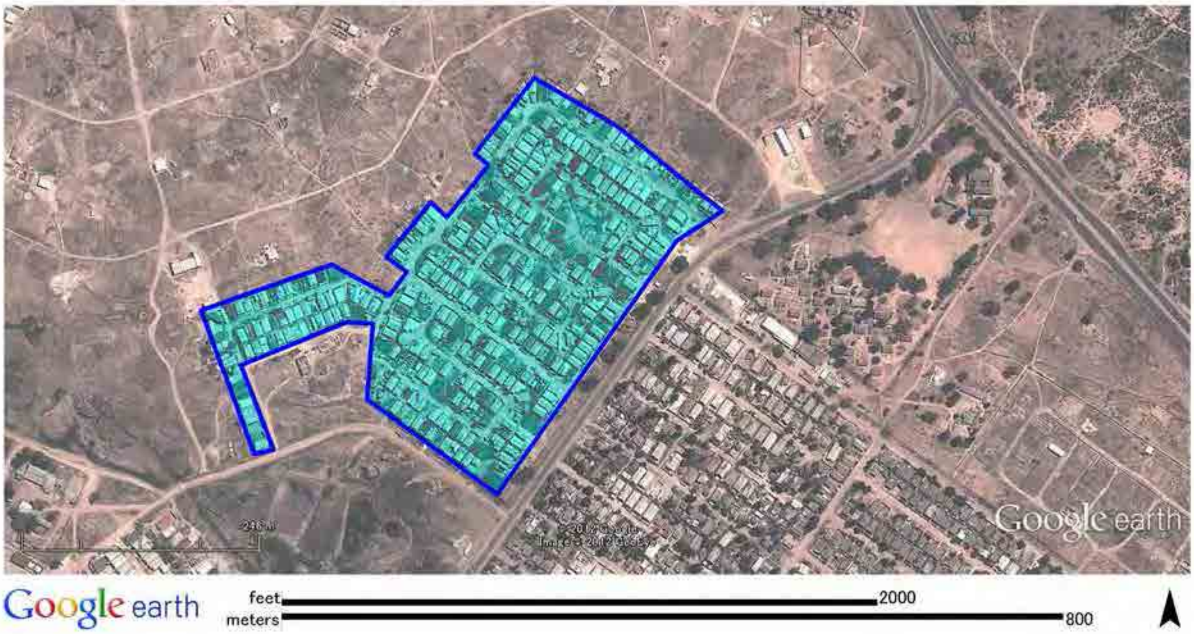


Figure 7.1.5 (1) Area "e" Location

Figure 7.1.5 (2) Area "f" Location

Table 7.1.2 shows conditions of each measurement point. As shown in the table, eight (8) points cannot be measured because there is no water flow and only one flow meter is available. The measurements were carried out from the 19th to 24th of November.

Table 7.1.2 Explanation of Measurement Points

Pipe No.	Diameter (mm)	Execution	Explanation of the point	Reason not to measure
①	225	Yes	Branch from Main	
②	300	Yes	Branch from Main	
③	350	Yes	Branch from Main	
④	350	Yes	Branch from Main	
⑤	375	Yes(2times)	Branch from Main	
⑥	250	No	Branch from Elevated Tank	No water
⑦	300	No	Branch from Elevated Tank	No water
⑧	300	Yes	Branch from Main	
⑨	300	No	Branch from Main	No water
⑩	450	No	Inflow to Reservoir	No water
a	300	No	Original Leakage Survey Point	Utilizing one flow meter
b	300	No	Original Leakage Survey Point	Utilizing one flow meter
c	300	No	Original Leakage Survey Point	Utilizing one flow meter
d	300	No	Original Leakage Survey Point	Utilizing one flow meter
e	150	Yes	Actual Leakage Survey Point	
f	100	Yes	Actual Leakage Survey Point	

Source: JICA Project Team

(3) Result of leakage survey

Measurement results were shown in Figure 7.1.6 and 7.1.7. As shown in the figures, in the midnight the water flow apparently decreases, and daytime consumption is larger than early morning and evening according to the two hour intervals of measurement. Based on the figures, if water consumption in midnight is assumed to be the water leakage, water leakage ratio of each area is calculated as shown below:

Area e: 4.5/14.5=31.0%

Area f: 6.5/20.5=31.7%

In the municipality, since the water has been supplied intermittently and the schedule has been unknown, people tend to keep water in various buckets/tanks whenever water is distributed.

In the case of Area ”e”, the above condition can be applied, while in the case of Area “f” water supply is seldom stopped, but some of the hospital staffs are working for 24 hours consuming water. Even in the night some rate of water is considered to be used, the NRW ratio of 25% in the municipality suggested in Chapter 8.1 is considered reasonable. Illegal connections in the municipality are assumed to be few by the municipality.

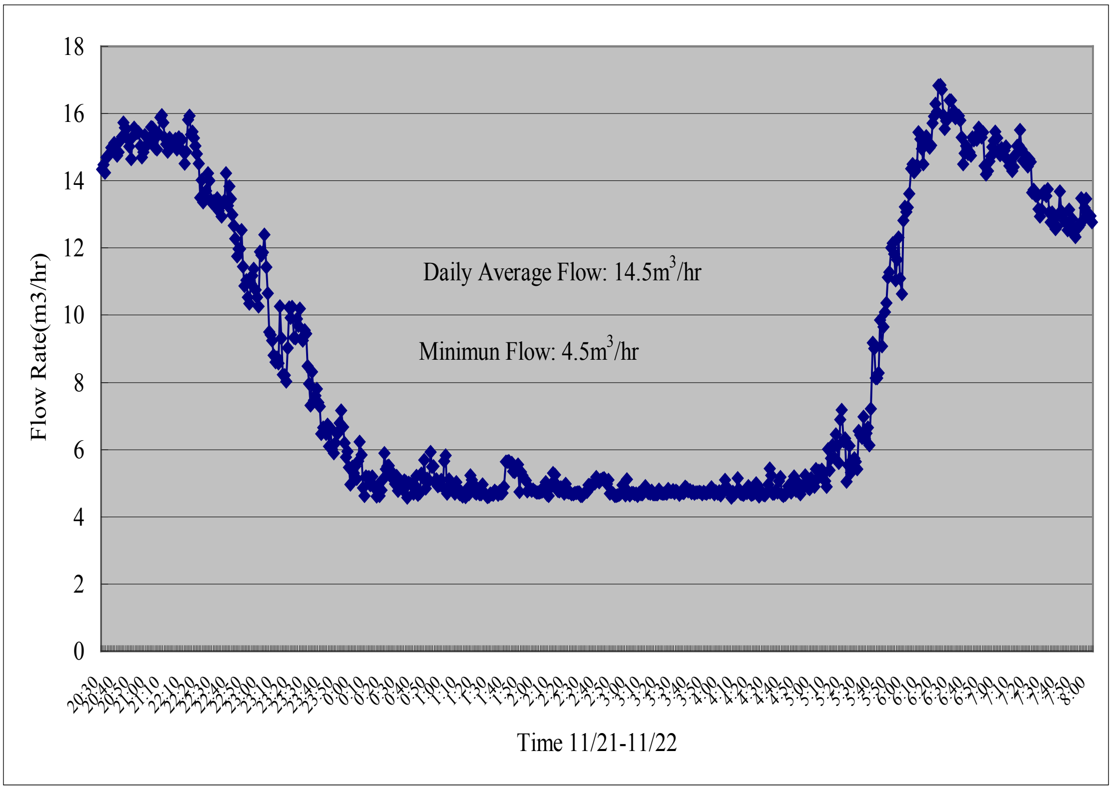


Figure 7.1.6 Measurement Results of Area “e”

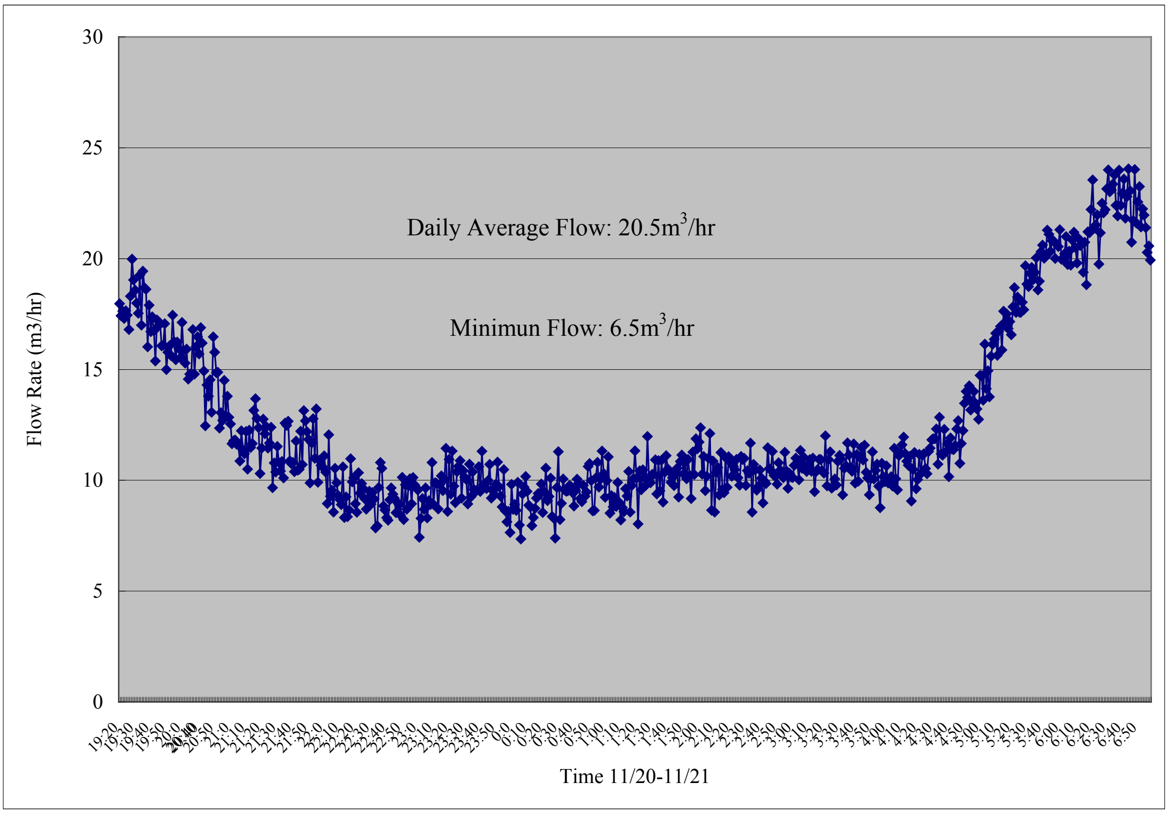


Figure 7.1.7 Measurement Results of Area “f”

(4) Flow measurement results

Unfortunately, since the water distribution to the municipality from Harare Water Works was not enough, 15,000-18,000 m^3/day, during flow measurement, the cases of flow measurement were limited. During the week, water could not reach reservoirs and places located on high elevation areas due to low water flow rate. Water flow rate for branch pipes was limited because of trouble with Valve ⑤, therefore, flows in branch ⑥, ⑦, ⑨ and ⑩ could not be measured. In addition, various water flow conditions could not be created from the operating conditions of valves due to low water flow. Water flow from City of Harare was around 15,000 m^3/d from 19th to 23rd morning, and 18,000 m^3/d from 23rd to noon of the 24th.

The results of measurement were arranged by three (3) conditions as shown in Table 7.1.3:

Table 7.1.3 Water Flow in terms of Conditions

Item	Case	Total Flow (m^3/hr)	Branch Name							Total
			①	②	③	④	⑤	⑧	⑨	
Valve Dia.(mm)			225	300	350	350	375	300	300	
Valve condition	1	620	O	O	O	C	O	C	C	
	2	620	O	C	C	O	O	O	C	
	3	760	O	C	C	C	O	O	O	
Measured Flow (m^3/hr)	1	620	12.6	126.3	100.7	---	?	---	---	239.6
	2	620	?	---	---	229.7	196	?	---	425.7
	3	760	?	---	---	---	405.1	313.7	0*	718.8

Note: O=open, C=closed *Cannot be measured due to non full flow

Source: JICA Project Team

7.1.3 Groundwater Resource Survey (Refer to Appendix 7.3)

(1) Purpose

It was reported that the groundwater potential is better than that of City of Harare according to Professor I. NhapI (Zimbabwe University), and the current use of groundwater from shallow wells and boreholes in the municipality is large. Groundwater resource of Chitungwiza should be pursued.

Currently, the water supply capacity of Harare Water Works is apparently insufficient to cover the service areas reflecting the shortage of supply water. The bulk water supply to Chitungwiza Municipality is frequently stopped and/or drastically reduced. Some of the reasons of that are the outstanding overdue bills of the bulk water to Harare Water Works and the insufficient water supply of amount of the Works.

In the near future, Harare Water Works will have to refurbish the managing facilities thoroughly and expand the water resource and production capacity.

However huge investment will be required for the substantiation. Although the funds for refurbishing can be secured from foreign donors such as Chinese and Indian Organizations, there are no concrete plans for the development of water resources and construction of new WTPs.

(2) First stage survey

In Chitungwiza Municipality, there are over 3,000 shallow wells and around 50 boreholes, and these are used by people living mainly in Seke North and Seke South, where water supply is distributed only for several hours in a week. These wells do not dry up by daily consumption even in dry seasons.

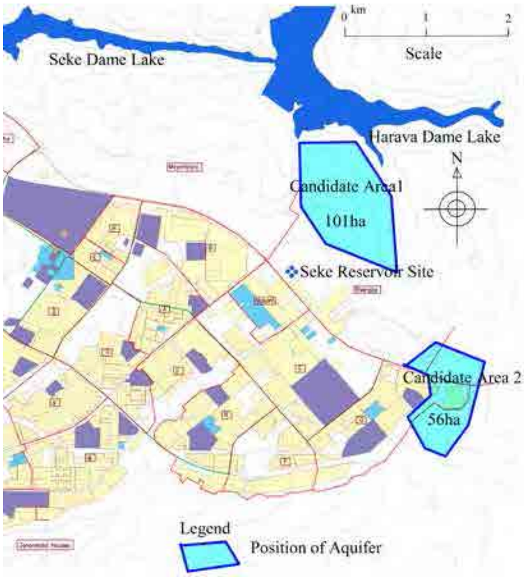


Figure 7.1.8 Potential Areas of Aquifer

Thus, the survey to find groundwater resources started in the surrounding area of the municipality. The survey was determined due to current shortage of water, obscure future development plans and active utilization of groundwater by the people in the municipality. From the results of first stage survey through hiring of local hydro-geologists, potential aquifers shown in Figure 7.1.8 were clarified through electrical resistance tests.

The locations of the aquifers are very near to Seke reservoir site, and the recharge for potential area 1 is considered to be from Harava Dam and Manyame catchment area. The report mentioned that quite a large yield capacity of group wells can be constructed in the target area. According to the recommendation, a test well was installed, expecting yielded 20 litres/sec of yield (1,728 m^3/d), but actual yield capacity was only 1/20 of the original plan with around 1 litre/sec (86 m^3/d) even though the well had a depth of 100m as shown in Photo 7.1.2.

Photo 7.1.2 Yield Water from First Test Well

(3) Reset of the survey

After the result was obvious, hearing survey was conducted from some hydro-geologists, and their opinions were; 1) such large yield capacity of well is unbelievable, and 2) since there is a granite zone nearby Harava Dam, the possibility of the existence of the aquifer is quite low. Accordingly, a survey by a definitive hydro-geologist in Harare Area was re-conducted, and it revealed the doubt of the existence of the aquifer in the potential area 1. In addition, although the groundwater potential of potential area 2 is well-known because of the existence of red-soil, the actual intake capacity was also doubtful because many private boreholes have already been installed in this area.

Thus new aquifers were again explored in the surrounding area of the municipality by a team headed by the hydro-geologist previously mentioned. The hydro-geologist found that the eastern area of the municipality shown in Figure 7.1.9 has many faults of granite and is widely covered by red-soil, which is a sign that an aquifer exists beneath. Potential area 3 was selected first because of an existing well with good yield capacity in the area and many potentially good points were found by electrical resistance tests.

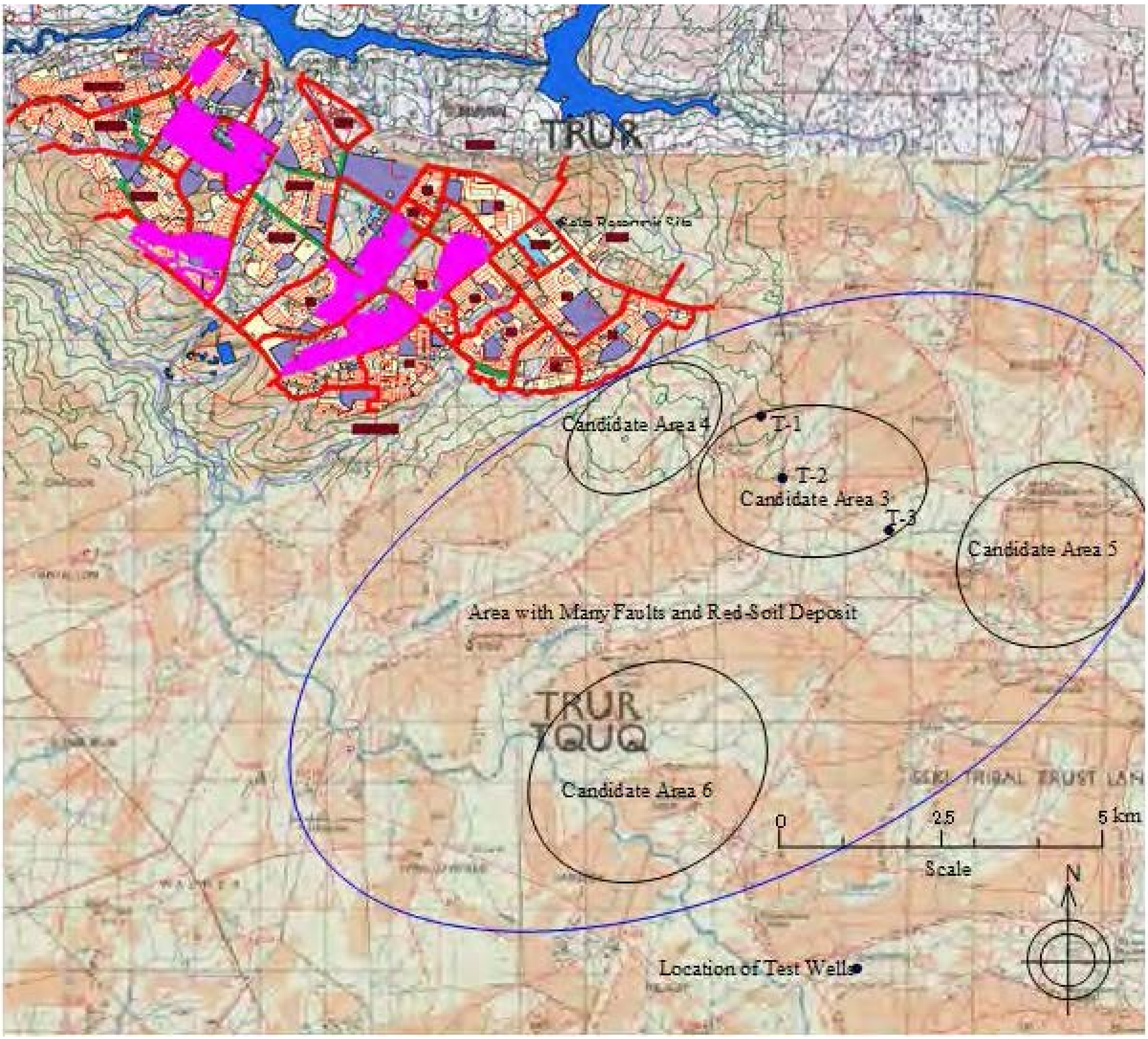


Figure 7.1.9 Surveyed Areas for Groundwater

Source: JICA Project Team

Three test wells with borehole diameter of 150 mm were installed based on the results, and the results of yield capacity tests are shown in Table 7.1.4. As shown in the table, the yield capacities of T-2 and

T-3 are large, while those of boreholes located in Chitungwiza Municipality are less than 1.5 L/sec. As the results of the test wells installation indicate, candidate points of wells should be selected carefully and a rate of failure must be accepted.

Table 7.1.4 Results of Yield Capacity Tests of Test Wells

No.	Geology	Elevation (m)	Well Depth (m)	Water Level (GL-m)		Yield capacity		
				Initial	Dynamic	L/sec	m^3/hr	m^3/day
T-1	Red-soil	1,458	60	7	33	0.3	1.1	26
T-2	Fault of granite	1,442	60	1.8	24	3.5	12.6	302
T-3	Fault of dolerite	1,440	60	1.4	15	3.9	14.0	337

Source: JICA Project Team

The water qualities for Test well-2(T-1) and Test well-2(T-2) is shown in Table 7.1.5, and the quality of wells are not so good as water resource, especially for low pH, and high concentration of bacteria and coliform.

Table 7.1.5 Water Quality of Test Wells

Item	unit	WHO Standard	T2	T3
pH	---	6.5-8.9	5.7	5.7
Conductivity	μs/cm	1,600	14	70
TDS	mg/L	1,000	10	49
Alkalinity	mg/L	---	10	20
Hardness	mg/L	250	15	13
Calcium	mg/L	250	3.1	3.2
Turbidity	NTS	5	0.2	0.1
Iron	mg/L	0.3	0.10	0.08
Manganese	mg/L	0.1	0.03	0.05
Copper	mg/L	0.30	0.03	0.02
Zinc	mg/L	0.10	0.02	0.02
Nitrate	mg/L	50	0.93	0.93
Potassium	mg/L	---	1.7	4.6
Magnesium	mg/L	150	1.7	1.2
Sodium	mg/L	200	4.5	6.7
Sulphate	mg/L	250	6	18
Chloride	mg/L	250	6	18
Bacteria	no./ml	100	2,900	110
Coliform	no./100ml	Nil	209	109
E-coli	---	Negative	Negative	Negative

Source: JICA Project Team

Even though these problems can be solved by chlorine and lime injection, careful control of the injection will be required. The discharge transparency condition of water for the test well T-2 is shown in Photo 7.1.2.

Photo 7.1.3 Yield Water from Test Well T-3

(4) Conclusion

The hydro-geologist concluded:

1) The recharge capacity of the four selected areas is limited and the total intake ability is assumed to be less than 5,000 m^3/day,

2) Average yield capacity of wells will be 3-5 m^3/hr (72-120 m^3/day).

From the results of the survey (Pilot Project), utilization of large scale of groundwater is un-seemingly considered feasible.

7.2 Sewerage

7.2.1 General

Sand deposit in the sewers and facilities in the Chitungwiza Municipality is big problem causing clogging of the sewer reticulation, malfunction of PSs (Pump Station) and STP (Sewage Treatment Plant) as shown in the Chapter 5. Once a part of the reticulation is clogged, sewage keeps spilling out from manholes. Removal of the deposited sand in the reticulation is very difficult since the collection sewers and main collection sewers are mostly located at the backyard of the residents. Taking into consideration of the negative impact of the deposited sand against the equipment, maintenance, operation and aquatic environment of the water sources, study for the issue is urgently needed. The wasted cost, broken equipment by abrasion, required time for solution and pollution brought about are thought to be incredible.

Although the cause of the sand has been suspected as sand used for pot-washing in the residents, there were no real proofs for it. In this context, residents' cooperation on the survey is absolutely imperative. It will also contribute as the enlightenment activity for consciousness of sanitation of the residents. Besides, the knowledge and perception from the study will be leveraged in entire Zimbabwe, in which sand use is widely made in most part. The information will be useful for the sand removal work after mechanical sand removing vehicles are supplied under the Zim-fund Project as well.

The survey will clarify the cause of the sand and its unit generation rate. It will be a useful sample to estimate the amount of the sand and its maintenance cost from the sewers.

In the pilot project for the sewerage, the survey was conducted with the cooperation of the residents, counter-part and local consultants (under contracts) as follows:

1) Confirmation of current status of manholes and sewers
2) Unit generation rate of sand in the sewage in Chitungwiza Municipality,
3) Reached unit sand volume to Zengeza STP,

As a result, unit generation rate of sand was proposed as shown in 7.2.3, and it was confirmed by the field survey on sand deposit at the STP in 7.2.5.

7.2.2 Confirmation of Status of Manholes and Sand Deposit

Other than sand, various problems were confirmed in the sewer reticulation as shown below:

(1) Blockages and overflows

Information collected in the field showed that sewage was flowing smoothly in 55% of manholes. The other 45% of manholes were either blocked somehow or overflowing. Photo 7.2.1 below shows photos of overflowing manholes. The kind of materials flowing out with the sewage shows why blockages are occurring in the system.

Photo 7.2.1 Overflowing Manholes

(2) Sludge build-up

Photo 7.2.2 below shows successive manholes between Kukodzi and Haka Road in Zengeza 2 with stagnant sewage. As can be seen by the worms in one of the manholes, the accumulated sludge has been there for a while. MC19, which is immediately upstream of the shown manholes, is not flowing at all because of these downstream manholes that are blocked.

Photo 7.2.2 Stagnant Sewage MC20 MC21

(3) Stormwater inflow

Twenty five percent (25%) of the surveyed manholes in the field are receiving storm water inflow mainly because of improperly covered manholes that are level with or below the ground. Photo 7.2.3 shows stormwater ingress through a manhole without a concrete cover.

No concrete cover Stormwater inflow

Photo 7.2.3 Stormwater Inflow into Manhole

(4) Subsurface infiltration

Subsurface water is finding its way into 4% of manholes via concrete ring joints and brick joints. These weak points may enlarge and cause tree roots and soil to get into the manhole. Eventually this might lead to disintegration of the manhole.

Subsurface inflow through rings Poor workmanship causing subsurface infiltration

Photo 7.2.4 Subsurface Infiltration

(5) Sand

Due to the following reasons in the field, there is an alarming magnitude of sand deposition in the sewerage system:

- ☐ Manholes without lids or concrete covers and level with or below the ground
- ☐ Indiscriminate dish-washing habits of residents
- ☐ Little water returned into the sewerage system
- ☐ Intermittent water supply

Both dry and wet sand was seen deposited on benching, base channels, and sides of manholes (see images in Photo 7.2.5 below).

Photo 7.2.5 Sand on Benching and Base Channel

Approximately 33% of the surveyed manholes had sand inside. Of these, 17% had the following problems:

- Broken lid
- No lid
- Broken concrete cover
- No concrete cover

This indicates that there is a lot of sand that is also introduced into the system by residents. This might be when they wash dishes with sand. Most of the sand in the sewers, however minimal, is not being carried along with the sewage. This is because in some areas, the velocity of sewage rarely exceeds the “self-cleansing velocity”. Another reason is inadequate water entering the sewerage system. For the manholes that are level with or below ground, the sand found in manholes may have fallen in when the manholes were opened.

(6) Other debris

Different kinds of debris were found in various manholes. These include plastics, newspapers, rubble, mud, bones, cloth, leaves, eggshells, mango seeds, pampers, wooden sticks, chicken feathers, etc. Underlying reasons why these unwanted elements found their way into the sewerage systems are:

- uncovered or improperly covered manholes
- ignorance of residents in the way sewers work

Photo 7.2.6 to Photo 7.2.7 below show how various debris are entering into the sewerage system.

Photo 7.2.6 Debris in the Manhole because of Close Rubbish Dumps

Photo 7.2.7 Debris in Manholes because of Improper Lid and Use of Newspapers by Residents

Manhole C78 (left picture in Photo 7.2.8 below) has an intact cast iron lid but there is a lot of debris in it because residents have chosen to use it as a bin. Luckily this has not affected the downstream manholes.

Containers, bottles, soil

Broken stove plate

Photo 7.2.8 Manholes in Residential Stands Used as Rubbish Dumps

The manhole in Photo 7.2.9 below is located by the roadside and behind TM Supermarket. It doesn't have a proper and the public have decided to dump rubbish in there. This shows that the public in general do not have an understanding the functioning of sewers.

Photo 7.2.9 Manhole in a Public Area Used as Rubbish Dump

The debris found in manholes cause blockages, damage manhole components and presents challenges to the treatment works.

7.2.3 Study on Generation of Sand in the Sewerage (Refer to Appendix 8.1)

(1) Objective

Although rehabilitation work has been on-going under the AfDB scheme (Multi donor fund) for city of Harare and Chitungwiza municipalities, clogging problems of reticulation by sand deposit or malfunction of pump stations recurrences frequently: Clogging of sewers, sewage spilling out from manholes polluting streets, buried grit chamber・trickling filters in the STP by sand deposit and flooding in the pump station due to inappropriate sand disposal method around the sewerage facility.

The origin of the sand has been considered to be a sole reason of pot washing by residents; however, no identification was made for the real reason. In order to plan right counter measures for the sand issue, series of field tests was conducted. A Pilot Project for the sand issue was conducted to identify the unit generation rate of sand in the sewerage to prove the origin of the sand and also to get the detailed information of the sewered area.

(2) Study area

150 residences were selected from the 5 areas in Chitungwiza Municipality for the study.

The Study Area was divided into Sub-Areas namely;

- Area 1- Manyame Park and Old St Mary's,
- Area 2- Zengeza 1, Zengeza 2, Zengeza 3 and Zengeza 5,

- Area 3- Zengeza 4,
- Area 4- Unit A, B, C, H, E, D, J and K, and
- Area 5- Unit F, M, N, L, G, O and P.

The total number of properties/houses in the Areas, Sub-Areas and Study Area are as outlined in the Table below. These figures were extracted from the Household Dwellings Survey that was conducted in August 2012 by JICA Study Team. These houses will be used to calculate the quantity of grit from each Study Area.

Table 7.2.1 The Total Number of Properties/ Houses in the Areas

Area	Sub-Area	Total Number of Houses
1	Manyame Park and Old St Mary's	5,700
2	Zengeza 1, Zengeza 2, Zengeza 3 and Zengeza 5	10,680
3	Zengeza 4	2,700
4	Unit A, B, C, H, E, D, J and K	10,443
5	Unit F, M, N, G, O and P	8,492
Total Houses Study Area		38,015

Source: JICA Project Team

Households per area where household grit traps were installed in kitchen gullies are as outlined in table below;

Table 7.2.2 Study Area and House Numbers of Sewerage Pilot Project

Area	Sub-Area	Number of Households
1	Manyame Park and Old St Mary's	25
2	Zengeza 1, Zengeza 2, Zengeza 3 and Zengeza 5	40
3	Zengeza 4	20
4	Unit A, B, C, H, E, D, J and K	30
5	Unit F, M, N, G, O and P	35
Total		150

Source: JICA Project Team

Residents of the selected houses were cooperative to the field study.

(3) Sand trap

Prototype sand trap was developed as shown in the Photo 7.2.10 and Figure 7.2.1. The structure is similar to the grease trap but it has bottom of sieve to catch the sand. In the survey, effectiveness of the trap and unit sand generation rate per capita were studied. The trap was designed to release fine particles of the sand and silt under 425 micro metre going through the sieve to avoid clogging of the devices by the fine particle.

Source: JICA Project Team

Photo 7.2.10 Sand and Grease Trap

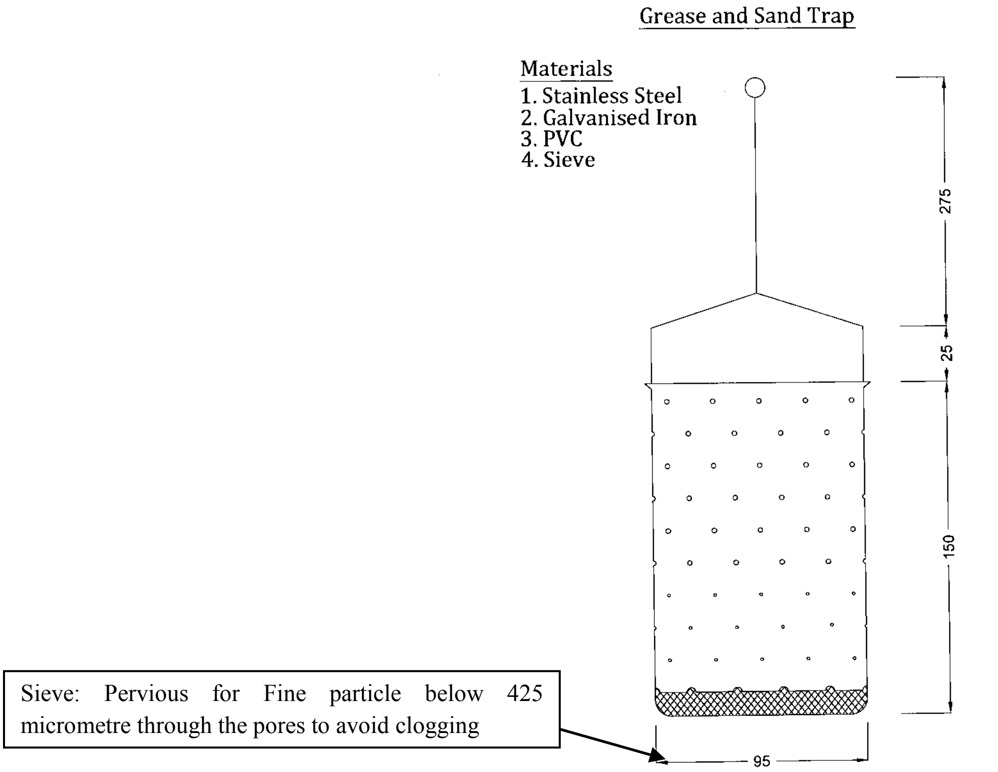


Figure 7.2.1 Configuration of Sand Trap Source: JICA Project Team

(3) Monitoring

Monitoring was planned to be conducted in the dry season in order to avoid the influence of the rain. Monitoring of the devices was conducted over the following period;

Table 7.2.3 Monitoring Period

Area	Sub-Area	Day of Installation	Number of Readings
1	Manyame Park and Old St Mary's	22/10/2012, 23/10/2012, 24/10/2012, 26/10/2012, 31/10/2012, 2/11/2012	90
2	Zengeza 1, Zengeza 2, Zengeza 3 and Zengeza 5	22/10/2012, 23/10/2012, 25/10/2012, 1/11/2012	128
3	Zengeza 4	22/10/2012, 25/10/2012, 30/10/2012, 1/11/2012	60
4	Unit A, B, C, H, E, D, J and K	24/10/2012, 29/10/2012 2/10/2012, 26/10/2012	66
5	Unit F, M, N, G, O and P	24/10/2012, 29/10/2012 2/10/2012, 26/10/2012	86

Source: JICA Project Team

Because of the tightness of the grit trap devices, during monitoring it was observed that upon clogging the devices were getting flooded including in extreme cases, poorly drained areas around the gully. As a result, a number of grit traps were removed by the residents so as not to make further hazards for residents. The table below shows the number of grit traps removed before and during the monitoring period;

Table 7.2.4 Removed Units before Completion of Monitoring

Area	Sub-Area	Number Removed
1	Manyame Park and Old St Mary's	4
2	Zengeza 1, Zengeza 2, Zengeza 3 and Zengeza 5	4
3	Zengeza 4	None
4	Unit A, B, C, H, E, D, J and K	4
5	Unit F, M, N, G, O and P	4

Source: JICA Project Team

The devices were monitored for more than two weeks. Monitoring was not on a daily basis. This is because Chitungwiza Municipality is currently facing serious water supply challenges. The emergency supply regime lacks any structure. Consequently it was noted that behavioural habits of the targeted house- holds have been affected by this intermittent water supply situation. People are more conscious of conserving every drop of water; hence the amount of anticipated sand entering the sewerage network might be small compared with that which would enter the same network during normal water supply periods. The table below does show the number of days the devices were in operation;

Table 7.2.5 Number of Days for Monitoring

Area	Sub-Area	Day of Installation	Removal Date	Total number of days in operation
1	Manyame Park and Old St Mary's	15/10/2012	02/11/2012	19
2	Zengeza 1, Zengeza 2, Zengeza 3 and Zengeza 5	15/10/2012 and 16/10/2012	02/11/2012	18.5 (19 and 18)
3	Zengeza 4	16/10/2012	02/11/2012	18
4	Unit A, B, C, H, E, D, J and K	17/10/2012	01/11/2012	16
5	Unit F, M, N, G, O and P	17/10/2012	01/11/2012	16

Source: JICA Project Team

(4) Water supply situation

Number of times that the various areas were supplied with water during the monitoring period is checked and found water supply was made only three or four times outlined during the monitoring periods as shown in the table below:

Table 7.2.6 Frequencies of Water Supply to the Area during the monitoring

Area	Sub-Area	Total number of times areas received water
1	Manyame Park and Old St Mary's	4
2	Zengeza 1, Zengeza 2, Zengeza 3 and Zengeza 5	4
3	Zengeza 4	4
4	Unit A, B, C, H, E, D, J and K	3
5	Unit F, M, N, G, O and P	3

Source: JICA Project Team

As a result of the above, sampling in Areas 4 and 5 were limited to only 3 times due to this problem of water supply. The residents do not drain used water to sewerage without water supply, then the devices were not used when the tap water was not supplied. In areas 4 and 5 residents rely more on boreholes and wells. Residents normally hoard water when the water is available and use them sparingly thereby distorting the real impact of the amount of sand entering the sewerage network.

7.2.4 Result of the Field Work and Analysis

(1) Basis of calculations

The following assumptions were made in the calculation of anticipated amount of sand entering the sewerage network;

- The Prototype device dimensions as depicted in Figure 7.2.1 are assumed to be the standard dimensions for calculation purposes,
- Trapped sand contained about 40% of debris other than sand from the preparation work. Therefore, this amount was considered the calculation of the study.

- "% of silt" in the sand was assumed to be 50% from the former result of the grading test in the ZSTP in 1997.
- Unit weight of the sand was assumed to be $1.56 t/m^3$ from the result of geo test in 1997.

(2) Formula used

Trapped sand depth was measured using scale rules and the measured depth was multiplied by the surface area of the sand trap device to give the volume of trapped sand less the assumed volume of trapped debris. Part of the trapped debris was first removed from the device before measurement. It was observed that in most cases sand settled at the bottom and debris at the top. This was most likely due to the different specific gravities of the various substances. Regarding the dimensions and configuration of the device, refer to the Figure 7.2.1.

(3) The amount of sand in the field study

The result of the field work is summarised in the table 7.2.6. In total about 14,000 ml of sand excluding garbage was monitored through the field work. Refer to Appendix 8.1 for the details. Since fine particle like silt goes through the pores of the sieve, correction is needed.

Table 7.2.7 Amount of Sand Collected by Sand Traps

Area	Sub-Area	Volume of the Sand collected for the Period
1	Manyame Park and Old St Mary's	2,621 ml
2	Zengeza 1, Zengeza 2, Zengeza 3 and Zengeza 5	1,931 ml
3	Zengeza 4	5,145 ml
4	Unit A, B, C, H, E, D, J and K	1,212 ml
5	Unit F, M, N, G, O and P	3,150 ml
Total		14,059 ml

Source: JICA Project Team

(4) Unit generation rate of sand from study area

Unit Generation of Sand and Silt from the houses were calculated as follows:

- Amount of silt added (×2, rate of content of Silt is 50%)
- Conversion to weight(×1.56, unit weight of the sand is $1.56 t/m^3$)
- House-Water supplied day(Total of (house no) ×days-water supplied)
- Unit Sand Generation per water supplied days per house
  (Total Sand and Silt)/(House-water supplied day)
- Unit Sand Generation per capita per water supplied day
  9.1people/residents

From the computation, unit generation rate will be obtained. Collected Sand and silt is shown in Table 7.2.8.

Table 7.2.8 Collected Sand and Silt from Study Area

Area	Sub-Area	Number of Houses	days of water supply /operation (day)	House-water supplied day/operation (day)	Sand and Silt from Houses (ml)	(g)
1	Manyame Park/ Old St Mary	27	4/19	108/513	5,241	8,177
2	Zengeza 1, 2, 3 and 5	35	4/18.5	140/647.5	3,862	6,025
3	Zengeza 4	16	4/18	64/288	10,290	16,052
4	Unit A, B, C, H, E, D, J and K	31	3/16	93/496	6,299	9,827
5	Unit F, M, N, G, O and P	28	3/16	84/448	2,425	3,783
Total		137		489/2392.5	28,118	43,863

Source: JICA Project Team

Therefore, unit sand generation rate is as follows:

- 43,863/489=89.7 g/house/day
- 28,118/489=57.5 ml/house/day
- 89.7/9.1=9.86 g/capita/day

The amount is considered to be reasonable from the experience of the field survey of the pot washing. Unit generation rate of sand was determined as follows:

Per capita sand generation rate: 10 g/capita/day
6.4 ml/capita/day
Per house sand generation rate : 90 g/house/day
57.7ml/house/day

Besides, Rate of water supplied days during the days of operation was 489/2392.5=0.204, which means that days of water supplied is averagely only 1.4 days (7days×0.204=1.43days) per week through the entire municipality. It can be said that the residents are withstanding severe living condition in the Municipality. Boreholes and shallow wells are considered to be the core water source for the residents.

Rate of water supplied days: 0.204

(5) Findings

Findings were summarised as follows:

1) All the 137 houses selected were using the sand for every washing work regardless of availability of water, which proves the manner as a common manner.
2) Water supply during the period of the study, water was supplied only 3 or 4 times from the taps. Availability of water supply was computed as averagely 20% and it was almost common in all the area. (Refer to above (4))
4) Thus, water from well or stored water was assumed to be used for about 80% of the days from the computation.

5) The sewage after the washing was discharged to the sewerage in the kitchen when water is available, but when unavailable, sewage was disposed in the garden or outside, since the water is not derived from the tap in the kitchen but from outside. (Refer to above (4))
6) About 90g of sand was averagely used in a house a day by computation from the derived data. (Refer to above (4))
7) Unit sand generation rate per capita was about 10g/capita/day. (Refer to above (4))
8) Soot of the pots was deemed to come from firewood, gas or paraffin, when the electricity is out due to power failure which was confirmed by interviews, observation at the field. However, since using firewood is a traditional way, it might be a regular way even when the residents have power in their houses. Anyhow, power failure is considered to be affecting the pot washing.

From these facts, since the residents have been using the sand for pot washing whether they have water or not, inflow of the sand into the sewers will increase when the water supply is improved. Thus, sand use is independent matter with the water supply.

Although sand removal would be done by the municipality as required after the refurbishment and improvement, most desirable way is the stoppage of the use of the sand in the residents to cope with the sand issue. For this purpose, activities below will be needed:

1) Educational/Enlightenment activity for the residents
2) Continuous power supply
3) Alternative economic cleansing powder
4) Penal regulation for sand use for pot wash

7.2.5 Zengeza Sewage Works – Inlet Works Grit Survey

(1) Confirmation of sand inflow to Zengeza STP

Confirmation of sand inflow to Zengeza STP was conducted to prove the study on sand generation in section 7.2.2. The Zengeza STP comprises the following process units;

- Inlet works comprising static screens, grit chambers and a bypass system.
- Anaerobic ponds,
- Trickling Filters,
- Maturation Ponds, and
- An off-line BNR Plant.

More than 50% of sewage from the study area drains by gravity to these works. In order to validate the results obtained from the household grit survey as extrapolated above, it was proposed to measure the amount of grit reaching the works by gravity. All the sewage pumping stations were not working due to rehabilitation works currently going on at these facilities during the survey.

The survey was conducted at the inlet works chamber just before the screens and assumed that grit hitting the works will predominantly come from the following drainage areas indicated in the sewage unit rate study.

In this area of the inlet works, it was observed that due to the sudden slowing of sewage as it goes through the screens, grit settles to the bottom of the chamber. The area of the inlet works was therefore cleaned by a tanker just before the start of the study and plan dimensions were measured. The survey commenced on 21st of November at 14:30pm, immediately after the cleaning work. The survey ran for two weeks to match the number of days the household grit survey was conducted. The existing gates were throttled as small as possible to make the water level high in the chamber to slow down the velocity.

The number of properties connected to the STP in the study area, are limited due to pipeline clogging and breakdown of pump stations. It is outlined in the Table below;

Table 7.2.9 Connected Area to the STP

Area	Sub-Area	Total Number of Houses
2	Zengeza 2, Zengeza 3 and 50% of Zengeza 5	6,472
3	Zengeza 4	2,700
4	About 50% of Unit A, B, C, H, E, D, J and K	5,605
5	Unit F, M, N, G, O and P	8,492
Total Houses Study Area		23,269

Source: JICA Project Team

Therefore, the adjusted volume of sand from households to ZSTP was 3.837m^3 as shown below;

Table 7.2.10 Assumed amount of sand to the STP

<table>
<tr><th>Area</th><th>Sub-Area</th><th>Total Number of Houses</th><th>Unit Sand Generation Rate</th><th>Test Periods (days)</th><th>Assumed Total Sand from Area (m^3)</th></tr>
<tr><td>2</td><td>Zengeza 1, Zengeza 2, Zengeza 3 and Zengeza 5</td><td>6,472</td><td rowspan="5">57.7 ×0.204 =11.78 ml/house/day</td><td>14</td><td>1.067</td></tr>
<tr><td>3</td><td>Zengeza 4</td><td>2,700</td><td>14</td><td>0.445</td></tr>
<tr><td>4</td><td>Unit A, B, C, H, E, D, J and K</td><td>5,605</td><td>14</td><td>0.924</td></tr>
<tr><td>5</td><td>Unit F, M, N, G, O and P</td><td>8,492</td><td>14</td><td>1.401</td></tr>
<tr><td colspan="2">Total</td><td>23,269</td><td></td><td>3.837</td></tr>
</table>

Source: JICA Project Team

Then, deposit of about 4m^3 in the chamber was assumed during 2 weeks.

(2) Actual sand deposit in ZSTP

Plans below are the Plan dimensions of the measured part of the Inlet Works;

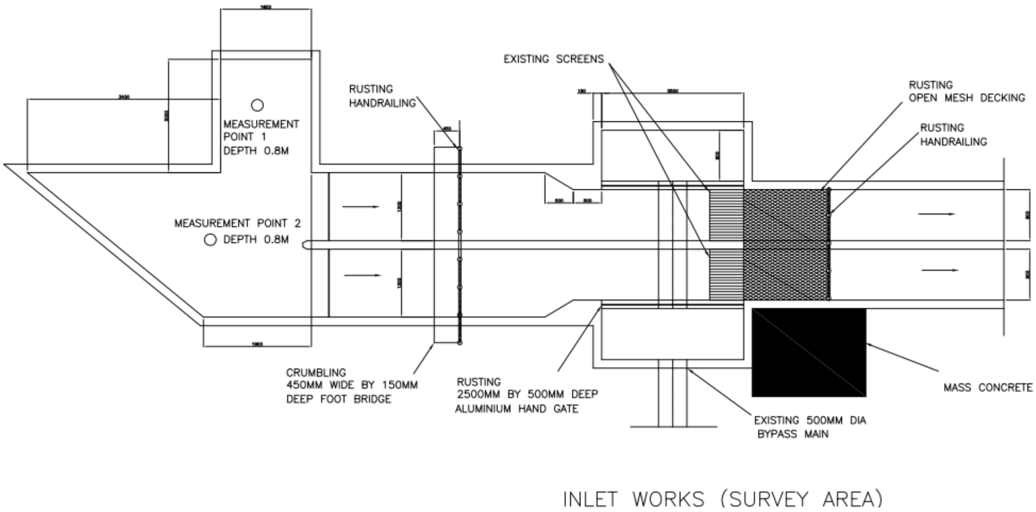


Figure 7.2.2 Entrance of Grit Chamber

The shaded area was used for the measurement of sand deposit.

A = 1/2×(1.5+5.0) ×2.5 = 8.125m^2 Point 1 was not used for the measurement.

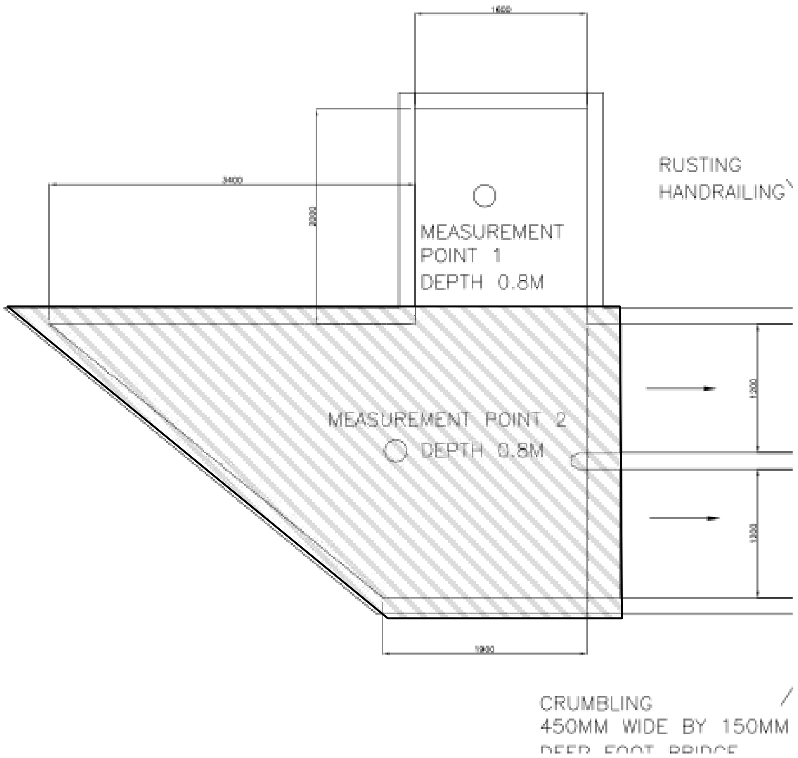


Figure 7.2.3 Area of the Depth Measurement

Based on the above structure and dimensions, the amount of grit that has accumulated in the surveyed Inlet structure over a period of 2 weeks is derived as follows:

-Sand depth: t = 0.6 m

-Sand deposit: V = 8.125×0.6 = 4.875m^3

(3) Evaluation of the result

The thinking process behind surveying the two extreme ends of the system was to try and ascertain if volumes of grit being received at the Sewage Works could be compared with that entering the system at the top-end.

Thus inflow of sand was assumed to be 3.837 m^3 for 2 weeks, and the volume of the sand deposit during 2 weeks was 4.875 m^3. Since the deposited sand for more than 10 years in the sewers could be washed out reaching the Inlet Chamber in the ZSTP for some reason, it is considered that the both result is showing fairly good consistency. From this result, the measurement conducted in the pilot project and computation technique was adopted as the sand generation projection.

(4) Findings

1) Assumption of the deposit was 3.8 m^3, while the actual measurement was 4.9 m^3.

2) Although there is a margin of error, computation of sand deposit in the ZSTP was close to the actual deposit in the chamber at the entrance of the inflow.

Although the household and inlet works survey period did not start at the same time, the two surveys were based on the same duration of 2 weeks. However, it must be noted that the following factors and occurrences did influence the rate at which grit was entering the system and its subsequent movement to the terminal point bringing the difference of assumption and actual measurement;

- Water supply over the study period,
- Blockages in the system,
- Settlement of grit in the system, and
- Carry-over of grit at works due to changes in sewage flow velocity.

7.2.6 Projection of Sand Generation in the Future

From the study, it was found that availability of water supply was very much limited to low level of about 20%, although the situation of water supply will be improved in the future. From our survey, volume of the sand inflowing to the ZSTP is directly connected to the availability of water supply as shown above.

Then, sand inflow to the ZSTP was assumed as follows:

1) Population: 354,500

2) Sewage flow: 23,270 m^3/day

(60 l/capita/day ×354,500 + 2000 (Industrial Wastewater))

3) Generation: 2 cases for water availability are 100% and 20%

Case 1

Water Availability 100%

354,5000×10 g/capita/day×100% = 3,545 kg/day

= 2.272 m^3/day (1.56t/m^3)

Case 2

Water Availability 20%

354,500×10 g/capita/day×20% = 709 kg/day

= 0.455 m^3/day

Therefore, volume of the sand inflowing the ZSTP will be 2.3 m^3/day in the Case 1, that is 69 m^3 in a month. It will be more than 800 m^3 in a year. Even under the current status, sand inflow of 12 m^3/month or 144 m^3/year. This seems what is seen in the old facility in the ZSTP, namely buried anaerobic ponds and sand-clogged trickling filters. This indicates usual sand removal work for STP, PS and sewers is very important to maintain the facility, if the sand inflow keeps on.

Assuming that the unit price of the sand removal work using high pressure jet vehicle and tanker is 20 USD/m^3, cost for the sand removal for the case 1 is thought to be 1,200 USD/month, when the water availability is 100%.

Monthly cost for sand removal by high pressure jet vehicle:

- 20 USD/m^3×2.3m^3 /d×30 days= 1,380 USD/month

7.2.7 Educational Activity

On the other hand, educational activity/enlightenment/introduction of penal regulations for the residents is very essential as well. Seminar for the residents, presentation to the schoolboys/girls regarding the sanitary, environment and sewage facility will be very useful to reduce the sand. In the latter part of the project, these activities will be planned and conducted.

Introduction of penal regulation must be done in parallel with the providing the alternative to the residents.

7.2.8 Alternative of the Sand

Alternative of the sand for pot washing must be found, since usage of sand might not disappear in spite of educational activity.

7.3 Solid Waste Management

7.3.1 Approach to Implementation of Pilot Project

(1) General

The following two major causes were estimated for the illegal dumping for the illegal dumping sites at any locations of the city;

- Communities do not comply with the rules or schedules of the municipality collection service or unaware of above rules / schedules, and they discharge their waste inappropriately.
- The municipality collection service cannot access the communities near the illegal dumping sites because road condition is not good or sewage is directly discharged into the nearby road.

In the pilot project, attempt of public education for the purpose of the changes of their attitude toward appropriate discharge and a combination of collection system of a primary collection by the community residents by using manual carts and the secondary collection of collection service of the municipality.

(2) Selection of project sites

The project sites of the pilot project were selected through identifying the non-collection service area in a map, discussions with the municipality and site inspection of candidate sites. Initially, St Mary’s (Manyame Park) and Zengeza 4 (Pagomba) were selected due to the inaccessibility and high volumes of waste on illegal dumps in these areas. A second inspection of the project sites was done to verify if the sites could be utilized for the pilot project. On the second inspection it was discovered that in St Mary’s (Manyame Park) most of the houses were still under construction and had not yet been occupied with households. Unit J Extension of Seke South was chosen instead of St Mary’s (Manyame Park). Finally, two communities of Zengeza 4 and Unit J extension of Seke South were selected. The target household number is 100 of 50 households from each site. The location map of above sites is shown in Figure 7.3.1.

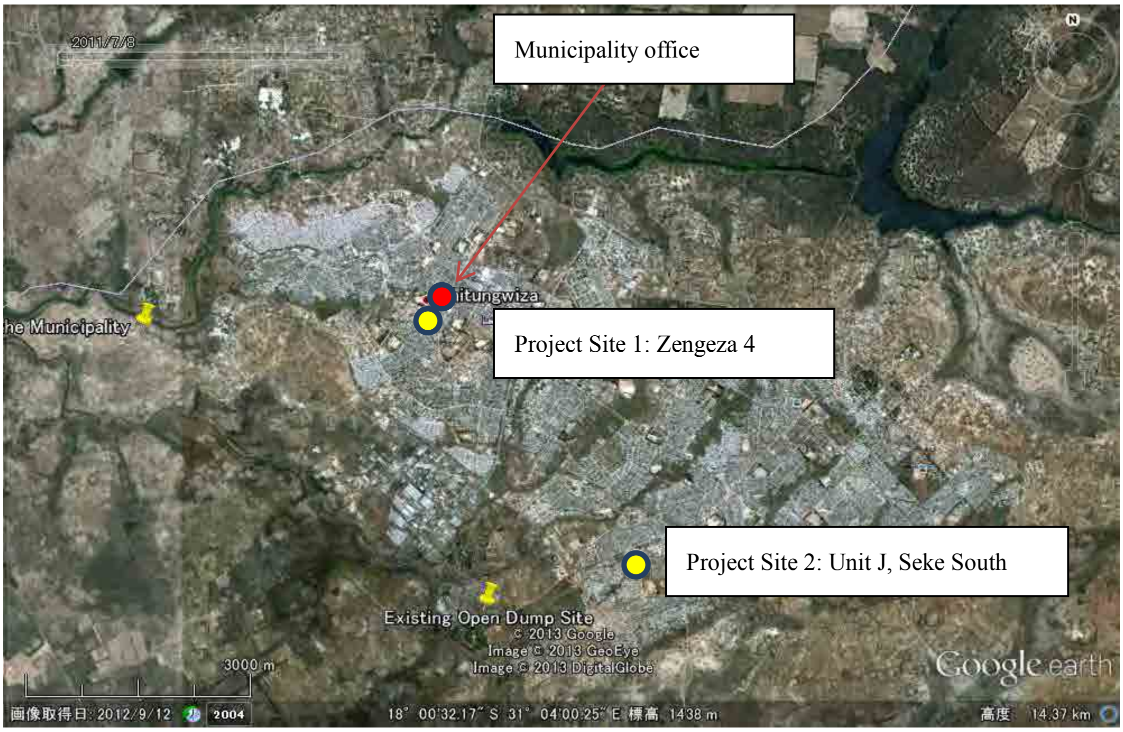


Figure 7.3.1 Location Map of Project Sites of Pilot Project

(3) Explanation of Pilot Project to community residents

The local consultants and the municipality's officers of solid waste department visited each household of the project sites on the explanation of the implementation of the pilot project. One banner and two posters with the JICA logo were set at each project sites.

(4) Public education

In the proposed pilot project, the public education was carried out by the following methods;

- To hold a community consultation meetings repeatedly
- To hold environment education in schools
- To prepare illustrated pamphlets, posters or warning boards on appropriate discharge such as separation collection, collection rules

(5) Proposed combination system of primary and secondary collection

1) Proposed collection system

In the non-collection service areas, a primary collection using of manual carts by CBOs (Community based Organizations) and their transport to a collection point is recommended combined with the secondary collection which is served by the municipality. The graphical image of the proposed collection system is shown in Figure 7.3.2.

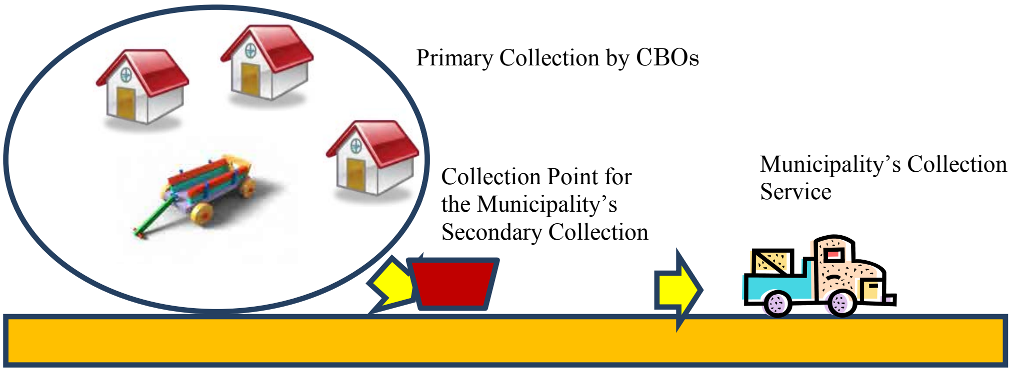


Figure 7.3.2 Proposed Collection System of Primary Collection and Secondary Collection

2) Organizing of operators for primary collection

An organizing of the primary collection was carried out through the discussions with the municipality and the community.

The primary collection team was organized by two (2) teams for two (2) project sites, total of 4 operators (2 operators x 1 teams). These operators were hired by the JICA project team.

3) Preparation of necessary equipment

The following equipment in Table 7.3.1 was procured for the implementation of the primary collection by the project.

Table 7.3.1 List of Equipment for Proposed Primary Collection in Pilot Project

No.	Name of Equipment	Specification	Quantity
1	Drums for storage of solid waste	Steel: 200 litter	20
2	Bucket	Plastics: 85 litter	4
3	Manual carts	Capacity: 100 kg	2
4	Drum handles	12 mm steel rod	-
5	Padlock	Steel	-
6	Gate chain	Steel	-

4) Selection of collection point for secondary collection

The community residents will have to transport the waste collected by primary collection to a designated area or station where the municipality collection service can access. One designated collection point was designated in each project site for the secondary collection service of the municipality. The site condition of the collection points is shown in Photo 7.3.1.

	
Zengeza 4	Unit J, Seke South

Photo 7.3.1 Collection Points for Secondary Collection Service

(6) Monitoring before and after Pilot Project

Before and after the implementation of the pilot project, a monitoring was carried out with the municipality (C/P) to verify the process of the activities, validity or efficiency of activities and input, outcome of the pilot project and their evaluation. The monitoring was carried out through a questionnaire survey with the residents of the target communities

(7) Stakeholder meetings

Stakeholder meetings were held to share the outcome of the pilot project.

(8) Actual work schedule

The pilot project was carried out for the period of 1st of October with the preparation works, the attempt of the proposed collection system of the primary and secondary collection and the preparation of the final report at the beginning of December.

The actual work progress on the implementation of the pilot project is shown in Table 7.3.2.

Table 7.3.2 Actual Work Schedule of Pilot Project

Work Item	Date	Period
Preparation of work plan	1 -14 October, 2012	10 days
Selection of project sites	10 October, 2012	1 day
Selection of collection points	12 October, 2012	1 day
Procurement of equipment	15 -19 October, 2012	5 days
Notification to residents	19-20 October, 2012	2 days
Interview with cart operators	19 October, 2012	1 day
Commencement of pilot project in project sites	22 October-30 November, 2012	30 days
Monitoring of project activities	22 October-30 November, 2012	30 days
Meeting with the District Education officer and District	30 October , 2012	1 day

Work Item	Date	Period
Administrator		
Meeting with the Provincial Education Officer	31 October, 2012	1 day
Public education in schools	6-14 November, 2012	1 week
Community awareness sessions	15-16 November, 2012	2 days
Conduct stakeholders meeting	20 November, 2012	1 day
Conduct questionnaire survey	3-5 December, 2012	3 days
Hold clean-up campaign	7 December, 2012	1 day
Preparation of final report (draft)	10-14 December, 2012	5 days

7.3.2 Results of Pilot Project

(1) Identification of causes of illegal dumping

Through the interviews with the local residents and the municipality, the following causes of illegal dumping were identified;

- Lack of public awareness on appropriate discharge or illegal dumping
- There is no municipal collection service where there are no access roads.
- Residents occupied the lands and built their houses before the construction of access roads by the municipality.
- Deteriorated collection vehicles which are poorly serviced affect the collection service of the municipality
- The municipality's budget for fuel and other consumables is not constantly supplied and therefore the municipality's collection service cannot reach residential areas regularly.
- Municipal collection service with once a week even for the accessible communities seem to be insufficient and the residents dump uncollected waste reluctantly.

(2) Establishment of operation rule

The following operation rules were determined through the discussions between the municipality and the community.

- Operators shall collect solid waste from residents twice a week on Mondays and Thursdays from am 0830 to 1300
- On Wednesday, operators shall clear solid waste on illegal dumps to the collection points
- The municipality shall collect waste twice a week from the central collection point on Monday, Wednesday and Thursday from 1400 to 1630
- At least two people shall lift a drum when emptying onto the skip bin
- Operator shall replace the waste container from the household into black container

- Residents shall not litter the surroundings on collection of solid waste
- Operator shall empty waste containers from every household in the pilot project

(3) Monitoring results

Monitoring before Pilot Project

Initially, a questionnaire survey was conducted for the residents at the project sites to assess the residents' knowledge and attitude towards the practice on solid waste management. The following results were obtained through the questionnaire survey.

- The majority of the residents (86%) show concern about issues of solid waste management and the diseases related to improper waste disposal.
- Some of the residents had experienced the typhoid and cholera outbreaks in the past years of 2010 and 2011.
- 90% of the respondents are willing to participate in the activities of waste reduction, recycling and composting waste at household level.
- Most of the residents replied that the infrastructure development such as roads can be a permanent solution compared to the attempt of the development of collection points since such collection points will become a dumping site if the municipality fails to collect the waste.

Monitoring results after Pilot Project

The monitoring after the implementation of the pilot project was carried out through another questionnaire survey at the communities at the end of the pilot project. The results of the final questionnaire survey are summarized as follows.

- The residents (97% of the respondents) think that the pilot project was a good attempt
- The majority of the residents think that they secured a cleaner environment after the pilot project compared to the previous state before the pilot project
- Most of the residents (82% of the respondents) are aware of the fact that a 20 USD fine has to be paid for an illegal dumping, but because there is no refuse collection in their communities they are forced to dump their waste illegally.
- Most of the residents (83% of the respondents) are willing to produce craft works from the recyclable materials for earning their income and also for the purpose of waste reduction

Interview results with operators of primary collection

An interview survey was carried out for the operators of the primary collection after the implementation of the pilot project. Table 7.3.3 shows the results of the interview.

Table 7.3.3 Results of Interview with Operators of Primary Collection

No.	Questions	Response
1	What is the waste composition of the garbage you are collecting?	All the operators indicated that Food Waste, Plastics, Papers, Yard Wastes are among the waste they are collecting from different households.
2	How many drums are you filling per day?	6 Drums per day
3	Are there any households in the pilot project from which you are not collecting garbage and why?	In Zengeza 4 area the operators are collecting garbage from all the households. However from Unit J area the operators are not collecting garbage from a few houses (on average 3households), the residents will have burnt their garbage or put in pits.
4	How do residents discharge their garbage?	Residents from the two areas discharge their garbage in a wide range of receptacles which include cement bags, empty metal tins, plastic bags and plastic bins. However some still discharge in their pits and some still even resort to illegal dumping.
5	What do you suggest to be the best way of storing garbage prior to collection by the residents?	The cart operators suggested that the residents must put their waste in plastic receptacles and put their bins outside their homes on the stipulated days of garbage collection
6	What do you think needs to be improved by the residents to make your operations easy?	The cart operators suggested that the residents must put their waste in plastic receptacles and put their bins outside their homes on the stipulated days of garbage collection
7	What do you think needs to be improved by the residents to make your operations easy?	Residents must put their waste receptacles outside their homes where it's accessible for the operators to collect the garbage. Residents staying close to the collection system (i.e. drums) must be encouraged to empty their own garbage directly into the drums.
8	Do you want to continue this work after this pilot project is finished?	All the operators showed willingness to continue with the work after the project is finished.

(4) Stakeholder meetings

Stakeholders identified

The stakeholders in this project are all those involved with Solid Waste Management in Chitungwiza. The identified stakeholders in the pilot project are listed below:

- Chitungwiza Municipality
- Communities
- Water, Sanitation and Health authorities (e.g. hospitals, health care centre)
- NGO groups (Green Africa Network)
- Private recycling group (Boston Plastics)
- Schools

Results of stakeholder meeting

The stakeholder meeting was held with other stakeholders of Chitungwiza to share the outcome of the pilot project. The attendant list is shown in Appendix 10.

1st Meeting

The followings are the opinions which were raised at the 1st stakeholder meeting;

- The educational awareness on appropriate discharge of waste should be carried out until there is an attitude change in the people towards waste reduction.
- One of NGO groups (GAN: Green Africa Network) can play an important role as a partner in public education including source separation, production of the products for secondary use such as hats, bags and baskets from recyclable materials.
- The municipality's collection service of once a week is not sufficient; therefore, the residents resorted to illegally dumping the excess waste. The service should be provided twice a week.

2nd Meeting

At the end of the Pilot Project, another meeting with the stakeholders was conducted at the Municipal workshop to discuss on the outcome of the Pilot Project in Zengeza 4 (Pagomba) and Unit J Extension.

- The municipality explained that they have no capacity to continue with collection in the project sites noting that the targeted houses are too few compared to the number of residents in these communities.
- Unit J Extension residents who are close to access roads could take out their waste for Municipal collection on Wednesday when the collection in Unit J is done.
- There will be a challenge in Zengeza 4 (Pagomba) as this is a swampy area and Municipal vehicles may get stuck during collection as the rainy season has started.

The minutes for the stakeholders' meeting are shown in Appendix 10.

(5) Outcome and challenges identified

Outcome

The following outcome was obtained through implementation of the pilot project.

- Most of the community residents have concern on the pilot project and they think that the pilot project was a good attempt.
- Most of the community residents recognize that they secured a cleaner environment after the pilot project compared to the previous state before the pilot project
- Most of the community residents are willing to participate in the activities of waste reduction, recycling and composting waste at household level.
- Most of the residents (83% of the respondents) are willing to produce craft works from the recyclable materials for earning their income generation and waste reduction, at the same time.

- The operators are willing to continue their work of primary collection after the implementation of the pilot project.
- Other communities in the municipality's non-collection areas who were not part of the pilot project expressed concern for the project to be implemented in their communities as well.

Challenges

The following are the major challenges identified during the pilot project;

- Throughout the duration of the pilot project, residents were asking for plastic bags to store their waste before collection by operators.
- Human excreta were part of the refuse collected from the households and this is because many houses have no toilet facilities in the pilot project communities.
- On several days there was no collection service for the secondary collection from collection points by the Municipality due to council strikes, breakdown of collection vehicles and fuel challenges.
- Some residents think that the pilot project only benefited a minute population of Chitungwiza.
- Residents were not practicing waste separation at source in order to reduce the amount of waste they put in the bins. Some of the residents put water in their refuse receptacles.

Efficiency of primary collection

From the informal interviews conducted during monitoring, the following suggestions are recommended to improve the efficiency of door to door collection

- Ideally each household should have a permanent refuse receptacle. There is a need to provide the residents with plastic bags to store their baggage as it was discovered that some residents had no storage containers during the Pilot Project.
- There is a need to encourage full participation from the residents in such programs as it was discovered during the course of the pilot project a few residents were still not taking out their waste for collection by the operators on collection days.
- There is a need to develop the sewer system so resident can have proper toilets as one of the problems faced by operators was human excreta in their waste.
- Some of the community residents delivered their waste to the collection points directly without waiting for collection by cart operators.

PART II MASTER PLAN

CHAPTER 8 IMPROVEMENT PLAN FOR WATER SUPPLY

8.1 General

As mentioned in Chapters 4.1 and 5.1, Chitungwiza Municipality's water supply system, which receives bulk water from Harare Water Works, is faced with numerous problems. This chapter discusses the improvement plan proposed for Harare Water Works as the distributor of bulk water, and improvement plan for Chitungwiza Municipality as the target entity.

8.2 Demand Projection

8.2.1 Population Projection

(1) Target year

Target year of Mater Plan (M/P) is stipulated to be year 2030, based on agreement between Japanese and Zimbabwean Government. In addition, middle target year of 2020 is stipulated as the target year of Feasibility Study (F/S).

(2) Harare Metropolitan Area

In Harare Metropolitan Area, the population growth rate will be raised along with the improvement of economy conditions. During census years between 2002 and 2012, the population growth rate of Harare Urban District was very low while that of Rural District was very high and these of surrounding areas are also high in spite of the hyperinflation. Because Harare urban area was seemed to be already full by premises/sites and the rural area and surrounding areas have much space, the results can be understood and this tendency will continue. Accordingly, for the population projection of 2020 and 2030, similar growth rates between 2002 and 2012 for rural District, Epworth District, Ruwa and Norton are adopted as shown in Table 8.2.1.

However that for Urban District is adopted to be 0.5 %/year considering economy recovery and that for Chitungwiza District was calculated in the later section. As shown the table, the total population of the water supply area of Harare Water Works will be almost double in 2030 to that in 2012.

Table 8.2.1 Population Projection in Supply Area of Harare Water Works

Division	Name	Area (km^2)	Population				Increase Rate (%)		
			2002	2012	2020	2030	'02-'12	'12-'20	'20-'30
Harare Province	Urban District	579	1,435,784	1,468,800	1,529,000	1,607,000	0.23	0.50	0.50
	Rural Dis.	225	23,023	113,100	346,000	1,075,000	17.25	15.00	12.00
	Chitungwiza Dis.	42	323,260	354,500	389,100	440,800	0.93	1.17	1.26
	Epworth Dis	26	114,067	161,800	213,000	300,000	3.56	3.50	3.50
	Sub-total	872	1,896,134	2,098,200	2,477,100	3,422,800	1.02	2.10	3.29

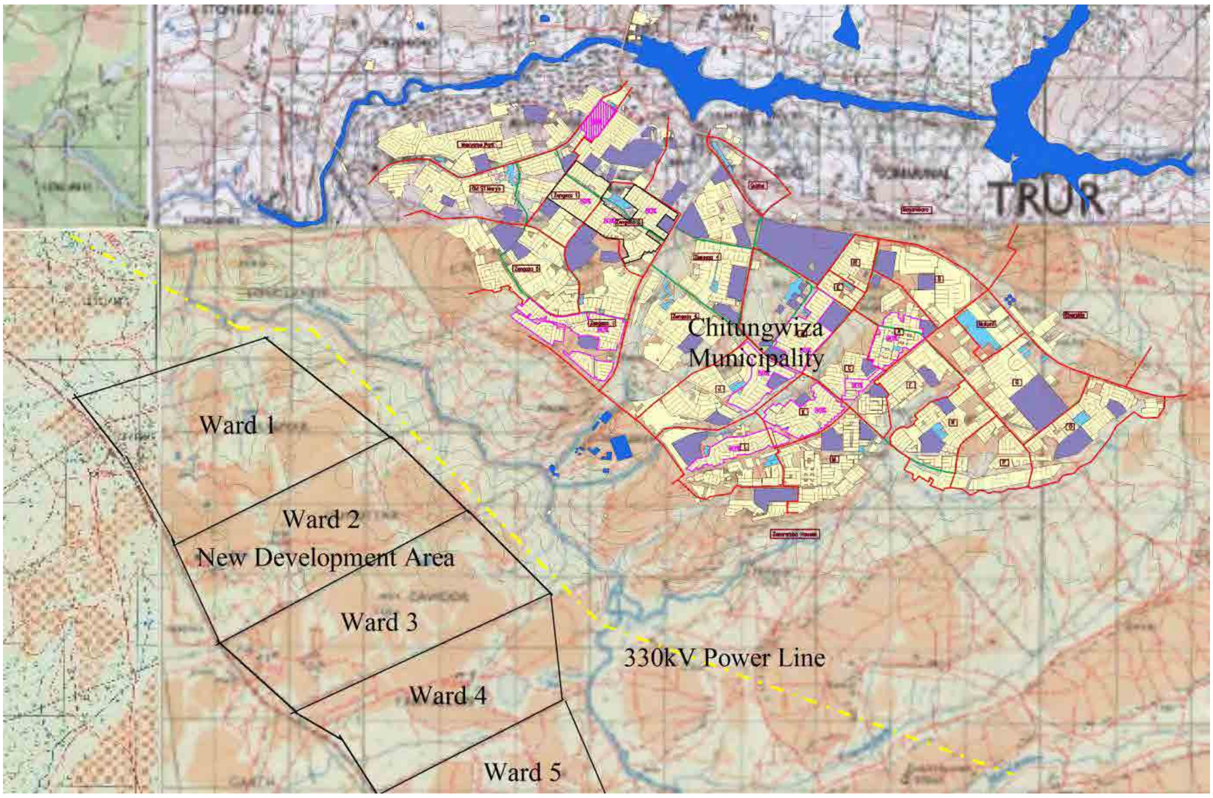
Division	Name	Area (km^2)	Population				Increase Rate (%)		
			2002	2012	2020	2030	'02-'12	'12-'20	'20-'30
Surrounding Area	Ruwa	8	23,681	56,300	112,000	265,000	9.05	9.00	9.00
	Norton	20	27,332	58,400	108,000	233,000	7.89	8.00	8.00
	Sub-total	28	51,013	114,700	220,000	498,000	8.44	8.48	8.51
Total		900	1,947,147	2,212,900	2,697,100	3,920,800	1.29	2.50	3.81

Source: JICA Project Team

(3) Chitungwiza municipality

1) Future Expansion Plan for Municipality

The municipality has a new expansion plan as shown in Figure 8.2.1.

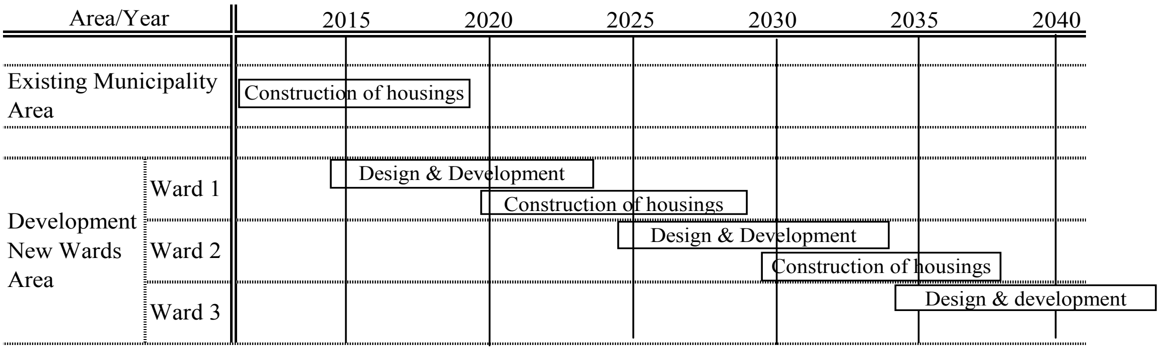


Source: JICA Project Team

Figure 8.2.1 New Development Plan for the Municipality

The development area will be located on the opposite side of Nyatsime River, and it will be divided to be six wards with each development housing unit of 20,000, total 120,000 units. Compared with the number of current residential housings of 37 thousands of counted number, the plan is a very ambitious one. However there are no designs even though a conceptual one is there. No proposal from developers, and then for the realization, a considerable period may be necessary.

From the results of the survey for the population, it was found that there are many vacant spaces in residential areas which had been already developed, and many housings units have been under construction. Therefore these vacant spaces will be filled in near future and in addition above mentioned new development area will be developed gradually. The schedule of the above development is assumed in Figure 8.2.2.



Source: JICA Project Team

Figure 8.2.2 Assumed Development Schedule in the Municipality

In spite of the ambitious plan of the Municipality, there are many nearer candidate sites in surrounding Harare Metropolitan area, and then the development plan in Chitungwiza area cannot be expected to progress so rapidly. Therefore the development schedule shown in Figure 8.2.2 is considered reasonable, even though the progress seems too slow.

2) Population projection

As mentioned in Section 1), all vacant areas in the existing municipality which have already been developed will be full and all residents will start to live in at middle target year of 2020. The design and development of Ward 1 of new development area will be progressing and construction of the housing units will start but no residents will live in 2020. The housing number of 20,000 is excessive compared to the available area and then average density (no./ha) of existing municipality is adapted to determine housing number of Ward 1. In addition, observing the condition of current municipality, since the construction of housings is not so rapidly progressed, the rate of housing number with the residents will be 70% to total premises in 2030. The design and construction for Ward 2 will be progressing with no residents.

The projection is calculated in Table 8.2.2(1) for housing number and .Table 8.2.2 (2) for population.

Table 8.2.2 (1) Projection of Housing Number

Area/Item	Current Area(ha)			Area(ha)	Housing Number			Density
	Total	Actual	Rest	2030	Current	2020	2030	No./ha
St. Mary	218.8	199.1	19.7	218.8	5,899	6,484	6,484	29.6
Zengeza	609.5	426.3	183.2	609.5	11,924	17,048	17,048	28.0
Seke S	439.1	373.6	65.5	439.1	11,145	13,098	13,098	29.8
Seke N	476.3	389.9	86.4	476.3	8,126	9,928	9,928	20.8
Ward 1	0	0.0	0	535.5[*3]	0	0	10,150[*2]	27.1[*1]
Total	1,743.7	1,388.9	354.8	2,279.2	37,094	46,558	56,708	

Source: JICA Project Team

*1: Average density of housing premises, *2: 70% of premises will be constructed with residents,
*3: 85% of all ward area of 650ha is used for residential areas

Table 8.2.2 (2) Population Projection of Chitungwiza Municipality

Area/Item	Number of Dweller			2012		2020		2030	
	Current	2020	2030	Population	Density(/ha)	Population	Density(/ha)*2	Population	Density(/ha)*3
St. Mary	11.9	11.2	10.6	70,400	353.6	72,500	331.2	68,800	314.6
Zengeza	8.2	7.4	7.0	97,200	228.0	125,800	206.3	119,500	196.0
Seke S	9.1	8.5	8.1	101,900	272.7	111,100	253.0	105,500	240.3
Seke N	10.5	9.6	9.2	85,000	218.0	95,800	201.2	91,000	191.1
Ward 1	0.0	0.0	7.0*1	0	0.0	0	0	71,100	132.8
Total				354,500		405,200		455,900	
Average	9.6	8.7	8.0		255.2		232.4		200.0

Source: JICA Project Team

*1: Minimum density was adopted, *2: Developed area; 95% to 2012 and new areas; 80% to 2012, *3: 95% to 2020

In the table, the number of dwellers/population density predicted to be decreased with the economic improvement. The decrease ratio from 2012 to 2020 and from 2021 to 2030 is assumed to be at 5%. As shown in Table 8.2.2(2), the estimated population in middle target year of 2020 is 405,200 and that in target year of 2030 is 455,900, respectively.

The annual growth rate to middle target year is : (405,200/354,500)^(1/8)=1.0168 → 1.68%

The annual growth rate to target year is : (455,900/405,200)^(1/10)=1.0119 → 1.19%

8.2.2 Daily Average Water Demand Projection

(1) Great Harare area

In nearby Chitungwiza Municipality, the yield capacity of ground water resources is limited. This constrains the supply of bulk water to Chitungwiza Municipality by the Harare Water Works. Current water distribution flow was estimated in Chapter 4.1 (Table 4.1.16), and based on the table, the per capita consumption in 2012 was estimated at 124 Lpcd. From Table 4.1.16 and Table 8.2.1, the demand projection was carried out as shown in Table 8.2 3.

Table 8.2.3 Water Demand Projections for Great Harare

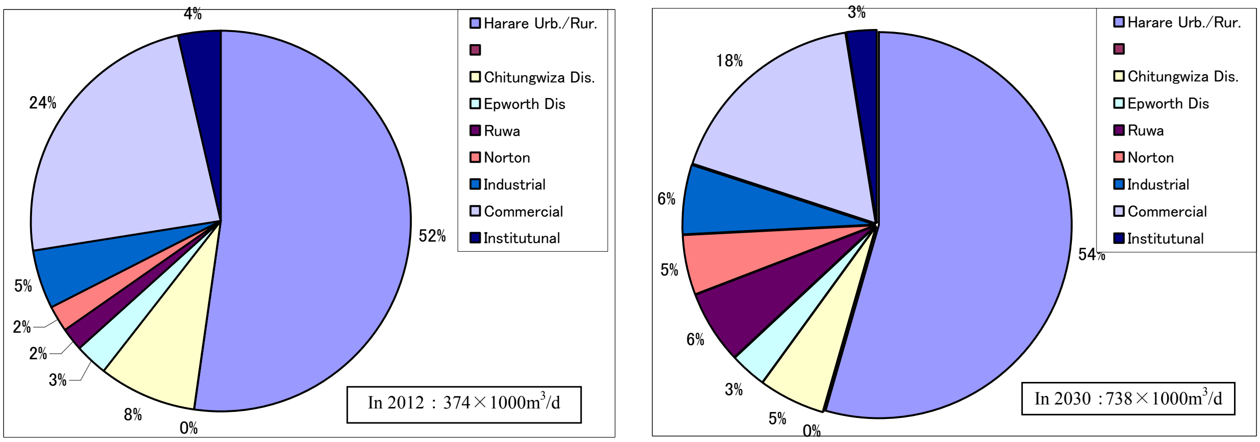
Division	Name	Area (km2)	Population			Consumption (m^3/d)			Per Target Year Increase
			2012	2020	2030	2012	2020	2030	
Harare Province	Harare Urb./Rur.	579	1,468,800	1,529,000	1,607,000	195,620	255,051	401,308	Demand 10%
		225	113,100	346,000	1,075,000				
	Chitungwiza Dis.	42	354,500	389,100	440,800	30,546	35,376	40,532	--
	Epworth Dis	26	161,800	213,000	300,000	10,791	15,626	24,209	Demand 10%
	Sub-total	872	2,098,200	2,477,100	3,422,800	236,956	306,053	466,049	
Surrounding Area	Ruwa	8	56,300	112,000	265,000	7,601	16,632	43,288	Demand 10%
	Norton	20	58,400	108,000	233,000	8,004	16,283	38,641	Demand 10%
	Sub-total	28	114,700	220,000	498,000	30,362	58,235	165,975	
Domestic Total		900	2,212,900	2,697,100	3,920,800	252,561	335,984	547,978	
Demand (m^3/d)	Industrial		0	0	0	18,516	27,774	41,661	50%
	Commercial		0	0	0	89,717	107,660	129,192	20%
	Institutional		0	0	0	13,218	15,862	19,034	20%
Total			0	0	0	374,012	487,280	737,866	
Domestic Unit Demand (Lpcd)						124	136	150	

Source: JICA Project Team

The conditions of the Table 8.2.3 are shown below:

1) From 2012 to 2020 and from 2020 to 2030, the domestic unit demand (Lpcd) of Harare urban and rural, Epworth, Ruwa and Norton will increase by 10%.
2) For the same periods, the industrial demand will increase by 50% on the assumption that there will be rapid economic recovery in the Harare Area.
3) For the same periods, the commercial and institutional demand will increase by 20% on the assumption of economy recovery with strict water conservation measures.
4) Water supply to Chitungwiza Municipality assumed as later section.

The demand of each area in 2012 and 2030 is shown in Figure 8.2.3.



Source: JICA Project Team

Figure 8.2.3 Water Demand Compositions in 2012 and 2030

(2) Chitungwiza municipality

1) Domestic use per capita demand

Currently, there is a shortage in water distribution flow to Chitungwiza Municipality, and actual water supply cannot meet demand. From the survey in Manyame Park, domestic unit demand was 84.1 Lpcd, but average consumption of whole municipality was assumed to be 56.0 Lpcd. The latter figure was supplemented by the water taken from around 3,000 shallow wells in the Seke area, where people are already accustomed to saving water. Thus, water demand in these areas will not increase much.

Therefore, current actual unit demand for domestic use is assumed to be 80 Lpcd, the figure normally used for very high-density areas of around 250 persons/ha. The population density of the municipality is shown in Table 8.2.4, and therefore the whole municipality should be categorized as very high-density area. The future demand will increase as the standard of living rises. But the availability of shallow wells, which can be used even in dry seasons, can augment water supply for laundry, cleaning, and irrigation purposes. Then, the unit domestic demand will not increase outside the range of the target year of M/P.

Table 8.2.4 Population Densities and Average Number of Dwellers for Housings

Area	Area (ha)	No. of Housings	Population	Density (p./ha)	Ave. Dwellers (p./house)
St. Mary's	199	5,899	70,400	354	11.9
Zengeza	426	11,924	97,200	228	8.2
Seke South	373	11,145	101,900	273	9.1
Seke North	390	8,126	85,000	218	10.5
Total	1,388	37,094	354,500	255	9.6

Source: JICA Project Team

2) Trend of demand for commercial, institution and industry

Water consumption of commercial, institution and industrial categories in the municipality is relatively small, as shown in Table 8.2.5. The increased demand rates in the future are assumed to be 20% for the commercial/institution, and 50% for industry, the same rates as with Harare Area.

Table 8.2.5 Current Water Consumption of Commercial/ Institution and Industry

Name/item	Consumption (m^3/d)		Number
	Average	Maximum	
Commercial/Institution	1,057	1,272	1,312
Industrial	1,129	1,409	15

Source: JICA Project Team

3) Projection

Table 8.2.6 shows water demand projection of the municipality, which was calculated, based on the above-mentioned conditions.

Table 8.2.6 Water Demand Projection of Chitungwiza Municipality

Category/Item		Population			Daily Average		
		2012	2020	2030	2012*	2020	2030
Domestic	St. Mary	70,400	72,500	68,800	5,632	5,800	5,504
	Zengeza	97,200	125,800	119,500	7,776	10,064	9,560
	Seke S	101,900	111,100	105,500	8,152	8,888	8,440
	Seke N	85,000	95,800	91,000	6,800	7,664	7,280
	Ward 1	0	0	71,100	0	0	5,688
	Sub-Total	354,500	405,200	455,900	28,360	32,416	36,472
Others	Commercial/Institution				1,057	1,270	1,520
	Industry				1,129	1,690	2,540
Total					30,546	35,376	40,532

Source: JICA Project Team

*: Assumed demands if the water supply to municipality was enough

8.2.3 Daily Maximum Water Demand Projection

(1) Great Harare

The daily average water demand of Great Harare Area was calculated in the previous section. The calculation of daily maximum flow for distribution network, daily factor f1 (=daily maximum/daily average) and NRW (Non-Revenue Water) must be determined.

In SAPROF Study, NRW rate was assumed to be at 30% in Harare Area, but it seems too small to comparison between assumed water demand and water production amount of MJ-WTP and PE-WTP. If the rate is exact, there must be no water shortage, but actually there have been much water shortage in the distribution areas as mentioned in Chapter 4.1.4. Harare Water Works has been trying to allocate the budget for the repair of distribution pipes. This will help to gradually reduce the NRW rate. The NRW rate in Harare Urban and Rural is predicted to be 57%* in 2012, 35%* in 2020 and 20% in 2030, while the NRW rate of bulk water supply is assumed to be 30% in 2012, 20% in 2020 and 15% in 2030 refer to the SAPROF Study. Daily factor of f1 is assumed to be 1.15. The daily maximum demand including NRW is calculated in Table 8.2.7.

*: From Urgent Infrastructure Rehabilitation-India Eximbank

In 2012, the total daily maximum demand is assumed to be around 932 thousands m^3/d when the NRW rate is assumed to be 57%. The average production of the two WTPs is 640,000 m^3/d (Morton Jaffray (MJ) WTP: 585,000 m^3/d and Prince Edward (PE) WTP: 55,000 m^3/d). As shown above, the production capacity is apparently short, and this explains the current actual water supply condition in Harare Area.

Table 8.2.7 Daily Maximum Demands for Great Harare Areas

Division	Name	Area	Daily Average			Daily Maximum			Daily Average with NRW			Daily Maximum with NRW		
		(km^2)	2012	2020	2030	2012	2020	2030	2012	2020	2030	2012	2020	2030
Harare Province	Urban District	579	195,620	255,051	401,308	224,963	293,309	461,504	454,930	392,387	535,077	523,169	451,245	615,339
	Rural Dis.	225												
	Chitungwiza Dis.	42	30,546	35,376	40,532	32,874	39,201	46,612	38,115	40,104	46,980	43,832	46,119	54,027
	Epworth Dis	26	10,791	15,626	24,209	12,409	17,970	27,841	15,415	19,532	28,481	17,728	22,462	32,754
	Sub-total	872	236,956	306,053	466,049	272,500	351,961	535,957	508,460	452,023	610,539	584,729	519,826	702,120
Surrounding Area	Ruwa	8	7,601	16,632	43,288	8,741	19,127	49,781	10,858	20,790	50,927	12,487	23,909	58,566
	Norton	20	8,004	16,283	38,641	9,205	18,725	44,437	11,435	20,353	45,460	13,150	23,406	52,279
	Sub-total	28	15,605	29,931	81,929	17,946	34,420	94,218	22,293	37,413	96,387	22,293	37,413	96,387
Total		900	252,561	335,984	547,978	290,445	386,382	630,175	530,752	489,436	706,926	607,021	557,239	798,507
Consumption (m^3/d)	Industrial		18,516	27,774	41,661	21,293	31,940	47,910	43,060	42,729	55,548	49,520	49,139	63,880
	Commercial		89,717	107,660	129,192	103,175	123,809	148,571	208,644	165,631	172,257	239,941	190,476	198,095
	Institutional		13,218	15,862	19,034	15,201	18,241	21,889	30,740	24,402	25,379	35,350	28,063	29,185
Total			374,012	487,280	737,866	430,114	560,372	848,545	813,196	722,199	960,109	931,832	824,917	1,089,668
Domentic Unit Demand			124	136	150	142	156	172	---	---	---	---	---	---

Source: JICA Project Team

(2) Chitungwiza municipality

1) Water leakage ratio

The staffs of the water supply section of Chitungwiza Municipality consider the leakage ratio to be very low. Actually, one of the staffs recorded that distribution flow seemed excessive as compared to actual supply to the municipality.

The leakage ratio is estimated as difference between the water supply and sewage inflow of Zengeza STP (Sewage Treatment Plant). All sewage P/Ss were broken during the study and sewage directly flows out to surrounding rivers. In addition, sewage from Zengeza and Seke Areas also flowed out due to a breakdown of some sewer pipes then. In Table 8.2.8, the sewered population to the STP is calculated together with the modified population counted for the actual distribution rate to each area. Thus, around only 60% of water supply was distributed to the collection area of STP then.

Table 8.2.8 Sewage Collecting Population in Chitungwiza Municipality

Area	Whole Area(ha)	Uncollected Area (ha)	Population	Population Density (p/ha)	Uncollected Area Pop.	Consump. Rate (%)	Modified	
							Population	Ratio(%)
St.Mary's	199	199	70,400	354	70,400	100	70,400	
Zengeza	426	12.5	97,200	228	2,850	75	2,138	
Seke South	373	102.9	101,900	273	28,110	50	14,055	
Seke North	390	78.9	85,000	218	17,200	50	8,600	
Total	1,388		354,500		118,560		95,193	40.2
The rest of population					235,940		141,558	59.8
Gross-Total					354,500	66.8	236,750	100.0

Source: JICA Project Team

Table 8.2.9(1) and 8.2.9(2) show two scenarios estimating water leakage ratio. In Table 8.2.9 (1) a water leakage ratio is calculated when water supply is around 45,000 m^3/d, which is a very large supply to the ordinary flow of 30,000 m^3/d. The flow of 45,000 m^3/d was decided to prevent a spread of typhoid fever. In Table 8.2.9 (2), another ratio with a supply of 16,500 m^3/d was calculated.

In latter case, due to insufficient water supply, majority of the wells in the municipality was used. Since the measurement was carried out only in the daytime then, wastewater flows from well water and industrial water were calculated to be double that of the daily usage.

Table 8.2.9 (1) Estimation of Leakage Ratio with Supply of 45,000 m^3/d

Item		Flow (m^3/d)	In Collection area flow(m^3/d)	Inflow to Sewer(m^3/d)	Leakage Ratio (%)
Water Supply	Supply Water	45,000	26,910	20,183	30.6
	Industry	-1,000	-1,000	-1,000	
	Total	44,000	25,910	19,183	
Sewage		13,000	13,000	13,000	

Source: JICA Project Team

Note: The measurement was continuously carried out for two days
Inflow rate to the sewer pipe is assumed to be 75% due to excessive water supply
Daily consumption of the industrial area is 1,000 m^3/d

Table 8.2.9 (2) Estimation of Leakage Ratio with Supply of 16,500 m^3/d

Item		Flow (m^3/d)	In Collection Area Flow (m^3/d)	Inflow to Sewer (m^3/d)	Leakage Ratio (%)
Supply	Supply Water	16,500	9,870	8,390	16.3
	Well Water	4,000	4,000	4,000	
	Industry	-2,000	-2,000	-2,000	
	Total	18,500	11,870	10,390	
Sewage		8,700	8,700	8,700	

Source: JICA Project Team

Note: The measurement was carried out during the daytime only
Inflow rate to the sewer pipe is assumed to be 85%
Daytime consumption of the industrial area is 2,000 m^3/d (double the daily consumption)
Wells were used in Zengeza and Seke Area, and in the collection area 4,000 m^3/d
(double the daily usage) of well water assumed to be used in the daytime,

As shown in Table 8.2.9(1) and (2), the assumed ratios are different, but the scenario shown in Table 8.2.9(1) is considered to be a special case and so the current NRW is assumed to be 25%. The NRW rate in 2020 and 2030 is assumed to be 15% by the effort of leakage reduction respectively. The daily factor of f1 is assumed to be 1.15. The daily maximum demand is calculated in Table 9.2.10.

By the Pilot Project of survey for water leakage ratio(shown in Appendix 9.2), survey at the two places shows that the assumed leakage ratio is less than 30%. It means that above leakage NRW is reasonable.

Table 8.2.10 Daily Maximum Water Demands for Chitungwiza Municipality

Category/Item		Daily Average			Daily Maximum			Daily Average with NRW			Daily Maximum with NRW		
		2012	2020	2030	2012	2020	2030	2012	2020	2030	2012	2020	2030
Domestic	St. Mary	5,632	5,800	5,504	6,477	6,670	6,330	7,509	6,824	6,475	8,636	7,847	7,447
	Zengeza	7,776	10,064	9,560	8,942	11,574	10,994	10,368	11,840	11,247	11,923	13,616	12,934
	Seke S	8,152	8,888	8,440	9,375	10,221	9,706	10,869	10,456	9,929	12,500	12,025	11,419
	Seke N	6,800	7,664	7,280	7,820	8,814	8,372	9,067	9,016	8,565	10,427	10,369	9,849
	Ward 1	0	0	5,688	0	0	6,541	0	0	5,987	0	0	6,885
	Sub-Total	28,360	31,128	36,472	32,614	37,278	41,943	37,813	38,136	42,204	43,485	43,857	48,534
Others	Commercial/ Institution	1,057	1,270	1,520	1,216	1,461	1,748	1,409	1,494	1,788	1,621	1,718	2,056
	Industry	1,129	1,690	2,540	1,298	1,944	2,921	1,505	1,988	2,988	1,731	2,286	3,436
Total		30,546	34,088	40,532	35,128	40,682	46,612	40,728	41,619	46,980	46,837	47,862	54,027

Source: JICA Project Team

*: Assumed demands if water supply to municipality was enough

8.3 Evaluation of Water Resource and Water Production in Great Harare Area

8.3.1 General

Current available water resources of Great Harare come from four dams (Chivero, Manyame, Seke and Harava dams), and effluent from the sewage treatment plants (STPs) flow into these dams. Thus, the water resources depend on the yield capacity of the dam, which come from rainfall and recycled water from STPs.

In Zimbabwe, the treated water that meets the discharge standard using advanced treatment process such as BNR can be directly discharged to the rivers, but treated water which does not meet the standard needs to be conveyed to farmlands and be used for irrigation. As of August 2012, the main treatment processes of majority of the STPs located in Manyame basin have not been functioning including the transmission pumps to farmland. The untreated discharge water flows mainly to the Manyame River Basin.

Since major part of sewage is discharged directly to Manyame River Basin, the majority of pollution loads discharged from Harare Metropolitan Area flows into the Lake Chivero, Lake Manyame, Seke and Harava lakes, which are water sources of the area. However, in the near future, the sewerage system will be rehabilitated and only water treated using advanced processes and which meets quality standards will be discharged directly to the receiving bodies, and the remaining water will be transmitted to the farmlands.

8.3.2 Recycled Water

The planned construction and recovery plan for BNR is concentrated in Firle and Crowborough STP and their capacities are 108,000 m^3/d and 18,000 m^3/d, respectively, based on the data provided by the Harare Water Works. The recovery work commenced in 2012, and will be completed within 2013. A total flow of 126,000 m^3/d can be calculated as recycled water after 2014. In the case of Chitungwiza, the municipality is planning to rehabilitate its sewerage system, and accordingly, all treated water will be transmitted to the farmlands, such that any treated/untreated waste water will not be made to flow into the basin.

8.3.3 Water Resource from Dams

(1) Current condition

The available dams for water supply are Chivero, Manyame, Seke and Harava Dams, and their yield capacities are as shown in Table 8.3.1. The average production of MJ-WTP was 585,000 m^3/d in 2011, while the yield capacity of Lakes Manyame and Chivero, as the water source of the WTP, was 559,600

m^3/d of 10% yield and 743,200 m^3/d of 20% yield.

Table 8.3.1 Yield Capacity of Dams

Item/Dam		Manyame	Chivero	Seke	Harava	Total
4% yield	1000m^3/y	60,379.0	93,916.0	1,153.0	3,928.0	159,376.0
	1000m^3/day	165.4	257.3	3.2	10.8	436.6
10% yield	1000m^3/y	85,083.0	119,159.0	2,471.0	7,175.0	213,888.0
	1000m^3/day	233.1	326.5	6.8	19.7	586.0
20% Yield	1000m^3/y	116,096.0	155,146.0	3,038.0	8,560.0	282,840.0
	1000m^3/day	318.1	425.1	8.3	23.5	774.9

Source: ZINWA

The average production of PW-WTP is 55,000 m^3/d in the normal season and 40,000 m^3/d in dry season, while the yield capacity of Seke and Harava Lake as the water source of the WTP is 26,500 m^3/d of 10% yield and 31,800 m^3/d of 20% yield. It means that the actual production (the intake flow is larger than 10-20% of production) of MJ-WTP exceeds the 10% yield, and there is no drought problem for Lake Manyame and Chivero. In the case of PE-WTP, the actual production exceeds the 20% yield.

(2) Future development of dam

The Kunzwi, the Musami and Muda dams are planned for the water resources of Great Harare Area. The outlines of the dams are shown in Table 8.3.2, and the total yield capacity is 536,800 m^3/d. Kunzwi dam is now being targeted for urgent construction, and donors are being scouted to provide the necessary fund. When Kunzwi and Musami dams are constructed, the new WTPs to meet with the yield capacities will also need to be constructed so that clear water can be transmitted to the distribution areas.

Table 8.3.2 Outline of Dam Construction Plan

Items	Unit	Kunzwi Dam	Musami Dam	Muda Dam
River	---	Nyagui	Chavanhowe	Mupfure
Catchment Area	km^2	730	1,040	952
Average annual rainfall	mm	950	920	750
Average annual runoff	mm	210	210	135
Distance from Harare	km	40	50	55
Storage Capacity	mil.m^3	158	307	43.6
4% Yield	1000m^3/d	192	304	40.8
Full supply level	m	1,230	1,337	1,310
Construction cost	mil.USD	14	23	8
No.of families affected	no.	165	200	--

Source: Zinwa

In the case of Muda dam, water withdrawn from the dam lake should be transmitted to Seke or Harava Dam and the mixed storage water will be treated by PE-WTP, which can withdraw an additional 40,800 m^3/d from Seke Dam on the average. The locations of these three dams are shown in Figure 8.3.1.

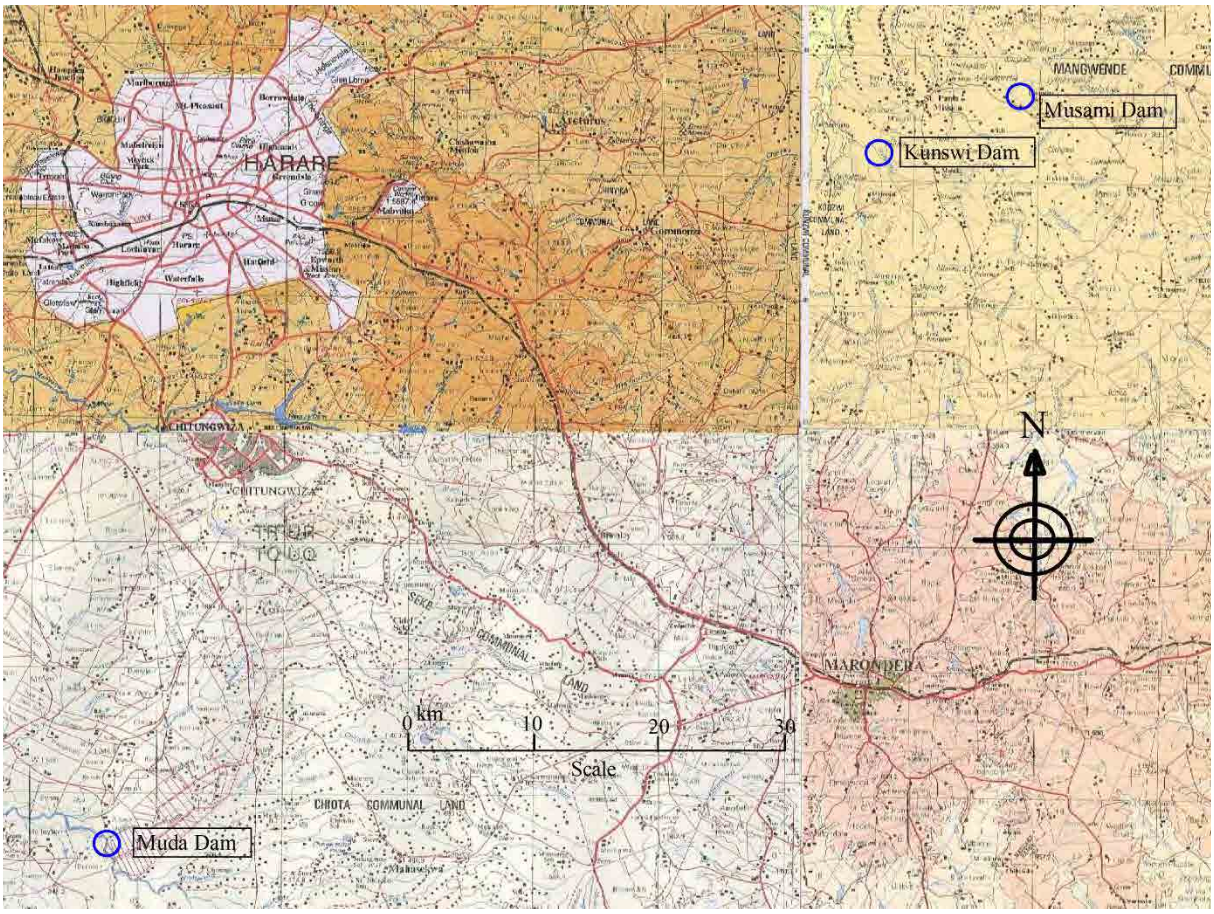


Figure 8.3.1 Planned Dams Location

8.3.4 Groundwater Resource

In Zimbabwe, groundwater is not considered a major water source. However in the Harare Metropolitan Area, groundwater is actually utilized by a large number of entities and individuals, and the majority of these wells can be used even in the dry season.

There are over 10,000 of wells and boreholes are installed in City of Harare (derived from Upper Manyame Sub-catchment Council) and then the utilisation of groundwater is significant. Yield capacities of the majority of boreholes are 20 - 100 m^3/day and a few exceed 500 m^3/day, but boreholes with yields of over 1,000 m^3/d are rare.

8.4 Balance between Water Demand and Water Resource/Production

8.4.1 Great Harare Area

Table 8.4.1 shows the annual balance between water demand and water resource. Even though the recycled water is included as water source, the calculation of the water source is still lesser than the demand. This condition shows the current water shortage in Harare Metropolitan Area. The construction of Kunzwi Dam and Musami Dam is required by 2020 and 2030, respectively.

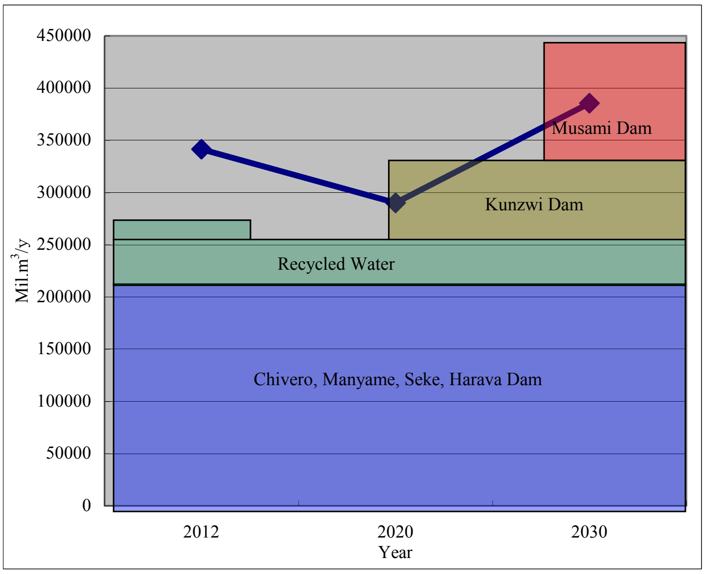
The balance is calculated as the annual base, while daily/monthly consumption fluctuates within the annual base of the resource. As shown in Table 8.4.1, currently the capacity of the four dams is much smaller than the water demand mainly due to high NRW of 57%, even if raw sewage discharge is counted as recycled water. In 2020, the development of Kunzwi dam is imperative to meet the demand together with a serious NRW reduction plan to reduce it from current level of 57% to 35%.

Table 8.4.1 Balance between Water Demand and Water Resource

Category/Year		2012	2020		2030		Note
			Figure	Action	Figure	Action	
Annual Demand ($1000m^3/y$)	In service area	296,603	263,603	NRW; 57%-35%	350,440	NRW; 35%-25%	Including NRW
	Whole	341,339	289,963	Loss: 15%-10%	385,484	Loss:10%	Including loss in WTP
Water Source ($1000m^3/y$)	Four Dams	213,888	213,888		213,888		
	Kunzwi Dam		73,365		73,365		
	Musami Dam				110,960		
	Recycled	54,750	45,990	BNR Operation	45,990	BNR Operation	
	Sub-total	268,638	333,243		444,203		
Balance ($1000m^3/y$)		-72,701	43,280		58,719		

Source: JICA Project Team

This includes a loss reduction in the WTP from 15% to 10%. In 2030, the development of Musami Dam is a necessity even if NRW is already reduced from 35% to 25%. The comparison between water demand and water resource is shown in Figure 8.4.1 indicating the projection for each target year.



Source: JICA Project Team

Figure 8.4.1 Comparisons between Water Demand and Source

Production capacity, as the total capacity of WTPs, must match daily maximum demands. The balance between the daily maximum demands and total capacity of

WTPs are shown in Table 8.4.2. The total capacity of the WTP is lesser than the demand, even if records from the Harare Water Works show that the actual production of MJ-WTP exceeds capacity.

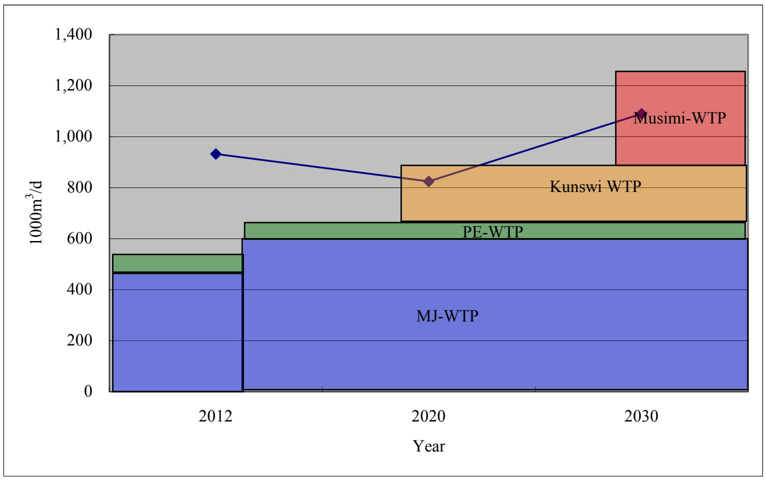
In 2020, the operation of the new Kunzwi WTP is necessary to meet the demand, in the same case as the water source. In 2030, the operation of new Musami WTP will also be required. The MJ-WTP and PE-WTP capacity can be increased by an additional volume of 150,000 and 50,000 m^3/d respectively, if the allowance of Chivero and Manyame dam is utilized, and if the Muda Dam, together with the transmission system from Muda Dam to Seke Dam, are completed. However, these expansion works are not necessary for the target year of 2030.

Table 8.4.2 Balance between Daily Maximum Demand and Capacity of WTP

Items/Year		2012	2020	2030	Water Resource
Daily Max. Demand (1000m^3/d)		932	825	1,090	
WTP Capacity (1000m^3/d)	MJ	520	600	750	10% Yield + Recycle=686
	PE	55	55	55	10% Yield =26.5
	Kunzwi		234	234	4% Yield: 201
	Musami			350	4% Yield: 304
	Total	575	889	1,239	
Balance (1000m^3/d)		-357	64	149	
Action	Demand	---	UFW:57%-35%	UFW:35%-25%	
	Dam Construction	---	Kunzwi	Musami	
	WTP Construction	---	Kunzwi	Musami	
	WTP Expansion			---	

Source: JICA Project Team

The comparisons between water demand and production capacity are shown Figure 8.4.2. In this case, the planned projects must be implemented to meet the demand.



Source: JICA Project Team

Figure 8.4.2 Comparisons between Water Demand and Production Capacity

8.4.2 Chitungwiza Municipality

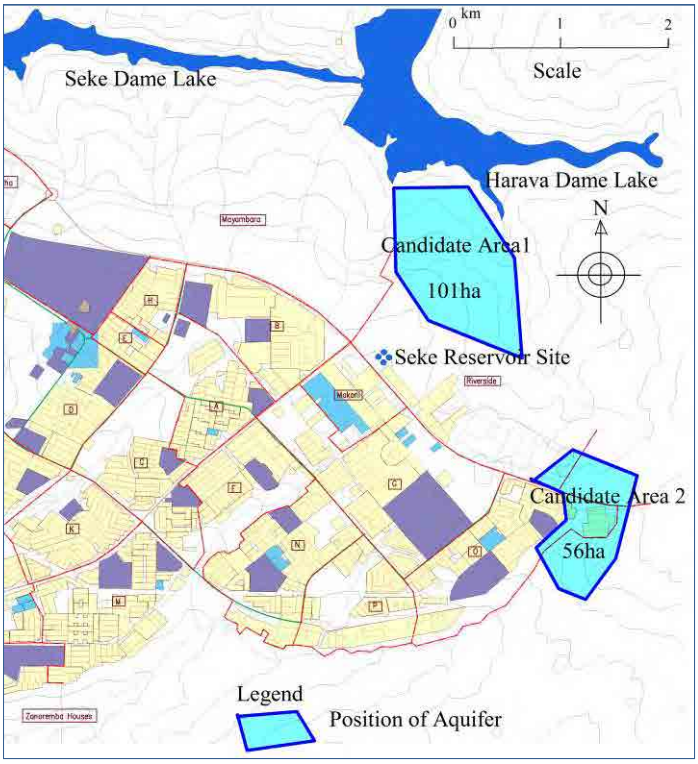
Since the water supply capacity of Harare Water Works is insufficient, bulk water supplied to Chitungwiza Municipality is either interrupted, or drastically reduced. Huge investment is required for Harare Water Works to rehabilitate its facilities, expand its water resources, and ultimately increase its production capacity. Funds to rehabilitate the facilities have been trying secured and as the results of the efforts a fund from China Cooperation was agreed in 2013 for rehabilitations for facilities.

However, there is no concrete plan for the development of pipe replacement, the water resources and the construction of new WTPs.

In Chitungwiza Municipality, there are over 3,000 of shallow wells and around 50 boreholes used by people living in Seke North and Seke South where piped water is distributed only several hours in a week. These wells continue to produce water even in the dry season. Thus, JICA Project Team started to find ground water resources surrounding the municipality.

As the results of the first stage survey hiring of local hydro-geologists, candidate aquifers shown in Figure 8.4.3 were found through electrical resistance tests. The locations are very near to Seke reservoir site, and the recharge for candidate area 1 accounts from the recharge from Harava Dam and Manyame catchment area. However, a resurvey from a definitive hydro-geologist in Harare Area was conducted after the failure of a test well in this area, which had a yield capacity of less than 50 m^3/day even though the depth of the well was 100 m.

This revealed doubtfulness of the existence of the aquifer for the candidate area 1. In addition, although the groundwater potential of candidate area 2 is well-known because of the existing of red-soil, the actual intake capacity was also doubtful because many private boreholes have already been installed in this area.



Source: JICA Project Team

Figure 8.4.3 Candidate Areas of Aquifer

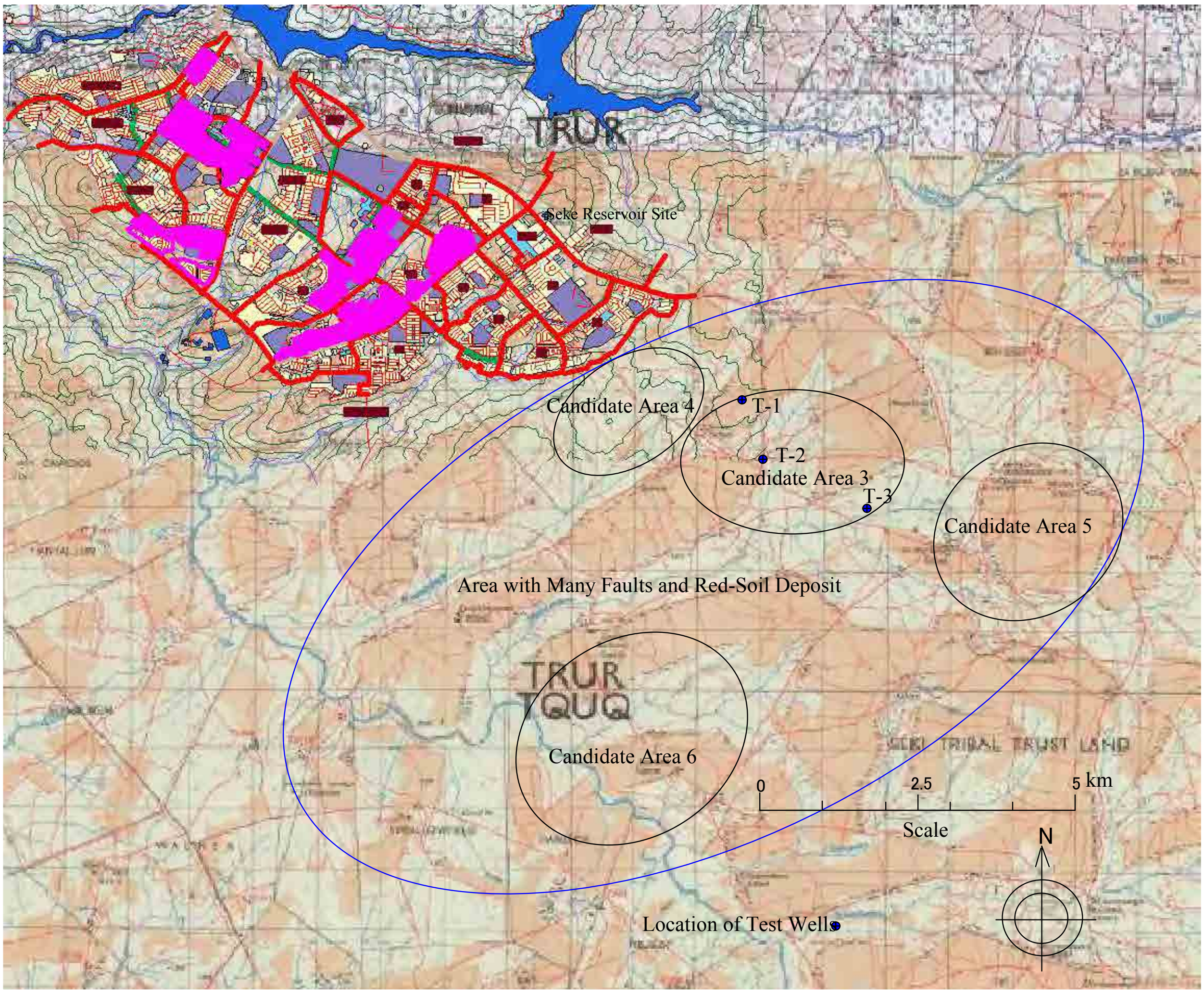
Thus new aquifers were again explored in the surrounding area of the municipality by a team headed by the previously mentioned hydro-geologist. The hydro-geologist found that the eastern area of the municipality shown in Figure 8.4.4 have many faults of granite and is widely covered by red-soil, which is a well-known sign that an aquifer exists beneath. Candidate area 3 was selected first because of an existing well with good yield capacity in the area and many potentially good points were found by electrical resistance tests.

Three test wells (with borehole diameter of 150 mm) were installed based on the results, and the results of yield capacity tests are shown in Table 8.4.3. As shown in the table, the yield capacities of T-2 and T-3 are large, while those of boreholes located in Chitungwiza Municipality are less than 1.5 L/sec. As the results of the test wells installation indicate, candidate points of wells should be selected carefully and a rate of failure drilling must be accepted.

Table 8.4.3 Results of Yield Capacity Tests of Test Wells

No.	Geology	Elevation (m)	Well Depth (m)	Water Level(GL-m)		Yield capacity		
				Initial	Dynamic	L/sec	m^3/hr	m^3/day
T-1	Red-soil	1,458	60	7	33	0.3	1.1	26
T-2	Fault of granite	1,442	60	1.8	24	3.5	12.6	302
T-3	Fault of dolerite	1,440	60	1.4	15	3.9	14.0	337

Source: JICA Project Team



Source: JICA Project Team

Figure 8.4.4 Surveyed Areas for Groundwater

The hydro-geologist recommended three other candidate areas, area 4, 5 and 6, which have similar geological features with the candidate area 3.

However, even though these helpful wells have been discovered, the recharge capacity of the wells location areas is critical because the planned intake will be continuous for 24hours/day and 365 days/year.

The hydro-geologist concluded:

1) The recharge capacity of the four selected areas is limited and the total intake ability is assumed to be less than 5,000 m^3/day,
2) Average yield capacity of wells will be 3-5 m^3/day (72-120 m^3/day).

From the results of the survey (Pilot Project), utilization of groundwater is un-seemingly feasible.

8.5 Improvement Plan for Harare Water Works

8.5.1 Refurbishment for Deteriorated Facilities

It cannot be overemphasized that almost all the facilities in the Harare Water Works are decrepit and are in urgent need of rehabilitation and/or replacement because of over inadequate and improper repair and maintenance. Almost all instrumentation, such as flow-meters, water level gauge and analysis equipment are no longer functioning. Pipelines, which are badly maintained, have been left with numerous leakages resulting to high NRW ratio for the entire system.

Harare Water Works has recognized the necessity of urgent rehabilitations. Accordingly, in order to acquire necessary funds for rehabilitations, "Commercial Contract detailing Scope of Works" was formulated by and between the City of Harare and the China National Machinery and Equipment Import and Export Corporation in March 2011. Then the fund provision was agreed on June 2013 with the contents shown in Table 8.5.2(1), which were concentrated to replace facilities such as WTP and STP (Sewage Treatment Plant). Pipe replacement and repair have also planned as shown in table 8.5.2(2), which was included in the "Urgent Infrastructure Rehabilitation - India Eximbank" formulated in April 2012.

In PE-WTP, the refurbishment of essential facilities, such as intake pumps, chemical dosing facilities, rapid sand filters and a distribution pump was completed from 2009 to 2012, but a planned power station was not refurbished.

Table 8.5.1 (1) Repair, Replacement and Refurbishment Plan for Facilities

<table>
<tr><th colspan="2">Facilities</th><th>Contents</th><th>Cost(mil.USD)</th></tr>
<tr><td rowspan="3">WTP</td><td>Morton Jaffray</td><td>Facilities replacement</td><td>18.51</td></tr>
<tr><td>Prince Edward</td><td>Facilities replacement</td><td>7.84</td></tr>
<tr><td>Laboratories</td><td>Equipment replacement</td><td>0.18</td></tr>
<tr><td rowspan="3">P/S</td><td>For water supply 13P/S</td><td rowspan="2">-Replacement of pumps,
- Rehabilitation of pipe works with actuate Valves,
-Supplying accessories,
-Replacement and refurbishing electrical facilities</td><td>2.16</td></tr>
<tr><td>For sewage 6P/S</td><td>0.72</td></tr>
<tr><td>Work shops for distribution</td><td>Equipment/tool/pipe materials</td><td>28.03</td></tr>
<tr><td rowspan="2">STP</td><td>Firle</td><td>Facilities replacement</td><td>24.01</td></tr>
<tr><td>Crowborough</td><td>Facilities replacement</td><td>6.88</td></tr>
<tr><td rowspan="2">Others</td><td>Maintenance workshops</td><td>Tools and Materials</td><td>1.24</td></tr>
<tr><td>Information equipment</td><td>computers, various networks, soft wares</td><td>9.53</td></tr>
<tr><td colspan="2">Other expenses</td><td>Transportation/insurance/provisional construction, technical services, taxes and charges</td><td>44.90</td></tr>
<tr><td colspan="2">Total</td><td></td><td>144.00</td></tr>
</table>

Source; JICA Project Team

Table 8.5.1(2) Table 8.5.1 (1) Repair, Replacement and Refurbishment Plan for Pipelines

Facilities		Contents	Cost(mil.USD)
Pipe Rehabilitation Works	Replacement	Dia.90-500mmx81.6km	41.00
	Repair	23.4km	
	Material Purchasing	Pipes and fitting, Meters15-1000mm:no.93,000,Valves50-1200mm:no.6313	

Source; JICA Project Team

Even with the refurbishment, the production capacity is still limited to 55,000 m^3/d of the design capacity of 90,000 m^3/d. Nevertheless, the plant will operate continuously next 10 to 15 years thanks to above rehabilitation. The yield capacity of water source of this WTP is 31.800 m^3/day with 20 % yield, and therefore, from the point of view of water resource, the actual production capacity cannot be increased.

8.5.2 Expansion Plan to Cope with Increasing Demand

(1) Target year 2020

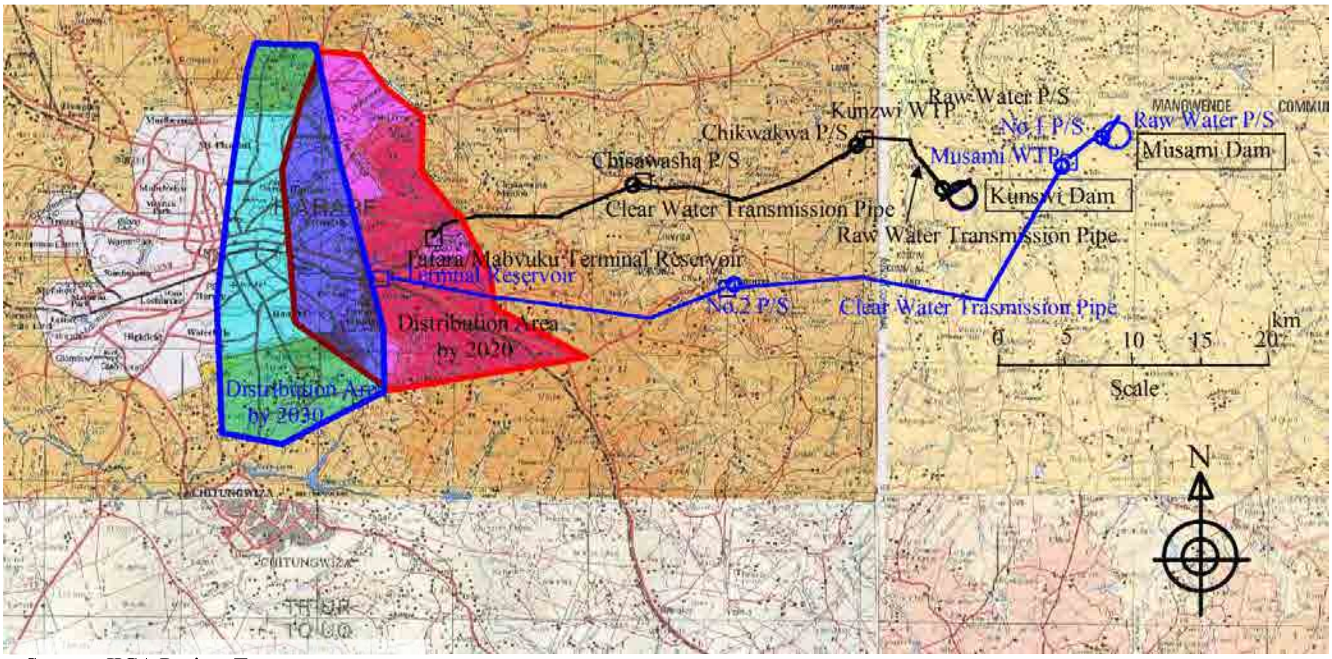
A water supply system expansion plan needs to be formulated for Harare Water Works. The plan formulated by the SAPROF Study has specified the construction of Kunzwi Dam, Kunzwi WTP, clear water transmission facilities and expanding distribution facilities including rehabilitation of existing distribution facilities in eastern areas of City of Harare. The layout of these facilities is shown in Figure 8.5.1 with the plan for target year of 2030. The contents are shown in Table 8.5.2 and the costs for the project were also calculated in the SAPROF Study. If the price escalation from 1996 to 2012 is 20% on the average, then the total current cost is 350.2 mil. USD. Thus, the total cost for the improvement of the water supply system of Harare Water Works by 2020 is approximately 535.2 (350.2+144+41) mil. USD.

Table 8.5.2 Contents of Project with the Costs for Target Year 2020

Division	Items	Specifications	Costs (mil.USD)	
			1996	2012
Water Source and Transmission	Kunzwi Dam Construction	-Dam construction V= 158 mil, m^3,	24.91	30
	Kunzwi WTP	-Raw water P/S: 2.91m^3/s × 91.2-64.2mH × 3430-2670kW, -Raw Water Transmission: D1,400 mm× 8,050m, -WTP: Production Capacity:234,000m^3/d with sludge blanket Clarifiers, sand filters and clear water reservoir , -Chikwakwa Clear Water P/S: 2.71m^3/s × 187.3-182.3mH × 6,340-6,170kW,	59.59	71.5
	Clear Water Transmission	-Chisawasha P/S: 2.71m^3/s ×187.1-182.1mH × 6,340-6,170kW with Reservoir: 20,000m3, -Transmission Pipeline:D1,400 mm× 31,470m, -Tafara/Mabvuku Terminal Reservoir: V-20,000m^3	46.98	56.4
Distribution Facilities	Main Distribution System	- Additional Reservoirs (Snake Park, Kuwadzana, Lochinvar, Marinba Park) total capacity 199,300m^3,	42.41	50.9

Division	Items	Specifications	Costs (mil.USD)	
			1996	2012
		-Additional main distribution pipes:D300-1200mm × 54km		
	Remaining Distribution System	Branch distribution network: D50-D300 including new development areas, length approximately 1,567km, 102,708 house connection, 10,507 no. of fire hydrant	64.90	77.9
	Rehabilitation Measures	Rehabilitation for existing pipeline network, Rearrangement of P/S and reservoirs	28.04	33.6
Others	Administrative Support	Office costs and administration costs	4.28	5.1
	Engineering and Consulting Services	Basic and detailed design and construction supervision	19.08	22.9
	Land Acquisition and Others	Acquisition, compensation and relocation	1.59	1.9
Total			291.78	350.2

Source: SAPROF Report modified



Source: JICA Project Team

Figure 8.5.1 Layout of Development Facilities for the Target Year

(2) Target year 2030

In target year 2030, Musami Dam development (dam, WTP and transmission facilities' construction) will be required, in addition to the expansion and rehabilitation of the distribution network in City of Harare. The layout plan is shown in Figure 8.5.1, which indicates that the pipeline route for clear water transmission was changed from the Kunzwi development plan to avoid low elevation areas and prevent high pressure in pipes, because the water level of Musami Dam is around 100m higher than the Kunzwi Dam. The contents are shown in Table 8.5.3 and the total of current cost is 422 mil.USD.

Table 8.5.3 Contents of Project with the Costs for Target Year 2030

Division	Items	Specifications	Costs (mil.USD)
Water Source and Transmission	Musami Dam Construction	-Dam construction V= 307mil, m^3,	49.0
	Kunzwi WTP	-Raw water P/S: 4.45 m^3/s × 65-40 mH × 3300-2000 kW, -Raw Water Transmission: D1,800 mm× 2,100 m, -WTP: Production Capacity:350,000 m^3/d with Sludge blanket Clarifiers, sand filters and clear water reservoir , -No.1 Clear Water P/S: 4.1 m^3/s × 125 mH ×8,000 kW,	89.0
	Clear Water Transmission	-No.2 P/S: 4.1 m^3/s × 125 mH × 6,000 kW with Reservoir: 30,000 m^3, -Transmission Pipeline: D1,800 mm× 48 km, -Terminal Reservoir: V=30,000 m^3	110.0
Distribution Facilities	Main Distribution System	- Additional Reservoirs total capacity 350,000 m^3, -Additional main distribution pipes: D300-1400 mm × 60 km	65.0
	Remaining Distribution System	Branch distribution network: D50-D300 length approximately 500 km	28.0
	Rehabilitation Measures	Rehabilitation for existing pipeline network, Rearrangement of P/S and reservoirs	45.0
Others	Administrative Support	Office costs and Administration costs	5.5
	Engineering and Consulting Services	Basic and detailed design and construction supervision	27.5
	Land Acquisition and Others	Acquisition, compensation and relocation	3.0
Total			422.0

Source: JICA Project Team

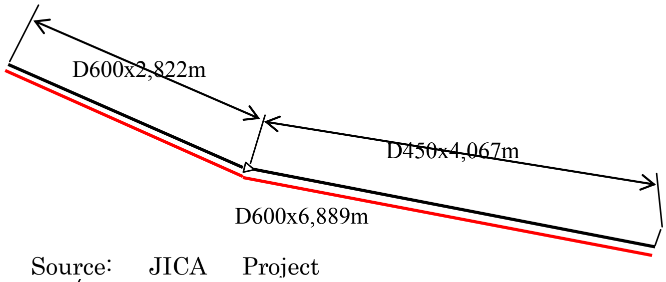
8.6 Improvement Plan for Chitungwiza Municipality

8.6.1 Evaluation of Function and Capacity of Facilities

As mentioned in Chapter 4.1.2, the water supply system of Chitungwiza Municipality is comprised of: a transmission pipe with diameter 600 mm transmitted from PE-WTP, four ground-reservoirs with a total capacity of 41,000 m^3, a lift P/S for an elevated tank with a capacity 1,144 m^3 and 600-50 mm diameter distribution pipes. Function and capacity of each facility is evaluated as below:

(1) Transmission pipe

The transmission pipe is fed with water by transmission pumps installed in PE-WTP, and delivers the water to the reservoirs, as shown in Figure 8.6.1. The feeding capacity is calculated in Table 8.6.1. While the planned transmission amount from PE-WTP to City of Harare will be planned to be around 52,400 m^3/d in 2030, the capacity of existing pipes is around 21,000 m^3/day, less than half to necessary capacity. Then a reinforced pipe is planed as shown Figure 8.6.1, and the capacity exceeds the necessary capacity.



Source: JICA Project

Figure 8.6.1 Transmission Pipe from PE-WTP to Seke Reservoir

Table 8.6.1 Capacity of Transmission Pipe

Pump Head 70m
h=70-(1465.3-1418)= 22.7m

Category	Dia.	L	C	D	Q		V	Δh
		m	--	m	m^3/min	m^3/d	m/s	m
Existing	D600	2,822	130	0.6	14.73		0.87	3.31
	D450	4,067	130	0.45	14.73		1.54	19.36
New	D600	6,889	130	0.6	25.74		1.52	22.69
Existing Total					14.73	21,211		22.67
Total Flow					40.47	58,277		

Source: JICA Project Team

(2) Ground reservoir

Based on the Zimbabwe Standard, the retention time for ground reservoirs is two days, which is longer than Japan or other countries' standard of 12 hours. A longer retention time may be better, but current total volume of 41,000 m^3 is considered sufficient to meet the daily maximum flow of 46,119 m^3/d in 2020 and 52,393 m^3/d in 2030.

(3) Remodelling of distribution system

The distribution of water to the municipality is through the main pipeline connected to the clear water transmission pumps in the PE-WTP. The distribution flow to the municipality is constant though distribution to the service areas should be regulated to meet with the demand. The existing pipelines cannot distribute to the entire service area the 45,000 m^3/d of bulk water, which is the maximum water supplied to the municipality from PE-WTP.

The system must be remodelled as: all the supplied water must be once received in the ground reservoirs. The low elevation areas will be distributed directly from ground reservoirs, and high elevation areas shall be distributed from an elevated tank. In order to realize above condition, refurbishing of the network, reinforcement of distribution pipes and replacement of the lift pumps to feed the elevated tank are required.

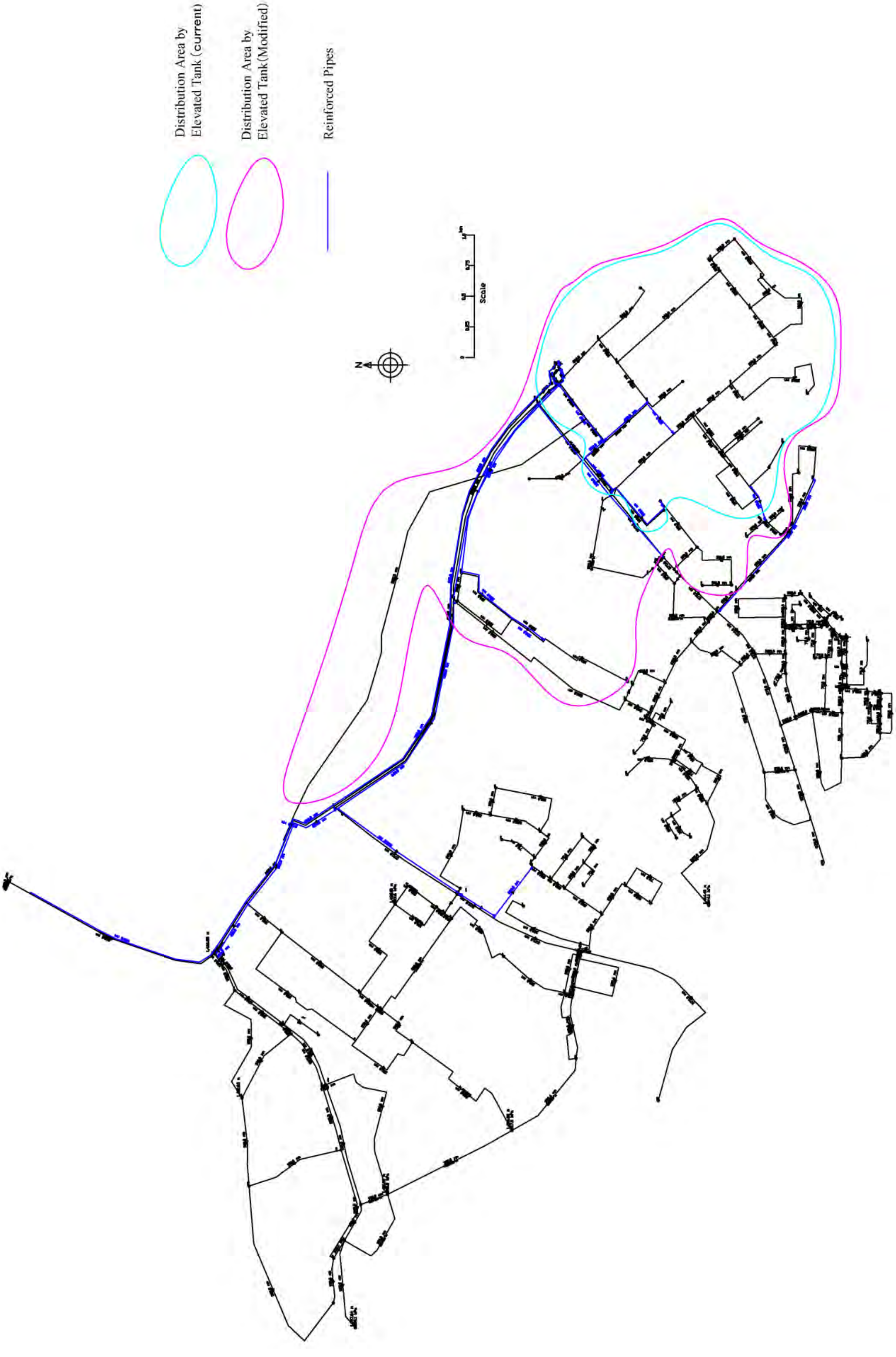
(4) Hydraulic calculations

The future population projection indicates that all the residential areas are considered to be fully developed in 2020. As such, the hydraulic calculation for the distribution pipes is as follows:

1) Projected population in 2020 is adapted because the population in the current municipality area is maximum figure in 2020.
2) Per capita demand is 100Lpcd and the actual flow (hourly maximum flow) is doubled.
3) Remodelling as shown in Section (3) is adopted.
4) Necessary reinforcement is planned to keep minimum around 100kPa of pressure at each junction.

Calculation results are shown in Figure 8.6.2.

Employing the above conditions, calculations were made and the results are shown in Figure 8.6.2. Results of calculated flow rate to whole areas, areas from ground reservoirs and areas from elevated tank are shown in Table 8.6.2. The flow rate to the distribution area from the elevated tank is calculated as: $18.8/61.4 \times 100 = 30.6\%$



Source: JICA Project Team

Figure 8.6.2 Hydraulic Calculation Results

As shown in Figure 8.6.2, pipe installations for reinforcement and to keep proper pressure in the distribution system are required. The list of reinforcement is shown in Table 8.6.3 based on the hydraulic calculations.

Table 8.6.2 Calculated Flow Rate

Item	Flow	
	m^3/min	m^3/d
Total	61.4	88,416
From ground reservoir	42.6	61,344
From elevated Tank	18.8	27,072

Source: JICA Project Team

Table 8.6.3 Reinforced Pipes

Pipe Dia.	Length(m)
D700	1,780
D600	3,290
D400	430
D350	2,850
D300	70
D250	40
D200	3,470
D150	4,100
Total	16,030

Source: JICA Project Team

(5) Pump station

Out of the three pumps, only one is operating while the two others have broken down. The capacity of existing pumps is estimated as below:

Pump motor: 60kW

Actual lifting head: 23m - total head is estimated to be 30m

From the formula, 1 kW = 0.163 × QH/ η

Q= kW× η /(0.163×H)=75×0.75/(0.163×30)=11.5 m^3/min

From the hydraulic calculation, the necessary feeding volume to elevated tank is 18.8 m^3/min as shown Table 8.6.2 and the current pump can be applied for a remodelled facility, but the sole duty pump has heavily deteriorated already. Accordingly, every pumps must be replaced.

(6) Elevated tank

Based on the Zimbabwe Standard, the retention time for elevated tanks is half a day. However, the retention time of over one hour is sufficient, especially if the pump capacity of list pumps meets the daily maximum flow. As mentioned in the previous section, pump capacity meets with hourly maximum flow. When maximum flow is 18.8 m^3/hr (=1,128 m^3/hr), the retention time of existing 1,144 m^3 of elevated tank is around one hour, which is adequate.

(7) Distribution pipelines

The distribution pipeline network needs to be remodelled and reinforced as mentioned in section (4), since the pipe flow capacity is too small and distribution areas form elevated tank must be expanded due to too small level difference between ground reservoirs and some area’s elevation. The contents are mentioned in section (4).

8.6.2 Improvement of Existing Facilities

(1) Alternative acquisition of water source

1) New resource

Chitungwiza Municipality is now receiving bulk water from Harare Water Works, but the amount is not enough and the supply is unstable partly due to water shortage of the water works and a huge amount of unpaid water charges for the bulk water to Harare Water Works. The municipality is thereby seeking an independent water resource. Many wells and boreholes are installed and utilized in the municipality, however since the yield capacity is limited, these are used for supplemental purpose. As the results of the pilot project, groundwater resource surrounding the municipality was found limited because of poor recharge capacity. It was estimated to be less than 5,000 m^3/day, and in addition, the average yield capacities of wells are estimated to be around 100 m^3/day. It means that groundwater can be only used for a supplemental purpose. However under current miserable water supply condition of the municipality, since majority of people living in the municipality can receive water two or three days in a week, this ground water should be used for the municipality. In addition, because the total intake amount of wells and borehole in the municipality is estimated to be less than 3,000 m^3/d, and therefore above 5,000 m^3/d of resource is not so small.

However the intake of the groundwater is limited to be supplemental resource and it is not included in the evaluation for later major water resource acquisition plan. Other possible water sources are dam development plans for Kunzwi, Musami and Muda Dam. On the development of Kunzwi and Musami Dam, the municipality must completely rely on City of Harare, and there is no concrete plan. While, the development plan for Muda Dam can be applied only for the municipality.

Possible alternative water source acquisition plans, which are relying on City of Harare, and Muda Dam development plan, are shown in Table 8.6.4, and the locations of each plan are shown in Figure 8.6.3. The above table shows that the development of Muda Dam (4% risk of yield capacity is 40,800 m^3/d) can be applied for an independent water source for the municipality. If the water is transmitted to Seke Dam, PE-WTP, which has a design capacity of 90,000 m^3/d (actual production is 55,000 m^3/d in normal season and 40,000 m^3/d in dry season due to restriction of water source), can produce the design capacity of treated water after a renovation of facilities so that full design capacity can be acquired.

Table 8.6.4 Alternative Acquisition Plan for Water Source

Item	Plan-1	Plan-2	Plan-3
Feature	All water source will be dependent on Harare Water Works	Water source will be independent but PE-WTP will be used for the water purification	All water supply system will be independent
Major water source	Bulk water	Muda Dam	Muda Dam
Increasing demand	Bulk Water	Groundwater	Groundwater
WTP	PE-WTP	PE-WTP	New WTP

Source: JICA Project Team

Required construction works and costs for each plan by each target year are described in Table 8.6.5. In the table, the municipality will rely on City of Harare for water resource and shoulder the costs for bulk water distributed by Harare Water Works proportional to the demand by 2020. In Plan 1, municipality will also rely on City of Harare for water resource and in Plan 2 and 3 the municipality will develop Muda Dam and construct other necessary facilities by 2030.

Source: JICA Project Team

Figure 8.6.3 Location of Muda Dam Development Plan

As shown in the table, the costs of Plan 2 and Plan 3 are much larger than Plan 1 and as shown in Table 8.6.6, the operation cost of Plan 3 is relatively small due to the good water quality of Maphure River, which is the water source for Muda Dam. However, the difference is much smaller when compared to that of construction costs.

Table 8.6.5 Alternative Plan for Water Resource of Chitungwiza Municipality

Year	Item/Plan	Plan-1	Plan-2	Plan-3
2020	Bulk Water(m^3/d)	41,600	41,600	41,600
	Costs (mil.USD)	157.9×41.6/757.6=8.34		
2030	Bulk Water(m^3/d)	47,000	2,000	2,000
	Muda Dam(m^3/d)		45,000	45,000
	Necessary Construction	Only Harare Water Works side Construction	1) Construction of Muda Dam (43.6 mil.m^3) 2) Transmission P/S (17.5 m^3/min × 160 mh × 600kW × 3units) 3) Transmission pipe D900 mm × 38.2 km 4) Refurbishing of PE-WTP (capacity 90,000 m^3/d)	1) Construction of Muda Dam (43.6 mil.m^3) 2) Transmission P/S (17.5 m^3/min × 140 mh × 550kW × 3umits) 3) Transmission pipe D900 mm × 35.0 km 4) Construction of New WTP (capacity 45,000 m^3/d)
	Costs (mil.USD)	248×47.0/1059.0=11.0	84.84	100.53
Total Costs		19.34	93.18	108.87

Source: JICA Project Team

Table 8.6.6 Comparison of Operation Costs for WTPs

Division	Item	Cost (K USD)	Water Amount (K USD)	Unit Cost (USD/m^3)	Note
(1) Harare Water Works	Chemical	26,700	231,775	0.115	
	Power	10,920	231,775	0.047	70% to Total Costs
	Others			0.049	30% to Chemical & Power
	Total	37,620	231,775	0.211	
(2) New WTP	Chemical	823	14,283	0.058	1/2 to Harare
	Power	671	14,283	0.047	
	Others			0.042	40% to Chemical & Power
	Total	2,092	14,283	0.146	

Source: JICA Project Team

Thus, as shown in Table 8.6.7, plan-1 is apparently positive compared to Plan -2 and -3 from an economical point of view, even though the progress is ambiguous and is facing difficulties in raising of funds for the Kunzwi Project. However, it seems more difficult to realize the construction of Muda Dam than Kunzwi Project.

Table 8.6.7 Evaluation of Each Plan

Item/Plan		Plan-1	Plan-2	Plan-3
Water source	($1000\ m^3/day$)	Harare Water: Ave. 40. 1	(Muda +PE-WTP) : Ave. 40.1	(Muda + New WTP): Ave. 40.1
Construction Costs	(mil. USD)	19.15	92.99	108.68
Operation Costs	(USD/m^3)	0.211	0.211	0.146
	(1000 USD/year)	3,088	3,088	2,137
Advantage		1) Low Investment 2) Operation facilities are few	1) Independent water source	1)Independent water source and water production 2) Relative low operation cost
Disadvantage		1) Completely depend on Harare	1) High investment but not to enable to be independent	1) High investment but not to enable to be independent 2) Required operation staff for WTP
Evaluation		Positive	Negative	Negative

Source: JICA Project Team

2) Reduction of water leakage

Currently, there is very severe water shortage in Harare Metropolitan Area due to high NRW ratio. It is estimated to be 57%, and only 43% of the produced water is the accounted volume. The most of NRW water is assumed to be leaking from transmission and distribution pipes. If the leakage ratio is 50% to the production water, only around 320,000(640,000×0.5) m^3/day of water reaches to consumers, while the actual average demand of Harare Area is assumed to be 374,000m^3/d in 2012.

Reduction of water leakage is not easy demanding leakage detection underground, followed by repair and replacement of pipes. However it must be carried out for the sustainable management of water supply works for Harare Metropolitan Area as soon as possible. Harare Water Works is seeking finance for pipe replacement/repair in order to prevent water leakage after the agreement of loan 144 million USD for water supply and sewage facilities' rehabilitation. The contents as shown in Table 8.5.1(2) are composed of 104 km of pipe rehabilitation, however the target length is seems not enough compared to the total length around 3,000 km of pipes for water supply. In addition, pipe rehabilitations must be carried out based on thorough survey of actual condition of pipeline network. Then a project should be formulated including survey of pipeline conditions with water leakage detections.

Harare Water Works plans to progress the Kunzwi Dam Project asking for the donor, but before progressing the project a project of water leakage reduction is recommendable. 10% of the leakage reduction produces over 60,000m^3/d which exceeds water demand of Chitungwiza Municipality.

Reduction of NRW ratio in Harare Metropolitan Area should be the first priority for the sake of sustainable water supply for Chitungwiza Municipality.

(2) Efficient utilization of limited water source

As mentioned section (1), the municipality cannot take alternative water resource with reasonable costs. It means that the municipality will continuously rely on the bulk water from Harare Water Works. Distribution water by Harare Water works is apparently short to the demand of the distribution areas, and then there are no room to increase supply amount to the municipality. In addition, the municipality has been compiled a huge amount of unpaid charge for the bulk water.

Under these condition, there is almost no possibility to rapidly improve current status of water supply. However, this condition must be improved for the sake of people living in the municipality.

In order to realize it, below actions are recommended:

1) For stable bulk water supply, to pay the charge for the bulk water on time to Harare Water Works; To keep stable bulk water supply of 30,000 m^3/d, which is normal distribution amount.
2) For a stable and efficient water distribution to the people, the distribution system must be refurbished, by which all bulk water is once received in ground reservoirs and it is distributed to the municipality directly or distributed through the elevated tank; To be able to become to distribute water every day at all area of the municipality, even though supply capacity is not enough at the time of peak demand.
3) For supplement of water shortage, existing wells and boreholes will be used more effectively, and installation of additional wells and boreholes to cope with the changed distribution condition; To acquire supplemental water without long time of work for water intake.
4) For stable management of water works, a stable water supply by above improvements must be realized and meter reading monthly or by-monthly must be carried out for saving water; To improve the bad feeling of people to water supply works and make easily to tariff collection.
5) For efficient water consumption, a definite grasp of each consumption through meter reading need to be realized and a strong campaign for water saving must be carried out; To save water

consumption in order to distribute water to all people with limited water source.

(3) Efficient utilization of wells and boreholes

1) Shallow well

As mentioned section (2), existing wells and bore hole should be utilized more effectively. As the results of pilot project for hand pump installation, it was found that the efficiency of well water utilization was much improved by a hand pump installation.

Currently over 3,000 numbers of shallow wells are installed at Zengeza 4, Seke South and Seke North because the distribution condition of piped water for these areas is very poor. However when refurbishing of distribution system is carried out, the condition of all area will be even and above areas condition will be much improved. However it must be noted that water quality of shallow wells is not enough for drinking purpose, but it can be used for washing, cleaning and other various house works. Under the above condition, for the improvement of shallow wells utilization, procedures below should be implemented:

i) Hand pump installation for existing wells

Since wells have been installed privately, municipality should give subsidy to owners, and the project should provide the subsidy to the municipality.

The number of well to be installed is calculated as below:

Housing number of areas with many well installation is (37,100-16,400 =) 20,700

A pump will be installed to 50 of housings and then 20,700/50 = 414 →420

ii) Install new wells for areas where the number wells is few

In St, Mary, Manyame Park, and Zengeza Area except for Zengeza 4, only a few number of wells were installed because water suspensions by water supply for these areas were unusual before, but after the refurbishing of the distribution system, water shortage condition has become worse, that is same condition with other areas.

Geological condition of these areas is not suitable for borehole installation because of the prevailing hard bed-rock of the underground, but the groundwater table of the areas is generally high. Then shallow wells should be installed for supplemental water intake.

Total Number of housings in these areas is 16,400 and the number of existing shallow wells is 55. If a shallow well is installed to each 50 of housings, other 280 (16,400/50-55=273→280) of wells need to be installed. Hand pump will be installed at these shallow wells.

The bases of a well per 50 housings are:

Average dweller number of housing is 9.1

Per capita consumption of people by shallow well is assumed to be 10 l/capita

Necessary yield capacity of a well is 9.1×50×10＝4,550 l/d

Therefore 4.6 m^3/day of yield capacity is required

2) Borehole

i) Utilization for existing borehole

Currently 54 of boreholes are managed by the municipality, and the date for some of them is shown in Table 8.6.8. From the table, the features of the wells are summarized:

a) The yield capacity is average 55 m^3/day, maximum 132 m^3/d and minimum 20 m^3/day.
b) The depths are average 50 m, maximum 60 m and minimum 40 m.
c) The static water level is 1.5-11 m, average 5.1 m.
d) The dynamic water level which determines the pump head, is averagely 30 m, maximum 44 m and minimum 12 m.

Basically the water quality of boreholes can be used for drinking purpose, but some of it includes high concentration of iron. Current boreholes will be used continuously, but electrical pump and elevated tank should be installed to the wells with over 50m^3 of yield capacity.

Table 8.6.8 Data of Boreholes in Municipality

No.	Water Level (GL-m)	Pump Capacity		Yield Cap.		Depth	Static WL	Dynamic WL
		L/stroke	L/min	L/min	m^3/d	m	m	m
3		1.11	33.3	51.0	73.4	40	1.5	19.6
10	10.7	0.76	22.8	40.0	57.6	45	11.3	14.9
11	4.1	1.33	39.9	60.0	86.4	40	8.4	40.0
12	3.2	1.17	35.1	32.5	46.8	45	1.9	24.4
13	7.3	0.95	28.5	14.6	21.0	55	4.1	35.5
14		0.16	4.8	52.1	75.1	40	4.1	28.2
18	8.7	0.80	24	20.0	28.8	60	4.5	47.7
19	9.6	1.00	30	66.7	96.0	50	6.9	13.5
22	2.5	1.53	46	60.0	86.4	60	2.7	32.9
23	4.0	1.42	43	17.4	25.1	60	8.4	40.0
25	40.0	0.76	23	14.4	20.7	60	2.5	35.3
27	6.4	1.11	33	91.7	132.0	40	8.4	12.3
31	10.2	1.11	33	34.1	49.2	45	5.2	23.2
33	5.1	1.17	35	36.4	52.4	40	3.8	34.0
37	30.0	0.86	26	15.6	22.5	60	8.5	44.4
45				17.2	24.7	50	3.5	24.9
46	27.3	1.10	33	48.0	69.1	50	3.8	30.6
51	20.0		25x3	15.8	22.8	55	1.5	40.5
Ave.	12.6	1.00	30.6	38.2	55.0	49.7	5.1	30.1

Source: JICA Project Team

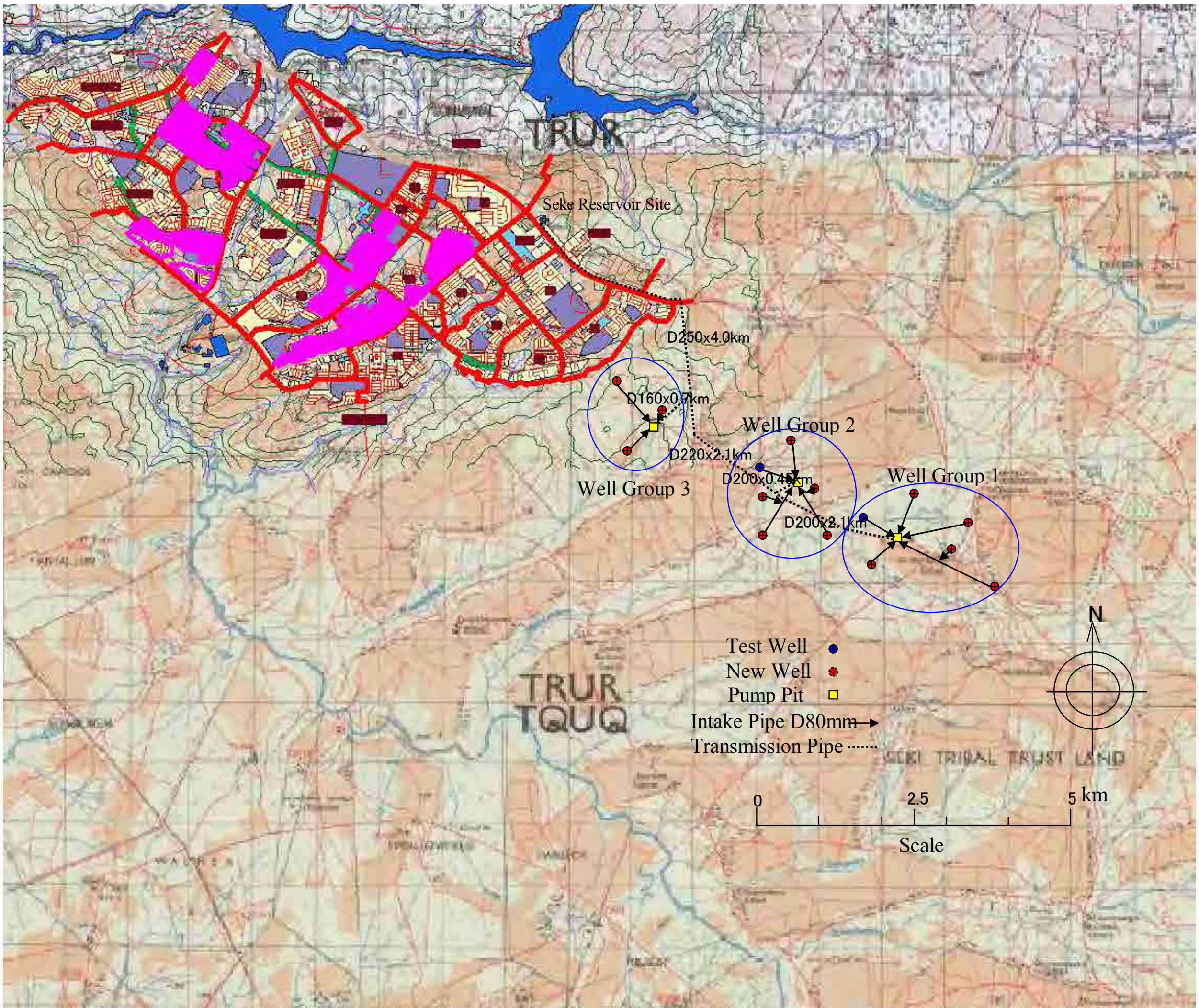
ii) New borehole

New boreholes will be installed at various public facilities such as; 28 of primary schools, eight (8) of high schools, five (5) of municipality council offices and 10 of major churches, while boreholes for hospitals had been installed by some donors. For above target facilities, the total number of boreholes is 51. For these wells electrical pumps will be installed and it pumps up to an elevated storage tank with capacity of 5 m^3.

(4) Acquisition plan for supplemental groundwater resource

As mentioned section (1), the municipality cannot take alternative water resource with reasonable costs. However since current condition of water supply caused by the lack of water source cannot be solved in the near future, ground water resource nearby municipality should be surveyed against the less cost effectiveness.

The layout of proposed well system is shown in Figure 8.6.4. In this plan, 15 wells with average yield capacity of 200 m^3/d will be installed, however 30 of well drilling will be required because of the difficulty of well finding with high yield capacity. The contents of well system are shown in Figure 8.6.5 of flow sheet.



(5) Improvement of the pipe network system of the municipality

1) As mentioned previously, bulk water to the municipality is transmitted from Harare Water Works, however the water has not been utilized properly due to insufficient facilities. The bulk water must be transmitted to Seke ground reservoirs directly and then it should be distributed in the municipality from ground reservoirs and the elevated tank as shown in Figure 8.6.5 of

water supply system flow sheet.

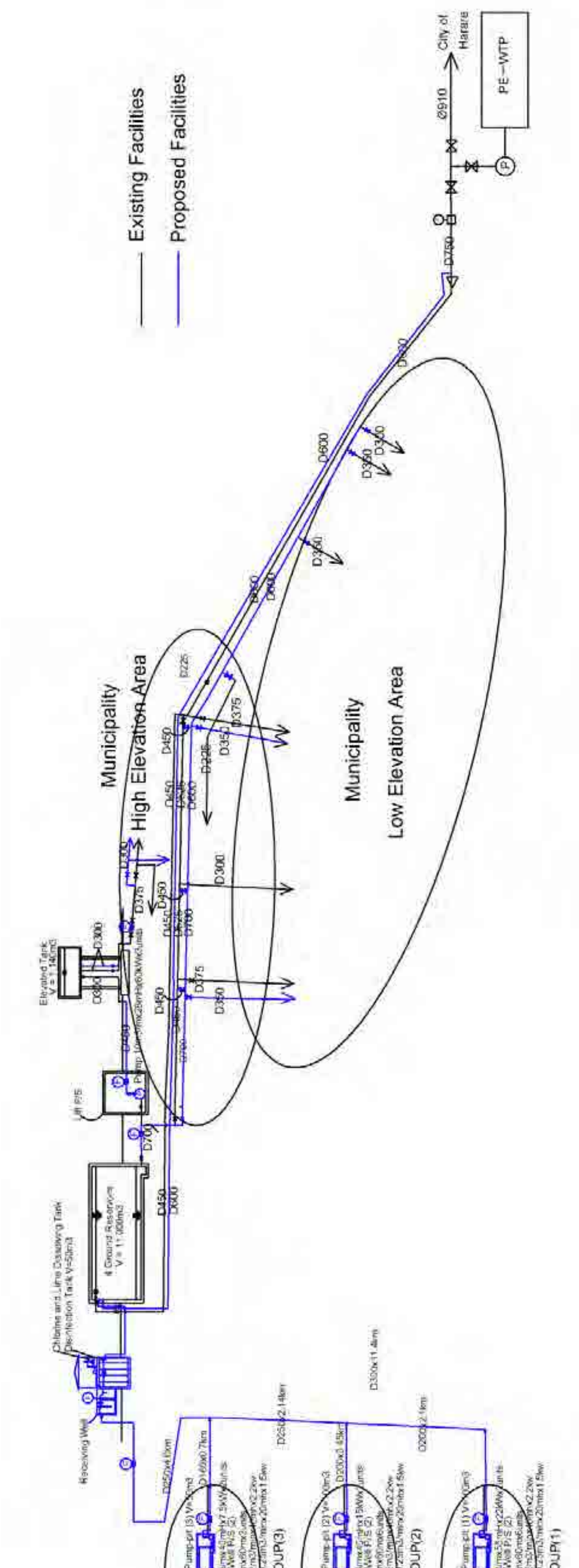


Figure 8.6.5 Flow Sheet of Water Supply System

Accordingly, the ground reservoirs in Seke reservoir site should be used properly in order to cope with the consumers' hourly demands, and in order to realize this, current distribution network must be improved as below:

1) To select a distribution main for the feeding pipe to Seke ground reservoirs, and to reinforce the transmission main from PE-WTP to the reservoirs,
2) To replace lift pumps, connection pipes and the electrical facilities to the elevated tank, and its capacity must be match with necessary capacity of hourly maximum,
3) To enlarge distribution area from elevated tank, where cannot be kept a proper pressure due to the high elevation and too much head loss,
4) To connect reinforced and/or newly installed distribution pipes derived from reservoirs to main branch pipes, which is currently branched form transmission pipe provided by transmission pumps at PE-WTP,
5) To reinforce distribution pipes to keep proper pressure for all distribution area,
6) To receive well water shown in section (4), and
7) Proper pressure with around 100 kPa or more.

(6) Refurbishing of distribution network

The reinforcement of pipes is shown in Figure 8.6.6 and detailed drawings are shown in Figure 8.6.7(1) and (2).Concepts of modification for major connection points are described below:

1) To connect existing D300 asbestos cement pipe to newly installed D300 distribution pipe,
2) To connect existing D350 asbestos cement pipe to newly installed D400 distribution pipe,
3) To connect existing D350 asbestos cement pipe to newly installed D600 distribution pipe,
4) To connect existing D225 asbestos cement pipe to newly installed D600 distribution pipe,
5) To connect existing D525 steel pipe and D375 asbestos cement pipe to newly installed D600 distribution main,
6) To connect existing D300 asbestos cement pipe to newly installed D700 distribution pipe,
7) To connect existing D100 asbestos cement pipe to newly installed D150 distribution pipe for reinforcement, which pipe is connected by D 200 new pipe extended from the elevated tank,
8) To connect D525 steel pipe and D375 asbestos cement pipe to newly installed D700 distribution main,
9) From the ground reservoirs: to connect existing D450 steel pipe to newly installed D700 distribution main, and
10) From Elevated tank: D350 asbestos cement pipe will be branched from existing D375 asbestos cement pipe.

(7) Improvement of Seke reservoir site and reinforcement of transmission pipe from PE-WTP

With the improvement of Seke ground reservoir site is modified as shown in Figure 8.6.5 of flow sheet and Figure 8.6.8 of layout plan and the concepts are shown below:

1) Existing inflow pipe from City of Harare, which is composed of D600 and D450 mm, will be

used and a new reinforcing transmission pipe will be connected to the reservoirs.

2) Additional 600mm of distribution main will be installed for reinforcement.

3) Existing outflow pipes from the ground reservoirs will be reinforced due to rapid velocity of the pipes.

4) All lift pumps to the elevated tank will be replaced with the electrical facilities and outflow pipes.

5) An outflow pipe from the elevated tank will be reinforced.

6) Diameter 700mm of out flow pipe from the site will be reinforced.

7) Flow meters of outflow pipe from ground reservoir, from the elevated tank from the lift pumps will be installed.

8) Disinfection tank and chemical dosing room, by which well water is received and chlorine and lime for neutralization are injected, will be constructed.

Source: JICA Project Team Figure 8.6.6 Modified Distribution Network

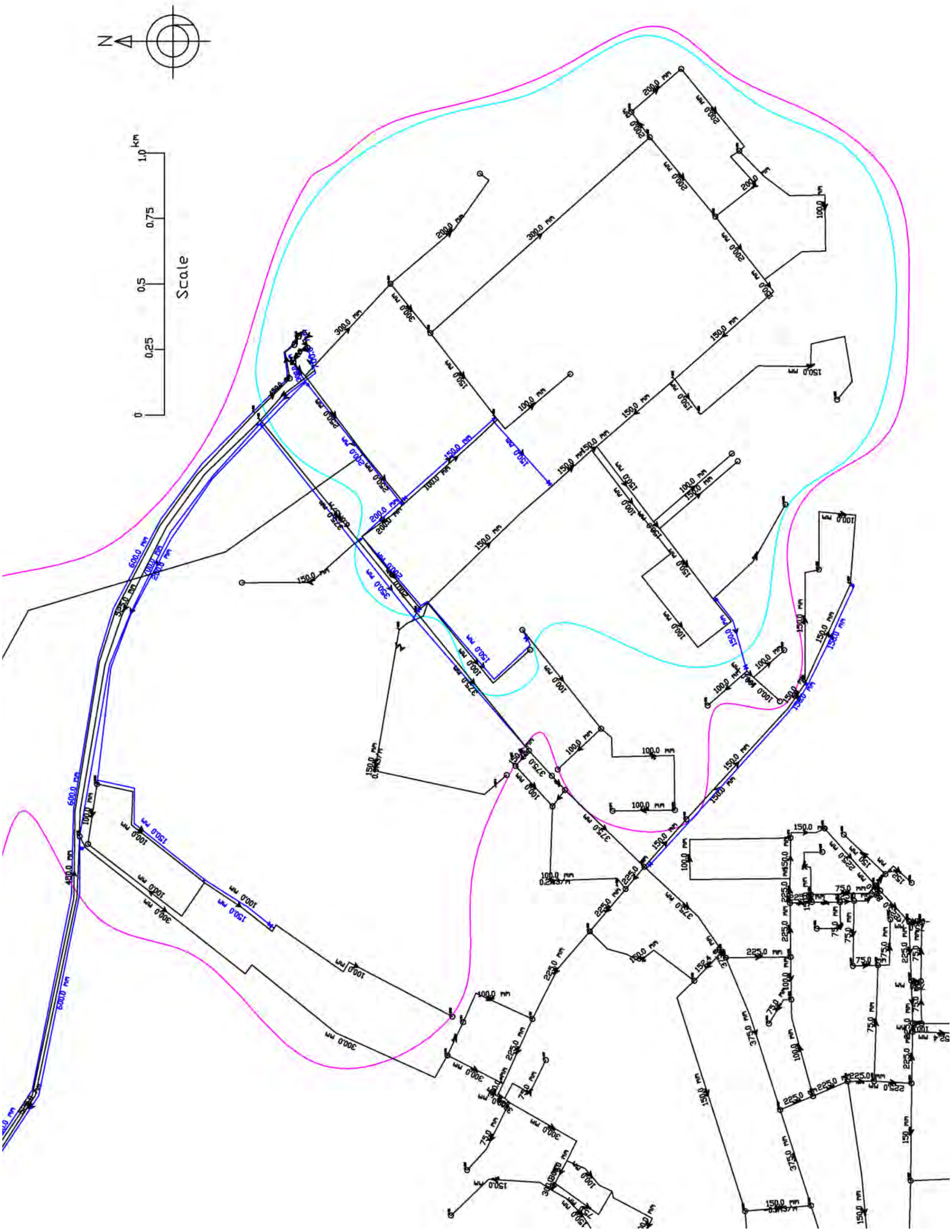


Figure 8.6.7 (1) Modified Distribution Network Detail (1)

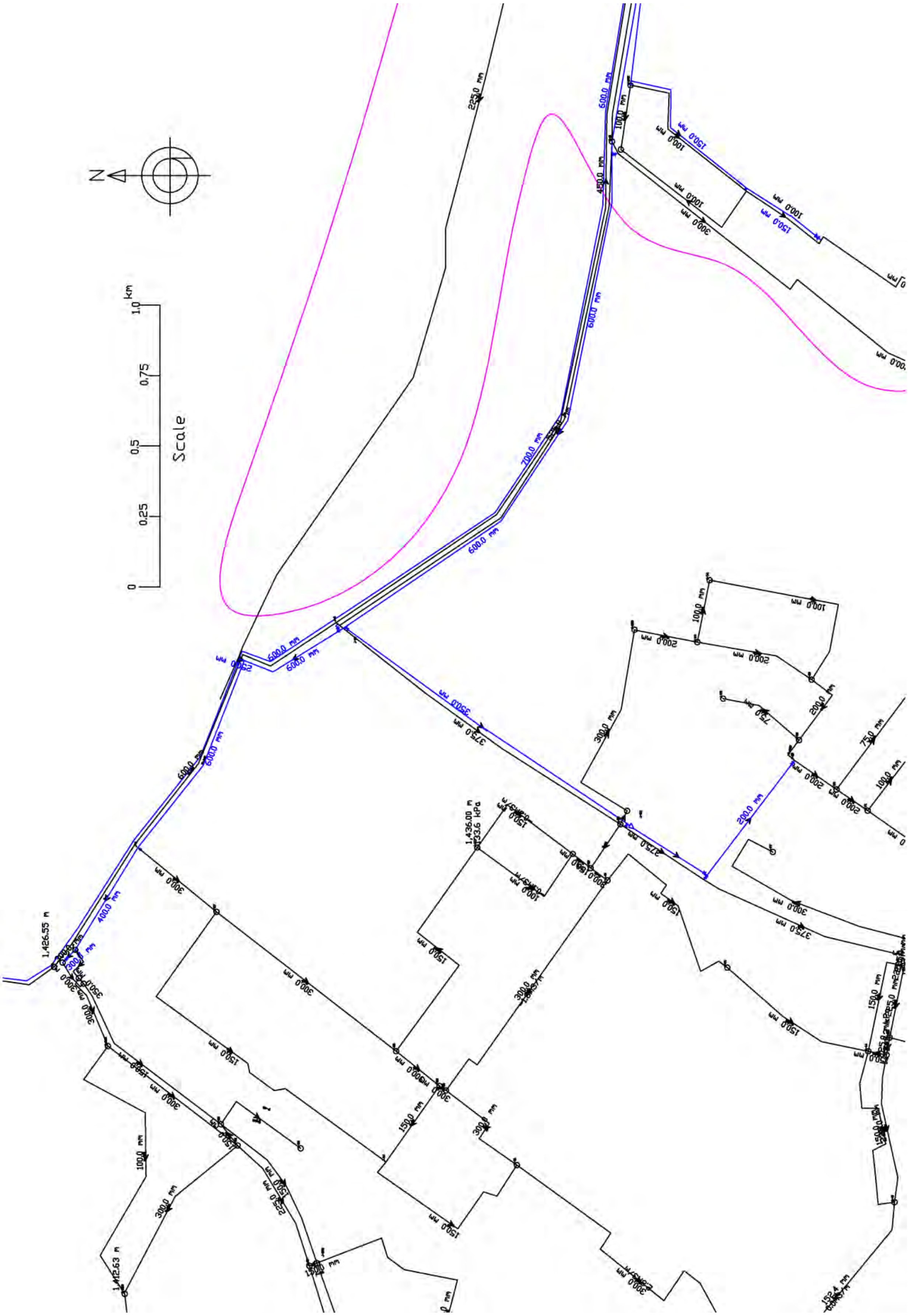
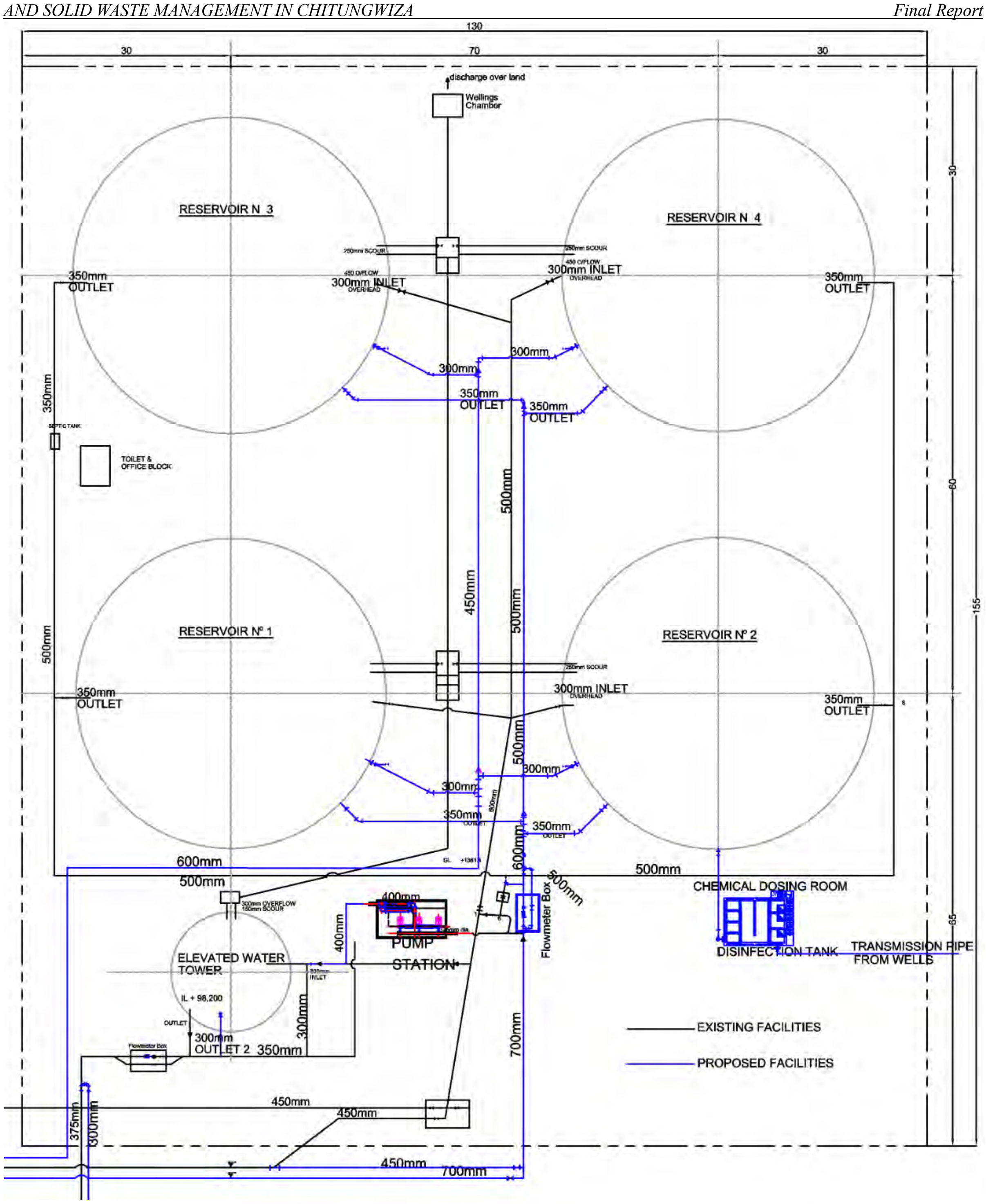


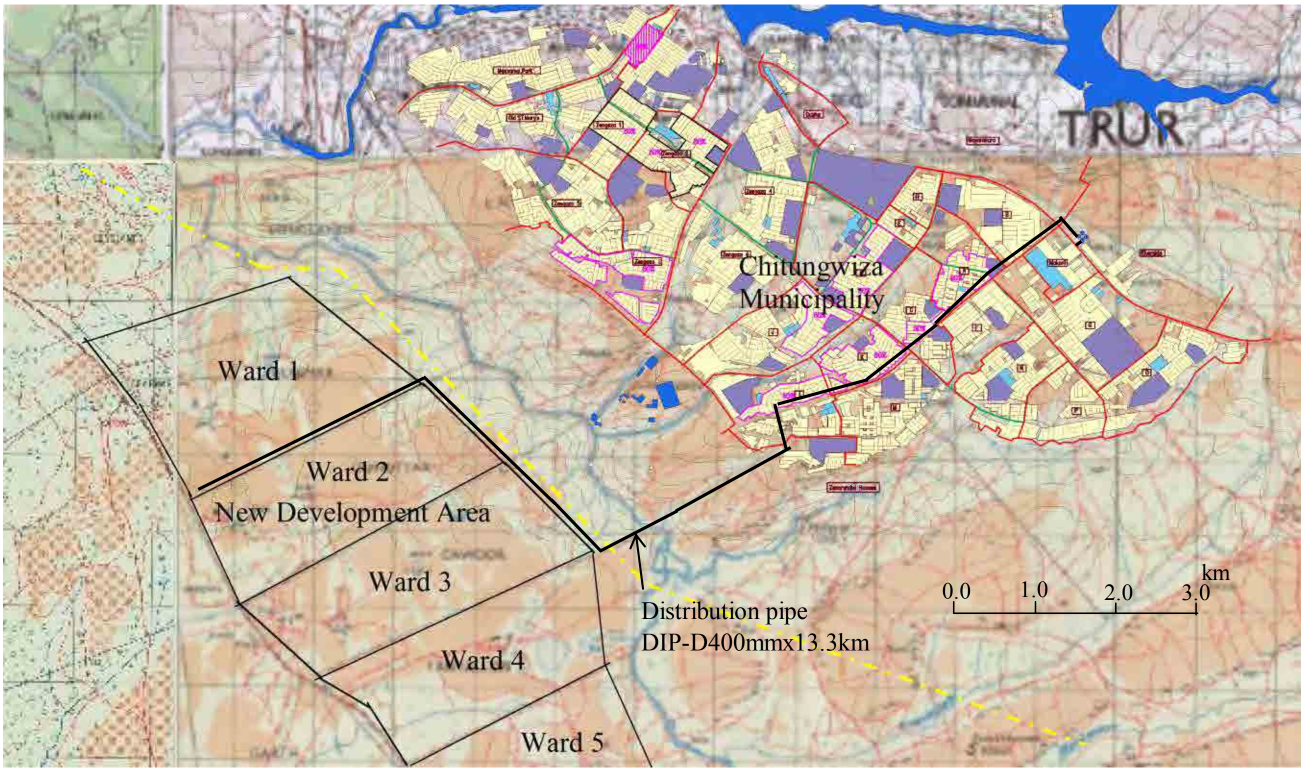
Figure 8.6.7 (2) Modified Distribution Network Detail (2)



Source: JICA Project Team Figure 8.6.8 Modification Plan for Seke Reservoir Site

8.6.3 Improvement Plan for 2030

Water distribution facilities for ward 1 will be required in 2030. In this plan, distribution pipes in the ward will be predicted to be constructed by developers of Wards, but a distribution main from the reservoir to the ward needs to be constructed from the project funds. Additional water resource for Chitungwiza Municipality will be increased as water supply by bulk water of Harare Water Works. The layout of distribution main is shown in Figure 8.6.9, for the plan, the condition of distribution main is below.



Source: JICA Project Team

Figure 8.6.9 Layout of Distribution Main

1) All increased bulk water will be received in Seke Reservoir Site.
2) Distribution main from Seke Reservoirs to the ward is installed as follows:
   The low water level of Seke reservoir is 1,458.3 m and elevation of Ward 1 is 1,420-1,400 m, therefore the minimum difference is 38.3 m. Accordingly 400mm diameter distribution pipes (total loss is 14.5 m) are necessary.

8.6.4 Operation and Maintenance

This evaluation for operation and maintenance of water supply works in Chitungwiza Municipality only includes operation of the facilities shown in Figure 8.6.5 in 2020.

(1) Power consumption

Target facilities are only lift pumps in Seke reservoir site. The power and chemical costs are calculated in Table 8.6.9(1) and 8.6.9(2) in the case of average distribution amount in 2020. The unit consumption per distribution water is also calculated in the table.

Table 8.6.9(1) Power Consumption for Proposed System

Name	Power (kW)	unit (duty)	Operation time (hr)	Consumption Rate	Consumption (kWh)
Lift pump in Seke	60	2	10	0.8	960
Well pumps	3.7	15	20	0.8	888
Transmission Pump	22	1	16	0.8	282
	15	1	16	0.8	192
	7.5	1	16	0.8	96
Total					2,418
Daily average water distribution (m^3/d)					40,104
Unit consumption(kWh/m^3)					0.060

Source: JICA Project Team

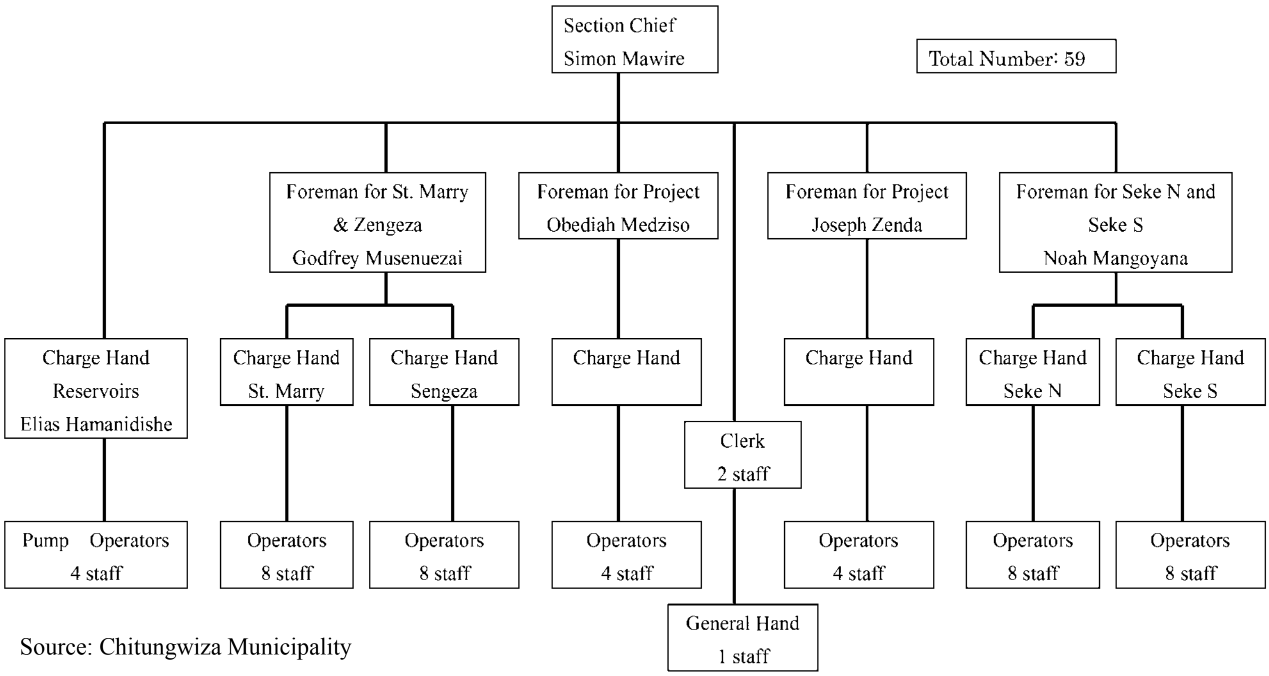
Table 8.6.9(2) Chemical Consumption for Proposed System

Name	Well water (m3/d)	Injection Ratio (mg/L)	Necessary chlorine (kg)	Hypo-chlorite (kg)
Hypo-chlorite	3,000	1.0	3.0	5.0
Daily average water distribution (m^3/d)				41,619
Unit consumption($kg/1000m^3$)				0.120

Source: JICA Project Team

(3) Organization and the personal cost

Current organization of water supply is shown in Figure 8.6.10.



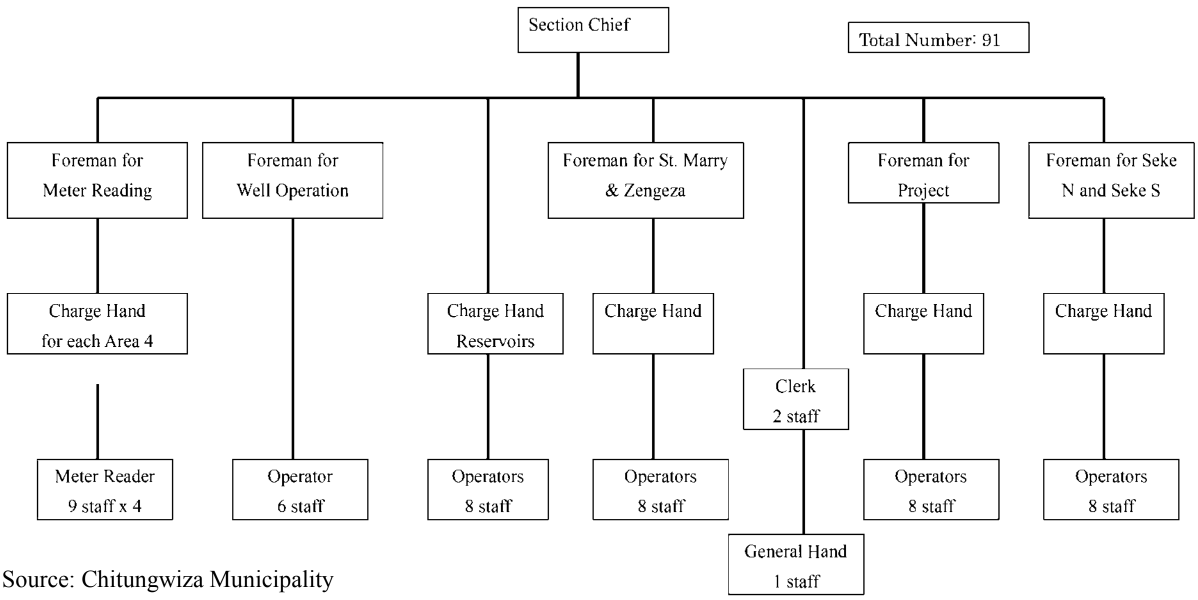
Source: Chitungwiza Municipality

Figure 8.6.10 Current Organization Chart of Water Supply Section

Under the discussion with major staff of water supply section, they were deeply concerned about current water supply management and conditions. In order to improve the condition, they suggested; i) the account for water supply should be independent from municipality account, and then pay for bulk water charge on time, ii) To secure bulk water supply of 30,000 m^3/day based on the condition of i), iii) To involve meter reading section and carry out meter reading periodically. These were quite reasonable requirements, accordingly when proposed system is completed, the organization should be modified as follows:

1) Currently, due to inefficient distribution network frequent valve operations have been required but after the completion of proposed system, necessity of the operation will be drastically reduced. The number of operators in St.Mary, Zengeza, and Seke area can then be reduced.
2) In Seke reservoir site, pump operators will be busy therefore the number of operators will be increased.
3) For well operation, a new organization should be established.
4) Meter reading section should be established with 41 members as shown below figure.

The proposed new organization chart is shown in Figure 8.6.11, 32 of total staff number will be increased.



Source: Chitungwiza Municipality

Figure 8.6.11 Proposed Organization Chart of Water Supply Section

(4) Repair and maintenance

Currently, the lift P/S in Seke reservoir site is only one mechanical and electrical facility managed by Chitungwiza Municipality. Others are distribution networks which are composed pipes and valves and reservoir structures. The corrosion of valves and fittings for old pipes installed before 1960th causes problems, and the continuous repair and replacement is required.

When the proposed system is completed, composition of facilities will remain the same, and since well systems will be introduced, pumps for these will be required. Mechanical and electrical facilities require continuous observation, frequent maintenance such as oil exchange and replacement of parts, and repair is also necessary.

The costs of repair and maintenance for these facilities are much higher than structures and pipes. The cost estimation rate of repair and maintenance is estimated as shown in Table8.6.10, while actual construction costs are shown in Chapter 11.7.1 and O&M costs are shown in 11.8.2.

Table 8.6.10 Proposed Rate of Maintenance Cost

Facilities	Rate to Construction Cost(%/year)	Construction cost (mil.USD)
M&E Facilities	5.0	Form Cost Estimation
Existing Distribution Network	1.0 (including replacement)	30
New Pipes	0.2	Form Cost Estimation
Existing Structures	0.1	4
New Structures	0.05	Form Cost Estimation

Source: JICA Project Team

(5) Bulk water

In 2020, bulk water from Harare Water Works needs to be distributed. The usual daily volume is 41,619 m^3/day and the price is 0.30 USD/m^3, except for tax. However the Kunzwi Project will be completed in 2020, and then the costs will be burdened to the bulk water costs.

The costs of the water source development plan is 157.9 mil. USD and the daily average distribution amount is 757,579 m^3/day. The costs were considered to be burdened by 10 years of distribution amount. The cost per cubic meter is calculated as follows:

$$157{,}900{,}000 \text{ USD} / (757{,}579 \times 365 \times 10) = 0.057 \text{ USD/m}^3$$

The unit price of bulk water in 2020 is predicted to be 0.36 (0.30+0.057) USD/m^3 to predicted daily average bulk water flow of 41,619 m^3/day.

CHAPTER 9 IMPROVEMENT PLAN FOR THE SEWAGE

9.1 Current Status of the Flow Balance in the Catchment

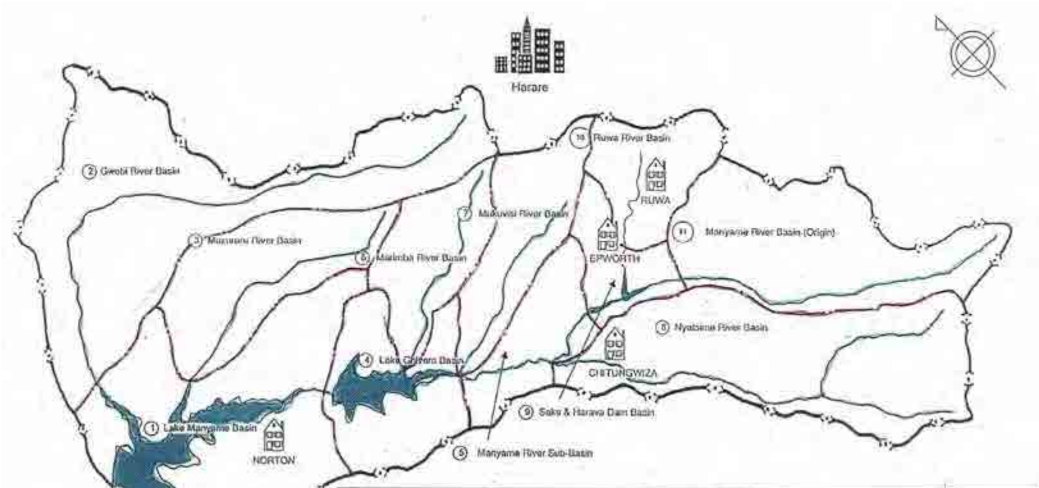
The Manyame Catchment (3,600 km^2) consists of three major river systems – Lake Manyame River system, Lake Chivero River system and Seke/Harava river system, as follows:

(1) Lake Manyame river system (1,670 km^2): Gwebi River, Muzururu River

(2) Lake Chivero river system (1,146 km^2): Marimba R., Mukuvisi R., Nyatsime R.

(3) Seke & Harava dam (784 km^2): Ruwa R., Manyame R.

Lake Chivero and Lake Manyame were originally constructed as the man-made reservoirs for water source and irrigation of the greater Harare in the Manyame catchment area. The total area of the basin area is 3,600 km^2. Since the annual average flowrate to these two lakes is approximately 23 m^3/sec (Chapter 6), the specific discharge of the catchment is approximately 0.006 m^3/km^2/sec (23 m^3/sec /3,600 km^2).



SUB-BASIN AREA

	Basin Name	Area (km^2)		Basin Name	Area (km^2)
1	Lake Manyame Basin	590	7	Mukuvisi River Basin	230
2	Gwebi River Basin	770	8	Nyatsime River Basin	580
3	Muzururu River Basin	310	9	Seke & Harava Dam Basin	115
4	Lake Chivero Basin	255	10	Ruwa River Basin	195
5	Manyame River Sub-Basin	168	11	Manyame River Basin (Origin)	474
6	Marimba River Basin	215		Total	3,900

Source: JICA Project Team

Figure 9.1.1 Upper Manyame River Basin

The specific discharge is somewhat smaller compared to those in Japan which range from 0.03 to 0.01 m^3/km^2/sec. The storage capacities are 480 million m^3 in the Lake Manyame, 257 million m^3 in the Lake Chivero as indicated in Table 9.1.1. The retention time by the natural runoff is 3.80 years in Lake Manyame and 0.82 years in Lake Chivero.

Table 9.1.1 Fundamentals of upper-Manyame Catchment

	Seke & Harava Dam	Lake Chivero	Lake Manyame
Lake area	3.3 km^2	26.3 km^2	81.0 km^2
Storage capacity	12.4×10^6 m^3	257.181×10^6 m^3	480.236×10^6 m^3
Control water level (max.)		1,363.59 m	1,341.1 m
Max Water depth	3.8 m (average)	30.9 m	23.6 m
Retention time	43 days	0.82 yr	3.80 yr
Basin Area	784 km^2	1,146 km^2	1,670 km^2
Construction	1929, 1973	1952	1976

Source : Dams of Zimbabwe by ZIMCOLD, JICA Project Team

Lake Chivero was constructed in 1953, and was located in a serene and green mountain area. The lake has been the source of drinking water and irrigation since 1953. The fishery service was established in 1956 although the quantities of fish taken are unknown. The fishery is practically extinct as of 2012. It is assumed that the water pollution in the Lake Chivero started in the mid-1960s and progressed as the population grew, and urban development, industrial and mining activities developed. The water pollution problem in the Lake Chivero has become a big state-wide environmental issue, such that water pollution control legislation was finally improved and was framed upon the following principles:

1) Quality standards for waters of the country,
2) Discharge standards and
3) The polluter pay principle

These are contained in the current Water Act and its associated regulations.

However, the threat of water pollution increases every year because of the population growth in the Greater Harare and worsening sanitary conditions as evidenced by the Cholera outbreak in 2008. The population of 119 thousand in 1951 increased to 883 thousand in 1979 or about eight times in the last 30 years. The annual average growth rate for the last nine years (2002-2012) is a high 1.4%. The current population in the catchment area in 2012 was assumed to be 2,302,500 as indicated in the Chapter 8, population analysis. Population growth brings with it increased domestic wastewater that is discharged into the Lakes with limited treatment as many of the STPs are not being properly maintained due to lack of funds brought about by the economic crisis.

9.2 Requirement for the Environment Improvement

(1) Water Recycling in the Catchment

From the water balance of the lakes shown in the Table 9.2.1, about half of the water inflow to both lakes is taken from Morton Jaffray WTP as a water source. , The evaporation of 44% in the Lake Chivero and 27% in the Lake Manyame is excluded from the inflow. Inflow of effluent and raw sewage from existing STPs of about 46,000 m^3/day (11,928m^3/d from Crowborough, 9,300 m^3/d from Firle, 22,000 m^3/d from Zengeza STP and 2,900 m^3/d from Ruwa STP), which is about 2.3% of the inflow, is also included in both lakes. Concentration of the pollutants in the effluent is attributable to the evaporation in both lakes. Thus, the water has been recirculated in the catchment and reused for water supply and the effluent is discharged to the river from the STPs.

Table 9.2.1 Flow Balance in the Lake Chivero and Lake Manyame Unit: 1000 m^3/d

	Inflow	Evaporation	Intake by WTP	Discharge	Balance
Lake Chivero	1,024.2	455.1	238.0	76.5	254.6
	100%	44.4%	23.2%	7.5%	24.9%
Lake Manyame	929.1	247.8	357.0	261.8	62.5
	100%	26.7%	38.4%	28.2%	6.7%

Source: JICA Project Team

Lake Chivero is more actively utilized than Lake Manyame in terms of water recycle and water reuse. In the inflow from Manyame, Mukuvisi and Marimba rivers, include raw sewage or effluent from the existing STPs in Ruwa, Chitungwiza and Harare. Discharge from the lake is only 76,500 m^3/d or 7.5% of the total inflow of the lake Chivero. Morton Jaffray WTP also takes water from the lake.

Lake Manyame has been getting inflow from Gwebi River, Muzururu River, also gets the discharge from Lake Chivero and return water from the Morton Jaffray WTP. These two rivers do not include effluent pollution load from any STP other than non-point source. The return water from the Morton Jaffray WTP flows into Lake Manyame. Morton Jaffray WTP has been extracting the raw water of about 240,000 m^3/d from Lake Chivero, and about 360,000 m^3/d from Lake Manyame, which has the . Norton STP at its left shore, discharging the raw sewage to the Lake Manyame directly.

Both lakes are important as the sole water resource for water supply in greater Harare. Although a new water source such as Kunzwi dam has been planned, it has not yet been realized. As shown in the improvement plan for the water supply, groundwater is not as abundant as hoped for use in the future.

(2) Needs for sewage treatment in the catchment

The water cycle, which includes the two lakes in the catchment, is an important feature of treatment. Morton Jaffray WTP has been treating approximately 600,000 m^3/d of raw water, comprised of about 60% from Lake Manyame and about 40% from Lake Chivero. The two lakes are working as a sequential treatment process. Lake Chivero is working as a pre-treatment process for Lake Manyame, and Lake Manyame as subsequent process protected from the pollution load. The water quality in Lake Manyame shows better values than Lake Chivero and the result of the pollution analysis as confirmed in this study.

Since both lakes have big capacity, self-purification is effective for now as computed in the pollution analysis. However, since the sewage treatment plants are operating far below their capacities, the water cycle in the catchment will be adversely affected making the water quality worse than it already is as shown in the Scenario 0 in the pollution analysis. Improvement of the aquatic environment by the sewerage system is required urgently. In this context, the Master Plan for the sewerage facility's rehabilitation and construction and its implementation schedule must proceed.

(3) Challenges for pollutant load reduction

It is necessary to keep a continuous inflow of clean water to the lake body, and improve the lake's aerobic condition to make the lake water clean. This is one of the most difficult conditions in the catchment especially that the dry season is long, where sometimes even droughts occur. Specific flow rate of the catchment was computed as 0.006 $m^3/km^2/sec$ (23 m^3/sec for 3,600 km^2) which is half or one-tenth of the values in other countries. In Japan for example, it ranges from 0.01 to 0.04 $m^3/km^2/sec$.

This is one reason that T-N and T-P show very high value in the analysis, although BOD_5 is low. Therefore, concentration of these nutrients easily occurs in Lake Chivero and Lake Manyame due to low flowrate and evaporation.

One of the best ways to improve the aquatic environment will be to introduce raw water from another catchment to realise the dilution of the nutrients, although this is almost impossible. This means that transferring the pollution loads outside of the catchment, that is reuse of effluent for irrigation, will be the practical alternative.

Since there are not sufficient water quality data in the catchment area, it is very important to activate the water quality monitoring system by EMA in the catchment.

9.3 Concept of Improvement Plan for the Sewerage

(1) Fundamentals

1) Target year

Taking into consideration the scale of the lake and basin, the current situation of environmental administration in the basin, and the schedule of the urgent Plan, the target years are set at 2020 for the medium-term, and 2030 for the long-term.

2) Target level of water quality in the lakes and rivers

The purpose of the ambient water quality standard is to establish the specific and desirable conservation values / targets. There are no ambient water quality standards in Zimbabwe, as of year 2012. EMA has been controlling and regulating the disposal and discharge according to the Acts that require any person to get the license granted by EMA and pay the prescribed fee according to the grade of license. The regulation is following polluter pay principle through licensing four classes. However, it is independent of the ambient pollution status, as long as the polluters pay the fee according to the regulation.

The proposal for the ambient water quality standard was made in the 1996 Study by JICA which was followed. Figure 9.2.1 shows the environmental standards for freshwater and drinking water. As proposed in the Chapter 6, the standards for Class 1 are completely same as those for Class 2 in both parameters and values in terms of inorganic and organic matters. Only values of total phosphorous are different in Classes 1 and 2. These values are classified according to the usage of the natural water as follows:

a. Natural Environmental Preservation
b. Potable Water
c. Recreation/Swimming
d. Fishery
e. Irrigation/Industrial
f. Minimum Requirement for Environment

The parameters and values defined in the environmental standards for freshwater and drinking water standards are not necessarily identical, but the environmental standards include all the parameters other than surfactants out of inorganic matters for human health defined in the drinking water standards, and their requirements are more stringent or equal to those in the drinking water standards.

From the result of the pollution analysis, it was confirmed that after the proposed urgent improvement such as sewage treatment and irrigation use of effluent, BOD value at some points can be improved below the proposed standard. However, the concentration of T-N and T-P are far higher than the standard. Although it will be very difficult to keep the standard, the proposed value is set here as a future target. As discussed in the 9.2, it will take a longer time to get data required to judge if the standard is appropriate or not. There are still ambiguities in the unit pollution load such as natural pollution load, or reaching ratio to the water body from generated point.

The water quality conservation target is tentatively proposed so as to meet the environmental standards by 2030 with the interim target for the intermediate year or 2020. This target considers the requirement for the water supply and current pollution status of Lake Chivero and Lake Manyame. Table 9.2.3 shows the medium-term (provisional) and long-term targets for water quality conservation. Further verification is required if these standards are appropriate or not after the cumulative data acquisition.

Table 9.2.3 Water Quality Conservation Target

Parameter		Lake			River	
		Seke & Harava	Lake Chivero	Lake Manyame	Manyame Origin	Manyame
Provisional Standard (2020)						
Class		C	C	C	C	C
E. Coli	(MPN/100mL)	L.E.1000MPN	ditto	ditto	ditto	-
BOD_5	(mg/L)	-	-	-	<3	<5
COD	(mg/L)	<3	<3	<3	-	-
TN	(mg/L)	<1.0	<1.0	<1.0	-	-
TP	(mg/L)	<0.08	<0.08	<0.08	<0.08	<0.08
Long term Standard						
Class		A	A	A	A	B
E. Coli	(MPN/100mL)	L.E.1000MPN	ditto	ditto	ditto	-
BOD_5	(mg/L)	-	-	-	<3	<5
COD	(mg/L)	<3	<3	<3	-	-
TN	(mg/L)	<0.2	<0.2	<0.2	-	-
TP	(mg/L)	<0.01	<0.01	<0.01	<0.01	<0.01

Source: JICA Project Team

(2) Basis for the sewerage planning

To reduce domestic pollutant loads, the HARARE WATER has led the way for sewerage construction and achieved high-level rates of connection and treatment before the economic crisis. However, the sewerage systems constructed in the developed area of the catchment has not been functioning well since the economic crisis. The same was true in Chitungwiza Municipality where house connection rates were 100% then.

The current status of the aquatic environment and result of the pollution analysis show the critical status of the catchment. To deal with the problem, Zim-Fund project and AWF project have been on-going in both of the City of Harare and Chitungwiza Municipality. Urgent rehabilitation of water supply and sewerage has been implemented in the program but not completed yet. The effects of the rehabilitation program on the improvement of the environment were already reflected in the pollution analysis:

Rehabilitation of

1) Crowborough STP,

2) Firle STP and

3) Zengeza STP

As indicated in the pollution analysis, these STP contribute a large part of the pollution loads. The leading projects by Zim-Fund and AWF will be the first step to improve the environment. Further improvement will be seen with the developments included in the master plan.

Norton STP is another pollution source for Lake Manyame. Norton STP has not been operating since 2000 and has been discharging raw sewage to the lake. Since its rehabilitation is not included in the program of Zim-Fund or AWF project, it must be included in the Master Plan.

(3) Un-sewered area

An unsewered population of 370 thousand residents were identified in the pollution analysis. The population is considered to be using septic tanks. The soak-away load from the septic tank infiltrates and pollutes the groundwater which, in the end, will become a nonpoint pollution source. As a result of the pollution analysis, non-point sources such as load from septic tank and natural pollution seem to be rather big.

The construction of sewerage in unsewered areas is not financially feasible at this time. However, according to the analysis, measures will still have to be taken particularly in densely populated areas such as Epworth (120,000, for Ruwa River and Mukuvisi River), Marondera Rural (60,000 for Nyatsime River) and Harare (86,600 for Gwebi River) to deal with the soak-away from the septic tanks.

(4) Engineering countermeasures

Various countermeasures will be developed for pollutant load reduction for the lakes. Possible alternatives for sewerage were already shown in the scenarios of the pollution analysis. Economical treatment processes must be chosen for sustainability and O&M.

Alternative approaches other than advanced wastewater treatment such as BNR will be necessary to realize the diverse needs of the water environment in addition to water supply. For example, the use of effluent is the best way to reduce the nutrient pollution load, and in this case, the employment of BNR will not be a requirement of the effluent water quality.

(5) Capital investment and sustainability

Capital investment by donors is needed to rehabilitate the STPs in the catchment considering the present financial status of the municipalities in the catchment area. The most economical solutions in the construction and operation are required to promote the sustainability of the STPs and this must be incorporated in the planning and design of the treatment process. In addition, the tariff system must be re-established to further contribute to operational sustainability.

(6) Public enlightenment and environmental education

According to the survey on public enlightenment and environmental education, the people living in the basin of Lake Chivero are not very aware of their contribution to lake pollution and have low willingness-to pay for the wastewater charge. It is important that a program to raise the awareness of the people on the impact of their actions and practices on the basin's environment and the necessity of paying the wastewater charge. Public enlightenment and environmental education should include all the stakeholders to inform them of their shared and cooperative responsibility in water quality conservation of the lake.

9.4 Project Frame

(1) Population projection

Tabel 9.4.1 Population Projection in the Catchment

Population				
Sub-basin/District		Population		
		2012	2020	2030
1	Chegutu Rural	3,600	3,815	3,798
2	Chitungwiza Municipality	354,500	389,100	440,800
3	Epworth Local Board	115,502	152,064	214,268
4	Goromonzi Rural	2,800	3,672	5,063
5	Harare City	1,441,832	1,500,661	1,577,341
6	Harare Rural	85,995	263,072	817,235
7	Manyame Rural	10,871	28,070	81,048
8	Marondera Rural	60,000	110,363	249,006
9	Mazowe Rural	5,100	5,342	5,599
10	Norton Town	58,400	108,000	233,000
11	Ruwa Local Board	56,300	112,000	265,000
12	Zvimba Rural	18,000	20,940	28,462
	Total	2,212,900	2,697,100	3,920,800

Table 9.4.2 Population Projection of Chitungwiza

Area/Item	Housing Number			Population		
	2012	2020	2030	2012	2020	2030
St. Mary	5,899	6,484	6,484	69,966	68,400	65,398
Zengeza	11,924	17,048	17,048	96,670	122,900	117,515
Seke S	11,145	13,098	13,098	101,394	106,000	101,317
Seke N	8,126	9,928	9,928	84,458	91,800	87,733
Ward 1	0	0	20,000	0	0	66,807
Total	37,094	46,558	66,558	354,500	389,100	440,800

(2) Domestic wastewater flow

Tabel 9.4.3 Domestic Wastewater Flow Projection in the Cachment

Sub-basin/District		Wastewater Flow (m^3/day)		
		2012	2020	2030
1	Chegutu Rural	216	248	278
2	Chitungwiza Municipality	21,270	25,292	30,856

Sub-basin/District		Wastewater Flow (m^3/day)		
		2012	2020	2030
3	Epworth Local Board	6,930	9,884	14,999
4	Goromonzi Rural	168	239	354
5	Harare City	152,522	169,781	184,596
6	Harare Rural	5,160	17,100	57,206
7	Manyame Rural	652	1,825	5,673
8	Marondera Rural	3,600	7,174	17,430
9	Mazowe Rural	306	347	392
10	Norton Town	4,655	8,098	18,582
11	Ruwa Local Board	4,849	10,119	25,121
12	Zvimba Rural	1,080	1,361	1,992
	Total	201,407	251,466	357,482

Table 9.4.4 Wastewater Projection from Chitungwiza

Area/Item	Wastewater (m3/day)		
	2012	2020	2030
St. Mary	4,198	4,446	4,578
Zengeza	5,800	7,989	8,226
Seke S	6,084	6,890	7,092
Seke N	5,067	5,967	5,703
Ward 1	-	-	4,676
Total	21,149	25,292	30,275

(3) Industrial wastewater

Table 9.4.5 Industrial Wastewater Projection

Industrial and Future Industrial Waste Water Load

Local Authority	Sub-basin	No. of Industrial Type	Type of Industry	Ratio of Employees (%)	Unit Wastewater Flow (m^3/day person)	Present				2015 Year				2020 Year				2030 Year			
							Wastewater Flow(m^3/day)				Wastewater Flow(m^3/day)				Wastewater Flow(m^3/day)				Wastewater Flow(m^3/day)		
						Number of Employees	Total	Sewered	Unsewered	Number of Emplyees	Total	Sewered	Unsewered	Number of Emplyees	Total	Sewered	Unsewered	Number of Emplyees	Total	Sewered	Unsewered
Harare City	Marimba River	1	Processed Foodstuffs	41.6	0.507	5,826	2,954	2,954	-	9,277	4,703	4,703	-	9,277	4,703	4,703	-	9,277	4,703	4,703	-
	Sub-basin	6	Chemicals	13.4	0.095	1,877	178	178	-	2,988	284	284	-	2,988	284	284	-	2,988	284	284	-
		7	Plastic Products	5.0	0.176	700	123	123	-	1,115	196	196	-	1,115	196	196	-	1,115	196	196	-
		11	Ceramics, Stone & Clay Products	8.2	13.889	1,148	15,945	15,945	-	1,829	25,403	25,403	-	1,829	25,403	25,403	-	1,829	25,403	25,403	-
		17	Transportation Equipment	8.2	0.297	1,148	341	341	-	1,829	543	543	-	1,829	543	543	-	1,829	543	543	-
		19	Other Industry Products	2.3	0.662	3,305	2,188	2,188	-	5,262	3,483	3,483	-	5,262	3,483	3,483	-	5,262	3,483	3,483	-
			Total	**78.7**		**14,004**	**21,729**	**21,729**	**-**	**22,300**	**34,612**	**34,612**	**-**	**22,300**	**34,612**	**34,612**	**-**	**22,300**	**34,612**	**34,612**	**-**
	Mukuvisi River	1	Processed Foodstuffs	41.6	0.507	16,641	8,437	7,593	844	31,158	15,797	14,953	844	31,158	15,797	14,953	844	34,278	17,379	16,535	844
	Sub-basin	6	Chemicals	13.4	0.095	5,360	509	458	51	10,037	954	903	51	10,037	954	903	51	11,042	1,049	998	51
		7	Plastic Products	5.0	0.176	2,000	352	317	35	3,745	659	624	35	3,745	659	624	35	4,120	725	690	35
		11	Ceramics, Stone & Clay Products	8.2	13.889	3,280	45,556	41,000	4,556	6,142	85,306	80,750	4,556	6,142	85,306	80,750	4,556	6,757	93,848	89,292	4,556
		17	Transportation Equipment	8.2	0.297	3,280	974	877	97	6,142	1,824	1,727	97	6,142	1,824	1,727	97	6,757	2,007	1,910	97
		19	Other Industry Products	2.3	0.662	9,443	6,251	5,626	625	17,676	11,702	11,077	625	17,676	11,702	11,077	625	19,446	12,873	12,248	625
			Total	**78.7**		**40,004**	**62,079**	**55,871**	**6,208**	**74,900**	**116,242**	**110,034**	**6,208**	**74,900**	**116,242**	**110,034**	**6,208**	**82,400**	**127,881**	**121,673**	**6,208**
	Ruwa River	1	Processed Foodstuffs	41.6	0.507	-	-	-	-	-	-	-	-	-	-	-	-	20,883	10,588	10,588	-
	Sub-basin	6	Chemicals	13.4	0.095	-	-	-	-	-	-	-	-	-	-	-	-	6,727	639	639	-
		7	Plastic Products	5.0	0.176	-	-	-	-	-	-	-	-	-	-	-	-	2,510	442	442	-
		11	Ceramics, Stone & Clay Products	8.2	13.889	-	-	-	-	-	-	-	-	-	-	-	-	4,116	57,167	57,167	-
		17	Transportation Equipment	8.2	0.297	-	-	-	-	-	-	-	-	-	-	-	-	4,116	1,222	1,222	-
		19	Other Industry Products	2.3	0.662	-	-	-	-	-	-	-	-	-	-	-	-	11,848	7,843	7,843	-
			Total	**78.7**		**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**50,200**	**77,901**	**77,901**	**-**
	Manyame	1	Processed Foodstuffs	41.6	0.507	-	-	-	-	1,248	633	633	-	32,198	16,324	16,324	-	32,198	16,324	16,324	-
	River Sub-basin	6	Chemicals	13.4	0.095	-	-	-	-	402	38	38	-	10,372	985	985	-	10,372	985	985	-
		7	Plastic Products	5.0	0.176	-	-	-	-	150	26	26	-	3,870	681	681	-	3,870	681	681	-
		11	Ceramics, Stone & Clay Products	8.2	13.889	-	-	-	-	246	3,417	3,417	-	6,347	88,153	88,153	-	6,347	88,153	88,153	-
		17	Transportation Equipment	8.2	0.297	-	-	-	-	246	73	73	-	6,347	1,885	1,885	-	6,347	1,885	1,885	-
		19	Other Industry Products	2.3	0.662	-	-	-	-	708	469	469	-	18,266	12,092	12,092	-	18,266	12,092	12,092	-
			Total	**78.7**		**-**	**-**	**-**	**-**	**3,000**	**4,656**	**4,656**	**-**	**77,400**	**120,120**	**120,120**	**-**	**77,400**	**120,120**	**120,120**	**-**
	Grand Total					**54,008**	**83,808**	**77,600**	**6,208**	**100,200**	**155,510**	**149,302**	**6,208**	**174,600**	**270,974**	**264,766**	**6,208**	**232,300**	**360,514**	**354,306**	**6,208**
Chitungwiza	Nyatsime River	1	Processed Foodstuffs	42.0	0.507	659	334	334	-	818	415	415	-	950	482	482	-	7,280	3,691	3,691	-
Municipality	Sub-basin	6	Chemicals	0.0	0.095	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		7	Plastic Products	1.3	0.176	20	4	4	-	25	4	4	-	29	5	5	-	225	40	40	-
		11	Ceramics, Stone & Clay Products	1.5	13.889	24	333	333	-	29	403	403	-	34	472	472	-	260	3,611	3,611	-
		17	Transportation Equipment	43.9	0.297	689	205	205	-	855	254	254	-	992	295	295	-	7,609	2,260	2,260	-
		19	Other Industry Products	6.6	0.662	178	118	118	-	220	146	146	-	256	169	169	-	1,959	1,297	1,297	-
			Total	**95.3**		**1,570**	**994**	**994**	**-**	**1,947**	**1,222**	**1,222**	**-**	**2,261**	**1,423**	**1,423**	**-**	**17,333**	**10,899**	**10,899**	**-**
	Manyame	1	Processed Foodstuffs	42.0	0.507	-	-	-	-	-	-	-	-	-	-	-	-	1,372	696	696	-
	River Sub-basin	6	Chemicals	0.0	0.095	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		7	Plastic Products	1.3	0.176	-	-	-	-	-	-	-	-	-	-	-	-	42	7	7	-
		11	Ceramics, Stone & Clay Products	1.5	13.889	-	-	-	-	-	-	-	-	-	-	-	-	49	681	681	-
		17	Transportation Equipment	43.9	0.297	-	-	-	-	-	-	-	-	-	-	-	-	1,434	426	426	-
		19	Other Industry Products	6.6	0.662	-	-	-	-	-	-	-	-	-	-	-	-	369	244	244	-
			Total	**95.3**		**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**3,266**	**2,054**	**2,054**	**-**
	Grand Total					**1,570**	**994**	**994**	**-**	**1,947**	**1,222**	**1,222**	**-**	**2,261**	**1,423**	**1,423**	**-**	**20,598**	**12,953**	**12,953**	**-**
Norton Town	Lake Manyame	1	Processed Foodstuffs	13.8	0.507	191	97	17	80	334	169	42	127	496	251	124	127	1,558	790	663	127
Council	Sub-basin	6	Chemicals	1.6	0.095	22	2	-	2	39	4	1	3	57	5	2	3	181	17	14	3
		7	Plastic Products	0.0	0.176	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		11	Ceramics, Stone & Clay Products	3.4	13.889	47	653	115	538	82	1,139	285	854	122	1,694	839	855	384	5,333	4,477	856
		17	Transportation Equipment	10.0	0.297	138	41	7	34	242	72	18	54	359	107	53	54	1,129	335	281	54
		19	Other Industry Products	40.6	0.662	983	651	114	537	1,722	1,140	286	854	2,558	1,693	838	855	8,036	5,320	4,466	854
			Total	**69.4**		**1,381**	**1,444**	**253**	**1,191**	**2,419**	**2,524**	**632**	**1,892**	**3,592**	**3,750**	**1,856**	**1,894**	**11,288**	**11,795**	**9,901**	**1,894**
Ruwa Local	Ruwa River	1	Processed Foodstuffs	5.3	0.507	77	39	39	-	493	250	250	-	657	333	333	-	859	436	436	-
Board	Sub-basin	6	Chemicals	2.6	0.095	38	4	4	-	242	23	23	-	322	31	31	-	421	40	40	-
		7	Plastic Products	19.1	0.176	276	49	49	-	1,776	313	313	-	2,368	417	417	-	3,094	545	545	-
		11	Ceramics, Stone & Clay Products	1.5	13.889	22	306	306	-	140	1,944	1,944	-	186	2,583	2,583	-	243	3,375	3,375	-
		17	Transportation Equipment	0.0	0.297	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		19	Other Industry Products	60.1	0.662	1,031	683	683	-	6,649	4,402	4,402	-	8,867	5,870	5,870	-	11,583	7,668	7,668	-
			Total	**88.6**		**1,444**	**1,081**	**1,081**	**-**	**9,300**	**6,932**	**6,932**	**-**	**12,400**	**9,234**	**9,234**	**-**	**16,200**	**12,064**	**12,064**	**-**
Total		1	Processed Foodstuffs			23,394	11,861	10,937	924	43,328	21,967	20,996	971	74,736	37,890	36,919	971	107,705	54,607	53,636	971
		6	Chemicals			7,297	693	640	53	13,708	1,303	1,249	54	23,776	2,259	2,205	54	31,731	3,014	2,960	54
		7	Plastic Products			2,996	528	493	35	6,811	1,198	1,163	35	11,127	1,958	1,923	35	14,976	2,636	2,601	35
		11	Ceramics, Stone & Clay Products			4,521	62,793	57,699	5,094	8,468	117,612	112,202	5,410	14,660	203,611	198,200	5,411	19,985	277,571	272,159	5,412
		17	Transportation Equipment			5,255	1,561	1,430	131	9,314	2,766	2,615	151	15,669	4,654	4,503	151	29,221	8,678	8,527	151
		19	Other Industry Products			14,940	9,891	8,729	1,162	32,237	21,342	19,863	1,479	52,885	35,009	33,529	1,480	76,769	50,820	49,341	1,479
			Total			**58,403**	**87,327**	**79,928**	**7,399**	**113,866**	**166,188**	**158,088**	**8,100**	**192,853**	**285,381**	**277,279**	**8,102**	**280,387**	**397,326**	**389,224**	**8,102**

9.5 Improvement Plan for Sewage

(1) Sewerage rehabilitation in the catchment area

Domestic sewage is considered to be the main source of the inflow of pollution load for upper-Manyame Catchment. This is aggravated by state of the sewerage system's facilities and the continuous increase of the urban area's population. It is imperative to have a plan for load reduction (treatment of generated sewage) and moving of loads. (Offsite treatment i.e. sewerage) The rehabilitation of the sewerage facility is the first priority in the plan. Transferring pollution loads outside the basin is desirable in terms of load reduction, and transmission facilities such as pump stations and sewers are necessary for its purpose.

<Urgent Phase>

City of Harare and Chitungwiza Municipality are covered by Zim-Fund project and AWF project:

City of Harare: Rehabilitation of Crowborough STP and Firle STP and Sewers

Chitungwiza: Rehabilitation of Zengeza STP and Pump Stations/Sewers

Norton STP also needs rehabilitation work; however, there is still no backing by any donor. Urgent rehabilitation work must be conducted to protect the water source. Ruwa STP needs de-sludging work to recover its treatment capacity.

<Mid-Term>

Augmentation of the Facilities

City of Harare: Crowborough STP and Firle STP

Chitungwiza: Zengeza STP

This implementation will be the main frame of the improvement plan.

(2) Development plan in Chitungwiza municipality

Development of the Ward 1 project would be completed in Chitungwiza in 2030, as shown in the figure 9.2.1, and the new sewer trunk line (Force main) and a sewage pump station must be constructed according to the development plan. Augmentation of the sewage treatment plant will also be necessary.

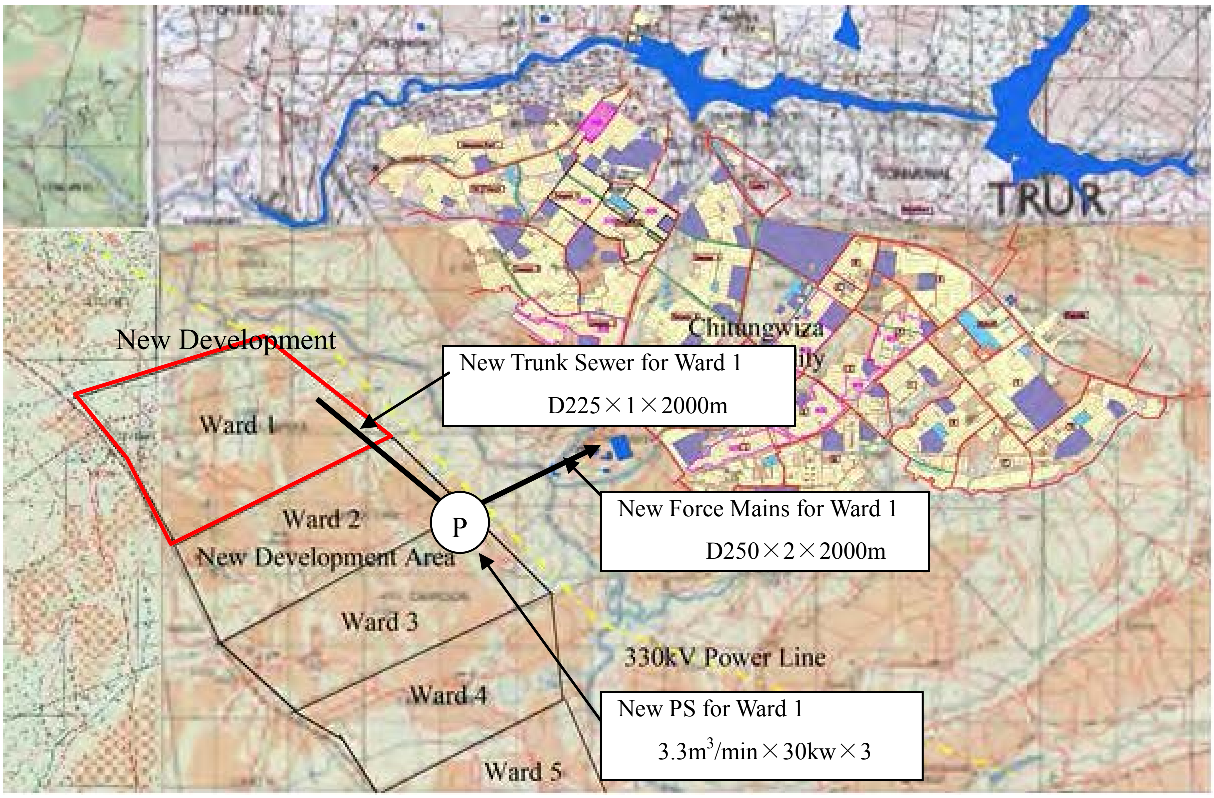


Figure 9.5.1 Ward 1 development and plan of sewerage

(3) Sewer clogging by sand

Sewers are clogged because of the presence of sand, and the cause of this phenomenon was researched in Chitungwiza. It was found out that the practice (custom) of residents is use sand when washing their cooking pots. Thus, unit sand generation was studied in this area by using the sand traps at selected residents' homes. A parallel study on sand accumulation in the Zengeza STP was also made to supplement the study on the sand generation.

It was confirmed that a lot of sewer alignments have been buried by sand, and that heavy siltation is a problem that is worsened when the sand solidifies. From the site survey it was revealed that the intermittent water supply has added another problem to sand clogging as it is very difficult to flush the consolidated sand out even if the flow is strong enough to wash it out. Thus, sand must be removed because of the following reasons: firstly, there is little hope that the intermittent water supply will be improved; secondly, flushing with water does not necessarily solve the problem; and thirdly, the existing sewers are not constructed under good hydraulic condition in terms of gradient.

The education and enlightenment program is aimed at the residents to reduce the use of sand. But at the same time, Jet Cleaning Machine or other similar machine is required to de-silt the sewers. This work will be included in the implementation plan.

(4) Measures for the sludge deposited at the bottom of the lake

The sludge at the bottom of the lake is distributed along the entire area of the Lake Manyame (81 km^2) and Lake Chivero (26 km^2). This has a big and continuing environmental impact on the water quality of the lake.

The bottom sludge has a direct influence on water pollution as it produces nutrients such as Nitrogen and Phosphorus when the water is in the anaerobic atmosphere. The huge amount of sediment deposited in the bottom of the lake comes from urban wastewater. Taking Lake Chivero, which was contracted in 1952, as an example: Since the rate of the sedimentation is from generally 1 mm/yr to 10 mm/yr, thickness of the sludge is thought to be about 130,000 m^3 : 26.3 km^2 $\times$0.001~0.0010 m = 26,300 ~ 263,000 m^3 $\Rightarrow$ intermediate value: 130,000 m^3

Lake Chivero would certainly need dredging, as well as the transfer, treatment and disposal of the sludge of 130,000 m^3 at a cost of 13,000,000 USD, assuming the unit cost to be 100 USD/m^3. Sludge removal work is not only very difficult but also takes extraordinary time and cost, and is therefore not practical as of this time.

The effect of the sludge to the water quality is important and should be researched on. However, this was not clarified in this study owing to the period of study and capability/experience of the local engineering consultant for both of sludge quality analysis and sludge sampling. EMA should gather additional water quality data, as well as monitor and research more on the sludge.

(5) Aeration of the water in the lake (Direct Purification)

In case aeration is adopted for a direct improvement of water quality in the lake, a mechanical aerator shall be most suitable and efficient choice. However, this method is only applicable to a small area and for a specific purpose. It is not appropriate in this case as a lot of aerators will be required in such a limited area, which will also require much electric power. Furthermore, the possibility to reduce BOD is insignificant, and may not be able to eliminate the nutritious salts. Another problem is that the location for aerators will be restricted since Morton Jaffray WTP takes water in each lake, and increased turbidity by mixing the water must be avoided for water treatment.

The necessity of this implementation should be studied by EMA, ZINWA and HARARE WATER, since the both lakes are used as water source for the Morton-Jaffray WTP.

(6) Purification by aquatic plant

Purification by aquatic plants complements sewage treatment if there is a low concentration of or diluted polluted water. Therefore, it is necessary to avoid the areas where raw sewage is discharged without treatment in the lake.

For this purpose, reed swamps must be shallow (approximately 0.6 m) to stimulate growth. Its treatment process is summarized to sedimentation, filtration and absorption. Although both lakes have a lot of creeks or arms, wide and shallow creeks and arms which enables this treatment are few with the depth increasing suddenly according to the distance from the shore. This is the reason why big reed clusters are rare in Lake Manyame and Chivero. To use approach to treat the lakes, it will be necessary to reclaim the creeks and arms to have a broader and more appropriate location for the reed field.

The system will include a sedimentation basin, and a set of reed shallow ponds. Periodical removal of anaerobic sludge from the sedimentation basin, the harvest of reeds and the prevention of mosquitoes must be regularly conducted. Since mosquitoes are the great cause of Dengue fever, careful maintenance must be taken. As an alternative to reeds, the water hyacinth can be another candidate for this method and these plants have been observed in Lake Chivero. The water hyacinth is native of South America, grows fast and has good nitrogen and phosphorus absorption capability. Because of its nature of floating growth, cultivation and harvest are easy. It also has high value as biomass resource. Removal of nitrogen and phosphorus of the lake can be greatly expected, although periodical harvesting, treatment and disposal of the plants are essential to the conservation of the water quality.

Since the implementation of this approach necessitates frequent harvest, the matter should be studied by EMA, ZINWA and HARARE WATER.

(7) Improvement of sanitary facilities

Septic tanks are sanitary facilities currently in use, and whose use will grow in number. Even in Chitungwiza Municipality where coverage of sewerage is 100%, new development areas still employ septic tanks. Harare South is also an area where septic tanks are commonly used, but where sanitation facilities need future improvement.

Effluent from septic tanks infiltrates the ground and is treated by the layers of soil. However, this can be a hazard to the groundwater if the soil condition is not suitable for infiltration. With the growth in the use of septic tanks, the quality of groundwater must be guarded through close monitoring,

< Conclusion >

To conclude, therefore, the Master Plan should adopt the rehabilitation of the sewerage system in the catchment area as a countermeasure for improvement of the current status. The on-going Zim-Fund project will rehabilitate the Crowborough and Firle STPs in Harare while both of the AWF project and Zim-Fund project will be applied for Chitungwiza. These are deemed to be appropriate from the result of pollution analysis. Augmentation of the facility will be needed for the Zengeza STP in 2020. Donors for the Norton Council must be looked for. Countermeasure for the sand issue will be taken as well.

New development area such as planned in Chitungwiza Municipality will be listed in the Master Plan for it to be included in future plans.

The procurement of heavy equipment to haul away sand removed from the site is indispensable in the sand removal program. They will be procured by Zim-Fund Also, water supply should be continuous and this should be ensured in the water supply plans.

The approaches such as sludge removal, aeration and the use of aquatic plants for treating lake water might be necessary in the future, but the Government must evaluate the effects of all these approaches. The local government, on the other hand, should establish a comprehensive sanitary facilities' program beyond this Master Plan.

9.6 Sewerage Planning in the Catchment

From the discussion made in the former section, sewerage planning was selected as the priority in the catchment. These activities are essential for water source conservation of the catchment. The planning philosophy and the outline of the facility plan for each city/municipality are enumerated in the Table 9.6.1:

Table 9.6.1 Sewerage Planning in the Catchment

City/Town	Planning Philosophy	Outline of the Plan	Supplemental Notes
Harare	1. Reduction of pollution load to the Mukuvisi, Marimba, Ruwa and Gwebi Rivers 2. Water recycle of the effluent from BNR facility 3. Irrigation use for the effluent from TF for both of pollution reduction and water reuse	1. Existing BNR and trickling filters (TF) to be rehabilitated urgently 2. Effluent from BNR to be discharged to the river 3. Effluent from TF to be sent to the Farms for irrigation 4. New construction of the STP for unswered area to be made in the mid term	1. Current Catchment population: 1,765,500 2. For urgent, old facility will be rehabilitated by **Zim-Fund** project
Chitungwiza	1. Reduction of pollution load to the Nyatsime River 2. Refurbishing the STP and employment of sustainable sewage treatment process 3. Irrigation use of the effluent from STP for both of pollution reduction and water reuse	1. Existing trickling filters to be rehabilitated urgently 2. Effluent to be sent to Imbwa Farm for irrigation. 3. Existing BNR process to be renovated to a modified activated sludge process to deal with the sewage flow increase in the mid-term 4. Effluent to be sent to Imbwa Farm for irrigation at the mid-term stage	1. Current Catchment population: 330,000 2. For urgent, old facility to be rehabilitated by **AWF** project and Zim Fund under AfDB 3.. For Mid Term: Facility 2000 (BNR Process commissioned in 2000) to be rehabilitated as an appropriate process as Oxidation Ditch Process before 2017
Ruwa	1. Reduction of pollution load to the Ruwa River 2. Irrigation use of the effluent from TF for both of pollution reduction and water reuse 3. Upgrading the existing facility	1. Existing Sewage Stabilization Ponds to be rehabilitated urgently. Effluent will be sent to the Farm for irrigation 2. Expansion of the facility to be made in the mid term to cope with the flow increase	1. Current Catchment population: 25,000 2. Funding to be secured for the rehabilitation work
Epworth	1. Reduction of pollution load to the Mukuvisi and Ruwa Rivers 2. Monitoring and evaluatin of the current sanitation system	1. Study/Plannning of sewerage system 2. Improvement of the existing system 3. New Construction of sewerage system	1. Current Catchment population: 131,000 2. For urgent, commencement of the study on environment/sewerage 3. Finding of funding source or donors
Norton	1. Reduction of pollution load to the Lake Manyame 2. Irrigation use for the effluent from TF for both of pollution reduction and water reuse 3. Refurbishing the STP and augmentation of the sewage treatment capacity	1. Existing trickling filters and pump station to be rehabilitated urgently 2. Effluent to be sent to the Farm for irrigation. 3. New construction of the additional trickling filters to be made to deal with the sewage increase after finding funds or donor.	1. Current Catchment population: 51,000 2. For urgent, donors /funding source to be found for the rehabilitation of the existing facility 3. For Mid Term, Expansion of the facility for sewage increase

Source: JICA Project Team

1) Urgent measure

Urgent rehabilitation programs in the catchment for Harare and Chitungwiza have been implemented by Zim Fund and AWF project as stated in section 9.5. Since the evaluation of both projects made through the pollution analysis was basically effective, urgent measures for the sewerage in both municipalities are sufficient except for the areas excluded from the project. However, in the above-mentioned project, the Municipality/Council of Ruwa, Epworth and Norton are not included from the Zim-Fund or the AWF.

The result of the pollution analysis shows that the employment of the advanced BNR system does not have much advantage compared to conventional system in terms of water quality conservation. Thus, it is not necessary to use the BNR process.

< Norton >

Before 2000, the sewerage system of Norton was functioning, and the effluent was being sent to irrigate farmlands. However, after 2000, the sewerage system malfunctioned, and vandals broke the pump station handling effluent water for irrigation purposes. Thus, raw sewage is being directly discharged to Lake Manyame, polluting the lake. Urgent measures must be taken to rehabilitate the facility in order to save the water source. A study on the sewerage plan will be required, and donors must be found to fund this project.

< Ruwa >

It is necessary to rehabilitate/upgrade the existing wastewater stabilization pond. Effluent should be transferred to the farms for irrigation to conserve water quality in Ruwa River. A study on the improvement of the sewerage facilities will be required, and donors must be found to fund this project.

< Epworth >

The municipality does not have a sewerage system, but this will be needed in the near future in order to secure the groundwater source. A study on the sewerage plan/ system will be required, and donors must be found to fund this project.

9.7 Planning of Zengeza STP

For the Zengeza STP, urgent rehabilitation and augmentation in the mid-term are necessary. Urgent rehabilitation has been conducted under AWF project (AfDB, donation) for pipelines and pump stations. Bidding has been on-going for the Zengeza STP rehabilitation. The Scope of Works is rehabilitation of the old trickling filters for the capacity of about 20,000 m^3/day including pump stations to send the effluent to the Imbwa Farm. It does not include the rehabilitation of existing BNR facility. Even sludge treatment plant will not be needed. Sludge (Humus from Trickling Filters) can be sent to the Imbwa Farm after the stabilization in the maturation ponds. For the urgent measure within five years, rehabilitation of the trickling filters will be adequate for the inflow of about 20,000 m^3/day. However, augmentation of the facility will be needed after five years due to population growth. The existing BNR facility can be used for the augmentation planning.

Table 9.7.1 shows the Alternatives for the Zengeza STP Rehabilitation as follows:

Plan 1 Stabilization Pond: New Construction of Stabilization Ponds

Plan 2 Trickling Filters + Oxidation Ditch:
Rehabilitation of existing TF by Zim=Fund Project,
Remodelling of the existing BNR
with reuse of existing sludge treatment facility

Plan 3 Trickling Filters + BNR:
Rehabilitation of existing TF by Zim=Fund Project,
Full-Rehabilitation of existing BNR

For the Plan 1, new construction of stabilization pond, a lot / area of 100 ha must be secured to execute the plan. This facility can be constructed in the existing waste disposal site without any cost for the land. Capital expenditure (CAPEX) for the Stabilization pond will be 128.6 mil. USD, although the operation expenditure (OPEX) will be lower, at 1,077 thousand USD/yr. For the Plan 2, CAPEX will be 20.1 mil USD with the OPEX of 2,405 thousand USD/yr. For the plan 3, CAPEX will be 15.4 mil USD with the OPEX of 4,687 thousand USD/yr.

Although land acquisition cost is zero, Plan 1 is most expensive for the facility construction. The reason of the highest construction cost is rock excavation and necessity of water proof sheet for the facility. Opex of the Plan 1 is cheapest. Since the plan does not use the existing BNR facility, it will waste the existing BNR facility and sludge treatment facility. Effluent must be sent to Farms for irrigation, not suitable for discharge into the river.

Plan 2 is a plan which utilises the rehabilitated TF and existing BNR facility after changing the structure for Oxidation Ditch Process. The plan 2 cannot discharge the effluent to the river either due to unsatisfactory water quality for discharge to the river. Existing sludge treatment facility will be used.

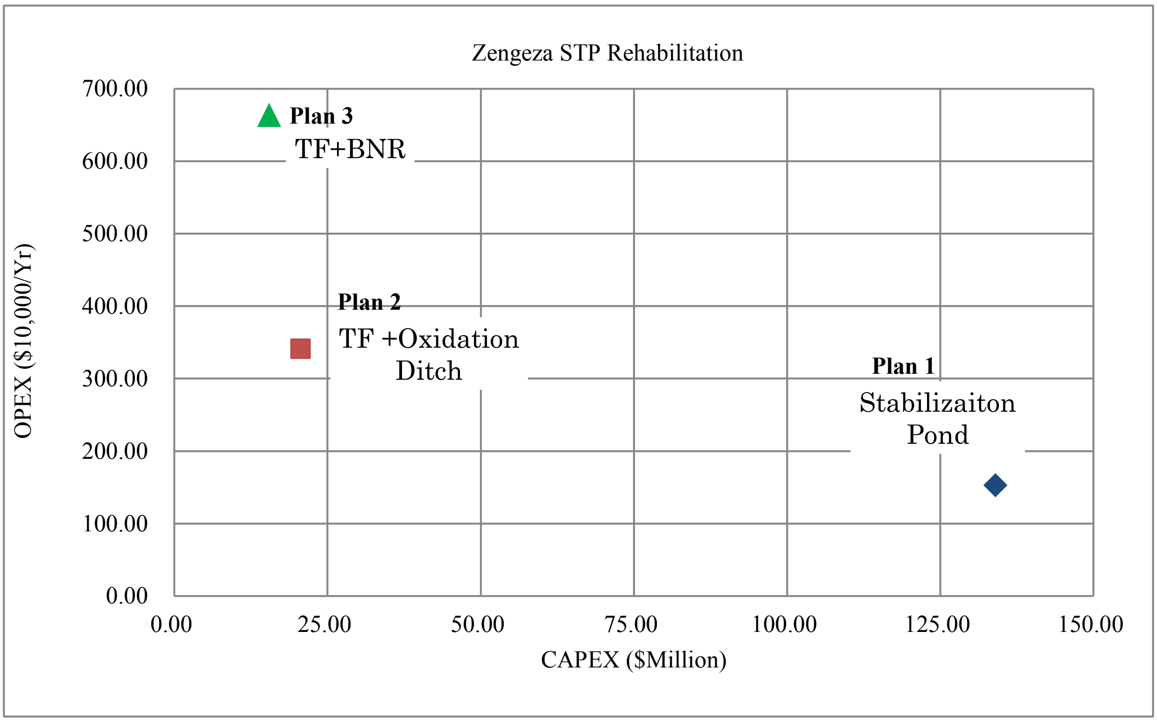
Plan 3 uses the rehabilitated TF and refurbished existing BNR, with the highest electricity consumption, and highest O&M cost. Electricity cost will be far higher than Plan 2. Effluent from BNR can be discharged to the river having the effluent return to the natural water cycle. Effluent from TF must be sent to the Farms for irrigation.

From these reasons, Plan 2 is recommended, from the standpoint of utilizing the existing BNR facility, having fairly good effluent water quality, economical, and having an aspect of easy operation and maintenance.

Table 9.7.1 Evaluation of Alternatives for the Zengeza STP Rehabilitation

Plan	Process	CAPEX USD ($\times 10^6$)	OPEX USD/Yr ($\times 10^4$)
Plan 1	Stabilization Pond	128.6	107.7
Plan 2	Oxidation Ditch +Trickling Filter	20.1	240.5
Plan 3	BNR + Trickling Filter	15.4	468.7

Source: JICA Project Team



Source: JICA Project Team

Figure 9.7.1 Evaluation of 3 Plans for ZENGEZA STP Rehabilitation

CHAPTER 10 IMPROVEMENT PLAN ON SOLID WASTE MANAGEMENT

10.1 Approach to the Formulation of the Improvement Plan

The approach to the formulation of the improvement plan on the solid waste management is shown in Figure 10.1.1. Based on the review of current issues / problems as well as the requirement of the laws, regulations and national strategies which were collected and identified in the field survey, improvement options are proposed. These options are then evaluated, selected, and prioritized for implementation. The planning framework, such as future waste generation amount, target collection, waste diversion level and the waste stream for the target years, are then set up to put each improvement plan into proper and tangible perspective. Finally, the cost estimate, implementation plan and the prioritization toward actual implementation are discussed.

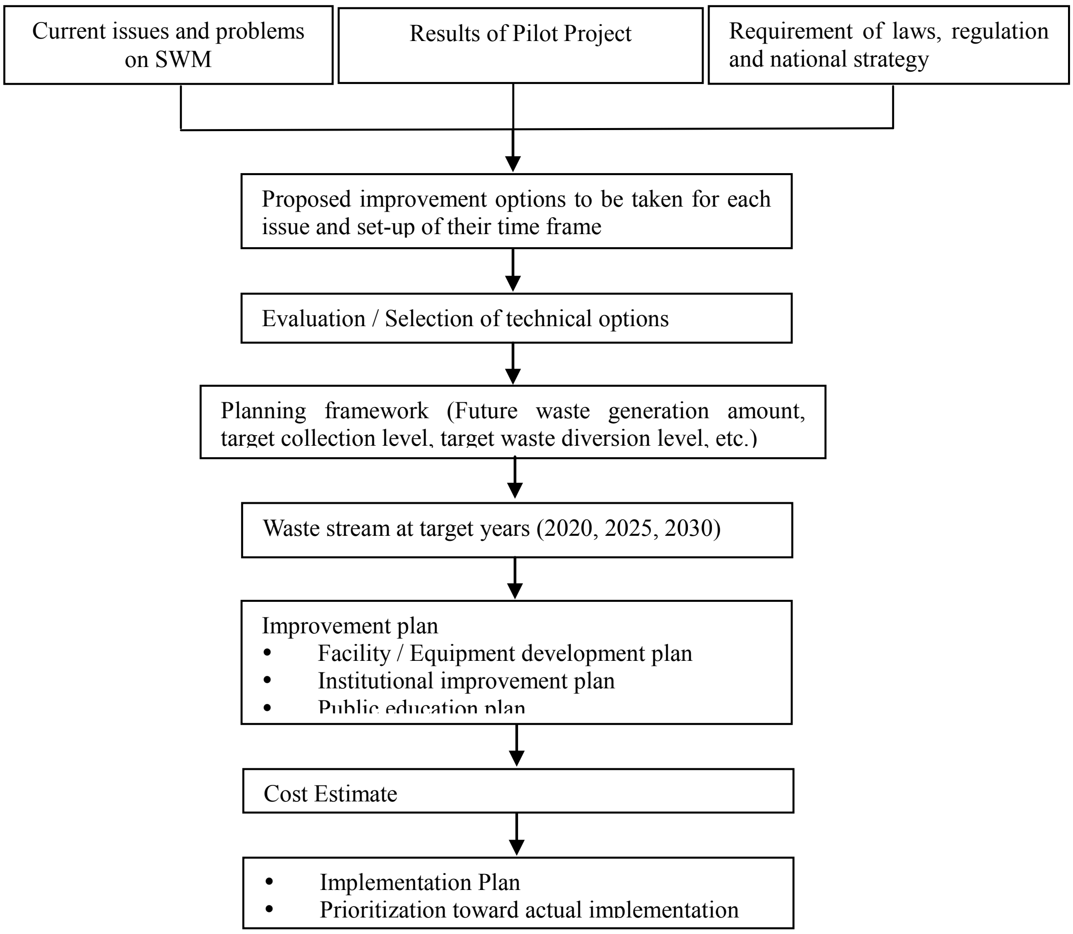


Figure 10.1.1 Approach to the Formulation of the Master Plan on SWM

10.2 Identification of Current Issues and Problems on Solid Waste Management

The following issues and problems were identified through the field survey in relation to solid waste management. Littering and illegal dumping were identified in and around the city and the practice of the final disposal is still open dumping without any measures for pollution control. The lack of the municipality's capacity on collection and transport was also identified as shown in the lack of collection vehicles and heavy machines.

- Illegal dumping sites in and around the city caused by inappropriate discharge of the community residents and the lack of collection capacity
- Insufficient collection and transport capacity of the municipality
- Open dumping of existing final landfill which is not properly managed (EMA made recommendation order to improvement of existing final landfill)
- Insufficient capacity in operation and maintenance (e.g. non-regular supply of fuel and tire)
- No concrete future plan for the municipality's solid waste management and waste diversion plan (waste reduction or 3Rs)

10.3 Results of Pilot Project

As mentioned in Chapter 7.3, a pilot project was carried out in order to examine the possibility of combination collection system of primary collection by the communities and the secondary collection by the municipality for the non-collection service area of the municipality.

The following outcome was obtained through the implementation of the pilot project;

- Most of the community residents had concern on the pilot project and they recognized that the pilot project was a good attempt.
- Most of the community residents recognized that they secured a cleaner environment after the pilot project compared to the previous state before the pilot project.
- Most of the community residents were willing to participate in the activities of waste reduction, recycling and composting waste at household level.
- The operators were willing to continue their work of primary collection after the implementation of the pilot project.
- Other communities in the municipality's non-collection areas who were not part of the pilot project expressed their concern for the implementation of the pilot project in their communities as well.

The communities' opinion as shown below was confirmed at the stakeholder meetings, on one hand;

- One of NGO groups can play an important role as a partner in public education including source separation.

- The municipality's collection service of once a week is not sufficient, the service should be provided twice a week.

Above results shows that the attempt of the pilot project can utilized for formulation of the improvement plan on SWM.

10.4 Requirement of Laws, Regulations and National Strategy on Solid Waste Management

The proposed improvement plan should basically follow the requirement of the laws and regulations and the national strategies on solid waste management.
The major items of the requirement are shown as below.

- Recommended collection level based on national strategy
- Recommended waste diversion level based on the results of field survey
- Improvement of final landfill (development of sanitary landfill)
- Recommendation of EMA for improvement of existing final landfill

The target level on waste collection and diversion should be set up based on the national strategy. The recommendation order of EMA was issued to improve the existing open dumpsite. This can be done by safely closing the open dumpsite and developing a sanitary landfill.

10.5 Potential Improvement Measures on Solid Waste Management

The issues and problems on solid waste management widely range from the current inappropriate discharge, collection / transport, inter-mediate treatment and final disposal. Improvement measures should be taken at each treatment stage of the waste stream.

<u>Discharge</u>

Some of the causes of the littering and the illegal dumping are lack of awareness of the residents of the municipality's rules on collection / transport, and/or plain indifference. Implementation of cleanup and the strengthening of law enforcement are possible measures. A promotion of home composting through source separation and waste reduction at generation source is also an important measure.

<u>Collection and Transport</u>

Non-collection service areas, or areas where the municipality's collection service cannot access, were identified. The lack of access to collection service can also be another cause of littering and illegal dumping. In any case, the major cause of non-collection service is insufficient number of collection vehicles, container and heavy machines to collect and transport waste. Implementation of cleanup at the illegal dumping areas should be an urgent component of the measures. Procurement of collection vehicles and heavy machines should be implemented at an early stage of the master plan. The primary collection by CBOs (Community Based Organizations) at non-collection service areas as described previously also should be included in the improvement measures.

Intermediate Treatment

The municipality has neither concrete plan nor action plans for 3Rs and waste diversion to reduce the amount of waste disposed at the open dumping site. As an intermediate treatment, a recovery of recyclable materials through development of community composting of biodegradable waste, a central composting facility or a MRF (Material Recovery Facility) should be developed as one of the improvement options.

Final Disposal

The existing final disposal is carried out by open dumping in unsanitary conditions. The municipality was in receipt of a recommendation order to improve the existing open dumping. Safety closure of existing open dumpsite and a development of sanitary landfill are proposed for the measure.
The improvement options are summarized in Table 10.5.1.

Table 10.5.1 Summary of Improvement Measures

Solid Waste Management	Problem	Potential Measures for Improvement
Discharge	• Illegal dumping was identified throughout the city which may cause environmental or public health risks • Reduction of waste generation	• Implementation of cleanup activities • Enhancement of enforcement of laws and regulation • Source separation • Home composting
Collection and transport	• Illegal dumping due to the local conditions beyond the municipality's collection service • Insufficient capacity of collection and transport due to breakage and traffic accidents	• Implementation of cleanup activities • Development or procurement plan of equipment for collection and transport operation • Community based collection activity (Primary collection by CBOs)
Intermediate treatment	No concrete action plan for waste diversion / 3Rs or development of intermediate treatment facilities	• Development of intermediate treatment facilities for waste diversion (e.g. Home composting, community composting, central composting, material recovery facility, incineration and bio-gasification, etc.)
Final disposal	Open dumping site without appropriate management may cause environmental and public health problems	• Safe closure of existing open dumping • Development plan of sanitary landfill

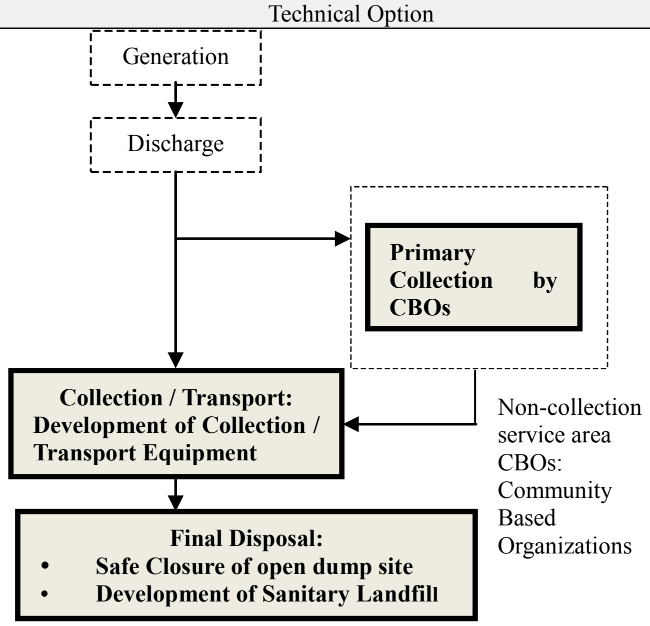
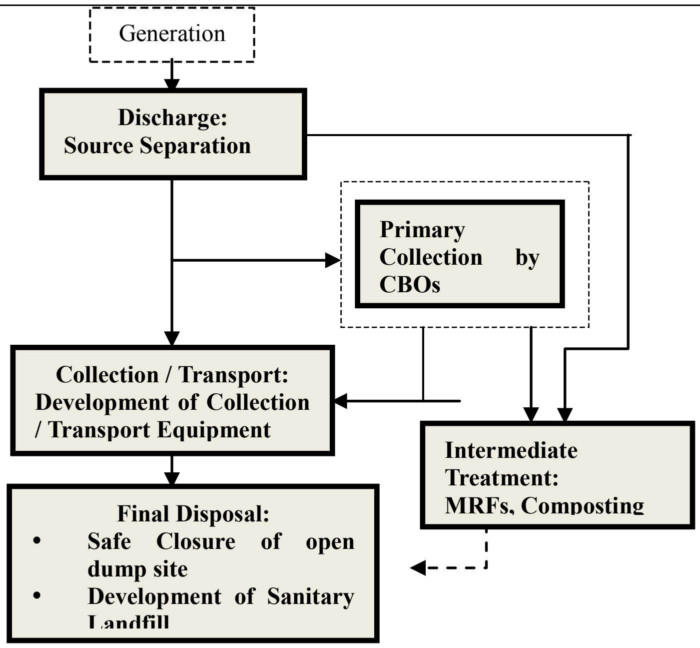
10.6 Evaluation and Selection of Technical Options and Proposed Improvement Plan on Solid Waste Management

10.6.1 Possible Technical Options

Solid waste management is composed of a series of treatment processes in the waste stream from the waste generation, collection, transport, intermediate treatment and final disposal. Possible technical options and their outline in the waste stream are given in Table 10.6.1 (The characters in bold face inside a bold rectangle line shows the proposed component in the master plan.).

Table 10.6.1 Possible Technical Options in Waste Stream

	Technical Option	Outline
Zero Option	Generation ↓ Discharge ↓ Collection / Transport ↓ Final Disposal	Zero option shows the municipality's existing solid waste treatment system without any development or procurement of collection / transport equipment and facility for intermediate treatment and final disposal. The option still uses the existing system
Option 1	Generation ↓ Discharge ↓ **Collection / Transport: Development of Collection / Transport Equipment** ↓ Final Disposal	Only a procurement of collection / transport equipment is added to existing system (Zero Option). Option 1 has neither a development of a final disposal facility which was recommended by EMA nor an intermediate treatment facility.
Option 2	Generation ↓ Discharge ↓ Collection / Transport ↓ **Final Disposal:** • **Safe Closure of open dump site** • **Development of Sanitary Landfill**	This option implements a safety closure of the existing dumping site and the development of a sanitary landfill in compliance of EMA's recommendation order for improvement.

<table>
<tr><th></th><th>Technical Option</th><th>Outline</th></tr>
<tr><td>Option 3</td><td>
</td><td>A combination of primary collection by CBOs and secondary collection by the municipality's collection services is developed for the current non-collection service areas through procurement of collection / transport equipment.
In addition, safety closure of existing open dumpsite and development of sanitary landfill are implemented.</td></tr>
<tr><td>Option 4</td><td>
</td><td>Intermediate treatment facilities are added to Option 3.</td></tr>
</table>

10.6.2 Evaluation of Technical Options

The evaluation of each technical option is shown in Table 10.6.2. Zero option will still leave the city in unsanitary condition with the existing non-collection service area, illegal dumping sites and adverse risk on surrounding environment at the existing open dumping site. In Option 1, collection situation is expected to be improved to some extent. However, in this case, non-collection service areas due to the lack of access of the municipality's collection service and the unsanitary condition of existing open dumping in final landfill, will still exist. In option 2, the existing open dumping at final landfill is improved. However, the current state of illegal dumping and existence of non-collection area will continue to exist. In option 3, collection and final disposal system are improved except waste diversion.

Option 4 shows the improvement of collection and final disposal system including cleanup of illegal dumping sites and the elimination of non-collection service area. The demerit would be the high cost of development as well as operation and maintenance.

Taking the time frame of the master plan up to 2030, the cleanup of illegal dumping and the procurement of collection/ transport equipment should be implemented as high priority. The safe closure of existing open dumpsite and the development of sanitary landfill which is currently recommended by EMA should follow these components. The intermediate treatment of recyclable waste such as development of MRF (Material Recycle Facility) and central compost facility should be implemented at the phase where a level of SWM maturity has been achieved. The home composting and community composting should be implemented as early as possible in terms of waste reduction at generation source.

Table 10.6.2 Evaluation of Technical Options

	Evaluation Criteria							Overall Evaluation
	Sanitation Improvement of Illegal dumping sites	Sanitation Improvement caused by Expansion of Collection Service Area	Sanitation Improvement of Final Landfill	Reduction of Incoming Waste Amount to Final Landfill	Improvement of Surrounding Environment	Development Cost	Operation and Maintenance Cost	
Zero Option	×	×	×	×	×	○	○	×: Sanitation improvement is not expected.
Option 1	×	○	×	×	△	△	△	△: The collection area is expanded. However, non-collection service area and illegal dumping areas still exist. Final landfill is not improved.
Option 2	×	×	○	×	△	×	△	△: Final landfill is improved. However, illegal dumping area and non- collection areas still exist.
Option 3	○	○	○	×	○	×	△	△: Improvement of collection and final disposal is expected except waste reduction of waste amount to final landfill.
Option 4	○	○	○	○	○	×	△	○: Improvement of collection and final disposal is expected.

Notes; ×: Not suitable, △: Partially suitable, ○: Suitable

10.7 Setup of Planning Framework

10.7.1 Projection of Future Waste Generation Amount

(1) Approach to projection

There is a positive correlation between the growth of per capita GDP and waste generation. The waste generation is also influenced by socio-cultural background and lifestyle. Taking all these into account, the future waste generation can be estimated in view of the economic development level, socio-cultural background, and lifestyle of the country. The flow of the projection of future waste generation amount per capita is shown in Figure 10.7.1.

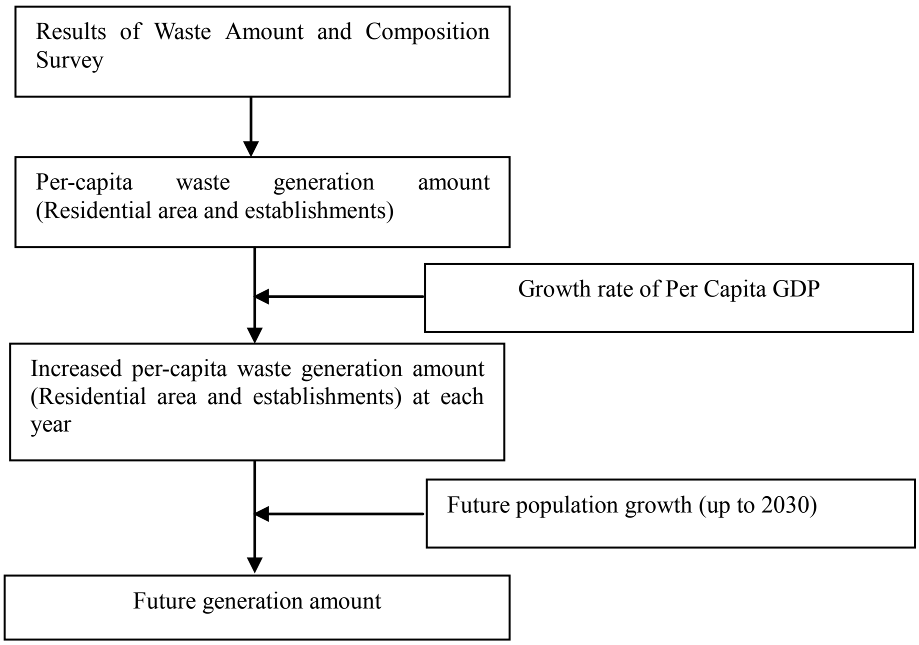


Figure 10.7.1 Flow of Projection of Future Waste Generation Amount per Capita

According to the data source of "World Fact Sheet, 2001" and "World Bank, 2003", the growth rate of waste generation per capita from 2010 to 2030 is estimated as almost 1.0% for the predicted growth rate of GDP per capita in developing countries as shown in Table 10.7.1. Table 10.7.2 shows the past performance of the growth rate GDP per capita in Zimbabwe in the recent years. As shown in Table 10.7.2, the average growth rate of GDP per capita for 2009 to 2011 is almost 7.0 %. Therefore, the growth rate of 1.0 % of waste generation per capita can be applied for the study to project the amount of waste generated in the future.

Table 10.7.1 Projection of Growth Rate of GDP per capita and Waste Generation per Capita

Countries	Growth Rate of GDP per capita (%)		Waste Generation per Capita (kg/day/person)		Growth Rate of Waste Generation per Capita (2010 - 2030)
	2010	2030	2010	2030	
India	6.0	7.0	0.79	0.97	0.010

Countries	Growth Rate of GDP per capita (%)		Waste Generation per Capita (kg/day/person)		Growth Rate of Waste Generation per Capita (2010 - 2030)
	2010	2030	2010	2030	
Nepal	3.0	4.2	0.35	0.44	0.012
Pakistan	4.8	5.2	0.44	0.55	0.011
Bangladesh	4.8	5.0	0.73	0.98	0.015
Sri Lanka	4.9	5.3	0.59	0.73	0.011
Average					0.012

Source: World fact sheet, 2001 and World Bank, 2003

Table 10.7.2 Growth Rate of GDP per Capita in Past 4 Years in Zimbabwe

Unit: %

	Year			
	2009	2010	2011	2012
Growth Rate	5.80	8.10	9.32	4.67
Average of Growth Rate per Capita (2009-2012)				6.97

Source: IMF - World Economic Outlook Databases, 2012

(2) Projection of future waste generation amount

The daily waste generation amount per capita is estimated to increase by 1.0% annually. Accordingly, the household waste generation is expected to increase by same rate of 1.0% annually. The waste generation of establishments is calculated by using the current ratio of existing waste generation amount of residential areas with those of establishments. The future waste generation amount at each target year is shown in Table 10.7.3 and Figure 10.7.2.

Table 10.7.3 Future Waste Generation Amount

Unit: ton/day

	Year				
	2012	2015	2020	2025	2030
High	2.9	3.2	3.6	4.0	4.5
Middle	39.6	43.0	49.0	54.7	60.9
Low	119.2	129.4	147.5	164.7	183.3
Schools	1.3	1.5	1.7	1.9	2.1
Corner shops	0.2	0.3	0.3	0.3	0.4
Shops	4.3	5.0	5.7	6.4	7.1
Factories	7.1	8.3	9.5	10.6	11.8
Markets	12.9	15.1	17.2	19.2	21.4
Total	187.5	205.7	234.5	261.9	291.5

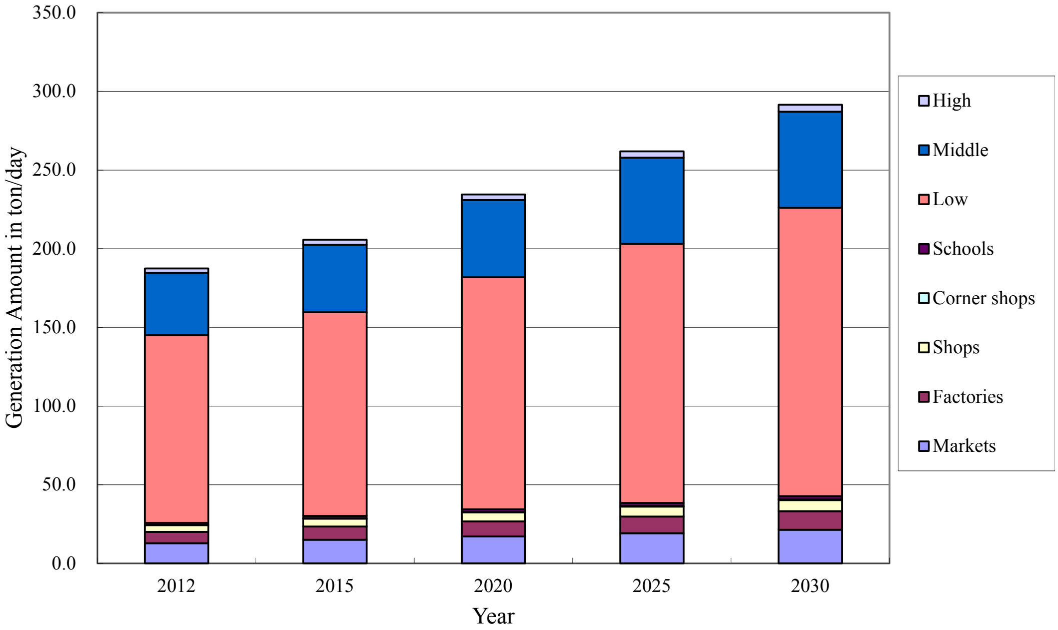


Figure 10.7.2 Future Waste Generation Amount

10.7.2 Setup of Target Collection and Waste Diversion Level

(1) Approach to setup of future waste collection level

The approach to setting up the future collection ratio for the target years of 2020, 2025 and 2030 is shown in Figure 10.7.3. The each ratio of future waste collection and diversion is set up by referring to the recommendation of the draft national strategy.

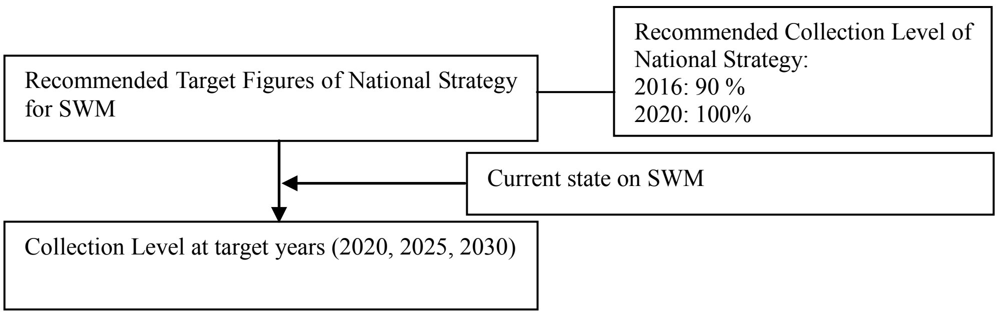


Figure 10.7.3 Flow of Setting-Up of Future Waste Collection and Diversion Ratio

As shown in Table 10.7.4, the future waste collection ratio is set as 100 percent from 2020 to 2030.

Table 10.7.4 Planned Waste Collection Level

Unit: %

	Target Year			
	Current	2020	2025	2030
Waste Generation	100.0	100.0	100.0	100.0
Waste Collection Level to Waste Generation	35.9	100.0	100.0	100.0

(2) Approach to setup of future waste diversion level

The approach to setting up the future waste diversion ratio at the target years of 2020, 2025 and 2030 is shown in Figure 10.7.4. The future waste diversion ratio is set up based on the results of WACS (Waste Amount and Composition Survey).

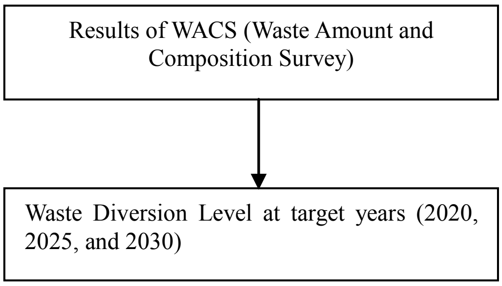


Figure 10.7.4 Flow of Setting-Up of Future Waste Diversion Level

Table 10.7.5 shows the results of WACS indicating that the ratio of the recyclable waste of plastics, metals, carton box and used papers to total waste generation is 8.0% (= 4.5 + 0.7 + 2.8) and the ratio of the organic waste to the total generation is about 85%. The target diversion level at 2030 is set as 30 percent of the results. Thus, the waste diversion level of recyclable materials is set as 3.0% (≒ 8.0 × 0.3), and the ratio of total compostable waste is set as 25% (= 85.0 × 0.3), 28%. Therefore, the future waste diversion level consisting of recycling of recyclable materials and composting of organic (biodegradable) waste is set as shown in Table 10.7.6.

Table 10.7.5 Results of Waste Composition from WACS

Generation Source	Composition in Percentage				Waste Generation (t/day)	Waste Generation (%)
	Plastics	Metals	Cardboard + Used Papers	Organic Waste		
High	5.20	0.83	2.43	80.53	2.9	1.5
Middle	5.70	0.84	2.25	77.99	39.6	21.1
Low	3.10	0.67	1.90	89.13	119.2	63.6
School	11.69	0.68	16.41	51.14	1.27	0.7
Corner Shops	29.3	0.58	32.98	29.94	0.23	0.1
Shops	12.49	0.09	13.91	72.15	4.29	2.3
Factories	7.39	0.08	4.31	76.38	7.13	3.8
Market	6.98	0.98	6.08	78.33	12.91	6.9
Total					187.53	100.0
Average	10.20	0.60	10.00	69.40		
Composition to Whole Waste (%)	4.50	0.70	2.80	84.60		

Table 10.7.6 Planned Waste Diversion Level

	Year			
	2012 (Current)	2020	2025	2030
Recovery Ratio of Recyclable Materials (%)	0.4	2	3	3
Composting of Biodegradable Waste (%)	0	8	12	25
Target WD Ratio (%)	0.4	10	15	28

10.7.3 Setup of Waste Stream at Target Years

(1) Procurement of equipment and development of facilities

To attain the target collection and waste diversion ratio, the procurement of collection/ transport equipment and the development of intermediate treatment facilities (MRF and Composting Facilities) should be implemented. In addition, the source separation at generation and the primary collection by CBOs (Community Based Organizations) at the non-collection service areas should be implemented. The implementation plans of attaining the target collection waste diversion level are proposed in Table 10.7.7.

Table 10.7.7 Proposed Component for Waste Collection at Target Collection Level

Target Improvement Level and Improvement Plan		Target Years			
		2012	2020	2025	2030
Improvement of Waste Collection	Target Waste Collection Level (%)	38 (Current)	100	100	100
	Proposed Improvement Plan	-	• Procurement of Collection Equipment • Procurement of Skip Bins • Implementation of Primary and Secondary Collection	• Procurement of Skip Bins • Implementation of Primary and Secondary Collection	• Procurement of Skip Bins • Implementation of Primary and Secondary Collection
Improvement of Waste Diversion	Target Waste Diversion Level (%)	-	10	15	28
	Proposed Improvement Plan	-	• MRF (2) • Home Composting (3) • Community Composting (5)	• MRF (3) • Home Composting (5) • Community Composting (7)	• MRF (3) • Home Composting (7) • Community Composting (8) • Central Compost Facility (10)

Notes: The figures including those in parenthesis show the target ratio to total generation amount.

(2) Waste stream at target years

Based on the set-up ratio of future waste collection and diversion for the target years of current, 2020, 2025 and 2030, the waste stream is shown in Figures 10.7.5 through 10.7.8.

Current

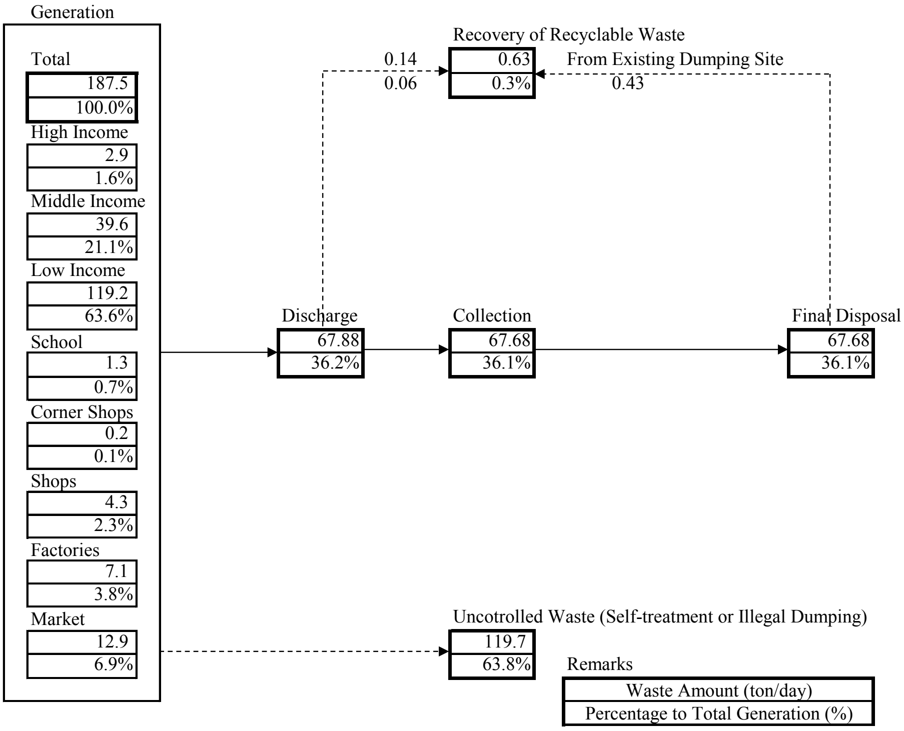


Figure 10.7.5 Waste Stream (Current)

At 2020

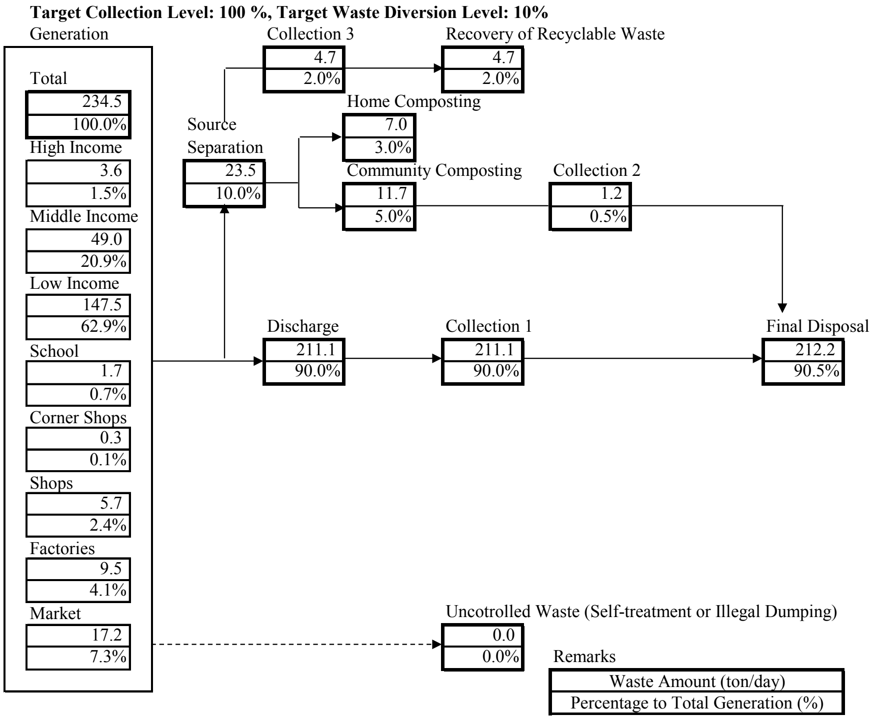


Figure 10.7.6 Waste Stream (2020)

At 2025

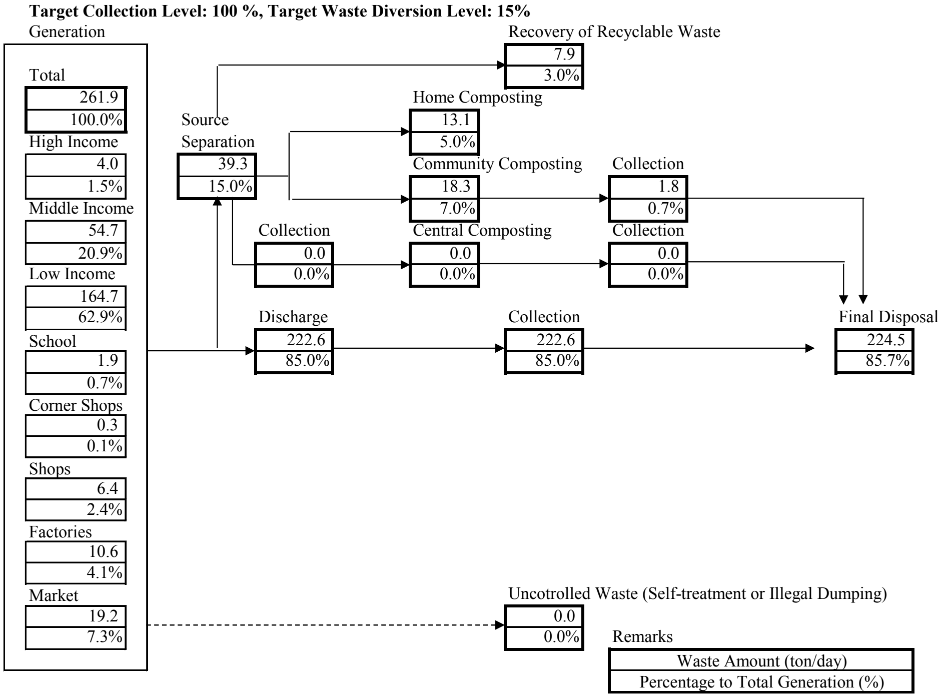


Figure 10.7.7 Waste Stream (2025)

At 2030

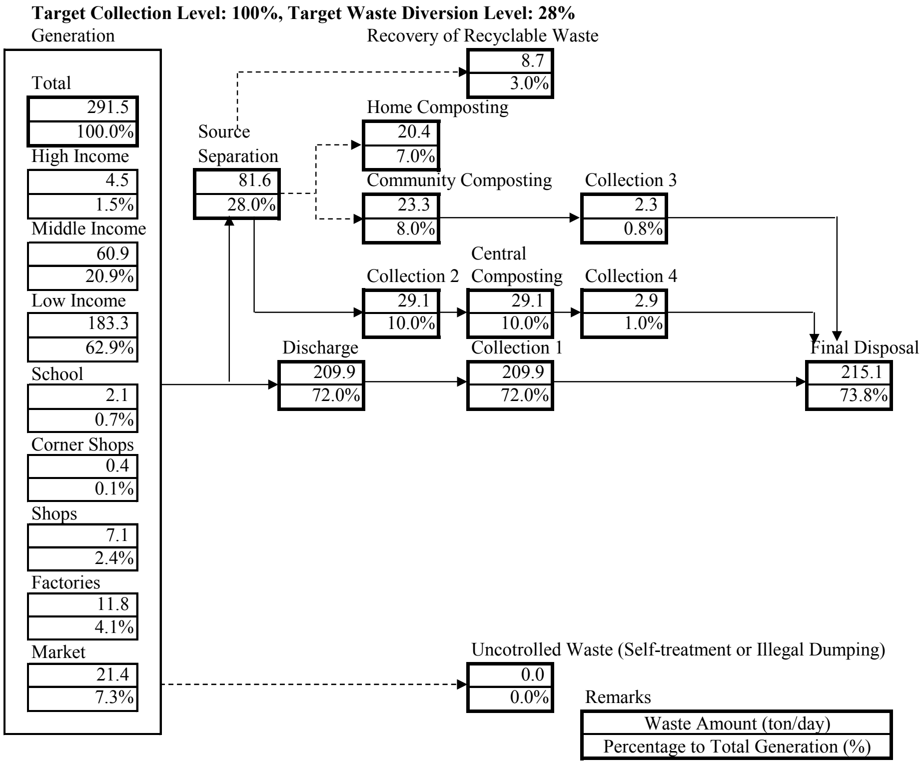


Figure 10.7.8 Waste Stream (2030)

10.8 Materials / Equipment Development Plan

In this section, the equipment requirements for collection / transport are studied. The future discharge at generation source and collection system should be set up prior to estimating the unit number of collection vehicles and container (skip bin), after which the unit number of collection vehicles and skip bins is computed.

10.8.1 Collection System

House-to-house collection is currently carried out in the city. A drastic change to other collection methods could bring adverse impacts. Therefore, the current house-to-house collection system should be continued in the future. However, in the non-collection service areas, primary collection using of manual carts by CBOs (Community based Organizations) is recommended combined with the secondary collection service by the municipality, after the community's transport to each collection station.

10.8.2 Frequency of Collection

Presently, the waste at the residential areas is collected once a week by the municipality. The waste of establishments, which is supposed to be daily, is actually collected irregularly. The collection frequency at the residential areas should be increased to twice a week at a minimum to maintain the community in good sanitary condition. The waste at establishments should be collected daily based on the municipality's original plan.

10.8.3 Collection System by Type of Waste Generation

Table 10.8.1 shows the proposed collection system for the master plan. It proposes two types of collection systems for the areas accessible of the municipality's collection service at the residential areas. Two types of vehicles are proposed – tipper truck for its easy maintenance, and compactor truck for its workability and low personnel cost. Both vehicles will each target 50% of collection volume. As for the non-collection service areas, the combination system of primary collection using manual carts by CBOs and secondary collection using multi-loader plus skip bin by the municipality collection service is proposed. For the waste generation of the establishments, the system using multi loader plus skip bin is proposed.

Table 10.8.1 Proposed Collection System by Generation Source

Generation Source		Type of Equipment for Collection	Frequency of Collection
Residential Area	Areas of accessible of municipality's collection service	• Tipper truck (for 50% of target collection volume) • Compactor truck (for 50% of target	Twice a week

Generation Source		Type of Equipment for Collection	Frequency of Collection
		collection volume)	
	Areas of not accessible of municipality's collection service	Primary collection by CBOs (manual carts) + Secondary collection by municipality (multi loader) + Skip Bin	Twice a week
Establishments		Multi loader + Skip Bin	Daily

10.8.4 Estimation of Required Quantity of Collection Equipment

(1) Approach for computation of planned collection equipment

The planned number of collection vehicles and containers (skip bins) are shown in the flow of Figure 10.8.1 and 10.8.2. In estimating the collection amount for the target year, the waste amount is calculated from the carrying capacity of existing collection vehicles. After setting the planned carrying capacity, the required number of collection vehicles is obtained for the amount of waste to be collected for the target year. The required number of containers (skip bins) at the non-collection service areas and establishments is computed similar to that of the collection vehicles.

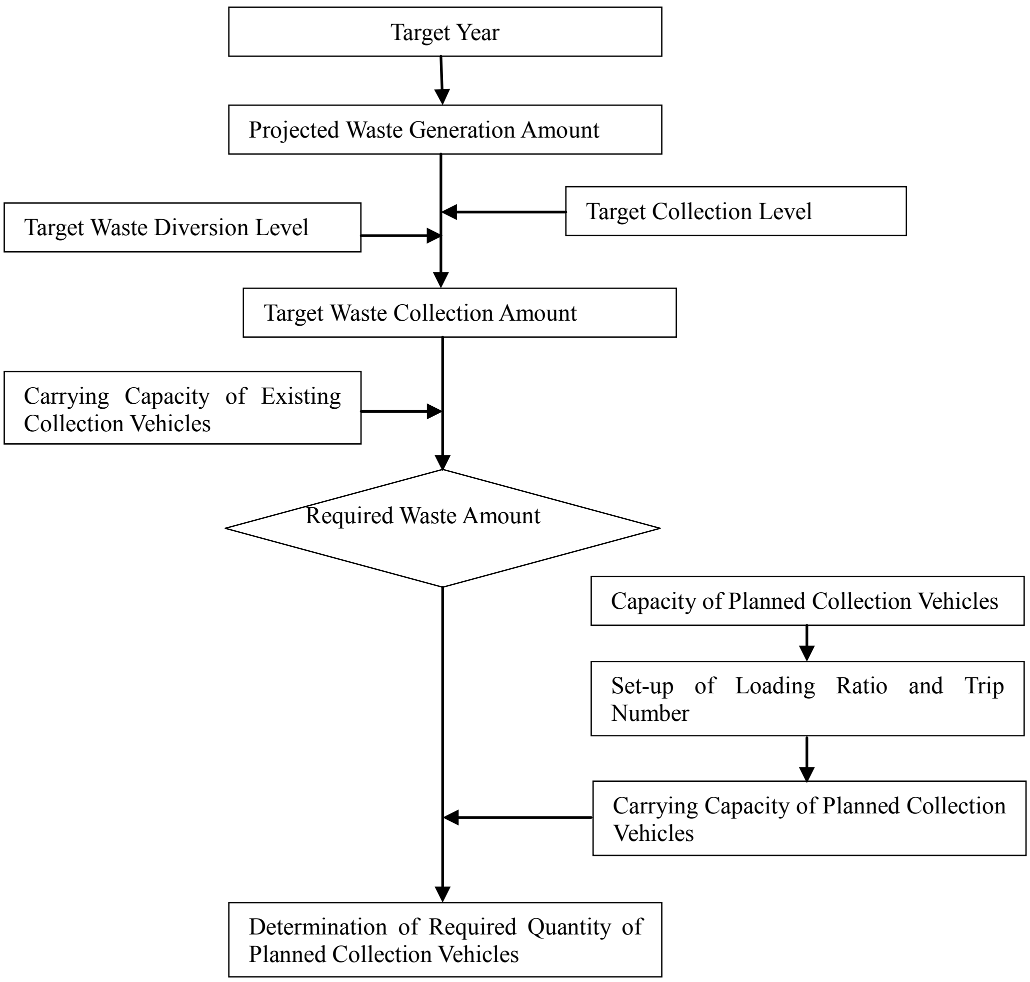


Figure 10.8.1 Flow of Estimation of Quantity of Collection Vehicles

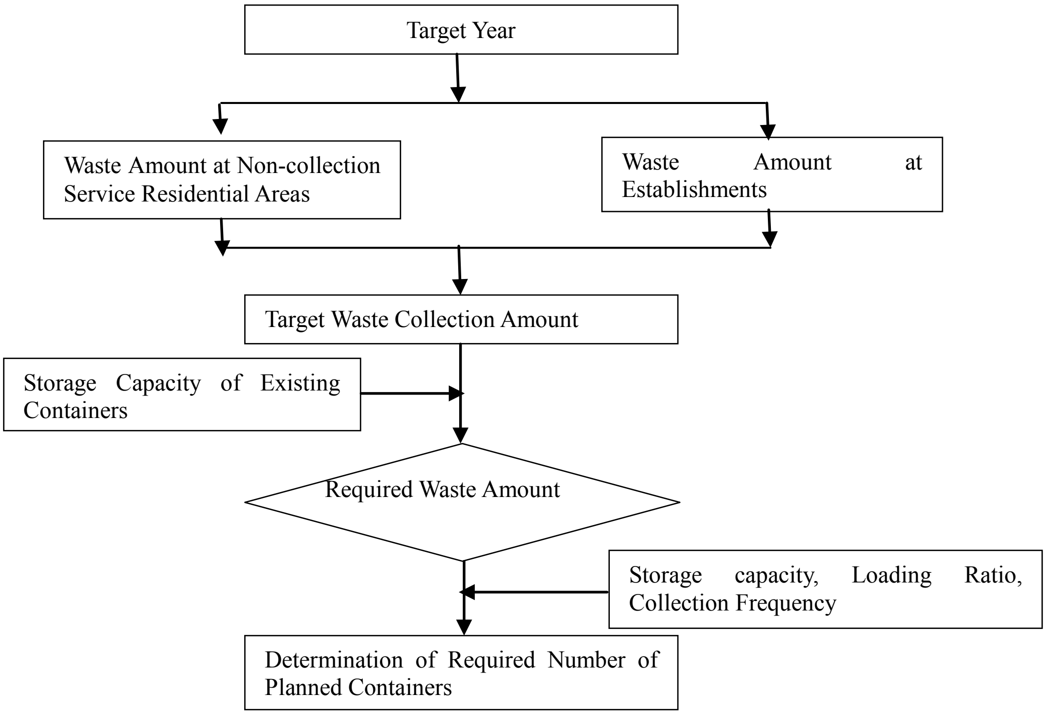


Figure 10.8.2 Flow of Estimation of Quantity of Containers (Skip Bins)

(2) Condition for computation of procurement

The condition of loading capacity, ratio and trip number is shown in Table 10.8.2. The condition of discarding for collection equipment is shown in Table 10.8.3. The planned procurement year is shown in Table 10.7.6.

Table 10.8.2 Condition of Loading Capacity, Ratio and Trip Number

Type of Equipment	Loading Capacity (m^3)	Loading Factor	Trip Number per Day
Tipper Truck	10	0.8	4
Compactor Truck	8	0.8	4
Multi Loader	- ($5m^3$ Skip Bin)	0.8	8
Container	5	0.8	-

Table 10.8.3 Condition of Discarding for Collection Equipment

Type of Collection Equipment	Condition of Discarding in Computation
Existing Vehicles	10 % discarded annually for the original number of vehicles commencing the year of 2013
Vehicles Newly Procured	100 % usable for 10 years from the procurement year and followed by 10 % discarded annually 10 years from the procurement
Container (Skip Bin)	20 % discarded annually for the original number of containers for five years from the procurement

Table 10.8.4 Planned Procurement Year

Type of Collection Equipment	Planned Year of Procurement
Collection Vehicle	2020
Container (Skip Bin)	2020, 2025, 2030

(3) Unit number of collection equipment for procurement

The estimated quantity of the collection equipment is shown in Table 10.8.7 by type of equipment and year of procurement.

Table 10.8.5 Estimated Quantity of Collection Equipment

Type of Equipment	Year of Procurement		
	2020	2025	2030
Tipper Truck (10 m^3)	10	-	-
Compactor Truck (8 m^3)	8	-	-
Multi Loader	20	-	-
Container (5 m^3)	364	364	364

10.9 Facility Development Plan

10.9.1 Intermediate Treatment Facility

(1) Home composting

Home composting of biodegradable waste at households will be a useful approach to reduce waste at generation source. The home composting will be implemented through promotion activities by facilitators by providing containers and composting seeds. The home composting pilot activity will target 100 households.

(2) Community composting

Community composting is also a useful method in terms of waste reduction at the community level in addition to home composting. The community composting is implemented by constructing a small-scale facility with a capacity of 250 kg/day, and equipped with shredder, scale and water jet machine. Its operation will be implemented as part of the activities of the CBOs (Community based Organizations) through the construction of 10 pilot facilities in 10 communities.

(3) Central composting facility

From the waste stream, a central composting facility of 30 ton/day is proposed to be developed in 2025 as a long-term SWM plan. A window-type composting process should be applied for the facility whose location is proposed at the existing open dump site. The major component of the facility is shown in Table 10.9.1.

Table 10.9.1 Facility Outline of Central Compost Facility

Item No.	Description	Unit	Quantity
1.	Land area	m^2	Approx. 7,700
2.	Building Area • Compost Building • Administration Building • Receiving Area	m^2	Approx. 5,700

Item No.	Description	Unit	Quantity
	• Primary Sorting Area • Others		
3.	Equipment for operation • Truck scale • Belt conveyor • Drum Cutter, Screen and Segregation, etc. • Wheel Loader • Open Dump Truck (2 ton , 4 ton)	LS	1

(4) MRF (Material Recovery Facility)

As earlier explained, in setting up the target waste diversion ratio and waste stream, a MRF (Materials Recycle Facility) with the capacity of 9.0 ton/day is proposed for development in 2020 as a mid-term stage. The facility is proposed to be constructed at existing open dump site. The MRF will be operated by applying manual sorting for plastics and metals.

The outline of the MRF is shown in Table 10.9.2. Some dealers are currently trading recyclable materials such as plastics, used papers, cardboard papers and used batteries in Harare. A recycling market was identified that they go to Chitungwiza to collect / buy these recyclable materials, process them in their facilities and sell to the domestic or overseas end users. The proposed MRF is estimated to enhance the incentive of above dealers for buying the recyclable materials through sorting and washing them at the MRF.

Table 10.9.2 Outline of MRF

Item No.	Description	Unit	Quantity
1.	Land area	m^2	1,500
2.	Building Area • Operation building (sorting, washing) • Administration Building	m^2	Approx. 420
	Other areas: • Temporary storage area for incoming recyclable materials • Truck scale • Storage areas (sorted materials) • Parking areas	m^2	Approx. 350
3.	Equipment for operation • Truck scale • Belt conveyor • Drum Cutter, Screen and Segregation, etc. • Wheel Loader • Open Dump Truck (2 ton , 4 ton)	LS	1

10.9.2 Final Disposal Facility

(1) Cleanup of illegal dumping sites

The illegal dumping identified throughout the city should be cleaned up immediately to preserve the urban sanitation landscape. The clean-up of about 897,000 m^3 of the illegally dumped waste (estimated by the subcontracted survey) should be carried out in one year by using the heavy machines of a front-end loader and a dump truck.

(2) Safety closure of existing open dump site

The existing final landfill is an unsanitary open dumping where leachate water, offensive odor and pests cannot be controlled. The municipality has received an improvement order for the existing open dumping to be improved and/or be safely closed down. The proposed safe closure of the existing open dumping site is composed of a removal / refilling of existing dumped waste in the designated area of the existing land, carrying out of soil covering, and installation of gas vent pipes and drain ditch. The outline of the safety closure of the existing open dumpsite is shown in Table 10.9.3.

Table 10.9.3 Outline of Safety Closure of Existing Open Dumpsite

Item	Description
Land area for safety closure	About 8.2 ha
Removal of existing dumped waste	About 724,000 m^3
Landfilling of waste	About 724,000 m^3
Soil covering	50 cm of soil cover
Rain water drain system	Drain ditch (About 1,300 m)
Fence (H = 2.5 m)	About 1,300 m
Gas vent pipe	40 units

(3) Development plan of new sanitary landfill

1) Evaluation of candidate sites of new landfill

Two candidate sites' suitability as a new sanitary landfill was evaluated. One candidate site was proposed by the urban planning services of the municipality and another site is the existing open dumping site. Table 10.9.4 shows the evaluation results on the sites' suitability. The candidate site proposed by the urban planning services is adjacent to the future lands for schools, housing lots and also to the existing river course which will be damaged by possible flood occurrence. Therefore, the existing dumping site should be utilized as a new landfill site.

Table 10.9.4 Evaluation on Suitability on New Sanitary Landfill Site

Evaluation Criteria	Candidate Site proposed by the Urban Planning Services*1		Existing Open Dump Site	
	Condition	Evaluation	Condition	Evaluation
Land ownership	State	Good	Municipality	Good
Possible land space for landfill	38.1 ha*2	Good	Approx. 25 ha	Good
Geological condition	Not clear	-	Estimated granite bed rock below 5m from the surface*3	below 5m from the surface is not recommended
Land use	Existing: Vacant land Future: Schools and	Unsuitable	Existing: Solid waste dumping site, Sewage Treatment Plant, no residential areas	Suitable

Evaluation Criteria	Candidate Site proposed by the Urban Planning Services*1		Existing Open Dump Site	
	Condition	Evaluation	Condition	Evaluation
	housing lots adjacent to the proposed site		Future: Possible same land use as existing	
Accessibility from city center and existing roads	4km from city center	Good	4km from city center	Good
Impact on or from surrounding water body	Adjacent to Hunyani River	Unsuitable	100 m from the drainage river receiving human sewage	Good
Overall Evaluation	Not suitable		Suitable	

Notes:
1) The candidate site was released by the municipality's official letter of A/3/13 dated 20 February 2012 addressing to the acting director of health service from the director of urban planning services
2) The figure is based on the same letter of above 1).
3) The geological condition is based on the geological survey which was carried out for the planning existing sewage treatment plant.

2) Facility plan of proposed sanitary landfill

i) Landfill site capacity requirement

Table 10.9.5 shows the required volume capacity which was computed from the incoming waste amount to the new landfill commencing the landfilling in 2019. A landfilling volume of about 1.6 million m^3 is required at the proposed existing dumping site.

Table 10.9.5 Estimated Landfilled Volume for New Sanitary Landfill

Year	Daily Incoming Waste Amount (t/day)	Annual Incoming Waste Amount (t/year)	Annual Incoming Waste Volume (m^3/year) (A)	Volume of Cover Soil (m^3/year) (B=30% × (A))	Total Embankment Volume per Year (m^3/year)	Accumulated Embankment Volume (m^3)
2019	205	74,739	93,424	28,027	121,451	121,451
2020	212	77,470	96,837	29,051	125,888	247,339
2021	215	78,361	97,951	29,385	127,337	374,676
2022	217	79,252	99,066	29,720	128,785	503,461
2023	220	80,144	100,180	30,054	130,234	633,694
2024	222	81,035	101,294	30,388	131,682	765,377
2025	224	81,927	102,408	30,722	133,131	898,507
2026	223	81,244	101,555	30,467	132,022	1,030,529
2027	221	80,562	100,702	30,211	130,913	1,161,442
2028	219	79,880	99,850	29,955	129,804	1,291,247
2029	217	79,197	98,997	29,699	128,696	1,419,943
2030	215	78,515	98,144	29,443	127,587	1,547,530

ii) Landfill method

A semi-aerobic landfilling method is applied as a sanitary landfill. The method utilizes the early stabilization of leachate, drainage of rain water, landfill gas vent and appropriate drainage of rain water.

iii) Outline of facility

Table 10.9.6 shows the outline of the new sanitary landfill. The new landfill will be composed of a truck scale, embankment dike, leachate collection facilities (impermeable liner sheet, leachate collection pipes, leachate reservoir pit), leachate treatment pond, rainwater drainage, access / onsite roads, groundwater monitoring wells, landfill gas vent pipes and administration office. For the construction of the new landfill, an excavation up to 5 m from the surface of existing dumpsite will be carried out after the removal of the existing dumped waste and an embankment dyke will be constructed at the lowest elevation.

Table 10.9.6 Outline of New Sanitary Landfill

Item	Component
1. Structure	• Excavation of existing open dump site and a construction of an enclosure dike • Estimated land landfill area: 200m × 380m
2. Landfill methods	• Semi-aerobic landfilling
3. Leachate collection facilities	• Impermeable liner sheet • Leachate collection pipes (main, branch) • Leachate reservoir pit
4. Leachate treatment	Recirculating method using pump
5. Rain water drain system	Rainwater drain ditch
6. Connection Road	Access road / onsite road
7. Groundwater monitoring	Groundwater monitoring wells
8. Weighing system of incoming waste	Truck scale
9. Landfill gas	Landfill gas vent pipes

10.9.3 Cost Estimate

For the engineering estimated construction cost, operation and maintenance cost on the solid waste management refer to Section 11.7.4 and 11.8.3. The total estimated cost for the proposed solid waste management system is 71,086 K USD, respectively. The total operation and maintenance cost, on one hand, is estimated 3,910 K USD at the target year of 2030.

10.10 Implementation Schedule

The implementation schedule is shown in Figure 10.10.1. The following component should be implemented with high priority

- Cleanup of illegal dumping sites
- Procurement of collection equipment
- Home composting
- Safety closure of existing open dumping site

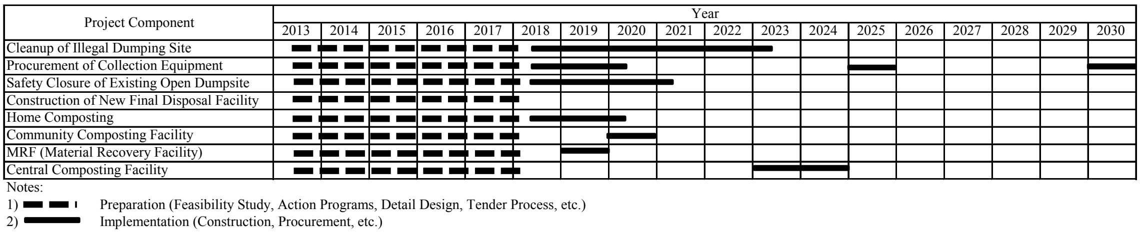


Figure 10.10.1 Implementation Schedule of the master Plan on Solid Waste Management

CHAPTER 11 COST ESTIMATE AND FINANCIAL STUDY

11.1 General

The cost estimation for each major component in the Improvement of Water Supply, Sewage, and Solid Waste Management in Chitungwiza project is prepared in this chapter. The following descriptions indicate brief summaries of the proposed improvements for each component.

(1) Water supply

As discussed in Chapter 9 earlier in this report, Plan 1 was recommended for the water supply improvement of this Project. Therefore, the cost estimation and O&M cost only for Plan 1 are provided in this chapter.

For Plan 1, two major water supply facilities are proposed to improve the current conditions of potable water supply system to Chitungwiza: 1) Distribution Pipe and 2) Seke Reservoir Site. In addition, the pipe distribution system for the future development is also proposed. The water supply works include the installations of approximately 16 km distribution pipes, and rehabilitation and modification of the existing Seke Ground Reservoir.

(2) Sanitation/ Sewerage

To utilize the designed capacity of the existing Zengeza STP for the sewage process, the rehabilitation and/or modification to the existing STP is proposed. For the existing Zengeza STP, three alternative improvement options are provided for review, namely: 1) New Stabilization Pond, 2) Trickling Filters + OD, and 3) Trickling Filters + BNR. The description of each option is explained later in this chapter. In addition to these options, the sewer pipe network system is also proposed for future development.

(3) Solid waste management

Seven solid waste management facilities are proposed to improve the existing solid waste collection system in Chitungwiza, where existing designated dumping sites are not properly managed, and many illegal dumping sites are observed throughout the city. The proposed components include: 1) clean up of illegal dumping sites, 2) procurement of collection equipment to enhance the current solid waste collection capacity and transport, 3) safety closure of existing open dump site 4) construction of new final disposal facility to improve the existing open dumping site to sanitary landfill, 5) development of home composts, 6) development of community compost plant, and 7) construction of material recovery facility.

11.2 Condition and Assumption for Cost Estimates

To prepare the cost estimates for this project, the following conditions are assumed:

(1) Cost construction

1) Exchange rate 1 USD = 77.98 yen

Table 11.2.1 2012 Exchange Rate

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	AVE
75.98	77.40	81.46	80.55	78.75	78.30	78.02	77.68	77.17	77.98	77.98

Source: Mitsubishi UFJ

2) Price escalation rate Local Currency = 1.8 %

For reference purpose, price escalation for Local Currency (USD) applied to the construction costs is estimated using the forecasted MUV Index published by World Bank. The average price escalation of 1.8% from 2012 to 2030 is utilized for Local Currency based on the table below.

Table 11.2.2 World Bank Forecasted Price Escalation

Year	2012	2013	2014	2015	2016	2017 to 2030
Price Escal	-1.9	1.9	2.2	1.9	1.8	1.8

Source: World Bank

(2) Taxes

1) VAT : 15% of the expenditure

2) Import Tax Average 10% of the expenditure for civil -elated works according to Zimbabwe Revenue Authority (Import Taxes varies depending on import goods according to ZIMRA)

Table 11.2.3 Taxes in Zimbabwe

Import Goods			Non –Import Goods
VAT	Customs Duty	Total	VAT
15 %	+ 10%	= 25 %	15%

Custom Duty in Zimbabwe consists of the following four different taxes.

- COMESA- Common Market for East and Southern Africa. Website http://www.comesa.int/
- SADC – Southern Africa Development Community
- RSA- Republic of South Africa
- SADC (ZA) –Zimbabwe is a member of the 14-nation Southern African Development Community (SADC), which was formed to promote "regional integration."

(3) Others

1) Consulting services 7 % of the direct cost

2) Physical contingency 5 % of the direct cost and consulting services

Based on the previous bid documents obtained from Chitungwiza Municipality, a contingency rate of 10 to 15% was observed.

3) Price contingency 5% of the direct cost and consulting services (to simplify the price escalation)

11.3 Unit Cost

(1) Labour cost

The daily and monthly labour wage cost is collected from the local consultants and contractors in Zimbabwe, as shown in the table below.

Table 11.3.1 Labour Unit Cost

Classification	USD/day	Classification	USD/month
Air-conditioning and Ventilation Installer	19.71	Waterprrofing worker	16.92
Assistant Pipe Fitter	11.88	Welder	19.71
Assistant Surveyer	18.18	Accounting	800.00
Block layer	19.71	Assistant Accounting	400.00
Carpenter	19.71	Assistant Clerk/ Officer	500.00
Carpenter (Form Work)	19.71	Building Engineer (5years experience)	1500.00
Chief Party Surveyor	19.71	Building Engineer (10years experience)	2200.00
Common Worker	11.88	Building Engineer (15years experience)	2700.00
Common Worker (Light job)	11.88	Building Engineer (20years experience)	3400.00
Construction Machine Operator	16.92	CAD Operator	600.00
Driver	15.57	Chief CAD Operator	800.00
Electrician	19.71	Chief Security	800.00
Foreman	19.71	Civil Engineer (5 years experience)	1500.00
Interior finish worker	16.92	Civil Engineer (10 years experience)	2200.00
Mason (Incl. Tile)	16.92	Civil Engineer (15 years experience)	2700.00
Painter	19.71	Civil Engineer (20 years experience)	3400.00
Pipe Fitter	18.18	Clerk/ Officer	500.00
Pipe Fitter	342.54	Driver	342.54
Plasterer	15.57	Electric Engineer	2000.00
Quality Check surveyor	18.18	Guard	220.00
Reinforcing Steel Fixer	19.71	IT Staff	1200.00
Roofer	15.57	Mechanic	900.00
Scaffolding/ Structual Steel Work	15.57	Mechanical Engineer	2000.00
Security	10.00	Receptionist	500.00
Sheet metal worker	19.71	Security Officer	400.00
Special Technical Worker	18.18		
Surveyor Field support staff	11.88		

Source: BCHOD

(2) Site work and material costs

The site work and material costs were collected from the local contractors and consultants in Harare, Zimbabwe, as shown in the tables below.

Table 11.3.2 Site Work Cost (Unit Price:USD)

Items	Specification	Unit	Unit Price
Backfilling	Volume <1,000 m3	m^3	12.90
Backfilling	Volume >=1,000 m3	m^3	12.90
Concrete	10 MPA	m^3	321.00
Concrete	15 MPA	m^3	346.50
Concrete	25-30 MPA	m^3	388.70
Diesel		L	
Excavation	Normal Soil by Backhoe	m^3	5.10
Excavation	Blasting Rocks	m^3	150.00
Fence		m	48.37
Grading and Clearing		m^2	0.60
Gravel	D < 25 mm	m^3	18.35
Landscape	Including irrigation, plants, and topsoil	m^2	5.40
Pavement Works	including compaction	m^2	36.60
Petroleum		L	
Reinforced Concrete & Formwork	28 MPA	m^3	258.00
Surplus Soil Transport	L= 30 km	m^3	13.20
Surplus Soil Transport	L= 10 km	m^3	4.40
Surplus Soil Transport	L= 1 km	m^3	0.44

Table 11.3.3 Local Manufacture Retail Price of uPVC

uPVC CLASS 10 (Pressure)

D mm	Unit Price USD/m
110	9.88
125	12.70
140	15.90
160	20.53
200	32.44
250	50.81
315	81.31

SDR 34 (Non-Pressure)

D mm	Unit Price USD/m
160	15.41
200	24.24
250	37.72
315	60.67

Source: Proplastics, Zimbabwe

Table 11.3.4 Local Manufacture Retail Price of RCP

CLASS 60

D mm	Unit Price USD/m	D mm	Unit Price USD/m
450	147.75	1,050	686.00
525	159.25	1,200	810.15
600	189.00	1,350	1,210.00
675	265.10	1,500	1,871.05
750	315.00	1,650	2,249.95
825	330.55	1,800	2,695.60
900	366.75	2,300	3,234.95
975	560.00	2,500	3,881.25

Source: Hume Africa, Zimbabwe

(3) Equipment cost

The equipment cost was collected from local contractors through an interview, as shown in the table below.

Table 11.3.5 Equipment Cost

Classification		USD/day
Air Compressor	5m3/min	312.00
Compactor	60-100 kg	304.00
Concrete Mixer	0.2 m3	96.00
Concrete Mixer	0.5 m3	218.00
Concrete Mixer	1.0 m3	364.00
Concrete Pump Truck	Boom Type, Capacity = 90 -110 m3/hr	631.50
Dozer	6D	828.00
Dump Truck	2 ton	90.00
Dump Truck	4 ton	260.00
Excavator	20 ton	624.00
Generator	10kVA	42.00
Generator	60VA	90.00
Road Roller	10 ton	645.00
Trailer	25 ton	240.00
Truck	11 ton	210.00
Tyre Roller		645.00
Vibrating Roller	0.8 - 1.1 ton	320.00

Source: BCHOD

11.4 Procurement of Materials and Equipment

The water supply, sewage and solid waste management works were mainly constructed or/and rehabilitated by local contractors selected through the competitive tender procedure implemented by Chitungwiza Municipality. Many civil/building contractors registered in Construction Industry

Federation of Zimbabwe (Cifoz) are qualified to provide construction services to sewage, water supply, and solid waste management works.

(1) Construction materials

Most civil and building construction materials can be procured locally. These are cement, fuel, gasoline, reinforcement bar, asphalt bitumen, structural steel, explosives, timber, plywood, concrete pipe, polyvinyl chloride pipes up to 400 mm in diameter, ready mixed concrete, aggregate, sand, building materials while mechanical and electrical equipment for the works is imported mainly from South Africa.

(2) Pipes

A local manufacturer in Harare is ready to deliver uPVC pipes with a diameter up to 400 mm to construction sites. However, uPVC pipes more than 400 mm in diameter are required to be imported from neighbouring countries, mainly from South Africa, and delivery takes approximately two weeks after the date of order placed.

Ductile iron pipes are mainly imported from South Africa to Zimbabwe and manufactures of the ductile iron pipes are located in China, EU countries, India, and other Asian countries. The delivery time is determined based on quantities and sizes of pipes ordered.

Reinforced concrete pipes (RCP) are locally manufactured and widely available in Zimbabwe based on the Zimbabwe standard maintained by the Standard Association of Zimbabwe. The delivery time is approximately 14 days depending on sizes of pipes ordered. For quality assurances, specifications of pipes from manufacturers shall be examined to determine the most suitable pipes for the project.

(3) Pumps

Water and sewage pumps are available through local distributors in Harare. However, the orders for pumps need to be placed well in advance, approximately up to 42 weeks. According to the local suppliers, larger pump units can take as much as 36 to 42 weeks from date of order placed, medium sized pumps take approximately 12 to 20 weeks, and other smaller pumps take from two weeks up to six weeks. Based on the interview with the local consultant, the mechanical and electrical equipment for sewage and water supply works are usually faster to order directly through distributors, suppliers and contractors in South Africa rather than using the distributors in Zimbabwe.

Pumps available in Zimbabwe are mainly imported from China, EU countries, and Japan. For quality assurances, specifications of pumps from manufacturers shall be examined to determine the most suitable pump for the project.

(4) Heavy equipment

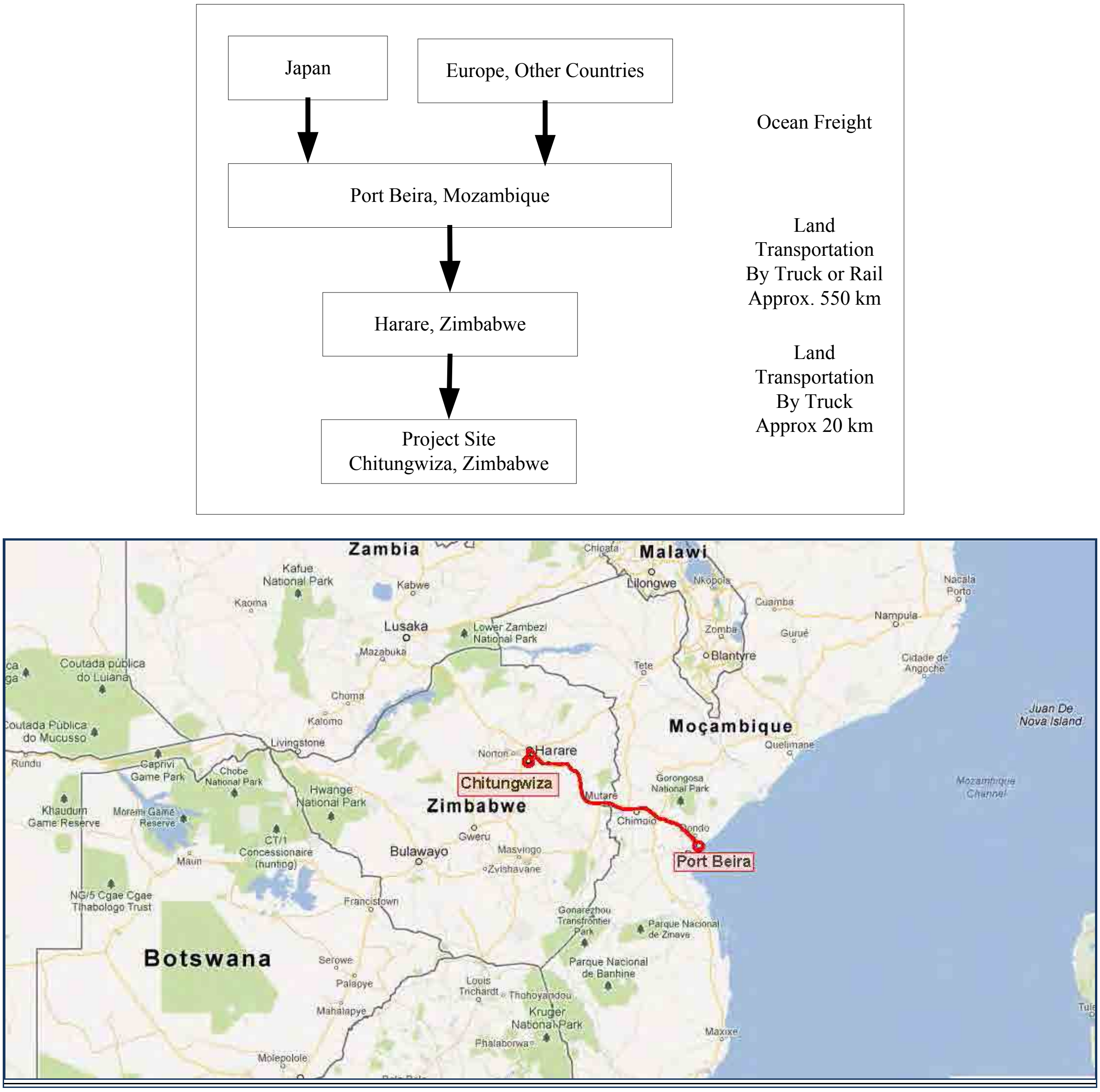
Per the interview with the local consultants and the contractors, most of the heavy equipment are locally available through local contractors and local rental or lease companies in Harare. If special heavy equipments such as cranes are necessary for this project, these are required to be transported from South Africa by trucks. The duration of the hauling from South Africa to Harare is estimated approximately 30 days after payment, but depends on the availability of equipment in South Africa. Import taxes are not imposed on rented or leased heavy equipment from other countries, mainly from South Africa.

11.4.1 Imported Materials and Equipment from South Africa

Most of the materials can be procured from South Africa located south of Zimbabwe. The procured materials and equipment can be delivered from South Africa to the project site by land transportation, using trucks. The driving distance between Chitungwiza to Johannesburg, South Africa is approximately 1,200 km.

11.4.2 Imported Materials and Equipment from Japan, Europe, and Other Asian Countries

As mentioned in the previous section, most of materials and equipment can be procured from South Africa and transferred to the project site in Zimbabwe by land transportation. However, if materials and equipment especially pumps, valves, and ductile iron pipes are necessary to be imported from other countries such as Japan, Europe, and other Asian countries, they will be delivered to Port Beira in Mozambique via ocean freight and then to the project site by land transportation, either by trucks or trains. According to the local import and export company, Port Moputo in Mozambique, this is not recommended due to delay in process that it has been experiencing.



Source: Google Map

Figure 11.4.1 Procurement Routes for Imported Materials and Equipment (N.T.S)

Table 11.4.1 Transportation Fees from Japan to Beira Port in Mozambique as of November 2012

Container Size	Japan to Beira	Beira to Chitungwiza	Approx USD
20 foot	Ocean Freight	By Truck	5,800
	Ocean Freight	By Truck	4,600
40 foot	Ocean Freight	By Truck	7,700
	Ocean Freight	By Truck	7,200

Fees including ocean freight, land transportation, any associated handling fees such as documents, excluding origin charges and customs clearance at Zimbabwe

11.5 Considerations for Transporting Goods from Other Countries

(1) Packaging

Depending on the transporting materials and equipment, valves and pumps are packed into cases, and pipes are stocked using media between layers such as bolsters, and secured with proper straps.

(2) Shipping cost

At least, three quotations from import and export companies shall be obtained to determine the most competitive and reliable shipping cost.

11.6 Considerations for Cost Estimation and Implementation

11.6.1 Tender Process

For the tender process of construction works in the City of Chitungwiza, Chitungwiza Municipality Procurement Policy and Procedures is adapted (see **Appendix 10.1-1**), however, Zimbabwe Chapter 22:14 Procurement Act supersedes Chitungwiza Municipality Procurement Policy (see **Appendix 10.1-2**). Based on a meeting with Director of Works, the duration of the tender process is approximately three months.

Chitungwiza Municipality Tender Process Duration

1.	Opening Bid to Closing Bid	2 weeks to 1 month
2.	Evaluation of the Bids	1 week
3.	Procurement Committee Meeting for Recommendation	1 day*
4.	Main Counselor Meeting to Bid Approval	1 day*
5.	Mobilization by Contractor	1 month Max
	Total	3 months**

*The end of Evaluation of the Bids (Step 2) to the end of Main Counselor Meeting (Step 4) takes approximately one week to one month according to the City of Chitungwiza Department of Works (DOW).

** However, bids are valid for 90 days from Opening Bid day. Therefore, the maximum duration of the tender process can be up to three months from the Opening bid day to the completion of Mobilization by Contractor according to DOW.

11.6.2 Design Standards

In the vicinity of the City of Harare including the City of Chitungwiza, the following standards listed in the precedence order are referenced for design, installation and construction of water and sanitation/sewerage facilities.

1. City of Harare Standard
2. Standard Association of Zimbabwe (SAZ)

If materials and construction methods are not covered by the standards mentioned above, the following standards listed in the precedence order will be referenced.

3. The British Standard
4. The South African Bureau of Standards Standardized Specification for Civil Engineering Construction

11.6.3 Specialized Technical Experts and Labours

Experienced specialized technical labours are not widely available in Zimbabwe, and the foreign expertise assistance is recommended to give more advanced technical guidance to local labours by knowledge sharing.

11.6.4 Working Hours in Zimbabwe

In Zimbabwe, the Labour Act is set forth by the Department of Law Development Commission. However, the obtained document does not stipulate the maximum working hours per week. Based on Doing Business Organization in the World Bank, the following information on working hours was obtained.

- Average 8.5 hours per day, maximum 44 hours per week or 10 hours in any given period of 24 hours.

In Chitungwiza municipality, general working schedule for full-time public government employees is as follows:

- 7.5 hours with one hour lunch break per day from Monday to Friday equivalent to 37.5 hours per week.

The following labour hours are implemented for this project:

- Regular Labour Hours: 8.5 hours /day × 5 days = 42.5 hours/week
- Maximum Labour Hours: 10 hours/ day, 44 hours/week

11.7 Estimated Construction Costs for Proposed/ Recommended Improvements

Each grand total of the cost estimation includes consulting services of 7%, price contingency of 5%, physical contingency of 5%, administration cost of 9%, VAT of 15%, and import tax of 10%. The detailed cost estimation is provided in **Appendix 10.2** to **4**.

11.7.1 Water Supply Facilities

In Chapter 8.6, Plan 1 was selected as the recommended option for the water supply improvements for this project. The following table is a summary of the estimated construction cost for Plan 1 Water Supply Facility improvements for the existing water supply system in Chitungwiza.

Table 11.7.1 Estimated Construction Cost for Water Supply Facilities (Target Year of 2020)

Sub-No	Facility	Brief Work Description	Total Cost (K USD)
1.1.1	Distribution Pipes	To increase the current water supply distributed by the existing water distribution system, install and supply the following new facilities to the existing: • New DI pipes with a diameter of 350 to 700 mm • New uPVC pipes with a diameter of 160 to 355 mm • New gate valves with a size of 100 to 700 mm	12,551
1.1.2.	Seke Reservoir Site	To utilize the capacity of the existing Seke Reservoir ground reservoir more efficiently for the water demand, install and supply: • Reinforced transmission pipe with diameter of 600 mm • Refurbishing of P/S • Construction of disinfection and neutralization facilities • Refurbishing of pipes works in the site with flow meter	13,494
1.1.3	Well Group	To take well water from surrounding areas • Three group of boreholes and transmission facilities • Transmission pipes	3,726
		Grand Total	29,771

Table 11.7.2 Estimated Construction Cost for Water Supply Facilities (Target Year of 2030)

Sub-No	Facility	Brief Work Description	Total Cost (K USD)
1.2.1	Distribution Pipes for Future Development	To increase the current water supply distributed by the existing water distribution system, install and supply the following new facilities to the existing: • New DI pipes with a diameter of 400 mm • New gate valves with a size of 400 mm • Mechanical works	13,116

Table 11.7.3 Estimated Construction Cost for Supplemental Water Supply Facilities (Urgent)

Sub-No	Facility	Brief Work Description	Total Cost (K USD)
1.3.1	Supplemental Water Supply	To take supplemental water and rehabilitate distribution network • To install shallow wells with hand pumps and borehole • To rehabilitate clogged pipes	2,747

11.7.2 Sanitation/Sewerage Facilities

The following table is a summary of the estimated construction cost and implementation plan for the Sanitation/ Sewerage Facility improvement alternative options in Chitungwiza. The detailed implementation plan for each option is discussed in the later section. Prior to the target year of 2020, the existing trickling filters in the old Zengeza STP will be rehabilitated by AfDB and planned construction will commence in early 2013 and be completed by the end of 2014. This plan has been approved based on the obtained information.

In this M/P, the construction cost of each of the three alternative options for the sewage facilities is compared for review. Therefore, each option has a different implementation plan. In addition, the construction of a new sewage pump station and installation of sewer pipes are proposed to facilitate the anticipated sewage from the future development area as one improvement for the target year of 2030.

Table 11.7.4 Cost Estimations for Recommended Improvement Options to Zengeza STP

Sub-No	Facility	Brief Work Description	Estimated Capacity (m^3/day)	Implementation Plan			Total Cost (K USD)
				Facility	Comen.	Comp	
2.1.1	New Stabilization Pond	Construction of new ponds	36,000	NSP	2018	2019	128,619
2.1.2.	Ex TF + Oxidation Ditch (OD)	Modification to the existing BNR with the replacement of the existing Anaerobic Anoxic Basins with oxidation ditch, and usage of the existing TF	20,000 + 21,750 (Ex. TF) = 41,750	Ex TF	2013	2014	20,121
				OD	2020	2022	
2.1.3.	Ex TF+ BNR	Rehabilitation to the existing BNR and usage of the existing TF	20,000 + 21,750 (Ex. TF) = 41,750	Ex TF	2013	2014	15,377
				BNR	2020	2022	

NSP= New Stabilization Pond, TF= Trickling Filters, Comen. = Commencement of Construction

Table 11.7.5 Cost Estimations for Sewer Pipes and Pump Station (Target Year of 2030)

	Facility	Brief Work Description	Total Cost (K USD)
2.2.1	Pump Station	Installation of 3.3m3/min × 30kW × 3 ea pumps in the building	2,592

Table 11.7.6 Cost Estimations for Tilcor Industrial Area (Urgent)

	Facility	Brief Work Description	Total Cost (K USD)
2.3.1	Tilcor Industrial Area	Installation of 28 kW × 3 ea pumps in the building Steel Pipe dia 200 mm with RC Pipe support ×2, L=100m ACP dia 300 mm ×2, L=100m	384

11.7.3 Solid Waste Management Facilities

The following table is a summary of the estimated construction cost for the recommended solid waste management improvements in Chitungwiza.

Table 11.7.7 Cost Estimations for Recommended Solid Waste Management System

Sub-No.	Facility	Brief Work Description	Total Cost (K USD)
3.1.1	Cleanup of Illegal Dumping Site	Cleanup of the existing illegal dump sites by equipment	6,403
3.1.2	Procurement of Collection Equipment	Purchasing new heavy duty equipment and bins: 16 tripper trucks, 12 compactor trucks, 32 multi-loaders, and 1,515 skip bins	18,160
3.1.3.	Safety Closure of Existing Open Dump Site	Modification to the existing disposal sites with construction of gas exhausts, operation roads, drainage ditches, and fences	21,378
3.1.4.	Construction of New Final Disposal Facility	Construction of the new final disposal facility including administration and warehouse buildings, disposal sites with leachate collection facilities, reservoir pit, leachate treatment ponds, drainage, ground monitoring wells, and fences and purchasing new equipment	14,645
3.1.5.	Home Compost	Pilot Project: demonstrating and educating local people about home composting by instructors and providing plastic containers.	88
3.1.6.	Community Compost Plant	Pilot Project: construction of a new community compost plant including compost proceeding building, guard house, and providing equipment.	199
3.1.7.	MRF (Material Recovery Facility)	Construction of a new material recovery facility including MRF and administration buildings, and providing equipment	1,485
3.1.8.	Central Composting Facility	Construction of a new central compost centre including compost and administration buildings, receiving, sorting, treatment, process and storage areas and providing equipment.	8,668
		Ground Total	71,086

11.7.4 Total Construction Cost

The summary table of the estimate construction costs for the urgent provision and proposed improvements for the target year of 2020 and 2030 is provided below.

Table 11.7.8 Construction Costs for Urgent Provisions

Item	Cost (K USD)
Water Supply	2,747
Sewage	384
Total	3,131

Table 11.7.9 Construction Costs for a Target Year of 2020 and 2030

Improvements	Option1			Option2			Option3		
Target Year	2020	2030	Total	2020	2030	Total	2020	2030	Total
Water Supply	29,771	13,116	42,887	29,771	13,116	42,887	29,771	13,116	42,887
Sewage	128,619	2,582	131,211	20,121	2,592	22,713	15,377	2,592	17,969
Solid Waste	51,864	19,222	71,086	51,864	19,222	71,086	51,864	19,222	71,086
Total (K USD)	**210,254**	**34,920**	**245,184**	**101,756**	**34,930**	**136,686**	**97,012**	**34,930**	**131,942**

11.8 Operation and Maintenance Cost

The detailed O&M cost estimation for each section is provided in **Appendix 10.5 to 7**.

11.8.1 Unit Cost and Cost Functions for Operation and Maintenance

The unit prices of labours are referenced from the "Total Personnel related cost" columns in the Water Supply, Sewage Facilities, and Solid Waste Management Employment Cost tables provided in Chapter 3.

Electricity Cost (Excluding 15% VAT)	
Energy charge per kWh	0.12 USD/kWh
A monthly capacity charge per unit of demand (each location)	6.84 USD/each

Source: ZETDC

11.8.2 Water Supply Facilities

In Chapter 9, Plan 1 was selected as the recommended option for the water supply facility improvements. The following table is a summary of the O&M cost for Plan 1 improvements to the existing water supply system in Chitungwiza.

Table 11.8.1 O&M for Water Supply Facilities

No.	Description	O&M Cost (K USD/ year)		Remarks
		2020	2030	
1	Staff Cost	793	872	
2	Electricity	130	130	
3	Chemicals	8	8	
4	Bulk Water	5,050	5,737	0.3 USD/m^3 + VAT (15%) 2020: Q = 40,104 (m^3/day) 2030: Q = 45,559 (m^3/day)
5	Facilities maintenance	501	527	
	New M&E Facilities	90	101	Direct Construction × 0.05
	New Pipes	36	53	Direct Construction × 0.002
	New Structures	70	70	Direct Construction × 0.05
	Existing Distribution Network	300	300	30 mil. USD × 0.01

No.	Description	O&M Cost (K USD/ year)		Remarks
		2020	2030	
	Existing Structure	4	4	4 mil. USD × 0.001
Total		6,983	7,803	

11.8.3 Sanitation/ Sewerage Facilities

There are three recommended improvement alternative options for the existing Zengeza STP. The O&M cost for each alternative option of the sanitation/sewerage facilities is estimated and provided in the following table. The price contingency was applied to the direct cost for possible price escalation.

Table 11.8. 2 O&M Cost Comparison for Zengeza STP

No.	Category	**Option 1** New Stabilization Ponds		**Option 2** TF+OD		**Option 3** TF+BNR	
		36,000 m^3/d		41,750 m^3/d		41,750 m^3/d	
		K USD	Remarks	K USD	Remarks	K USD	Remarks
1	Staff Cost	681		946		1,020	
2	Electricity	22		519		1,662	
3	Maintenance & Repairs	22	Electricity*1.0	311	Electricity*0.6	997	Electricity*0.6
4	Materials & Chemicals	11	Electricity*0.5	156	Electricity*0.3	499	Electricity*0.3
5	Others	341	Staff cost*0.5	473	Staff cost*0.5	510	Staff cost*0.5
Total		**1,077**		**2,405**		**4,687**	

Table 11.8.3 O&M Cost for Pump Station and Tilcor Industrial Area

No.	Category	O&M Cost (K USD/ year)		Remarks
		Pump Station	Tilcor I.A	
1	Staff Cost	44	4	
2	Electricity	27	68	
3	Maintenance & Repairs	27	4	Electricity × 1.0
4	Materials & Chemicals	14	0	Electricity × 0.5
5	Others	22	2	Staff cost × 0.5
Total		**133**	**77**	

11.8.4 Solid Waste Management

The O&M cost for the proposed Solid Waste Management components varies due to the implementation plans of the facilities. To simplify the overall O&M cost, the 2030 O&M, which assumed all components are completed, was selected to show the annual O&M cost for the Solid Waste Management Facilities. A summary of the 2030 O&M cost for the proposed Solid Waste Management improvements in Chitungwiza is provided in the table below. The price contingency was applied to the direct cost for possible price escalation.

Table 11.8.4 O&M Cost for Solid Waste Management

No.	O&M Facility	Total Cost (K USD/ year)
1	Collection Service Cost	3,096
2	Operation of Final Landfill	392
3	Operation of MRF (Material Recovery Facility)	229
4	Operation of Central Composting Facility	193
	Total	3,910

11.9 Implementation Plan

The Implementation plan for the Improvement of Water Supply, Sewage and Solid Waste Management in Chitungwiza project is prepared in this M/P for discussion purpose. More detailed implementation plan will be discussed in the future Feasibility Study.

(1) Process

Feasibility Study

Feasibility studies of the Water Supply, Sewage, and Solid Waste Management facilities, and Socioeconomic Studies, Financial Studies and Cost Estimations recommended and/ or proposed in this report shall be examined and studied in more depth to address the outcome of this M/P and any updates shall refine this M/P.

Action Programs

Action Programs consists of appraisal, pledging, and signing between involved parties. More detailed Action Programs will be discussed in the Feasibility Study.

Selection of Consultants

Selected consultants shall conduct and prepare the detailed design and tender documents for the Water Supply, Sewage, and Solid Waste Management facilities proposed in the Feasibility Study and manage the construction activities for the facilities. More detailed Selection of Consultants will be discussed in the Feasibility Study.

Detailed Design

The Water Supply, Sewage, and Solid Waste Management facilities proposed in the Feasibility Study shall be engineering designed based on the technical information, such as survey and geotechnical reports and be compiled into a set of drawings for construction works to be utilized.

Tender Document Process

Tender Documents shall be prepared to satisfy the regulations set forth by the involved parties. The further discussion on the terms and procedures of the tender document process will be addressed in the Feasibility Study.

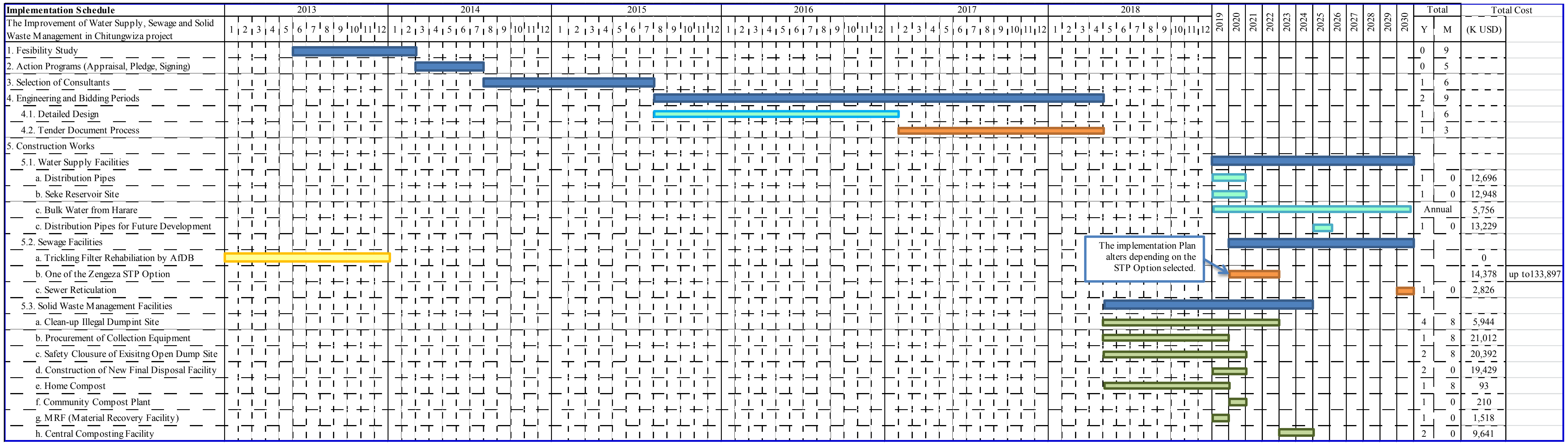
Construction Activities

The consultant as a construction manager will oversee the construction activities of the Water Supply, Sewage, and Solid Waste Management facilities based on the construction drawings prepared in the detailed design process.

(2) Implementation schedule

The overall rough implementation schedule is prepared as explained in the preceding sub-section. The implementation plan is depicted in the figure below.

Figure 11.9.1 Implementation Schedule



CHAPTER 12 FINANCIAL AND ECONOMIC ANALYSIS

12.1 Financial Analysis of the M/P Projects

12.1.1 Methodology and Assumptions

Conventionally the financial internal rates of return (FIRR) and the financial net present value (FNPV) are calculated for financial evaluation of a project from the perspective of the operating entity, rather than the economy as a whole. The FIRR is the discount rate that equalizes the present values of costs and revenues over the project life. The FIRR calculated on the net cash flows shows the project's profitability.

The financial viability of a project can be evaluated by comparing its FIRR with the financial opportunity cost of capital (FOCC). If the FIRR exceeds the FOCC, the project is regarded financially viable. This also means that the FNPV computed by using a discount rate equal to the FOCC will be positive when the project is financially viable. The FNPV is also useful to evaluate the financial viability of projects whose FIRR is not computable. The FOCC is proxied by the weighted average cost of capital (WACC). The WACC represents financial costs to be incurred by the operating entity in raising capital necessary to implement the project. The WACC can be computed based on market interest rates and inflation rates.

To estimate financial cash flows of the M/P projects, certain parameters and assumptions are set, distinguishing between "with project" and "without project" situations.

(1) Project life

The M/P projects comprise (i) the water supply M/P project, (ii) the sewerage M/P project (option 2) and (iii) the solid waste management M/P project.

It was assumed that the major disbursement periods of the M/P projects coincided with the construction (implementation) period. Each of the M/P projects was assumed to have the disbursement period as shown in Table 12.1.1. The project analysis periods were set from 2013 to 2052, as a 40 year period. The ending year was harmonized among the M/P projects as the comparative analysis became easier.

Table 12.1.1 Disbursement Period and Rate of M/P Project Capital Costs

Year	Water	Sewerage (Option 2)	Solid Waste
2014	6%	2%	
2015	22%	29%	
2016	22%	29%	
2017	22%	29%	
2018			30%
2019			43%
2020			13%
2021			2%
2022	14%	6%	6%
2023	14%	6%	6%
Total	100%	100%	100%

Source: JICA Project Team

(2) Capital Costs

The financial and economic analyses are done on the basis of constant monetary values which are free from the inflationary effects. Furthermore the economic analysis is made excluding effects of taxes. Also types of fixed assets to be constructed by the M/P projects determine the replacement period of the assets. To follow these steps in the financial and economic analyses, the M/P project capital costs were broken down as summarized in Tables 12.1.2 through 12.1.4. The M/P projects are composed of the urgent portion, the year 2020 target portion and the year 2030 target portion.

Table 12.1.2 Capital Cost Breakdown of the Water Supply M/P Project

(USD)

	(FC + LC)	(LC)	(FC)
Total project cost	45,634,000	18,720,000	26,914,000
Price contingency	1,588,854	365,519	1,223,335
Physical contingency	1,588,854	365,519	1,223,335
VAT & import duty	7,529,826	7,529,826	0
Project cost (excl. price cont. physical cont. tax) (incl. Direct cost, admin. Consultant)	34,926,465	10,459,135	24,467,330
Civil works portion	84%	60%	91%
Mechanical & electrical work portion	16%	40%	9%
Civil work portion in cost (excl. price cont. incl. physical cont and VAT)	37,134,522		
Mechanical & electrical work portion in cost (excl. price cont. incl. physical cont and VAT)	6,910,623		

Source: JICA Project Team

Table 12.1.3 Capital Cost Breakdown of the Sewerage M/P Project (Option 2)

(USD)

	(FC + LC)	(LC)	(FC)
Total project cost	23,097,000	12,024,000	11,073,000
Price contingency	809,649	307,460	502,189
Physical contingency	850,131	322,833	527,298
VAT & import duty	3,636,582	3,636,582	0
Project cost (excl. price cont. physical cont. tax) (incl. Direct cost, admin. Consultant)	17,800,638	7,757,125	10,043,513
Civil works portion	38%	83%	13%
Mechanical & electrical work portion	62%	17%	87%
Civil work portion in cost (excl. price cont. incl. physical cont and VAT)	8,465,036		
Mechanical & electrical work portion in cost (excl. price cont. incl. physical cont and VAT	13,822,315		

Source: JICA Project Team

Table 12.1.4 Capital Cost Breakdown of the Solid Waste Management M/P Project

(USD)

	(FC + LC)	(LC)	(FC)
Total project cost	71,086,000	35,314,125	35,771,875
Price contingency	2,488,874	866,722	1,622,152
Physical contingency	2,613,317	910,058	1,703,259
VAT & import duty	11,263,742	11,263,742	0
Project cost (excl. price cont. physical cont. tax) (incl. Direct cost, admin, consultant)	54,720,067	22,273,603	32,446,464
Expense component %	39%	36%	42%
Shorter useful life (20 years) component %	26%	17%	35%
Longer useful life (50 years) component %	35%	47%	23%
Expense component in price (excl. price cont. incl. physical cont and VAT)	26,951,146		
Shorter useful life component in price (excl. price cont. incl. physical cont and VAT)	17,716,212		
Longer useful life component in price (excl. price cont. incl. physical cont and VAT)	23,929,769		

Source: JICA Project Team

(3) O&M costs

The annual O&M costs of the M/P projects were assumed to be incurred from 2018 when the corresponding main facilities would have been constructed. The details of the O&M costs are shown in Chapter 11. It was also assumed that financial benefits would accrue while the O&M costs were incurred.

(4) Replacement costs

During the project analysis period only mechanical and electrical works need replacement as their usable lives are considered to be 20 years on average. Longer life assets like pipes which are considered to be included in civil works, are generally usable for 50 years, therefore require no replacement during the project period.

(5) Residual values

Residual values of the M/P projects at the end of the project analysis period are regarded as positive cash flow in the financial analysis. Mechanical and electrical works are considered to last for 20 years. Civil structures and pipes have 50 year usable life. The residual values of those assets at the end of the project period were computed by using these attrition rates.

(6) Tariff revenues

Under both “with project” and “without project” situations, the presumptive tariff levels to be applied during the analysis periods were set at the same levels as the current tariffs (Table 12.1.5). This setting was based on a finding explained in Section 3.4.11 (9) that the current tariffs are within the users’ ability to pay (ATP).

Table 12.1.5 Tariffs Applied in Financial Analysis

Item	Rate (2013 constant prices)	Unit
Water		
Fixed rate for domestic users	3.90	USD/connection/month
Fixed rate for non-domestic users	27.65 *	USD/connection/month
Volumetric rate for domestic users	0.38	USD/m^3
Volumetric rate for noon-domestic users	0.65	USD/m^3
Sewerage		
Fixed rate for domestic users	3.92	USD/connection/month
Fixed rate for non-domestic users	37.94 *	USD/connection/month
Solid Waste Management		
Fixed rate for domestic users	3.36	USD/connection/month
Fixed rate for non-domestic users	27.22 *	USD/connection/month

Source: JICA Project Team
Note: All the rates are exclusive of VAT.
*Weighted average value according to the number of existing users

(7) Domestic users and non-domestic users

As a result of the Housing Survey, the water consumption by domestic users was estimated at 18,400 m^3/day. Non-domestic users were estimated to consume 2,200 m^3/day water. The ratio of water consumption between domestic users and non-domestic users was therefore computed at 89:11. This ratio was also used to estimate the distribution of service provision of sewerage and solid waste management between domestic users and non-domestic users.

(8) User charge collection efficiency

The current situation of collection efficiency is very low, being around 60%, due to the residents' pervasive attitude of non-payment. Such a situation comes from grievance against the insufficient provision of WSSW services by the Council. It is likely, after the M/P project implementation, that the WSSW services will be satisfactorily provided to the residents and the payment rate, or the user charge collection efficiency will rise. Although the M/P projects do not include tangible components to improve the collection efficiency, the residents are naturally expected to pay their bills more willingly once the M/P projects turn out to be better service provision. Therefore the financial analysis assumes that under the "without-project" situation, the Council will somehow improve the collection efficiency rate to 80%. Under the "with-project" situation, the rate is assumed to further improve to 90%.

(9) Other assumptions

The water supply M/P project employs other major assumptions as follows:

- A water supply of 30,000 m^3/day is regarded as the current water supply, which is equivalent to the non-incremental water supply under both the "with project" and the "without project" situations.

- Wells newly dug by the project will produce 3,000 m^3/day water which is an incremental water under the "with project" situation.
- The bulk water purchase price from Harare will be the same as the current tariff, which is 0.345 USD per cubic metre under the both the "with project" and the "without project" situations.
- The well water newly developed by the M/P project will cost to the project at 40 USD per thousand cubic metre, which is the same rate as ZINWA is currently charging to borehole users.
- NRW will stay at the current 25% under the "without project" situation. Under the "with project" situation, it will be improved to 15%

12.1.2 Analysis of Financial Viability

The project financing scheme to be adopted by the Chitungwiza Council as a project operating entity is yet to be decided. A Japanese ODA loan is currently considered difficult to be extended to the GOZ or the Chitungwiza Council. Under the current financial status of the Council, domestic banks will hardly provide a fund to the Council. In fact the Council's attempt of asking a loan to a local bank in 2012 has failed. The most realistic financing source among alternatives with slim chances is the PSIP. But even the PSIP, making a full coverage of the project cost is unrealistic. It was therefore assumed that a PSIP loan would be made available to cover 50% of the initial capital cost (not including the price escalation). The remaining 50% was assumed to be financed by a local bank. The PSIP loan interest rate was estimated at 5% per annum, the same rate as the existing PSIP loan held at the Council. The prevailing interest rate of domestic US dollar long-term loans was estimated at 8.6%. Domestic inflation rate was 3.9%. Taking account of these assumptions, the WACC was computed at 2.8% (Table 12.1.6).

Table 12.1.6 Calculation of Weighted Average Cost of Capital

	PSIP fund		Domestic Bank	
Weighting	50.0%	a	50.0%	a
Nominal Cost	5.0%	b	8.6%	c
Inflation Rate	3.9%	d	3.9%	d
Real Cost	1.1%		4.5%	
Weighted Average Cost of Capital (Real Terms) = 2.8%				

Source: Computed by JICA Project Team Based on Data of AfDB
a) Assumption by JICA Project Team
b) Loan rate in 2012
c) Weighted average commercial bank loan rate in July 2012
d) Annual CPI change in July 2012

Financial cash flows of the M/P projects are presented in Tables 12.1.7 through 12.1.9. Each analysis is comprised of (i) "with-project" cash flow, (ii) "without-project" cash flow and (iii) differential cash flow between “with-project” situation and “without-project” situation.

The FIRRs in real terms resulted in minus 5.2% for the water supply M/P project, minus 17.1% for the sewerage M/P project (Option 2) and minus 12.0% for the solid waste management M/P project. Those FIRRs are all inferior to the FOCC of 2.8%, meaning that none of those projects are financially viable. The FNPV results were minus USD 40.6 million for the water supply M/P project, minus USD 41.4 million for the sewerage M/P project (Option 2) and minus USD 76.2 million for the solid waste management M/P project. These FNPVs too indicate that the projects are financially unviable.

Obvious reason of this financial inviability is that the tariffs are set at the affordable price levels, which are not as high as the full cost recovery levels. The FIRRs will never be positive unless the tariffs are set at the full cost recovery levels.

Table 12.1.7 Financial Cash Flows of Water Supply M/P Project

With-Project Situation (USD thousand in 2013 constant price)

Year	Capital cost (excl. price escalation)	M&E replace (excl. price escalation)	O/M cost (Excl. water purchase cost)	Well water payment to Zinwa	Bulk water payment to Harare	Total Costs	Fixed water charge from domestic users	Fixed water charge from non-domestic users	Volumteric water charge from domestic users	Volumteric water charge from non-domestic	Residual value	Total Benefits	Net benefit
2013						0						0	0
2014	2,651					2,651						0	-2,651
2015	9,578			44		9,622						0	-9,622
2016	9,578			44		9,622						0	-9,622
2017	9,578			44		9,622						0	-9,622
2018			1,933	44	4,672	6,649	1,819	439	3,801	676		6,734	85
2019			1,933	44	4,672	6,649	1,848	446	3,801	676		6,771	121
2020			1,933	44	4,672	6,649	1,878	453	3,801	676		6,807	158
2021			1,933	44	4,672	6,649	1,901	459	3,801	676		6,836	187
2022	6,330		1,933	44	4,672	12,979	1,925	464	3,801	676		6,866	-6,113
2023	6,330		1,933	44	4,672	12,979	1,948	470	3,801	676		6,895	-6,084
2024			2,066	44	5,359	7,469	1,972	476	4,318	768		7,533	64
2025			2,066	44	5,359	7,469	1,995	481	4,318	768		7,562	93
2026			2,066	44	5,359	7,469	2,019	487	4,318	768		7,591	122
2027			2,066	44	5,359	7,469	2,042	493	4,318	768		7,620	152
2028			2,066	44	5,359	7,469	2,066	498	4,318	768		7,649	181
2029			2,066	44	5,359	7,469	2,089	504	4,318	768		7,679	210
2030			2,066	44	5,359	7,469	2,112	510	4,318	768		7,708	239
2031			2,066	44	5,359	7,469	2,112	510	4,318	768		7,708	239
2032			2,066	44	5,359	7,469	2,112	510	4,318	768		7,708	239
2033			2,066	44	5,359	7,469	2,112	510	4,318	768		7,708	239
2034			2,066	44	5,359	7,469	2,112	510	4,318	768		7,708	239
2035			2,066	44	5,359	7,469	2,112	510	4,318	768		7,708	239
2036			2,066	44	5,359	7,469	2,112	510	4,318	768		7,708	239
2037		4,924	2,066	44	5,359	12,393	2,112	510	4,318	768		7,708	-4,685
2038			2,066	44	5,359	7,469	2,112	510	4,318	768		7,708	239
2039			2,066	44	5,359	7,469	2,112	510	4,318	768		7,708	239
2040			2,066	44	5,359	7,469	2,112	510	4,318	768		7,708	239
2041			2,066	44	5,359	7,469	2,112	510	4,318	768		7,708	239
2042			2,066	44	5,359	7,469	2,112	510	4,318	768		7,708	239
2043		1,986	2,066	44	5,359	9,455	2,112	510	4,318	768		7,708	-1,747
2044			2,066	44	5,359	7,469	2,112	510	4,318	768		7,708	239
2045			2,066	44	5,359	7,469	2,112	510	4,318	768		7,708	239
2046			2,066	44	5,359	7,469	2,112	510	4,318	768		7,708	239
2047			2,066	44	5,359	7,469	2,112	510	4,318	768		7,708	239
2048			2,066	44	5,359	7,469	2,112	510	4,318	768		7,708	239
2049			2,066	44	5,359	7,469	2,112	510	4,318	768		7,708	239
2050			2,066	44	5,359	7,469	2,112	510	4,318	768		7,708	239
2051			2,066	44	5,359	7,469	2,112	510	4,318	768		7,708	239
2052			2,066	44	5,359	7,469	2,112	510	4,318	768	14,745	22,452	14,984
Total	44,045	6,911	71,503	1,664	183,452	307,576	72,087	17,390	148,021	26,325	14,745	278,567	-29,009

Without-Project Situation (USD thousand in 2013 constant price)

Year	O/M cost (Excl. water purchase cost)	Water purchase from Harare	Total Costs	Fixed water charge from domestic users	Fixed water charge from non-domestic users	Volumteric water charge from domestic users	Volumteric water charge from non-domestic	Total Benefits	Net benefit
2013			0					0	0
2014			0					0	0
2015			0					0	0
2016			0					0	0
2017			0					0	0
2018	964	3,778	4,742	1,617	390	2,478	441	4,925	183
2019	964	3,778	4,742	1,643	396	2,478	441	4,958	215
2020	964	3,778	4,742	1,669	403	2,478	441	4,990	248
2021	964	3,778	4,742	1,690	408	2,478	441	5,016	274
2022	964	3,778	4,742	1,711	413	2,478	441	5,042	300
2023	964	3,778	4,742	1,732	418	2,478	441	5,068	326
2024	964	3,778	4,742	1,752	423	2,478	441	5,094	351
2025	964	3,778	4,742	1,773	428	2,478	441	5,120	377
2026	964	3,778	4,742	1,794	433	2,478	441	5,145	403
2027	964	3,778	4,742	1,815	438	2,478	441	5,171	429
2028	964	3,778	4,742	1,836	443	2,478	441	5,197	455
2029	964	3,778	4,742	1,857	448	2,478	441	5,223	481
2030	964	3,778	4,742	1,878	453	2,478	441	5,249	507
2031	964	3,778	4,742	1,878	453	2,478	441	5,249	507
2032	964	3,778	4,742	1,878	453	2,478	441	5,249	507
2033	964	3,778	4,742	1,878	453	2,478	441	5,249	507
2034	964	3,778	4,742	1,878	453	2,478	441	5,249	507
2035	964	3,778	4,742	1,878	453	2,478	441	5,249	507
2036	964	3,778	4,742	1,878	453	2,478	441	5,249	507
2037	964	3,778	4,742	1,878	453	2,478	441	5,249	507
2038	964	3,778	4,742	1,878	453	2,478	441	5,249	507
2039	964	3,778	4,742	1,878	453	2,478	441	5,249	507
2040	964	3,778	4,742	1,878	453	2,478	441	5,249	507
2041	964	3,778	4,742	1,878	453	2,478	441	5,249	507
2042	964	3,778	4,742	1,878	453	2,478	441	5,249	507
2043	964	3,778	4,742	1,878	453	2,478	441	5,249	507
2044	964	3,778	4,742	1,878	453	2,478	441	5,249	507
2045	964	3,778	4,742	1,878	453	2,478	441	5,249	507
2046	964	3,778	4,742	1,878	453	2,478	441	5,249	507
2047	964	3,778	4,742	1,878	453	2,478	441	5,249	507
2048	964	3,778	4,742	1,878	453	2,478	441	5,249	507
2049	964	3,778	4,742	1,878	453	2,478	441	5,249	507
2050	964	3,778	4,742	1,878	453	2,478	441	5,249	507
2051	964	3,778	4,742	1,878	453	2,478	441	5,249	507
2052	964	3,778	4,742	1,878	453	2,478	441	5,249	507
Total	33,756	132,221	165,977	64,077	15,457	86,721	15,423	181,679	15,702

Difference between "With-Project" and "Without-Project" situation (USD thousand in 2013 constant price)

Year	Cost	Benefit	Net Benefit
2013	0	0	0
2014	2,651	0	-2,651
2015	9,622	0	-9,622
2016	9,622	0	-9,622
2017	9,622	0	-9,622
2018	1,907	1,809	-98
2019	1,907	1,813	-94
2020	1,907	1,817	-90
2021	1,907	1,821	-87
2022	8,237	1,824	-6,413
2023	8,237	1,827	-6,410
2024	2,727	2,439	-287
2025	2,727	2,442	-284
2026	2,727	2,446	-281
2027	2,727	2,449	-278
2028	2,727	2,452	-274
2029	2,727	2,455	-271
2030	2,727	2,459	-268
2031	2,727	2,459	-268
2032	2,727	2,459	-268
2033	2,727	2,459	-268
2034	2,727	2,459	-268
2035	2,727	2,459	-268
2036	2,727	2,459	-268
2037	7,651	2,459	-5,192
2038	2,727	2,459	-268
2039	2,727	2,459	-268
2040	2,727	2,459	-268
2041	2,727	2,459	-268
2042	2,727	2,459	-268
2043	4,713	2,459	-2,254
2044	2,727	2,459	-268
2045	2,727	2,459	-268
2046	2,727	2,459	-268
2047	2,727	2,459	-268
2048	2,727	2,459	-268
2049	2,727	2,459	-268
2050	2,727	2,459	-268
2051	2,727	2,459	-268
2052	2,727	17,203	14,477
Total	141,599	96,888	-44,710

FNPV (discount rate 2.8%) = -40,623
FIRR = -5.2%

Table 12.1.8 Financial Cash Flows of Sewerage M/P Project (Option 2)

With-Project Situation (USD thousand in 2013 constant price)

Year	Capital cost (excl. price escalation)	M&E replace (excl. price escalation)	O/M cost	Total Costs	Fixed charge from domestic users	Fixed charge from non-domestic users	Residual value	Total Benefits	Net benefit
2013				0				0	0
2014	371			371				0	-371
2015	6,472		77	6,549				0	-6,549
2016	6,472		77	6,549				0	-6,549
2017	6,472		77	6,549				0	-6,549
2018			2,482	2,482	1,829	602		2,431	-51
2019			2,482	2,482	1,858	612		2,470	-12
2020			2,482	2,482	1,888	622		2,510	27
2021			2,482	2,482	1,912	629		2,541	59
2022	1,251		2,482	3,733	1,935	637		2,572	-1,161
2023	1,251		2,482	3,733	1,959	645		2,604	-1,129
2024			2,616	2,616	1,983	653		2,635	19
2025			2,616	2,616	2,006	660		2,667	51
2026			2,616	2,616	2,030	668		2,698	82
2027			2,616	2,616	2,053	676		2,729	114
2028			2,616	2,616	2,077	684		2,761	145
2029			2,616	2,616	2,101	691		2,792	176
2030			2,616	2,616	2,124	699		2,824	208
2031			2,616	2,616	2,124	699		2,824	208
2032			2,616	2,616	2,124	699		2,824	208
2033			2,616	2,616	2,124	699		2,824	208
2034			2,616	2,616	2,124	699		2,824	208
2035			2,616	2,616	2,124	699		2,824	208
2036			2,616	2,616	2,124	699		2,824	208
2037		12,271	2,616	14,887	2,124	699		2,824	-12,063
2038			2,616	2,616	2,124	699		2,824	208
2039			2,616	2,616	2,124	699		2,824	208
2040			2,616	2,616	2,124	699		2,824	208
2041			2,616	2,616	2,124	699		2,824	208
2042			2,616	2,616	2,124	699		2,824	208
2043		1,551	2,616	4,167	2,124	699		2,824	-1,343
2044			2,616	2,616	2,124	699		2,824	208
2045			2,616	2,616	2,124	699		2,824	208
2046			2,616	2,616	2,124	699		2,824	208
2047			2,616	2,616	2,124	699		2,824	208
2048			2,616	2,616	2,124	699		2,824	208
2049			2,616	2,616	2,124	699		2,824	208
2050			2,616	2,616	2,124	699		2,824	208
2051			2,616	2,616	2,124	699		2,824	208
2052			2,616	2,616	2,124	699	6,574	9,398	6,782
Total	22,287	13,822	90,986	127,095	72,489	23,862	6,574	102,925	-24,170

Without-Project Situation (USD thousand in 2013 constant price)

Year	O/M cost	Fixed charge from domestic users	Fixed charge from non-domestic users	Total Benefits	Net benefit
2013				0	0
2014				0	0
2015				0	0
2016				0	0
2017				0	0
2018	1,593	1,626	535	2,161	567
2019	1,593	1,652	544	2,196	602
2020	1,593	1,678	552	2,231	637
2021	1,593	1,699	559	2,259	665
2022	1,593	1,935	566	2,502	908
2023	1,593	1,959	573	2,532	939
2024	1,593	1,983	580	2,563	969
2025	1,593	2,006	587	2,593	1,000
2026	1,593	2,030	594	2,624	1,030
2027	1,593	2,053	601	2,654	1,061
2028	1,593	2,077	608	2,685	1,091
2029	1,593	2,101	615	2,715	1,122
2030	1,593	2,124	622	2,746	1,152
2031	1,593	2,124	622	2,746	1,152
2032	1,593	2,124	622	2,746	1,152
2033	1,593	2,124	622	2,746	1,152
2034	1,593	2,124	622	2,746	1,152
2035	1,593	2,124	622	2,746	1,152
2036	1,593	2,124	622	2,746	1,152
2037	1,593	2,124	622	2,746	1,152
2038	1,593	2,124	622	2,746	1,152
2039	1,593	2,124	622	2,746	1,152
2040	1,593	2,124	622	2,746	1,152
2041	1,593	2,124	622	2,746	1,152
2042	1,593	2,124	622	2,746	1,152
2043	1,593	2,124	622	2,746	1,152
2044	1,593	2,124	622	2,746	1,152
2045	1,593	2,124	622	2,746	1,152
2046	1,593	2,124	622	2,746	1,152
2047	1,593	2,124	622	2,746	1,152
2048	1,593	2,124	622	2,746	1,152
2049	1,593	2,124	622	2,746	1,152
2050	1,593	2,124	622	2,746	1,152
2051	1,593	2,124	622	2,746	1,152
2052	1,593	2,124	622	2,746	1,152
Total	55,772	71,657	21,211	92,868	37,096

Difference between "With-Project" and "Without-Project" situation

(USD thousand in 2013 constant price)

Year	Cost	Benefit	Net Benefit
2013	0	0	0
2014	371	0	-371
2015	6,549	0	-6,549
2016	6,549	0	-6,549
2017	6,549	0	-6,549
2018	889	270	-619
2019	889	274	-614
2020	889	279	-610
2021	889	282	-607
2022	2,139	71	-2,069
2023	2,139	72	-2,068
2024	1,022	73	-950
2025	1,022	73	-949
2026	1,022	74	-948
2027	1,022	75	-947
2028	1,022	76	-946
2029	1,022	77	-946
2030	1,022	78	-945
2031	1,022	78	-945
2032	1,022	78	-945
2033	1,022	78	-945
2034	1,022	78	-945
2035	1,022	78	-945
2036	1,022	78	-945
2037	13,293	78	-13,216
2038	1,022	78	-945
2039	1,022	78	-945
2040	1,022	78	-945
2041	1,022	78	-945
2042	1,022	78	-945
2043	2,574	78	-2,496
2044	1,022	78	-945
2045	1,022	78	-945
2046	1,022	78	-945
2047	1,022	78	-945
2048	1,022	78	-945
2049	1,022	78	-945
2050	1,022	78	-945
2051	1,022	78	-945
2052	1,022	6,652	5,630
Total	71,324	10,058	-61,266

FNPV (discount rate 2.8%) = -41,403
FIRR = -17.1%

Table 12.1.9 Financial Cash Flows of Solid Waste Management M/P Project

With-Project Situation (USD thousand in 2013 constant price)

Year	Capital cost (excl prc esc)	M&E replace (excl. price escalation)	O/M cost	Total Costs	Fixed charge from domestic users	Fixed charge from non-domestic users	Residual value	Total Benefits	Net benefit
2013				0				0	0
2014				0				0	0
2015				0				0	0
2016				0				0	0
2017				0				0	0
2018	20,774		889	21,663	1,567	480		2,047	-19,616
2019	29,274		1,291	30,565	1,592	488		2,080	-28,485
2020	8,625		1,601	10,227	1,618	495		2,113	-8,114
2021	1,559		3,179	4,738	1,638	502		2,139	-2,599
2022	4,182		3,329	7,511	1,658	508		2,166	-5,345
2023	4,182		3,346	7,528	1,678	514		2,192	-5,336
2024			3,540	3,540	1,699	520		2,219	-1,321
2025			3,576	3,576	1,719	526		2,245	-1,331
2026			3,640	3,640	1,739	533		2,272	-1,368
2027			3,657	3,657	1,759	539		2,298	-1,359
2028			3,681	3,681	1,780	545		2,325	-1,357
2029			3,895	3,895	1,800	551		2,351	-1,544
2030			3,910	3,910	1,820	557		2,377	-1,533
2031			3,910	3,910	1,820	557		2,377	-1,533
2032			3,910	3,910	1,820	557		2,377	-1,533
2033			3,910	3,910	1,820	557		2,377	-1,533
2034			3,910	3,910	1,820	557		2,377	-1,533
2035			3,910	3,910	1,820	557		2,377	-1,533
2036			3,910	3,910	1,820	557		2,377	-1,533
2037			3,910	3,910	1,820	557		2,377	-1,533
2038			3,910	3,910	1,820	557		2,377	-1,533
2039			3,910	3,910	1,820	557		2,377	-1,533
2040		17,716	3,910	21,626	1,820	557		2,377	-19,249
2041			3,910	3,910	1,820	557		2,377	-1,533
2042			3,910	3,910	1,820	557		2,377	-1,533
2043			3,910	3,910	1,820	557		2,377	-1,533
2044			3,910	3,910	1,820	557		2,377	-1,533
2045			3,910	3,910	1,820	557		2,377	-1,533
2046			3,910	3,910	1,820	557		2,377	-1,533
2047			3,910	3,910	1,820	557		2,377	-1,533
2048			3,910	3,910	1,820	557		2,377	-1,533
2049			3,910	3,910	1,820	557		2,377	-1,533
2050			3,910	3,910	1,820	557		2,377	-1,533
2051			3,910	3,910	1,820	557		2,377	-1,533
2052			3,910	3,910	1,820	557	15,701	18,079	14,169
Total	68,597	17,716	125,554	211,868	62,106	19,022	15,701	96,828	-115,039

Without-Project Situation (USD thousand in 2013 constant price)

Year	O/M cost	Fixed charge from domestic users	Fixed charge from non-domestic users	Total Benefits	Net benefit
2013				0	0
2014				0	0
2015				0	0
2016				0	0
2017				0	0
2018	2,302	1,393	427	1,819	-483
2019	2,302	1,415	433	1,849	-453
2020	2,302	1,438	440	1,878	-424
2021	2,302	1,456	446	1,902	-400
2022	2,302	1,474	451	1,925	-377
2023	2,302	1,492	457	1,949	-353
2024	2,302	1,510	462	1,972	-330
2025	2,302	1,528	468	1,996	-306
2026	2,302	1,546	473	2,019	-283
2027	2,302	1,564	479	2,043	-259
2028	2,302	1,582	484	2,066	-236
2029	2,302	1,600	490	2,090	-212
2030	2,302	1,618	495	2,113	-189
2031	2,302	1,618	495	2,113	-189
2032	2,302	1,618	495	2,113	-189
2033	2,302	1,618	495	2,113	-189
2034	2,302	1,618	495	2,113	-189
2035	2,302	1,618	495	2,113	-189
2036	2,302	1,618	495	2,113	-189
2037	2,302	1,618	495	2,113	-189
2038	2,302	1,618	495	2,113	-189
2039	2,302	1,618	495	2,113	-189
2040	2,302	1,618	495	2,113	-189
2041	2,302	1,618	495	2,113	-189
2042	2,302	1,618	495	2,113	-189
2043	2,302	1,618	495	2,113	-189
2044	2,302	1,618	495	2,113	-189
2045	2,302	1,618	495	2,113	-189
2046	2,302	1,618	495	2,113	-189
2047	2,302	1,618	495	2,113	-189
2048	2,302	1,618	495	2,113	-189
2049	2,302	1,618	495	2,113	-189
2050	2,302	1,618	495	2,113	-189
2051	2,302	1,618	495	2,113	-189
2052	2,302	1,618	495	2,113	-189
Total	80,571	55,205	16,908	72,113	-8,458

Difference between "With-Project" and "Without-Project" situation

(USD thousand in 2013 constant price)

Year	Cost	Benefit	Net Benefit
2013	0	0	0
2014	0	0	0
2015	0	0	0
2016	0	0	0
2017	0	0	0
2018	19,361	227	-19,134
2019	28,263	231	-28,032
2020	7,925	235	-7,690
2021	2,436	238	-2,199
2022	5,209	241	-4,968
2023	5,226	244	-4,982
2024	1,238	247	-991
2025	1,274	249	-1,025
2026	1,338	252	-1,085
2027	1,355	255	-1,100
2028	1,379	258	-1,121
2029	1,593	261	-1,332
2030	1,608	264	-1,344
2031	1,608	264	-1,344
2032	1,608	264	-1,344
2033	1,608	264	-1,344
2034	1,608	264	-1,344
2035	1,608	264	-1,344
2036	1,608	264	-1,344
2037	1,608	264	-1,344
2038	1,608	264	-1,344
2039	1,608	264	-1,344
2040	19,324	264	-19,060
2041	1,608	264	-1,344
2042	1,608	264	-1,344
2043	1,608	264	-1,344
2044	1,608	264	-1,344
2045	1,608	264	-1,344
2046	1,608	264	-1,344
2047	1,608	264	-1,344
2048	1,608	264	-1,344
2049	1,608	264	-1,344
2050	1,608	264	-1,344
2051	1,608	264	-1,344
2052	1,608	15,965	14,357
Total	131,296	24,715	-106,581

FNPV (discount rate 2.8%) = -76,173
FIRR = -12.0%

12.2 Economic Analysis of the M/P Projects

12.2.1 Methodology and Assumptions

Whereas financial analysis estimates the financial impact of a project on the project-operation entity, economic analysis estimates the economic impact on the country’s economy.

The time frame for economic evaluation was set as same as in the financial analyses, which was the 2013 - 2052 period. The economic analyses for the M/P projects were based on the comparison between the “with project” and “without project” situations. Economic internal rates of return (EIRRs) and economic net present values (ENPVs) were computed. The economic analyses compared the calculated EIRR to the economic opportunity cost of capital (EOCC), which was assumed to be the standard 12% per annum. Economic cash flows were discounted at the same 12% to compute the project ENPVs.

12.2.2 Conversion Factors

Financial costs of the projects were converted to economic costs in 2012 constant prices denominated in the US dollar. Such economic pricing is done at the domestic price level numeraire as economic benefits of WSSW projects are mostly non-tradable and thus represented at the domestic prices. The capital costs and the O&M costs should be split into tradable and non-tradable components. For this purpose, foreign cost portions of the M/P projects were considered to be tradable. Local cost portions of the M/P projects were assumed to be divisible into non-tradable component, skilled labor and unskilled labor.

Financial prices of tradable components as reduced by duties and taxes were converted to economic prices by a shadow exchange rate factor (SERF). The SERF was used to remove the trade distortion effect. The SERF is defined as follows:

$$\text{SERF} = \frac{(M + t_m - s_m) + (X - t_x + s_x)}{M + X}$$

Where:
M and X are total imports and exports, respectively, in a particular year at world prices
t_m and t_x are the tax collected to M and X, respectively.
s_m and t_x are the subsidy paid to M and X, respectively.

The latest annual trade data were available at a statistics database of the World Trade Organization. It showed Zimbabwe’s merchandise exports in 2011 as 3,500 mil. USD, the merchandise imports as

4,400 mil. USD, the service exports as 175 mil. USD and the service import as 183 mil. USD. The tariff binding coverage in the total imports was 21.9% and the average import duty was 15.9%. Thus the import duties levied was computed at 160 mil. USD (= (4400 + 183) × 21.9% × 15.9%). The average duty presumably levied upon the total import was computed back at 3.5% (= 160 ÷ (4400 + 183)). Applying these numbers to the above formula, the SERF was computed at 1.019.

Financial prices of non-tradable components were reduced by taxes only because the trade distortion effects were irrelevant at the domestic price level numeraire. The computation process of conversion factors and the results of the M/P projects are summarized in Tables 12.2.1 through 12.2.3.

Table 12.2.1 Computation of Conversion Factors for Water Supply M/P Project

Conversion factor of Water Supply M/P Project capital cost

Cost composition	Capital Cost (USD) (excl. tax & price cont.)	Conversio factor
Total cost	36,511,872	
Tradable goods & services	25,690,031	1.019
Non-tradable goods & services	10,821,841	
Non-labor cost (50%)	5,410,920	1.000
Skilled labor (5%)	541,092	1.000
Unskilled labor (45%)	4,869,828	0.600
	Weighted Average	0.960

Conversion factor of Water Supply M/P Project O/M Cost (2020 F/S)

Cost composition	Capital Cost (USD) (excl. tax & price cont.)	Conversio factor
Total cost	1,933,174	
Tradable goods & services	1,140,235	1.019
Non-tradable goods & services	792,939	
Skilled labor (10%)	79,294	1.000
Unskilled labor (90%)	713,645	0.600
	Weighted Average	0.864

Conversion factor of Water Supply M/P Project O/M Cost (2030 M/P)

Cost composition	Capital Cost (USD) (excl. tax & price cont.)	Conversio factor
Total cost	2,065,668	
Tradable goods & services	1,193,435	1.019
Non-tradable goods & services	872,233	
Skilled labor (10%)	79,294	1.000
Unskilled labor (90%)	713,645	0.600
	Weighted Average	0.834

Table 12.2.2 Computation of Conversion Factors for Sewerage M/P Project (Option 2)

Conversion factor of sewerage M/P project capital cost

Cost composition	Capital Cost (USD) (excl. tax & price cont.)	Conversio factor
Total cost	18,649,853	
Tradable goods & services	10,571,074	1.019
Non-tradable goods & services	8,078,779	
Non-labor cost (50%)	4,039,390	1.000
Skilled labor (5%)	403,939	1.000
Unskilled labor (45%)	3,635,451	0.600
	Weighted Average	0.933

Conversion factor of sewerage M/P project O/M cost

Cost composition	O&M Cost (USD) (excl. tax & price cont.)	Conversio factor
Total cost	2,615,830	
Tradable goods & services	1,622,491	1.019
Non-tradable goods & services	993,339	
Skilled labor (10%)	99,334	1.000
Unskilled labor (90%)	894,005	0.600
	Weighted Average	0.875

Table 12.2.3 Computation of Conversion Factors for Solid Waste Management M/P Project

Conversion factor of Solid Waste Management M/P Project capital cost

Cost composition	Capital Cost (USD) (excl. tax & price cont.)	Conversio factor
Total cost	57,329,957	
Tradable goods & services	34,146,296	1.019
Non-tradable goods & services	23,183,661	
Non-labor cost (50%)	11,591,831	1.000
Skilled labor (5%)	1,159,183	1.000
Unskilled labor (45%)	10,432,647	0.600
	Weighted Average	0.939

Conversion factor of Solid Waste Management M/P Project O/M Cost

Cost composition	O&M Cost (USD) (excl. tax & price cont.)	Conversio factor
Total cost	3,909,989	
Tradable goods & services	1,182,039	1.019
Non-tradable goods & services	2,727,950	
Skilled labor (10%)	272,795	1.000
Unskilled labor (90%)	2,455,155	0.600
	Weighted Average	0.755

12.2.3 Valuation of Economic Benefits

Among conceivable economic benefits of the M/P projects, attempts were made to quantify and price the following benefits.

- For Water Supply M/P Project
  - (1) Disability-adjusted life year (DALY) to be averted
  - (2) Willingness to pay
  - (3) Residual value of the system at the end of project life
  - (4) Economic value added to ground water newly exploited
- For Sewerage M/P Project
  - (1) DALY to be averted
  - (2) Willingness to pay
  - (3) Residual value of the system at the end of project life
- For Solid Waste Management M/P Project
  - (1) DALY to be averted
  - (2) Willingness to pay
  - (3) Residual value of the system at the end of project life

(1) DALYs to be averted

When valuating the morbidity and the mortality of a disease, a concept of the disability-adjusted life year (DALY) is used. DALY is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death. DALY is composed of two concepts, (i) Years of Life Lost (YLL), referring to potential years of life lost due to premature death and (ii) Years Lived with Disability (YLD), signifying equivalent years of healthy life lost due to poor health or disability. YLL is calculated from the number of deaths at each age multiplied by a global standard life expectancy for each age. YLD for a particular cause in a particular time period is estimated as (a number of incident cases in that period × average duration of the disease × weight factor).

By this way the mortality and the morbidity can be combined into a single measure. As DALY is calculated by taking the sum of these two components, it is represented in a formula of (DALY = YLL + YLD).

Among diseases which can be caused by poor sanitation, diarrhoeal diseases including cholera and typhoid fever are known to have strong causal relationship with the WSSW services. The morbidity and the mortality data of the world and Zimbabwe are available from WHO data base.

Table 12.2.4 shows the number of death classified by cause. A significant feature of Zimbabwe is that as many as 190,605 deaths are caused by HIV/AIDS, accounting for the highest 62% of the total. But globally the HIV/AIDS-caused death represents merely 3% of the total death. Diarrhoeal diseases are confirmed to be a strong cause of death, staying at the 6th highest position both in the world and Zimbabwean rankings.

Table 12.2.4 Total Deaths by Cause

Cause of Death	World		Zimbabwe	
Malignant neoplasms	7,411,626	13%	8,719	3%
Ischaemic heart disease	7,185,353	12%	6,477	2%
Cerebrovascular disease	5,704,843	10%	7,991	3%
Lower respiratory infections	4,172,088	7%	11,540	4%
Chronic obstructive pulmonary disease	3,022,110	5%	2,230	1%
Diarrhoeal diseases	2,162,076	4%	7,597	2%
HIV/AIDS	2,037,406	3%	190,605	62%
Tuberculosis	1,462,495	2%	8,024	3%
Road traffic accidents	1,272,245	2%	4,342	1%
Prematurity and low birth weight	1,178,017	2%	4,529	1%
Neuropsychiatric conditions	1,259,457	2%	2,143	1%
Neonatal infections and other conditions	1,143,425	2%	3,718	1%
Diabetes mellitus	1,135,920	2%	3,024	1%
Hypertensive heart disease	983,280	2%	1,179	0%
Malaria	888,252	2%	1,342	0%
Birth asphyxia and birth trauma	855,426	1%	3,203	1%
Childhood-cluster diseases	846,757	1%	407	0%
Self-inflicted injuries	843,595	1%	1,242	0%
Cirrhosis of the liver	770,403	1%	475	0%
Nephritis and nephrosis	737,141	1%	1,553	1%
All causes	58,676,486	100%	309,294	100%
Population	6,425 million		13 million	

Source: Compiled by JICA Project Team based on "Burden of Disease", WHO, Feb. 2009

Table 12.2.5 shows annual values of DALYs classified by cause. A high number of DALYs is caused by diarrhoeal diseases. It ranks 4th in both the world and Zimbabwe.

Table 12.2.5 DALYs by Cause

(Unit: 000)

Cause of DALY	World		Zimbabwe	
Neuropsychiatric conditions	198,917	13%	340	4%
Lower respiratory infections	94,367	6%	278	3%
Malignant neoplasms	77,609	5%	100	1%
Diarrhoeal diseases	72,632	5%	231	3%
Ischaemic heart disease	62,482	4%	61	1%
HIV/AIDS	58,451	4%	5,010	57%
Other unintentional disease	50,596	3%	138	2%
Cerebrovascular disease	46,531	3%	84	1%
Prematurity and low birth weight	44,366	3%	163	2%
Birth asphyxia and birth trauma	41,761	3%	156	2%
Road traffic accidents	41,140	3%	153	2%
Neonatal infections and other conditions	40,477	3%	133	1%
Maternal conditions	38,853	3%	170	2%
Tuberculosis	34,188	2%	202	2%
Malaria	33,941	2%	63	1%
Childhood-cluster diseases	30,183	2%	25	0%
Chronic obstructive pulmonary disease	30,163	2%	24	0%
Refractive errors	27,716	2%	24	0%
Hearing loss - adult onset	27,314	2%	39	0%
Congenital anomalies	25,224	2%	85	1%
All causes	1,521,022	100%	8,852	100%
Population	6,425 million		13 million	

Source: Compiled by JICA Project Team based on "Burden of Disease", WHO, Feb. 2009

Water, sanitation and hygiene (WASH) -related DALYs in Zimbabwe are also available from a WHO data[1]. The summary is shown in Table 12.2.6. According to this WHO total DALYs generated in Zimbabwe during a year was estimated at 8,851,873. Out of this DALYs, the WASH-related DALYs amounted to 465,859 DALYs, accounting for 5.3% of the total DALYs. Diseases or symptoms that are regarded to cause the WASH-related DALYs are (i) diarrhoeal diseases, (ii) intestinal nematode infections, (iii) protein-energy malnutrition, (iv) consequences of malnutrition, (v) trachoma, (vi) schistosomiasis, and (vii) lymphatic filariasis.

Table 12.2.6 Water, Sanitation and Hygiene-related DALYs in Zimbabwe

Total DALYs by all causes	8,851,873	
Total water, sanitation and hygiene-related DALYs	465,859	100%
Subtotal water supply, sanitation and hygiene	381,520	82%
Diarrhoeal diseases	202,479	43%
Intestinal nematode infections	16,906	4%
Protein-energy malnutrition	58,077	12%
Consequences of malnutrition	49,248	11%
Tracoma	6,300	1%
Schistosomiasis	33,543	7%
Lymphatic filariasis	14,969	3%
Subtotal water resources management	26,279	6%
Malaria	26,279	6%
Dengue	0	0%
Onchocerciasis	0	0%
Japanese encephalitis	0	0%
Safety of water environments	41,292	9%
Other infectious diseases	16,767	4%

Source: Compiled by JICA Project Team based on WHO estimates of DALYs 2004

A WHO study[2] indicates that the diarrhea morbidity will be reduced by 22% if the sanitation is reasonably improved. Where more rigorous analysis is possible, the median reduction rate will be 36%[3]. DALYs caused by diarrhea are estimated to also decrease by the same 36% if the sanitation is properly improved by the M/P projects.

Table 12.2.7 shows the diarrhea morbidity data in 2011 and 2012. The largest ever recorded outbreak of cholera in Zimbabwe occurred from 2008 to 2009. Another outbreak took place in 2012. As at the 46th week of the year 2012, the cumulative number of diarrhoea cases reached 418,765 nationwide, showing a 33% increase compared with the 52 week cumulative data of 2011. Chitungwiza data of

1 Deaths and DALYs estimates attributable to WSH, by country and by region, 2004

2 WHO. 2004. *Comparative quantification of Health Risks, Global and regional burden of disease attributable to selected major risk factors.*

3 A comprehensive literature review* identified 30 studies, from a variety of different countries (including Bangladesh, Brazil, Chile, Guatemala, Kenya, Malaysia and Panama), that examined the impact of sanitation on disease transmission. Twenty-one of those studies reported health improvements. The median reduction in diarrhea morbidity derived from eleven studies was 22%. A greater median reduction of 36% was computed from five rigorous studies.

2012 even shows a bigger increase which is 72.1%. Chitungwiza's percentage of diarrhea case in the national total was 2.4% in 2011 and increased to 3.1% in 2012.

Table 12.2.7 Incidence of Diarrhea in Zimbabwe

(Number of cases recorded, % of national total)

	National	Chitungwiza		Harare	
Diarrhea Cases in 2011	314,079	7,619	2.4%	32,256	10.3%
Diarrhea Cases in 2012 (46 weeks)	418,765	13,113	3.1%	38,904	9.3%
Rate of increase 2012/2011	33.3%	72.1%		20.6%	

Source: Compiled by JICA Project Team based on data of Ministry of Health and Child Welfare

According to a WHO report[4], it is possible to conventionally value each DALY at three times the per capita income. In other words, an intervention which can reduce one DALY at a cost of less than three times the per capita income is regarded cost effective. The per capita monthly income in Chitungwiza was estimated at 65.24 USD based on the two field studies (Base Line Study and Housing Study) conducted by JICA Project Team.

Under "with project" scenario, considerable numbers of the WASH-related DALYs are expected to be averted in the project area thanks to better hygienic conditions achieved by the M/P projects. Such WASH-related DALYs to be annually averted can be valuated by the following formula.

$$D_k = D_i \times R \times S \times (I \times 3)$$

Where:

D_k :the WASH-related DALYs to be averted in the project area.

D_i :the total WASH-related DALYs in Zimbabwe.

R :the reduction rate of WASH-related DALYs after the Project.

S :the share of the project area's WASH-related morbidities against the total of Zimbabwe.

I :the per capita annual income.

3 :the coefficient of DALY to annual income.

Presumably the reduction pattern of the WASH-related DALYs will be similar to that of the diarrhea cases. Table 12.2.8 shows predictions of the number of diarrhea cases, population and DALYs. WHO made the DALY valuation on the basis of the year 2004 data. There was no cholera outbreak in Zimbabwe in 2004, the same in 2011. There was no significant increase in the population of Zimbabwe between 2004 and 2011. Therefore a safe assumption is that the same DALY values in

[4] WHO. 2001. *Macroeconomics and health: investing in health for economic development*

2004 are applicable to those in 2011. However, there was notable outbreak of cholera in 2012, which was confirmed by a significant increase of diarrhoea cases in that year. In year 2013, the base year of the project analysis, the situations will have been normalized back to the status of year 2004 or 2011. Only the population increase is assumed to affect proportionately to the number of diarrhea cases during the project analysis period.

Table 12.2.8 Projection of Diarrhoea Incidence and DALYs

Year	Population of Chitungwiza *a (person)	Diarrhoeal cases in Chitungwiza without M/P projects (# of cases)	WASH-DALY in Chitungwiza without M/P projects (DALY)	WASH-DALY reduction due to M/P projects (DALY)
2011	354,500	7,619 *b	11,301 *d	0
2012	354,500	14,823 *c	21,987 *d	0
2013	360,838	7,755	11,503	0
2014	367,175	7,891	11,705	0
2015	373,513	8,028	11,907	0
2016	379,850	8,164	12,109	4,359
2017	386,188	8,300	12,311	4,432
2018	392,525	8,436	12,513	4,505
2019	398,863	8,572	12,715	4,577
2020	405,200	8,709	12,917	4,650
2021	410,270	8,818	13,079	4,708
2022	415,340	8,927	13,240	4,767
2023	420,410	9,036	13,402	4,825
2024	425,480	9,145	13,564	4,883
2025	430,550	9,253	13,725	4,941
2026	435,620	9,362	13,887	4,999
2027	440,690	9,471	14,049	5,057
2028	445,760	9,580	14,210	5,116
2029	450,830	9,689	14,372	5,174
2030 - 2045	455,900	9,798	14,533	5,232

Source: Compiled by JICA Project Team based on data of WHO and Ministry of Health
*a: Estimated by JICA Project Team
*b: Data of Ministry of Health and Child Welfare
*c: Estimated by JICA Project Team based on the 46 week cumulative data of Ministry of Health
*d: Assumed by JICA Project Team based on data of WHO and Ministry of Health

The economic benefit derived from DALYs to be averted is attributable to three infrastructure systems (water supply, sewerage, and solid waste management) which constitute the M/P projects. It is difficult to determine an appropriate distribution rate of the benefit among the three different systems. One way of doing so is to prorate the benefit value according to the project cost. However this automatically leads to the hypothesis that the bigger a project cost, the economically better, which is not always true. Thus, it is assumed that the DALY related benefit is equally distributed among the three infrastructure systems.

(2) Willingness to pay

The willingness to pay (WTP) for the water supply was investigated in the Environmental and Social Considerations Baseline Study in August 2012 (Baseline Study). The willingness to pay for sewerage and solid waste management services was not asked in the study. The result from 97 respondents showed that the mean amount the households were willing to pay for the water supply was 17.09 USD per month. As the average household size was 5.98 persons per household, the per-head monthly WTP for the water supply was computed at 2.86 USD.

The Baseline Study did not include questions to ask the WTP prices for the sewerage and the solid waste management. To estimate these WTPs, assumptions made were (i) the WTP for the WSSW services altogether are 5% of the income and (ii) the ratio among the WTP for the water and the WTP for the sewerage and the WTP for the solid waste management is 3 : 1.5 : 0.5. Applying these numbers, the per-head monthly WTPs for the sewerage and the solid waste management were computed at 1.43 USD and 0.48 USD respectively.

It should be noted that the DALY concept is partly reflected in the WTP. People benefitting from the M/P projects perceive that the WASH-related disease burden will be lessened by virtue of the projects. Other expectations such as time saving for water fetching, avoidance of purchasing higher priced vendor water and appreciation of more esthetic environments are not embodied in the DALY concept. Hence, valuation of such non DALY-related factor in WTP is not double-counting of benefits. Our assumption is that two thirds of the WTP values represent the DALY-related benefits and the remaining third is considered to be the non DALY-related benefits. Such non DALY-related benefits were computed at 0.95 USD per month per capita for the water supply, 0.48 USD for the sewerage and 0.16 USD for the solid waste management.

The WTP value of non-domestic users can be added to the economic benefits. Non-domestic users are often prepared to pay even higher charges than what they are currently paying for better WSSW services. However there was no study conducted to clarify the WTP of non-domestic users in Chitungwiza. Thus it was simply assumed that the ratio between the aggregate WTP from non-domestic users and the aggregate WTP of domestic users was the same as the ratio of water consumption, which was estimated by the Housing Survey as 11 (domestic) to 89 (non-domestic).

(3) Residual value at the end of project life

Residual values of the M/P projects at the end of the project lives are regarded as benefits in a same way as what was included in the financial evaluation. A residual value represented as a financial value needs to be converted to an economic value. The conversion factors used to arrive in the economic values were the same as those computed as the conversion factors of capital costs.

(4) Value added to ground water

The water output in the water supply M/P project is made up of two parts: incremental and nonincremental water. The quantity of nonincremental water is regarded as the same as the bulk water currently purchased from Harare and distributed in Chitungwiza. The incremental water can be further divided into two water types: bulk water additionally purchased from Harare and ground water from wells newly dug by the M/P project. In comparison between “with project” and “without project” situations, the nonincremental water generates no economic value. The incremental water originated from the Harare bulk water does not have additional economic value either as this water can be consumed equally whether in Harare or Chitungwiza. Therefore the water cost is economically same as the water price. The incremental water from the new wells has additional economic value which is considered as willingness to pay price. Currently many residents in and around Harare suffer from the protracted water shortage and purchase bowser water, which is delivered by trucks. The quality of bowser water is similar to the bulk water and the water to be produced by the M/P project. The bowser water is priced at 40 to 55 USD per five cubic metres, which is regarded as prevailing economic price for the treated water. The future water supply in Harare and its surrounding area will be ameliorated therefore such high economic price will not be lasting. Having a conservative stance in the economic analysis, the economic price of the treated water will be reduced to as low as 10 USD per five cubic metre, or 2 USD per cubic metre.

12.2.4 Analysis of Economic Viability

Economic cash flows of the M/P projects are presented in Tables 12.2.9 through 12.2.11. The EIRRs in real terms resulted in 28.5% for the water supply M/P project, 22.8% for the sewerage M/P project and 6.1% for the solid waste management M/P project. The EIRRs of the water supply project and the sewerage project exceed 12%, meaning that those projects are economically viable. However the EIRR of the solid waste management project is lower than 12%. Thus this project is regarded not economically viable. The ENPV results were 29.8 mil. USD for the water supply M/P project, 13.2 mil. USD for the sewerage M/P project and minus 9.2 mil. USD for the solid waste management M/P project. The positive ENPVs of the water supply M/P project and the sewerage M/P project also suggest that those projects are economically viable.

Table 12.2.9 Economic Cash Flows of Water Supply M/P Project

With-Project Situation (USD thousand in 2013 constant price)

Year	Capital cost	O&M cost	Bulk water opp. cost	Total Costs	DALYs averted	WTP of domestic users	WTP of non-domestic users	Bulk water opp. Price	Purified well water opp. price	Salvage value	Total Benefits	Net benefit
2013				0							0	0
2014	2,545			2,545							0	-2,545
2015	9,195			9,195					2,190		2,190	-7,005
2016	9,195			9,195					2,190		2,190	-7,005
2017	9,195			9,195					2,190		2,190	-7,005
2018	0	1,669	26,715	28,384	3,527	4,490	537	26,715	2,190		37,459	9,075
2019	0	1,669	26,715	28,384	3,584	4,563	546	26,715	2,190		37,597	9,213
2020	0	1,669	26,715	28,384	3,641	4,635	554	26,715	2,190		37,735	9,351
2021	0	1,669	26,715	28,384	3,686	4,693	561	26,715	2,190		37,846	9,461
2022	6,077	1,669	26,715	34,461	3,732	4,751	568	26,715	2,190		37,956	3,495
2023	6,077	1,669	26,715	34,461	3,777	4,809	575	26,715	2,190		38,067	3,606
2024	0	1,724	30,642	32,366	3,823	4,867	582	30,642	2,190		42,105	9,739
2025	0	1,724	30,642	32,366	3,868	4,925	589	30,642	2,190		42,215	9,849
2026	0	1,724	30,642	32,366	3,914	4,983	596	30,642	2,190		42,326	9,960
2027	0	1,724	30,642	32,366	3,959	5,041	603	30,642	2,190		42,436	10,070
2028	0	1,724	30,642	32,366	4,005	5,099	610	30,642	2,190		42,547	10,181
2029	0	1,724	30,642	32,366	4,050	5,157	617	30,642	2,190		42,657	10,291
2030	0	1,724	30,642	32,366	4,096	5,215	624	30,642	2,190		42,768	10,402
2031	0	1,724	30,642	32,366	4,096	5,215	624	30,642	2,190		42,768	10,402
2032	0	1,724	30,642	32,366	4,096	5,215	624	30,642	2,190		42,768	10,402
2033	0	1,724	30,642	32,366	4,096	5,215	624	30,642	2,190		42,768	10,402
2034	0	1,724	30,642	32,366	4,096	5,215	624	30,642	2,190		42,768	10,402
2035	0	1,724	30,642	32,366	4,096	5,215	624	30,642	2,190		42,768	10,402
2036	0	1,724	30,642	32,366	4,096	5,215	624	30,642	2,190		42,768	10,402
2037	4,728	1,724	30,642	37,094	4,096	5,215	624	30,642	2,190		42,768	5,674
2038	0	1,724	30,642	32,366	4,096	5,215	624	30,642	2,190		42,768	10,402
2039	0	1,724	30,642	32,366	4,096	5,215	624	30,642	2,190		42,768	10,402
2040	0	1,724	30,642	32,366	4,096	5,215	624	30,642	2,190		42,768	10,402
2041	0	1,724	30,642	32,366	4,096	5,215	624	30,642	2,190		42,768	10,402
2042	0	1,724	30,642	32,366	4,096	5,215	624	30,642	2,190		42,768	10,402
2043	1,907	1,724	30,642	34,273	4,096	5,215	624	30,642	2,190		42,768	8,495
2044	0	1,724	30,642	32,366	4,096	5,215	624	30,642	2,190		42,768	10,402
2045	0	1,724	30,642	32,366	4,096	5,215	624	30,642	2,190		42,768	10,402
2046	0	1,724	30,642	32,366	4,096	5,215	624	30,642	2,190		42,768	10,402
2047	0	1,724	30,642	32,366	4,096	5,215	624	30,642	2,190		42,768	10,402
2048	0	1,724	30,642	32,366	4,096	5,215	624	30,642	2,190		42,768	10,402
2049	0	1,724	30,642	32,366	4,096	5,215	624	30,642	2,190		42,768	10,402
2050	0	1,724	30,642	32,366	4,096	5,215	624	30,642	2,190		42,768	10,402
2051	0	1,724	30,642	32,366	4,096	5,215	624	30,642	2,190		42,768	10,402
2052	0	1,724	30,642	32,366	4,096	5,215	624	30,642	2,190	14,155	56,923	24,557
Total	48,918	60,000	1,048,921	1,157,840	139,774	177,975	21,280	1,048,921	83,220	14,155	1,485,325	327,485

Without-Project Situation (USD thousand in 2013 constant price)

Year	O&M cost	Bulk water opp. cost	Total Costs	Water sales opportunity price	Net benefit
2013			0		0
2014			0		0
2015			0		0
2016			0		0
2017			0		0
2018	833	21,900	22,733	21,900	-833
2019	833	21,900	22,733	21,900	-833
2020	833	21,900	22,733	21,900	-833
2021	833	21,900	22,733	21,900	-833
2022	833	21,900	22,733	21,900	-833
2023	833	21,900	22,733	21,900	-833
2024	833	21,900	22,733	21,900	-833
2025	833	21,900	22,733	21,900	-833
2026	833	21,900	22,733	21,900	-833
2027	833	21,900	22,733	21,900	-833
2028	833	21,900	22,733	21,900	-833
2029	833	21,900	22,733	21,900	-833
2030	833	21,900	22,733	21,900	-833
2031	833	21,900	22,733	21,900	-833
2032	833	21,900	22,733	21,900	-833
2033	833	21,900	22,733	21,900	-833
2034	833	21,900	22,733	21,900	-833
2035	833	21,900	22,733	21,900	-833
2036	833	21,900	22,733	21,900	-833
2037	833	21,900	22,733	21,900	-833
2038	833	21,900	22,733	21,900	-833
2039	833	21,900	22,733	21,900	-833
2040	833	21,900	22,733	21,900	-833
2041	833	21,900	22,733	21,900	-833
2042	833	21,900	22,733	21,900	-833
2043	833	21,900	22,733	21,900	-833
2044	833	21,900	22,733	21,900	-833
2045	833	21,900	22,733	21,900	-833
2046	833	21,900	22,733	21,900	-833
2047	833	21,900	22,733	21,900	-833
2048	833	21,900	22,733	21,900	-833
2049	833	21,900	22,733	21,900	-833
2050	833	21,900	22,733	21,900	-833
2051	833	21,900	22,733	21,900	-833
2052	833	21,900	22,733	21,900	-833
Total	29,149	766,500	795,649	766,500	-29,149

Difference between "With-Project" and "Without-Project" situation (USD thousand in 2013 constant price)

Year	Cost	Benefit	Net benefit
2013	0	0	0
2014	2,545	0	-2,545
2015	9,195	2,190	-7,005
2016	9,195	2,190	-7,005
2017	9,195	2,190	-7,005
2018	5,651	15,559	9,908
2019	5,651	15,697	10,046
2020	5,651	15,835	10,184
2021	5,651	15,946	10,294
2022	11,728	16,056	4,328
2023	11,728	16,167	4,439
2024	9,633	20,205	10,571
2025	9,633	20,315	10,682
2026	9,633	20,426	10,792
2027	9,633	20,536	10,903
2028	9,633	20,647	11,013
2029	9,633	20,757	11,124
2030	9,633	20,868	11,234
2031	9,633	20,868	11,234
2032	9,633	20,868	11,234
2033	9,633	20,868	11,234
2034	9,633	20,868	11,234
2035	9,633	20,868	11,234
2036	9,633	20,868	11,234
2037	14,361	20,868	6,507
2038	9,633	20,868	11,234
2039	9,633	20,868	11,234
2040	9,633	20,868	11,234
2041	9,633	20,868	11,234
2042	9,633	20,868	11,234
2043	11,540	20,868	9,328
2044	9,633	20,868	11,234
2045	9,633	20,868	11,234
2046	9,633	20,868	11,234
2047	9,633	20,868	11,234
2048	9,633	20,868	11,234
2049	9,633	20,868	11,234
2050	9,633	20,868	11,234
2051	9,633	20,868	11,234
2052	9,633	35,023	25,390
Total	362,191	718,825	356,634

ENPV (discount rate 12%) = 29,841
EIRR = 28.5%

Table 12.2.10 Economic Cash Flows of Sewerage M/P Project (Option 2)

With-Project Situation (USD thousand in 2013 constant price)

Year	Capital cost	O&M cost	Total Costs	DALYs averted	WTP of domestic users	WTP of non-domestic users	Salvage value	Total Benefits	Net benefit
2013			0					0	0
2014	346		346					0	-346
2015	6,037	68	6,105					0	-6,105
2016	6,037	68	6,105					0	-6,105
2017	6,037	68	6,105					0	-6,105
2018	0	2,172	2,172	3,527	2,245	268		6,040	3,868
2019	0	2,172	2,172	3,584	2,281	273		6,138	3,966
2020	0	2,172	2,172	3,641	2,318	277		6,235	4,063
2021	0	2,172	2,172	3,686	2,347	281		6,313	4,141
2022	1,167	2,172	3,339	3,732	2,376	284		6,391	3,053
2023	1,167	2,172	3,339	3,777	2,405	288		6,469	3,131
2024	0	2,289	2,289	3,823	2,434	291		6,547	4,258
2025	0	2,289	2,289	3,868	2,463	294		6,625	4,336
2026	0	2,289	2,289	3,914	2,492	298		6,704	4,414
2027	0	2,289	2,289	3,959	2,521	301		6,782	4,492
2028	0	2,289	2,289	4,005	2,550	305		6,860	4,570
2029	0	2,289	2,289	4,050	2,579	308		6,938	4,649
2030	0	2,289	2,289	4,096	2,608	312		7,016	4,727
2031	0	2,289	2,289	4,096	2,608	312		7,016	4,727
2032	0	2,289	2,289	4,096	2,608	312		7,016	4,727
2033	0	2,289	2,289	4,096	2,608	312		7,016	4,727
2034	0	2,289	2,289	4,096	2,608	312		7,016	4,727
2035	0	2,289	2,289	4,096	2,608	312		7,016	4,727
2036	0	2,289	2,289	4,096	2,608	312		7,016	4,727
2037	11,446	2,289	13,736	4,096	2,608	312		7,016	-6,720
2038	0	2,289	2,289	4,096	2,608	312		7,016	4,727
2039	0	2,289	2,289	4,096	2,608	312		7,016	4,727
2040	0	2,289	2,289	4,096	2,608	312		7,016	4,727
2041	0	2,289	2,289	4,096	2,608	312		7,016	4,727
2042	0	2,289	2,289	4,096	2,608	312		7,016	4,727
2043	1,447	2,289	3,736	4,096	2,608	312		7,016	3,280
2044	0	2,289	2,289	4,096	2,608	312		7,016	4,727
2045	0	2,289	2,289	4,096	2,608	312		7,016	4,727
2046	0	2,289	2,289	4,096	2,608	312		7,016	4,727
2047	0	2,289	2,289	4,096	2,608	312		7,016	4,727
2048	0	2,289	2,289	4,096	2,608	312		7,016	4,727
2049	0	2,289	2,289	4,096	2,608	312		7,016	4,727
2050	0	2,289	2,289	4,096	2,608	312		7,016	4,727
2051	0	2,289	2,289	4,096	2,608	312		7,016	4,727
2052	0	2,289	2,289	4,096	2,608	312	6,133	13,148	10,859
Total	33,683	79,619	113,302	139,774	88,987	10,640	6,133	245,534	132,232

Without-Project Situation (USD thousand in 2013 constant price)

Year	O&M cost	Benefit	Net benefit
2013			0
2014			0
2015			0
2016			0
2017			0
2018	1,394	0	-1,394
2019	1,394	0	-1,394
2020	1,394	0	-1,394
2021	1,394	0	-1,394
2022	1,394	0	-1,394
2023	1,394	0	-1,394
2024	1,394	0	-1,394
2025	1,394	0	-1,394
2026	1,394	0	-1,394
2027	1,394	0	-1,394
2028	1,394	0	-1,394
2029	1,394	0	-1,394
2030	1,394	0	-1,394
2031	1,394	0	-1,394
2032	1,394	0	-1,394
2033	1,394	0	-1,394
2034	1,394	0	-1,394
2035	1,394	0	-1,394
2036	1,394	0	-1,394
2037	1,394	0	-1,394
2038	1,394	0	-1,394
2039	1,394	0	-1,394
2040	1,394	0	-1,394
2041	1,394	0	-1,394
2042	1,394	0	-1,394
2043	1,394	0	-1,394
2044	1,394	0	-1,394
2045	1,394	0	-1,394
2046	1,394	0	-1,394
2047	1,394	0	-1,394
2048	1,394	0	-1,394
2049	1,394	0	-1,394
2050	1,394	0	-1,394
2051	1,394	0	-1,394
2052	1,394	0	-1,394
Total	48,805	0	-48,805

Difference between "With-Project" and "Without-Project" situation (USD thousand in 2013 constant price)

Year	Cost	Benefit	Net benefit
2013	0	0	0
2014	346	0	-346
2015	6,105	0	-6,105
2016	6,105	0	-6,105
2017	6,105	0	-6,105
2018	778	6,040	5,262
2019	778	6,138	5,360
2020	778	6,235	5,458
2021	778	6,313	5,536
2022	1,944	6,391	4,447
2023	1,944	6,469	4,525
2024	895	6,547	5,653
2025	895	6,625	5,731
2026	895	6,704	5,809
2027	895	6,782	5,887
2028	895	6,860	5,965
2029	895	6,938	6,043
2030	895	7,016	6,121
2031	895	7,016	6,121
2032	895	7,016	6,121
2033	895	7,016	6,121
2034	895	7,016	6,121
2035	895	7,016	6,121
2036	895	7,016	6,121
2037	12,341	7,016	-5,326
2038	895	7,016	6,121
2039	895	7,016	6,121
2040	895	7,016	6,121
2041	895	7,016	6,121
2042	895	7,016	6,121
2043	2,342	7,016	4,674
2044	895	7,016	6,121
2045	895	7,016	6,121
2046	895	7,016	6,121
2047	895	7,016	6,121
2048	895	7,016	6,121
2049	895	7,016	6,121
2050	895	7,016	6,121
2051	895	7,016	6,121
2052	895	13,148	12,254
Total	64,498	245,534	181,036

ENPV (discount rate 12%) = 13,171
EIRR = 22.8%

Table 12.2.11 Economic Cash Flows of Solid Waste Management M/P Project

With-Project Situation (USD thousand in 2013 constant price)

Year	Capital cost	O&M cost	Total Costs	DALYs averted	WTP of domestic users	WTP of non-domestic users	Salvage value	Total Benefits	Net benefit
2013			0					0	0
2014			0					0	0
2015			0					0	0
2016			0					0	0
2017			0					0	0
2018	19,497	671	20,168	3,527	754	90		4,370	-15,798
2019	27,474	974	28,448	3,584	766	92		4,441	-24,008
2020	8,095	1,208	9,303	3,641	778	93		4,512	-4,792
2021	1,463	2,399	3,862	3,686	788	94		4,568	706
2022	3,925	2,512	6,437	3,732	797	95		4,624	-1,812
2023	3,925	2,525	6,450	3,777	807	97		4,681	-1,769
2024	0	2,671	2,671	3,823	817	98		4,737	2,066
2025	0	2,699	2,699	3,868	827	99		4,794	2,095
2026	0	2,747	2,747	3,914	836	100		4,850	2,104
2027	0	2,759	2,759	3,959	846	101		4,907	2,147
2028	0	2,778	2,778	4,005	856	102		4,963	2,185
2029	0	2,939	2,939	4,050	866	103		5,020	2,080
2030	0	2,950	2,950	4,096	875	105		5,076	2,126
2031	0	2,950	2,950	4,096	875	105		5,076	2,126
2032	0	2,950	2,950	4,096	875	105		5,076	2,126
2033	0	2,950	2,950	4,096	875	105		5,076	2,126
2034	0	2,950	2,950	4,096	875	105		5,076	2,126
2035	0	2,950	2,950	4,096	875	105		5,076	2,126
2036	0	2,950	2,950	4,096	875	105		5,076	2,126
2037	0	2,950	2,950	4,096	875	105		5,076	2,126
2038	0	2,950	2,950	4,096	875	105		5,076	2,126
2039	0	2,950	2,950	4,096	875	105		5,076	2,126
2040	16,627	2,950	19,578	4,096	875	105		5,076	-14,501
2041	0	2,950	2,950	4,096	875	105		5,076	2,126
2042	0	2,950	2,950	4,096	875	105		5,076	2,126
2043	0	2,950	2,950	4,096	875	105		5,076	2,126
2044	0	2,950	2,950	4,096	875	105		5,076	2,126
2045	0	2,950	2,950	4,096	875	105		5,076	2,126
2046	0	2,950	2,950	4,096	875	105		5,076	2,126
2047	0	2,950	2,950	4,096	875	105		5,076	2,126
2048	0	2,950	2,950	4,096	875	105		5,076	2,126
2049	0	2,950	2,950	4,096	875	105		5,076	2,126
2050	0	2,950	2,950	4,096	875	105		5,076	2,126
2051	0	2,950	2,950	4,096	875	105		5,076	2,126
2052	0	2,950	2,950	4,096	875	105	14,736	19,812	16,862
Total	81,007	94,740	175,748	139,774	29,870	3,571	14,736	187,952	12,204

Without-Project Situation (USD thousand in 2013 constant price)

Year	O&M cost	WTP for satisfactory SWM	Net benefit
2013			0
2014			0
2015			0
2016			0
2017			0
2018	1,737	0	-1,737
2019	1,737	0	-1,737
2020	1,737	0	-1,737
2021	1,737	0	-1,737
2022	1,737	0	-1,737
2023	1,737	0	-1,737
2024	1,737	0	-1,737
2025	1,737	0	-1,737
2026	1,737	0	-1,737
2027	1,737	0	-1,737
2028	1,737	0	-1,737
2029	1,737	0	-1,737
2030	1,737	0	-1,737
2031	1,737	0	-1,737
2032	1,737	0	-1,737
2033	1,737	0	-1,737
2034	1,737	0	-1,737
2035	1,737	0	-1,737
2036	1,737	0	-1,737
2037	1,737	0	-1,737
2038	1,737	0	-1,737
2039	1,737	0	-1,737
2040	1,737	0	-1,737
2041	1,737	0	-1,737
2042	1,737	0	-1,737
2043	1,737	0	-1,737
2044	1,737	0	-1,737
2045	1,737	0	-1,737
2046	1,737	0	-1,737
2047	1,737	0	-1,737
2048	1,737	0	-1,737
2049	1,737	0	-1,737
2050	1,737	0	-1,737
2051	1,737	0	-1,737
2052	1,737	0	-1,737
Total	60,797	0	-60,797

Difference between "With-Project" and "Without-Project" situation (USD thousand in 2013 constant price)

Year	Cost	Benefit	Net Benefit
2013	0	0	0
2014	0	0	0
2015	0	0	0
2016	0	0	0
2017	0	0	0
2018	18,431	4,370	-14,061
2019	26,711	4,441	-22,270
2020	7,566	4,512	-3,055
2021	2,125	4,568	2,443
2022	4,700	4,624	-75
2023	4,713	4,681	-32
2024	934	4,737	3,803
2025	961	4,794	3,832
2026	1,010	4,850	3,841
2027	1,022	4,907	3,884
2028	1,041	4,963	3,922
2029	1,202	5,020	3,817
2030	1,213	5,076	3,863
2031	1,213	5,076	3,863
2032	1,213	5,076	3,863
2033	1,213	5,076	3,863
2034	1,213	5,076	3,863
2035	1,213	5,076	3,863
2036	1,213	5,076	3,863
2037	1,213	5,076	3,863
2038	1,213	5,076	3,863
2039	1,213	5,076	3,863
2040	17,840	5,076	-12,764
2041	1,213	5,076	3,863
2042	1,213	5,076	3,863
2043	1,213	5,076	3,863
2044	1,213	5,076	3,863
2045	1,213	5,076	3,863
2046	1,213	5,076	3,863
2047	1,213	5,076	3,863
2048	1,213	5,076	3,863
2049	1,213	5,076	3,863
2050	1,213	5,076	3,863
2051	1,213	5,076	3,863
2052	1,213	19,812	18,599
Total	114,951	187,952	73,001

ENPV (discount rate 12%) = -9,234
EIRR = 6.1%

12.3 Conclusion

IRRs and NPVs of each M/P project are summarized in Table 12.2.12. None of the M/P projects is financially viable. This is not surprising as the tariffs are not set to cover the capital costs, considering the affordability of users. The financial viabilities of the M/P projects are subject to external assistance such as grant from foreign development partners or subsidy of the GOZ.

Table 12.2.12 IRRs and NPVs of M/P Projects

	FIRR	FNPV (USD million)	EIRR	ENPV (USD million)
Water supply	-5.2%	-40.6	28.5%	29.8
Sewerage (Option 2)	-17.1%	-41.4	22.8%	13.2
Solid waste management	-12.0%	-76.2	6.1%	-9.2
Hurdle rate	2.8%		12.0%	

However, from the viewpoints of economical viability, the M/P projects are worth implementing. The low EIRR of the solid waste management project can be reinforced by combining with other projects. For example, if the water supply, the sewerage and the solid waste management projects are jointly implemented, the EIRR and the ENPV will be 18.1% and 25.7 mil. USD respectively (Table 12.2.13). Both results satisfy the economic viability requirement.

Discussions were held in July 2013 between the Japanese and the Zimbabwean sides, and this positive economic feasibility of the M/P projects were appreciated by the both sides. A usual next step was to proceed to the F/S study where the project area and scope would be further narrowed down. However, it was decided to put a certain period before the commencement of the F/S study in order to confirm the improvement of financial status through discussions between the both sides.

Table 12.2.13 Economic Cash Flow of Combined Project

(USD thousand in 2013 constant price)

Year	Water Net Benefit	Sewerage (Op2) Net Benefit	Solid waste Net Benefit	Combined net benefits of WSSW
2013	0	0	0	0
2014	-2,545	-346	0	-2,891
2015	-7,005	-6,105	0	-13,110
2016	-7,005	-6,105	0	-13,110
2017	-7,005	-6,105	0	-13,110
2018	9,908	5,262	-15,798	-628
2019	10,046	5,360	-24,008	-8,602
2020	10,184	5,458	-4,792	10,849
2021	10,294	5,536	706	16,536
2022	4,328	4,447	-1,812	6,963
2023	4,439	4,525	-1,769	7,195
2024	10,571	5,653	2,066	18,291
2025	10,682	5,731	2,095	18,508
2026	10,792	5,809	2,104	18,705
2027	10,903	5,887	2,147	18,937
2028	11,013	5,965	2,185	19,164
2029	11,124	6,043	2,080	19,247
2030	11,234	6,121	2,126	19,481
2031	11,234	6,121	2,126	19,481
2032	11,234	6,121	2,126	19,481
2033	11,234	6,121	2,126	19,481
2034	11,234	6,121	2,126	19,481
2035	11,234	6,121	2,126	19,481
2036	11,234	6,121	2,126	19,481
2037	6,507	-5,326	2,126	3,307
2038	11,234	6,121	2,126	19,481
2039	11,234	6,121	2,126	19,481
2040	11,234	6,121	-14,501	2,854
2041	11,234	6,121	2,126	19,481
2042	11,234	6,121	2,126	19,481
2043	9,328	4,674	2,126	16,127
2044	11,234	6,121	2,126	19,481
2045	11,234	6,121	2,126	19,481
2046	11,234	6,121	2,126	19,481
2047	11,234	6,121	2,126	19,481
2048	11,234	6,121	2,126	19,481
2049	11,234	6,121	2,126	19,481
2050	11,234	6,121	2,126	19,481
2051	11,234	6,121	2,126	19,481
2052	25,390	12,254	16,862	54,505
Total	356,634	181,036	12,204	549,875

ENPV = 25,720 EIRR = 18.1%

CHAPTER 13 CONCLUSION AND RECOMMENDATION

13.1 Background

- Zengeza STP was constructed by Japanese ODA project and transferred in 2000. Operation of the facility was suspended in 2004 due to O&M problem and its budget.
- Data Collection Study on Improvement of Sanitary Environment of Chitungwiza City was conducted during January and February in 2011. As a result of the investigation, it was recognized that a comprehensive approach is needed for water supply and solid waste management as well as sewage for the improvement of sanitary condition in Chitungwiza.
- The government of Japan appointed JICA to start the study on technical corporation for development for two years from April 2012: Phase I Basic Study, Phase II Establishment of Master Plan, Phase III Feasibility Study. (Conducted by NJS Consultants Co. Ltd.)
- City of Harare has been developing the "Greater Harare Water and Sanitation Strategic Plan" with the assist by WB to improve water supply and sanitation services for City of Harare and 4 municipalities (Chitungwiza, Ruwa, Epworth and Norton) by September 2013.
- Since investors meeting will be held in the project, it is expected that various investors will be involved for the project for concerned municipalities.

13.2 Analysis of current condition for Water Supply

- The actual production capacity of Harare Water Works in 2012 is around 640,000m^3/day, while the water demand was estimated to be 383,000m^3/day. The production capacity is considered not to enough because the necessary capacity is estimated 890,000m^3/day due to 57% of the NRW (Non-Revenue Water) of Harare distribution area.
- Chitungwiza Municipality (354,000 of population by 2012 census) almost completely depends on the bulk water distributed by Harare Water Works. The normal distributed flow is 30,000m^3/day, but it is frequently reduced to 12,000-15,000m^3/day.
- There are reservoirs with 41,000m^3 of volume in Chitungwiza, however these are not used for water supply regulation. Water distribution to Chitungwiza is pumped up constantly from Prince Edward WTP even though the water demand is fluctuated.
- Chitungwiza Municipality only paid 10% to the balk water bill to Harare Water Works; 1.2mil.USD out of total balk water bill of 12.7mil.USD for past three (3) years were paid on February 2013
- Water supply of balk water to Chitungwiza Municipality is restricted due to unpaid bill, and shortage of water amount and frequent breakdown of facilities of Harare Water

Works. Thus total over 3,000 of wells are used for supplemental water supply in the municipality

13.3 Current Status of Sewerage

- Raw sewage has been discharged to Manyame catchment area from City of Harare and the Municipalities.
- There are two sewage treatment facilities in Chitungwiza : Old facility of trickling filters constructed in 1978 with the capacity of 20,000m^3/d and latest facility of BNR with the capacity of 20,000m^3/d constructed by Japanese ODA.
- A part of St.Mary area, Seke North area and Seke South area in Chitungwiza were not covered due to break down of pump stations, clogging of sewers. One of the cause of the break down is the deposit of sand in the sewers. Residents have been using the sand for the pot washing. The sand in the sewer was cleaned by Jet Cleaning Machine before. After the breakdown of the cleaning machine it was made by manually after 2001.
- In the AWF project under AfDB, sewers and pump stations were rehabilitated, which will enable the whole sewage reach to the STP. Existing old Trickling filters in Zengeza STP will be rehabilitated by Zim Fund as well.

13.4 Analysis of current condition for Solid Waste Management

- Method is House–to-house collection of waste bags and collection of skip bin. Collected wastes are transported to the dumping site about 5km away from the municipality by truck once a week.
- Currently, the system cannot cover whole the area due to bad road condition.
- Wastes have been disposed in the open dumping site without any control.
- 390 Illegal dumping sites were found in the study with the total wastes amount of 60,000m^3.

13.5 Current Status of Water Cycle and Aquatic Environment

- Daily inflow to Lake Chivero is approx. 1,000,000m^3/d. Approx. 640,000m^3/d is taken as raw water for the water supply.
- Population of City of Harare is around 1,600,000 with two major STP of Crowborough （54,000m3/d） and Firle （144,000m3/d） . About 60 % of the sewage was treated by BNR process while rest of sewage was treated by trickling filter process. However, BNR process is not working because of breakdown.
- Total sewage generated in the Manyame catchment area is about 230,000 m3/d, with the 90 % share of Harare (approx. 200,000m3/d) and 10% share of Chitungwiza (22,000 m3/d).

- BOD loading for the catchment from Harare is 110,000kg-BOD/d, and that of Chitungwiza is 13,000kg-BOD/d（12% of Harare)

13.6 Current Status of Flow and Water Quality and Future Projection

- Worsening of every parameter of water quality was confirmed in the analysis.
- Since the catchment area has characteristics with low specific run-off and large variation of annual rainfall, it will not be easy to secure ample surface water. Then construction of sewerage and its appropriate operation & maintenance is essential to the environmental management on the premises of water cycle in the closed system.
- AWF project and ZIM Fund project in the catchment area were evaluated effective to the environmental improvement in the pollution analysis. Appropriate operation & maintenance and augmentation for the increase of wastewater flow.
- For the improvement of the water environment of the catchment, priority is the treatment of the sewage from City of Harare regardless of process employed.

13.7 Alternatives for Water Supply

- By increasing the capacity of distribution, coping with the demand can be executed. Even if the total distribution flow to the municipality is not enough, distribution will be made equally to all consumers. The plan will be affected by Harare Water Works. The municipality must pay the water bill constantly.
- By construction of well group, even though the intake capacity of 3,000m^3/day is small, it will enable to supplement the water supply when the reduction of water supply takes place.
- When alternatives above are implemented, all municipality will have equal water supply even though the water supply from Harare Water Works is unstable due to the water shortage . Then shallow wells for the areas where allocation of wells was few will be installed and some clogged old pipes will be replaced by the items of 1.3.1.

13.8 Alternatives for Sewerage

- Refurbishing the existing BNR facility to Oxidation Ditch system with lower O&M cost and easier maintenance is most appropriate plan in terms of engineering and economic aspects. However, it is not urgent issue since rehabilitation project of old system (Existing trickling filters) is under way by Zim Fund (As of July, 2013).
- After the rehabilitation of Zengeza STP, expenditure for the operation & maintenance will be minimum since the process is trickling filters which require less power than other processes.
- Chitungwiza municipality must take care of the facilities for the sanitation of the residents in the municipality. Revision of tariff for the sewage or securing another

income will be needed for the operation & maintenance. One of the promising income sources is selling the treated water for the irrigation. Appropriate unit rate will be important.

- For the augmentation of the facility in the mid-term, redesign of the existing BNR to Oxidation Ditch system will be the best plan in terms of cost and operation & maintenance.

13.9 Alternatives for Solid Waste Management

- Closing of the existing disposal site, new construction of the sanitary land fill and procurement of collection equipment were planned.

13.10 Financial Analysis

- FIRR and EIRR were examined for the analysis on Project Cost, O&M Cost for project life of 40 yrs
- Negative FIRRs were shown although the EIRRs were positive.
- Selling of treated water to irrigation has some possibility to improve the FIRR of sewage part.

13.11 Feasibility Study in Phase III

- Through the study of Phase I (Basic Study) and Phase II (Master Plan), JICA Project Team found that the main issue in Chitungwiza was not present in the sewage part but rather in the water supply. The improvement work of the sewerage in Chitungwiza (Urgent rehabilitation) was already on-going and from the result of the pollution analysis, the improvement work is deemed to benefit the improvement of the environment. Further, it was clarified that the main pollutants for the water source have been coming from City of Harare rather than Chitungwiza Municipality

- During the course of the project, JICA Project Team also encountered another problem of Chitungwiza Municipality as well as Zimbabwe Government, namely financial problem. The financial issue has been affecting every part of the domestic life and public administration.

- In order to guarantee the sustainability of the facilities to be developed in the future, it was decided through the discussion of both sides of Zimbabwe and Japan to put a certain period before the F/S to observe and confirm the financial status of Chitungwiza Municipality. Implementation of F/S will be considered when the restructuring of the municipality shows a certain progress.