CHAPTER 7 DISTRIBUTION FACILITIES OF ZONE 1

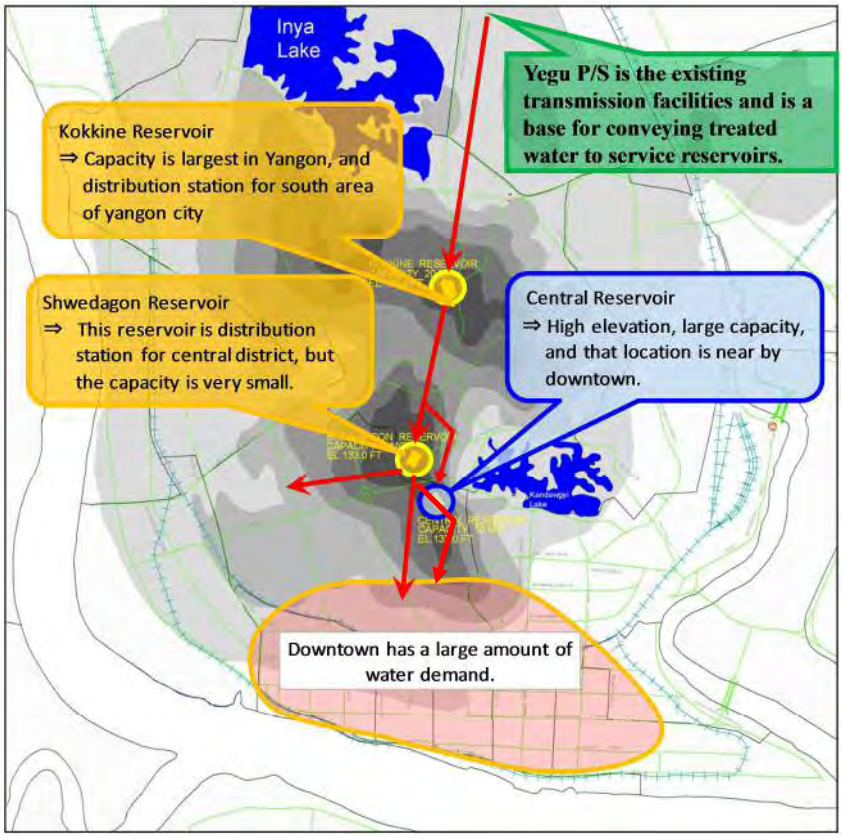
7.1 Outline of Planning

The water supply area of Zone 1 consists of CBD and IUR (see the Figure 3-8). These areas were initially developed by the British rulers along with the existing water supply systems in this zone. This water supply system has been used for long and is most likely in deteriorated condition with high leakage rate. Therefore, rehabilitation/renewal of the water supply system is required and study has been conducted keeping this in mind.

7.1.1 Review of Master Plan and Existing Condition

In the MP, construction of Kokkowa WTP, and related transmission facilities are proposed considering the increasing water demand and use of river water as alternative water source. Also, reconstruction of Central SR along with new pumping station is proposed for High subzone. For Low subzone, use of existing Kokine SR is suggested. Distribution pipes are also proposed to be constructed both in High as well as Low subzones.

Existing distribution system including SRs is illustrated in the following Figure. Presently, water distributed to Zone 1 is coming from Hlawga, Gyobyu and Ngamoeyeik reservoirs through the Yegu booster PS. According to the MP, in 2025 also, a part of this water (reduced amount) will be used for distribution to Kokine sub-Zone along with water from Kokkowa water supply system to be developed. The Yegu PS will be demolished when the Kokkowa water is available for Zones 1 and 3 by 2030.



Source: METI Study

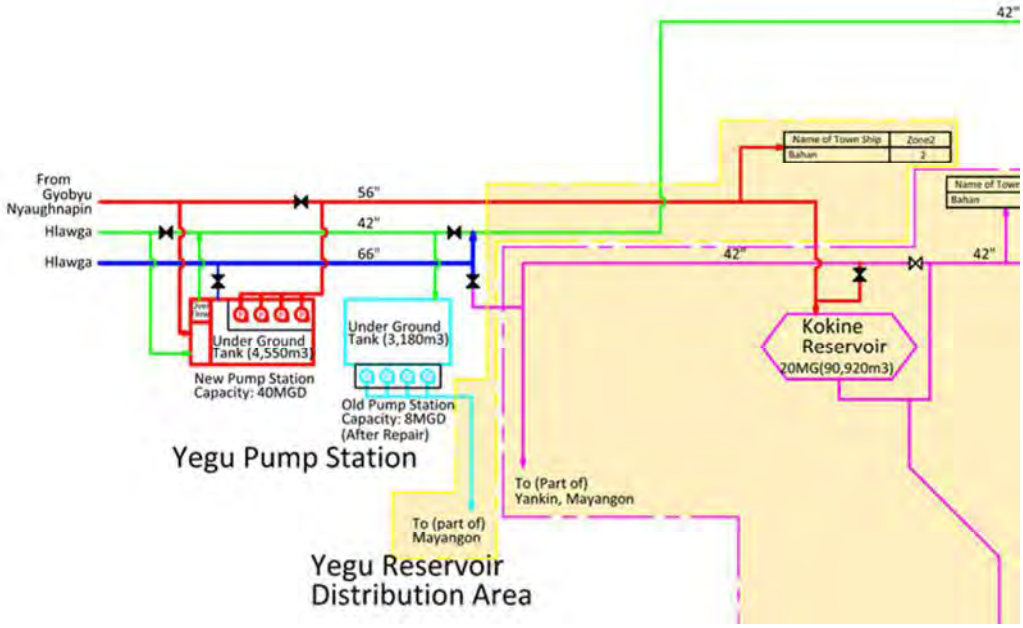
Figure 7-1 Existing SRs of Zone 1

7.1.2 Existing Condition of Yegu PS

Yegu PS receives raw water from Gyobyu and Hlawga (gravity) reservoirs and Nyaughnapin WTP and water from all these sources are mixed at Yegu PS before sending it to Kokine SR. Yegu PS consists of 2 systems: old and new systems/

There are 4 new pumps (installed in 2007) in the new system and all of them are in working condition. Of these, 2 pumps are duty and the other 2 are stand by), sending 20 MGD of water to existing Kokine SR through 1400 mm pipe. Water from Kokine SR is distributed via Shwedagon SR to entire southern and western areas of zone 1 excluding some eastern areas to which water goes directly from Yegu PS.

There are 7 old pumps (initially installed in 1964 and changed in 1990) in the old system, of which only 4 pumps are in good condition. The old pumps are used to pump small amount of water to downtown area through 1050 mm pipe.



Source: JICA study team

Figure 7-2 Schematic Diagram Showing Water Distribution from Yegu PS

Data on water quality in 2015 at Yegu PS is given in Table below. Water quality data indicates that despite mixing of water from three water sources, the maximum turbidity is 5.80 NTU and average turbidity is 2.71 NTU. In general, the water supplied is within the water quality standard.

Table 7-1 Water Quality Data at Yegu PS in 2015

No	Date	Lab Code	pH	TDS(mg/l)	EC(µS/cm)	Total Hardness	Fe(mg/L)	Mn(mg/L)	Turbidity(NTU)	NH4(mg/L)	Colour	Total Alkalinity	Ca	Mg	CO_3	HCO_3	Cl	E Coli	Salinity	Arsenic (As)
1	6.1.15	WC-150130	7.24	35.8	70.5	52	0.05		1.38			4	9.62	6.710	Nil	4	15		0.04	
3	13.1.15	WC-150158	7.27	30.2	60.6	32	0.02		0.00			4	4.81	4.790	Nil	4	17		0.03	
5	20.1.15	WC-150196	6.98	30.5	60.5	48	0.18		1.16			4	4.81	8.630	Nil	4	12		0.03	
7	27.1.15	WC-150104	7.24	35.5	70.5	52	0.04		1.61			4	9.62	6.710	Nil	4	15		0.04	
9	4.2.15	WC-150245	7.30	35.8	71.5	48	0.04		1.18			6	9.62	5.750	Nil	6	20		0.04	
12	11.2.15	WC-150268	7.30	49.2	98.4	44	0.07		1.61			4	6.41	6.710	Nil	4	13		0.05	
13	17.2.15	WC-150205	7.02	47.6	95.8	64	0.18		0.19			8	9.62	9.580	Nil	8	15		0.05	
15	24.2.15	WC-150211	7.56	31.8	63.6	28	0.06		0.88			2	6.41	2.870	Nil	2	13		0.04	
17	3.3.15	WC-150354	7.57	50.5	101.3	56	0.08		1.61			8	11.22	6.710	Nil	8	24		0.05	
19	10.3.15	WC-150366	7.77	48.3	96.7	72	0.10		4.05			6	3.62	15.11	Nil	6	20		0.05	
21	19.3.15	WC-150390	7.24	35.5	70.5	52	0.04		1.61			4	9.62	6.710	Nil	4	15		0.04	
23	24.3.15	WC-150392	6.78	49.2	98.4	64	0.08		2.12			4	11.22	55.34	Nil	4	26		0.05	
25	7.4.15	WC-150419	7.28	42.9	84.5	28	0.05		4.40			6	4.81	3.830	Nil	6	14		0.04	
27	27.4.15	WC-150464	7.11	52.1	106	72	0.04		2.35			8	8.02	12.47	Nil	8	354		0.05	
29	5.5.15	WC-150597	7.28	42.9	84.5	28	0.05		4.40			6	4.81	3.830	Nil	6	14		0.04	
31	12.5.15	WC-150524	7.40	43.10	86.1	25	0.03		3.58			4	35.00	3.800	Nil	4	16		0.02	
33	20.5.15	WC-150545	6.79	5.73	11.5	88	0.17		5.40			4	11.20	14.40	Nil	4	68		0.02	
35	26.5.15	WC-150555	7.02	5.79	11.47	80	0.17		5.80			4	19.23	7.66	Nil	4	40		0.02	
37	2.6.15	WC-150619	7.25	57.9	113.1	72	0.05	0.01	3.06			14	17.64	6.690	Nil	14	10		0.06	
39	17.6.15	WC-150651	6.70	50.3	100.5	64	0.21	0.013	3.22			32	12.82	7.67	Nil	32	16		0.05	
41	23.6.15	WC-150664	7.46	27.9	51.7	52	0.03	0.007	3.07			42	11.22	5.748	Nil	42	20		0.03	
43	1.7.15	WC-150797	7.28	42.8	85.4	32	0.21	0.093	2.25			26	6.413	3.83	Nil	26	8		0.05	
45	14.7.15	WC-150717	6.87	43.6	87.2	52	0.15	0.069	3.47			30	6.41	8.63	Nil	30	23		0.05	
47	21.7.15	WC-150740	7.08	17.54	35.1	56	0.14	0.087	2.45			32	8.016	8.630	Nil	32	12		0.02	
49	28.7.15	WC-150756	6.87	43.6	87.2	52	0.15	0.069	3.47			30	6.41	8.63	Nil	30	23		0.05	
51	4.8.15	WC-150874	7.24	43.0	85.6	52	0.16	0.046	3.37			34	17.63	1.899	Nil	34	16		0.05	
53	11.8.15	WC-150816	6.73	36.4	72.9	64	0.23	0.050	5.53			18	16.03	5.74	Nil	18	19		0.04	
55	17.8.15	WC-150835	7.01	34.2	68.5	28	0.14	0.064	1.69			58	4.81	3.83	Nil	58	16		0.04	
57	24.8.15	WC-150884	7.27	35.6	71.3	32	0.17	0.081	2.84			10	4.81	4.79	Nil	10	13		0.04	
59	1.9.15	WC-150933	7.98	41.6	82.8	48	0.16	0.079	2.86			58	11.22	4.79	Nil	58	15		0.05	
61	7.9.15	WC-150955	7.20	38.6	77.2	36	0.15	0.050	2.18			52	4.81	5.75	Nil	52	20		0.04	
63	14.9.15	WC-150985	6.38	38.8	77.6	26	0.17	0.058	1.79			56	6.412	2.39	Nil	56	9		0.04	
65	21.9.15	WC-150901	7.04	36.9	75.4	32	0.15	0.081	3.82			58	9.62	1.91	Nil	58	10		0.04	
67	28.9.15	WC-150922	7.22	42.9	82.1	32	0.16	0.072	2.94			64	4.81	4.79	Nil	64	16		0.05	
69	5.10.15	WC-151089	6.90	40.9	81.1	48	0.22	0.064	3.05			16	8.02	6.71	Nil	16	8		0.04	
71	13.10.15	WC-151030	6.91	30.6	61.2	48	0.32	0.108	2.77			48	8.016	5.75	Nil	48	9		0.03	
73	19.10.18	WC-151053	7.23	38..3	76.6	32	0.23	0.053	2.45			52	6.413	3.83	Nil	52	11		0.04	
75	26.10.15	WC-151098	7.04	44.2	87.9	80	0.33	0.088	1.89			66	11.22	12.47	Nil	66	14		0.05	
77	2.11.15	WC-151137	7.44	44.5	88.7	48	0.36	0.144	3.83			70	8.016	6.71	Nil	70	8		0.05	
79	9.11.15	WC-151174	6.54	45	88.9	40	0.38	0.160	2.00			68	8.016	4.79	Nil	68	7		0.05	
81	16.11.15	WC-151195	6.74	44.6	88.9	52	0.44	0.107	3.95			68	9.62	6.71	Nil	68	22		0.05	
83	23.11.15	WC-151127	7.14	44.3	90.1	36	0.66	0.227	4.72			70	8.016	3.83	Nil	70	10		0.05	
85	1.12.15	WC-151285	7.23	40.9	81.8	180	0.44	0.08	3.14			260	40.08	19.15	Nil	260	50		0.04	
87	8.12.15	WC-151244	7.47	39.2	79	72	0.27	0.03	0.24			60	3.21	15.35	Nil	60	14		0.04	

Source: YCDC

7.1.3 Existing Condition of Kokine SR

(1) Outline

The Kokine SR was constructed in 1926 for supplying water to high area at that time. The condition of structure itself is not known; however, based on discussion with YCDC no leakage is reported. Concrete test of the structure was carried out in May 2016 and it is observed that compressive strength of existing concrete is about 36 MPa, which indicates that concrete structure is strong enough.

On the other hand, in 2007 about 1.5 m (5 feet) high deposition of silt was reported, resulting in decrease of its effective storage volume. It was once desilted in 2007; however, the silt could be again accumulated and therefore, periodical cleaning of this SR is required. More fundamentally, turbidity needs to be removed from the raw water in the WTPs.

Table 7-2 Existing Characteristics of Kokine SR

Item	Specification
Construction Year	1925 to 1926
Site Size	559 feet x 286 feet
Structure	Underground RC

Item	Specification
Volume	90,920 m^3 (20MG)
Water Level	HWL +42.7 m (140 feet), LWL +36.6 m (120 feet)
Water Depth	6.1 m
Inlet Pipe	φ1400 mm Steel Pipe from Yegu PS
Existing Outlet Pipe	φ1050 mm Iron Pipe for Shwedagon SR φ1050 mm Iron Pipe for north townships φ1050 mm Iron Pipe for southwest townships

Source: JICA Study Team

(2) Retention Time

Retention time of the Kokine SR (excluding small 1 MG capacity Shwedagon Pagoda SR, constructed in 1894) to the total demand of Zone 1 is given in the following Table. Retention time is more than 8 hours up to 2025, which is the minimum retention time for diurnal demand fluctuation. However, after 2025, additional SR capacities are required to maintain the retention time of 8 hours.

Table 7-3 Forecast of Retention Time of The Kokine SR

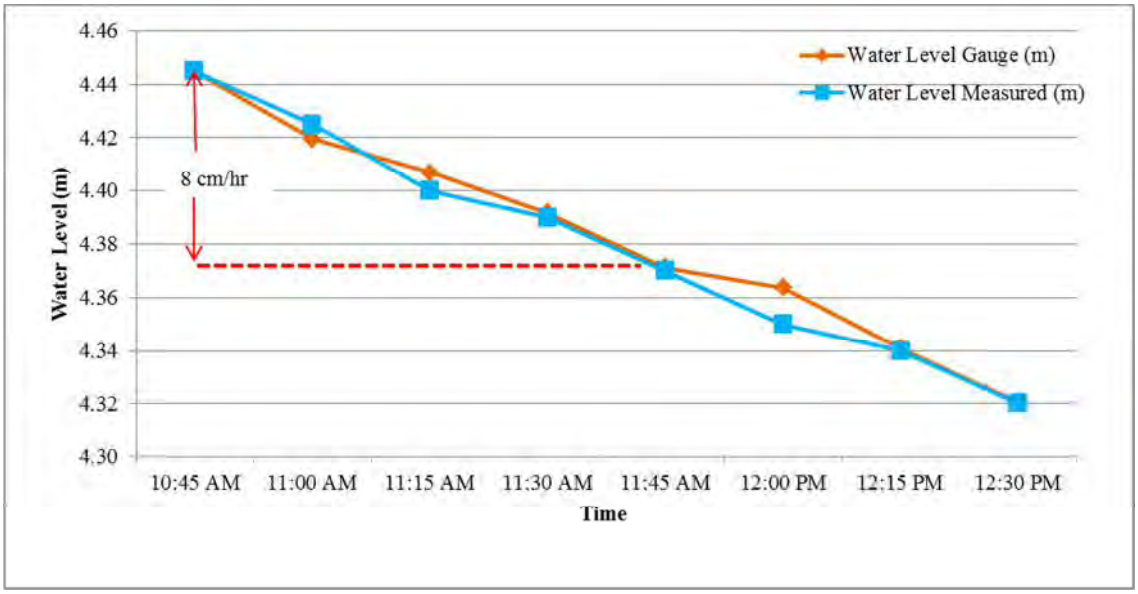
Item	2014	2025	2030	2035	2040
Daily Maximum Demand of total Zone 1	44 MGD	54 MGD	60 MGD	65 MGD	71 MGD
Retention Time*	11.0 hr	8.9 hr	8.0 hr	7.4 hr	6.8 hr

*Retention time is calculated as 20 MG divided by daily maximum demand.
Source: JICA Study Team

(3) Leakage from the Reservoir

In this Study, a survey was conducted to understand the situation of leakage in Kokine reservoir. At Kokine SR, the water level in reservoir was measured in order to check if there is reduction in water level even after stopping all the inflow to and outflow from this SR. For this purpose, the operation of Yegu PS was stopped and two inlet valves to Kokine SR were closed completely. Also, three outlet valves were closed completely.

After closing all valves, the water level in Kokine SR was measured every 15 minutes. Two measurements were recorded, one of the water level gauge installed at reservoir and another measured manually. The change in water in Kokine SR for two cases is shown in Figure below. The brown line represents water level measured by gauge installed at SR, and blue line indicates the water level measured manually. It is observed that in both measurements, water level in SR reduces by about 8 cm/hr. Thus, the total drop in water level of Kokine SR at this rate would be about 192 cm/day which will result into loss of a large amount of water.

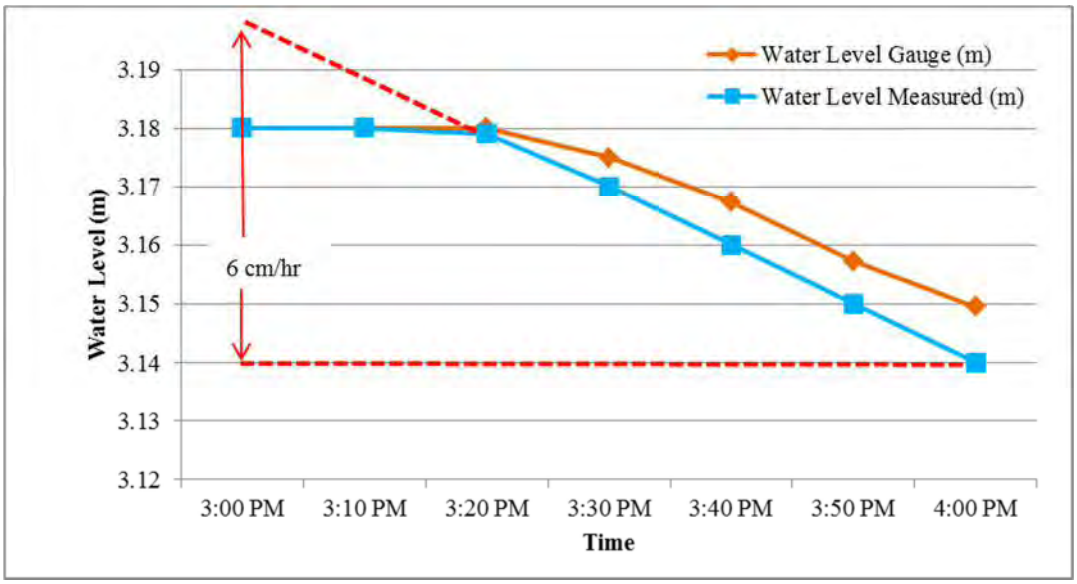


Source: JICA Study Team

Figure 7-3 Reduction in Water Level of Kokine SR

Upon discussion with EDWS it was learnt that the bottom level of pipe connecting to check valve is at about 10 feet and if there is less than 4 feet of head over the check valve on SR side, the check valve does not close properly and may result into leakage through check valve.

Considering the above explanation, the water level in SR was lowered (through supplying water) below the level of pipe connecting to check valve. Subsequently, after closing the outlet valves again, the reduction in water level was recorded to understand the situation of leakage in the SR without the influence of check valve leakage. The water level of Kokine SR thus recorded is shown in Figure below. In this case, the drop in water level of SR is observed as 6 cm/hr.



Source: JICA Study Team

Figure 7-4 Reduction in Water Level of Kokine SR without Influence of Check Valve

(4) Reason of Leakage and Necessity of Reservoir Rehabilitation

From above Figures, it is clear that the reduction in water level of SR is caused by leakage. However, it is not clear whether the leakage is through the valves or through the reservoir walls itself. It is possible that leakage occurs through inlet valves, check valve or outlet valves, as all of these structures are very old and may not be closing appropriately. It is also possible that there is leakage through the walls in reservoir itself. To confirm this, all the inlet and outlet valves will require to be changed first.

Hence, it is proposed that during construction works, all the valves be changed first with new ones. Upon installation of new valves, the water level in SR needs to be monitored after closing all inlet and outlet valves. If the monitored data indicates reduction in water level of SR, then there is certainly leakage through the SR structure itself. In that case, the SR should be emptied, cleaned and checked for leakage areas. Locations of leakage need to be repaired necessarily to enable the use of this SR safely again. Depending on the leakage locations, repair methods shall be selected and repair be carried out. Available space is limited at Kokine SR, therefore attention need to be paid during construction works and required space need to be made available.

Considering that concrete structure of Kokine SR is still strong enough, EDWS prefers to continue using this reservoir upon confirmation of leakage and rehabilitation (if required).

7.1.4 Existing Condition of Central SR and Shwedagon Pagoda SR

It is located at the top of hill near the Shwedagon Pagoda. The site belongs to the Army Department and is surrounded by pagoda and housing in the north and west sides. The existing RC flat slab structure is covered with earth on top and bottom-half is underground. It has no partition wall and total capacity is 10 MG (=45,460 m^3).

Structure has been left un-used for almost half a century. Rehabilitation efforts were made in the past; in 2009 by SIKA, Switzerland recently by SEGA, Thailand. However, it cannot be used anymore; Cracks are observed and reinforced bars are seen without concrete as shown in photos below. Therefore, reconstruction is planned in this Study.

The small-sized (1 MG) Shwedagon Pagoda SR exists near the Central SR. After the Central SR is put into operation, it will be demolished due to small-size and weak structure of its roof.

Table 7-4 Existing Characteristics of Central SR

Item	Specification
Construction Year	1965
Site Size	W 347 feet X L 220 feet
Structure	Underground RC
Volume	45,460 m^3 (10 MG)
Water Level	HWL +38.1 m (125 feet), LWL +32.0 m (105 feet)

Item	Specification
Water Depth	6.1 m
Outlet/Inlet Pipe	Existing inlet pipe is used both as inlet and outlet, and type is φ1200 mm cast iron pipe.
Connection Pipe	φ1050 mm Iron Pipe branched off from "Kokine – Shwedagon" transmission Pipe

Source: JICA Study Team

Photo 7-1 External Top View (Roof) of the SR

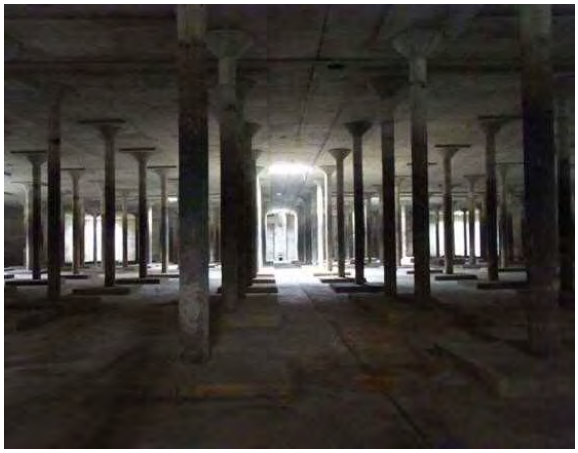


Photo 7-2 Internal View of the SR

Photo 7-3 Deteriorated Column

Photo 7-4 Rehabilitated Trace by SIKA

Source: METI Study

7.1.5 Planning Parameters

(1) Concept of Distribution System

Zone 1 will be divided into 2 sub-zones; high subzone including areas with relatively high ground elevation to be supplied water by pump distribution system and low subzone including areas with lower elevation to be supplied by gravitational distribution system (see the following Figure).

a) Existing reservoirs and their capacities

The existing two working SRs and abandoned one SR are located on the hills. The Kokine SR (20 MG) which is operational is located in the north of the Zone 1 while the operational Shwedagon SR (1 MG), and the abandoned Central SR (10 MG) are located in the south. Total capacity of existing SR is 31 MG.

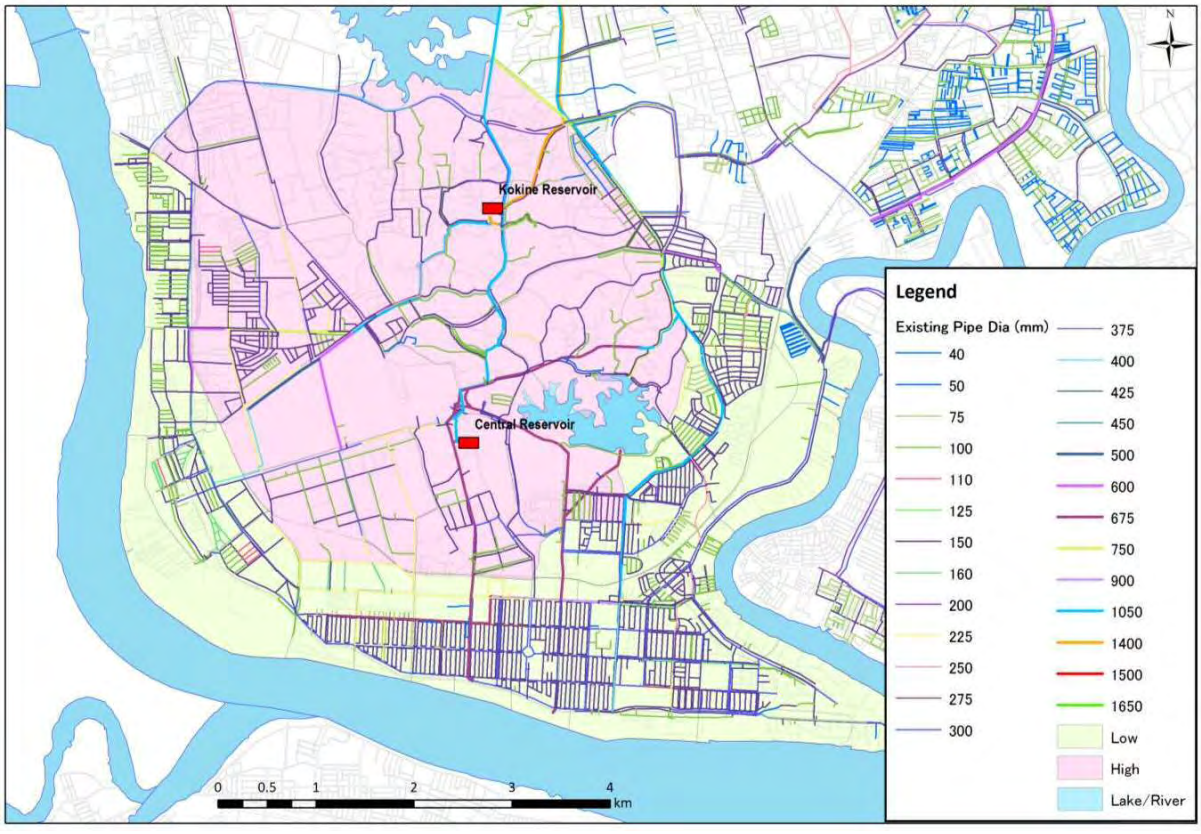
b) Two sub-zones

Hill stretches along north-south direction will be included in the high subzone and low areas along the rivers located in west, south and east of Zone 1 will be in the low subzone.

Water supply is not continuous and duration is less than 24 hours in townships of Dagon, Bahan, Sangyoung, etc., because they are located in the hilly areas with elevation ranging more than 10 to 20 m. Therefore, supply system in these areas is planned to be converted from the currently used gravitational system to pumping system. Although pump can be used at any SR, pumps are planned in the Central SR after its reconstruction. Kokine SR with elevation slightly higher than the Central SR will be used for gravitational flow system.

c) Water resource

From Kokkowa system, 40 MGD of water is planned to be delivered to Kokine reservoir to be distributed in Low subzone through gravity. On the other hand, water from Yegu system is planned to be conveyed to Central reservoir to be distributed in High subzone.



Source: JICA Study Team

Figure 7-5 Existing Pipe Network of Zone 1 with Proposed High and Low Sub-Zones

(2) Planning Parameters

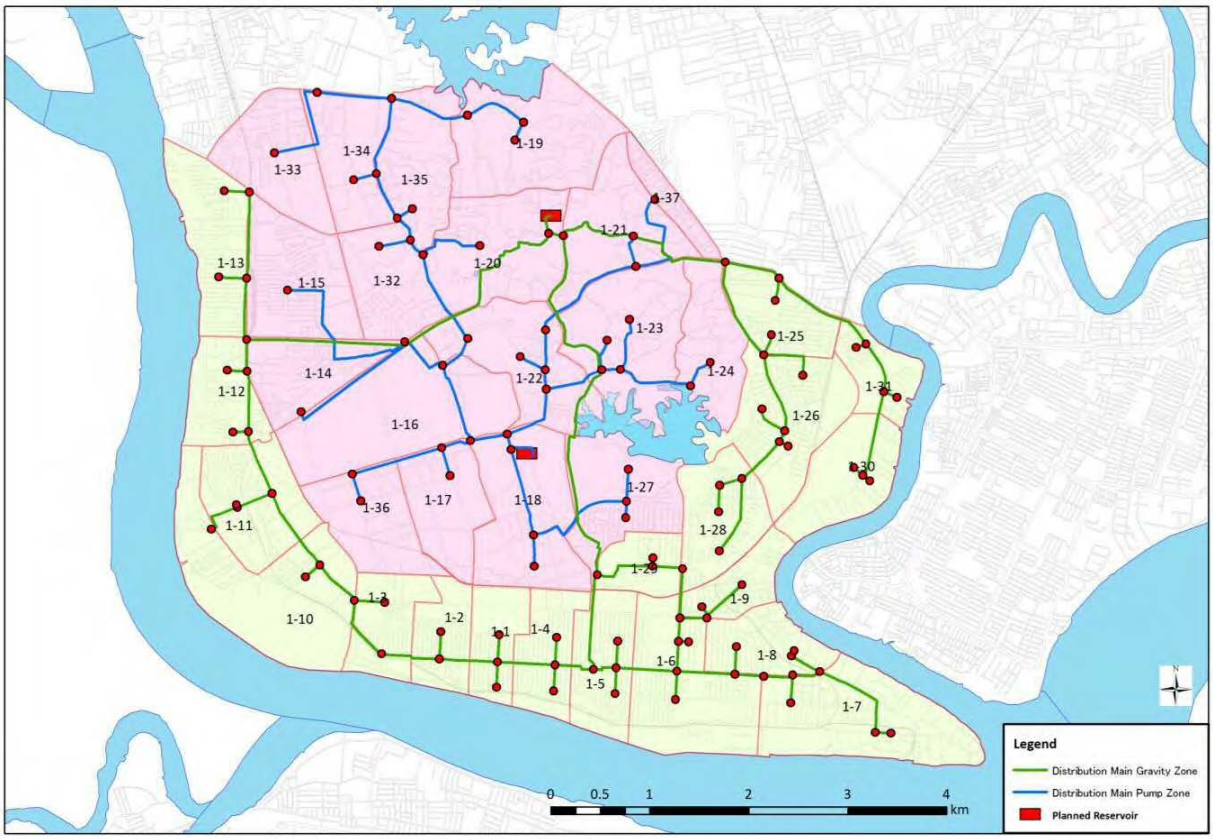
Planning parameters for Zone 1 are shown in the Chapter 3 and reproduced here in the following Table. Daily maximum demand will increase by 1.2 times in 2025 and by 1.6 times in 2040 compared to the

demand in 2014. Distribution main pipes are planned for the demand in 2040 considering that it is not easy to lay large diameter pipelines in densely populated city area with heavy traffic on roads. Zone 1 is divided into 37 DMAs as shown in the following Figure including proposed distribution main pipes also.

Table 7-5 Main Features by Distribution Zone in 2014, 2025, and 2040

Year	Population	Coverage rate	Served Population	Daily Max. demand	Daily Max. demand
	1,000	%	1,000	mld	MGD
Low Subzone					
2014	506	70	354	144	32
2025	557	81	452	166	37
2040	577	89	516	210	46
High Subzone					
2014	288	47	134	55	12
2025	309	70	215	79	17
2040	318	87	277	113	25
Zone 1					
2014	794	62	488	199	44
2025	866	77	667	245	54
2040	896	89	793	323	71

Source: JICA Study Team



Source: JICA Study Team

Figure 7-6 DMAs and Distribution Main Pipes for Zone 1 in 2025 (same as 2040)

(3) Water Amount for Distribution

Allocation of water sources to 10 Zones in Yangon is planned in the previous Chapter and corresponding allocation of water sources to Zone 1 is reproduced in the following Table. In 2014, the

demand of Zone 1 is supplied entirely from existing SR system using Kokine SR. In 2025, water will be conveyed to Zone 1, both from existing SR system as well as Kokkowa river system to be developed. In 2040, water to Zone 1 will be conveyed from Kokkowa or Toe river system.

Table 7-6 Water Supply from Source to Zone 1

(Unit: MGD)

Sub-Zone or SR	Year	Total	Existing Reservoir System	River System including Kokkowa
Low subzone (from Kokine SR)	2014	44	44	N/A
	2025	37	0	37
	2040	46	0	46
High subzone (from Central SR)	2014	N/A	N/A	N/A
	2025	17	17	0
	2040	25	25	0
Total	2014	44	44	N/A
	2025	54	17	37
	2040	71	25	46

Source: JICA study team

7.1.6 Comparison of Distribution Plan Options

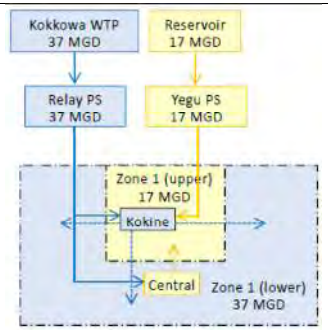
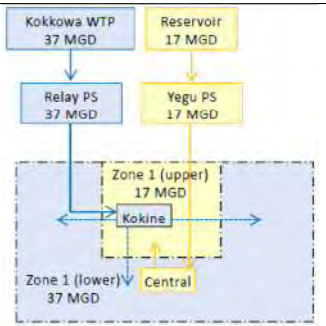
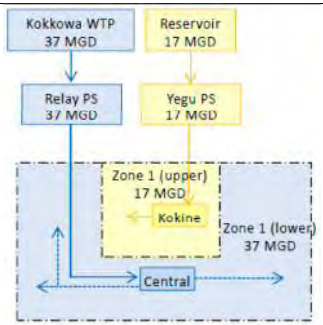
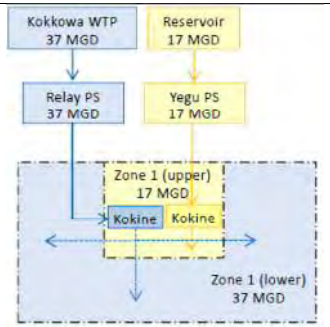
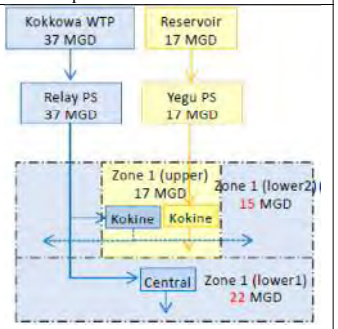
Initial plan was prepared considering the distribution of mixed water from Kokkowa system and Yegu system as presented in the MP (both mixed at Kokine SR). In consideration of the effectiveness of project through supply of safe water, JICA upon discussion with YCDC decided to distribute 40 MGD of Kokkowa water without mixing with Yegu water. This can be achieved through construction of WTP, transmission pumps, transmission pipelines and installation of distribution networks up to house connection to distribute 40 MGD of Kokkowa water separately in areas that has demand equivalent to 40 MGD. Considering these points, it is decided to distribute Kokkowa water in Low subzone of Zone 1.

Taking the above discussion into account, water distribution options are considered and comparison is made in terms of water quality and required water supply facilities in case of each plan as presented in Table below.

In Plan 0 (Original), Kokine SR supplies mixed water received from Kokkowa and Reservoir systems to Low Zone and Central SR supplies Kokkowa water to High Zone. This plan is considered not safe in terms of water quality because treated water from Kokkowa system is mixed with untreated water from Reservoir system before distribution and turbidity of supplied water cannot be maintained less than equal to 1 NTU in this case.

Plan 1 is basically same as Plan 0. However, in this plan, Kokine SR supplies only Kokkowa water to Low Zone and Central SR supplies only Reservoir water to High Zone, thus water from Kokkowa and Yegu sources are distributed separately. Also, in this case, replacement of pumps will be required at Yegu PS to convey the water to Central SR for high zone.

Table 7-7 Comparison of Water Distribution Plan Options

Item	Plan-0 (Original)	Plan-1 (JICA-YCDC discussion)	Plan-2	Plan-3	Plan-4
Outline of Water Supply	Kokine SR supplies mixed water of Kokkowa and Reservoir to Low Zone. Central SR supplies Kokkowa water to High Zone.	Kokine SR supplies Kokkowa water to Low Zone. Central SR supplies Reservoir water to High Zone.	Kokine SR supplies Reservoir water to High Zone. Central SR supplies Kokkowa water to Low Zone.	Kokine SR supplies Reservoir water to High Zone and Kokkowa water to Low Zone.	Kokine SR supplies Reservoir water to High Zone and Kokkowa water to western and eastern part of Low Zone. Central SR supplies Kokkowa water to southern part of Low Zone.
Schematic Diagram					
Required Capacity of SR	Kokine: 20 MG (Existing/Repair) Central: 8.3 MG	Kokine: 20 MG (Existing/Repair) Central: 8.3 MG	Kokine: 8.3 MG (**Replace**) Central: **15.3 MG** > 10 MG	Kokine: **23.6 MG** (**Replace**) > 20 MG Central: 0 MG	Kokine: 16 MG (**Replace**) Central: 7.7 MG
Required Facilities in 2025	■WTP Kokkowa WTP (40 MGD) ■Transmission Pump Station at WTP (40 MGD) Transmission Pipe WTP – Relay PS (φ1600) Relay PS (40 MGD) Transmission Pipe Relay PS - Junction (φ1600) Junction - Kokine SR (φ1400) Junction - Central SR (φ1000) ■Distribution Central SR/PS (17 MGD) Distribution Main (Low Zone) Distribution Network (Low Zone) Distribution Main (High Zone) Distribution Network (High Zone)	■WTP Kokkowa WTP (40 MGD) ■Transmission Pump Station at WTP (40 MGD) Transmission Pipe WTP – Relay PS (φ1600) Relay PS (40 MGD) Transmission Pipe Relay PS - Junction (φ1600) Junction - Kokine SR (φ1400) Pump Replacement at Yegu PS ■Distribution Central SR/PS (17 MGD) Distribution Main (Low Zone) Distribution Network (Low Zone) Distribution Main (High Zone) Distribution Network (High Zone)	■WTP Kokkowa WTP (40 MGD) ■Transmission Pump Station at WTP (40 MGD) Transmission Pipe WTP – Relay P.S (φ1600) Relay PS (40 MGD) Transmission Pipe Relay PS - Junction (φ1600) Junction - Central SR (φ1600) ■Distribution Central SR/PS (17MGD) Kokine SR Replacement Distribution Main (Low Zone) Distribution Network (Low Zone) Distribution Main (High Zone) Distribution Network (High Zone)	■WTP Kokkowa WTP (40 MGD) ■Transmission Pump Station at WTP (40 MGD) Transmission Pipe WTP – Relay PS (φ1600) Relay PS (40 MGD) Transmission Pipe Relay PS - Junction (φ1600) Junction – Kokine SR (φ1600) ■Distribution Kokine SR/PS Replacement Distribution Main (Low Zone) Distribution Network (Low Zone) Distribution Main (High Zone) Distribution Network (High Zone)	■WTP Kokkowa WTP (40 MGD) ■Transmission Pump Station at WTP (40 MGD) Transmission Pipe WTP – Relay PS (φ1600) Relay PS (40 MGD) Transmission Pipe Relay PS - Junction (φ1600) Junction - Kokine SR (φ1400) Junction - Central SR (φ1000) ■Distribution Central SR/PS (17MGD) Kokine SR Replacement Distribution Main (Low Zone) Distribution Network (Low Zone) Distribution Main (High Zone) Distribution Network (High Zone)
Salient Features	In this plan, Kokkowa water and Reservoir water are mixed at Kokine SR. ⇒ Rejected.	At Yegu PS, replacement of pumps is necessary.	Capacity of Central SR becomes larger. Kokine SR replacement is necessary.	Kokine SR replacement is necessary. Capacity of Kokine SR becomes larger. Construction of Central SR is not required in this case.	Kokine SR replacement is necessary. Water to Low Zone is distributed from 2 SRs.
Construction Cost (Mil. USD)	51.016 (Pipe: 44.779, Cen SR: 3.737, Ko SR: 2.500)	52.932 (Pipe: 44.779, Cen SR: 3.737, Ko SR: 2.500, E&M: 1.916)	59.001 (Pipe: 48.374, Cen SR: 6.890, Ko SR: 3.737)	56.528 (Pipe: 45.900, Ko SR: 10.628)	51.693 (Pipe: 41.020, Cen SR: 3.468, Ko SR: 7.205)
Result		◎			

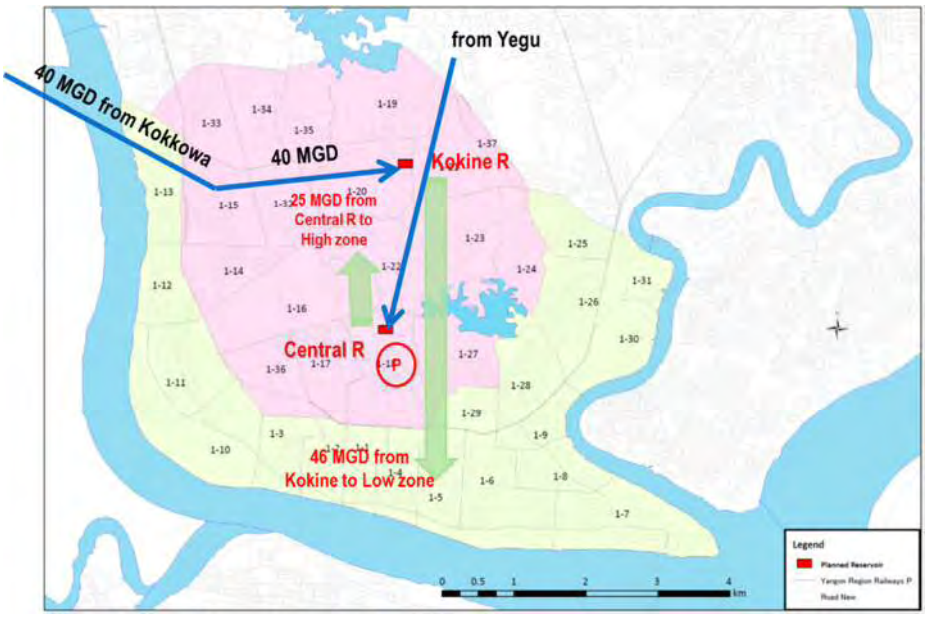
Source: JICA Study Team, details as Appendix 8

In Plan 2, Kokine SR supplies Reservoir water to High Zone and Central SR supplies Kokkowa water to Low Zone. In this case, to distribute 37 MGD of Kokkowa water from Central to low zone, the capacity of this SR will require to be increased to 15.3 MG and hence the height of Central reservoir will be more compared to other plans, which is not acceptable to YCDC in consideration of the location being near to Shwedagon Pagoda and relevant social issues. This plan will also require reconstruction of Kokine SR for PS.

In Plan 3, Kokine SR supplies Reservoir water to High Zone and Kokkowa water to Low Zone. For this purpose, Kokine SR will require to be reconstructed with higher capacity of 23.6 MG with 2 chambers, one for water from Reservoir system and another for Kokkowa system. Also, PS will be required at Kokine SR. On the other hand, central reservoir would not be required. Considering the reconstruction of larger Kokine SR and no possibility of use of Central SR, this option is excluded by EDWS due to risk management of water supply during the construction period of Kokine SR.

In Plan 4, Kokine SR supplies Reservoir water to High Zone and Kokkowa water to the western and eastern part of Low Zone. Central SR supplies Kokkowa water to southern part of Low Zone. This case will also require reconstruction of Kokine SR of 16 MG capacity with 2 chambers, one for Kokkowa water and another for Reservoir water.

In the opinion of Study Team, Plan 4 is the most suitable option considering cost and reliability. However, EDWS prefers to use the existing Kokine SR without reconstruction (refer to Section 7.1.3(4)) and therefore Plan 1 is selected. In consideration of the above discussed factors and based on discussion with EDWS on these plans, Plan 1 is considered as the most suitable option under this Study.



Source: JICA study team

Figure 7-7 Schematic Diagram showing Water Distribution in Case of Plan 1

7.2 Planned Service Reservoir and Distribution Pump

Two SRs are planned in Zone 1; existing Kokine SR for gravity sub-Zone and reconstructed Central SR for pump sub-Zone. The capacity of these SRs is given in the following Table.

Table 7-8 Rehabilitation of Kokine SR and Reconstruction of Central SR

Item	Kokine SR	Central SR
Name of Sub-zone	Low	High
Distribution Method	by Gravity	by Pumping
Capacity	20 MGD x 4,546 = 90,920 m^3 (Existing)	8.3 MGD x 4,546 = 37,882 m^3
Rehabilitation or Reconstruction	Rehabilitation depending on Leakage Test	Reconstruction Required

Source: JICA Study Team

7.2.1 Kokine SR

Structural soundness of the Kokine SR needs to be analyzed after cleaning the internal surfaces of SR. During the time of cleaning, operation of this SR will require to be stopped. Leakage check and repair is planned in this Study considering that structure is very old and may require repair or reconstruction.

The distribution facilities consist of Kokine SR, inflow control valve and outflow control valve (see the following Table). The inflow control valve is capable of controlling the inflow to set value. The outflow control valve is capable of controlling the pressure to set value. SCADA system will be introduced for these flow controls.

Table 7-9 Outline of Distribution Facilities at Kokine SR

No.	Facility	Specification	Quantity	
			Duty	Standby
1	Kokine SR	Reinforced Concrete Structure of 20 MG	1 unit	-
2	Inflow control valve	Motorized Flow Control Valve	2 units	-
3	Outflow control valve	Motorized Pressure Control Valve	3 units	-

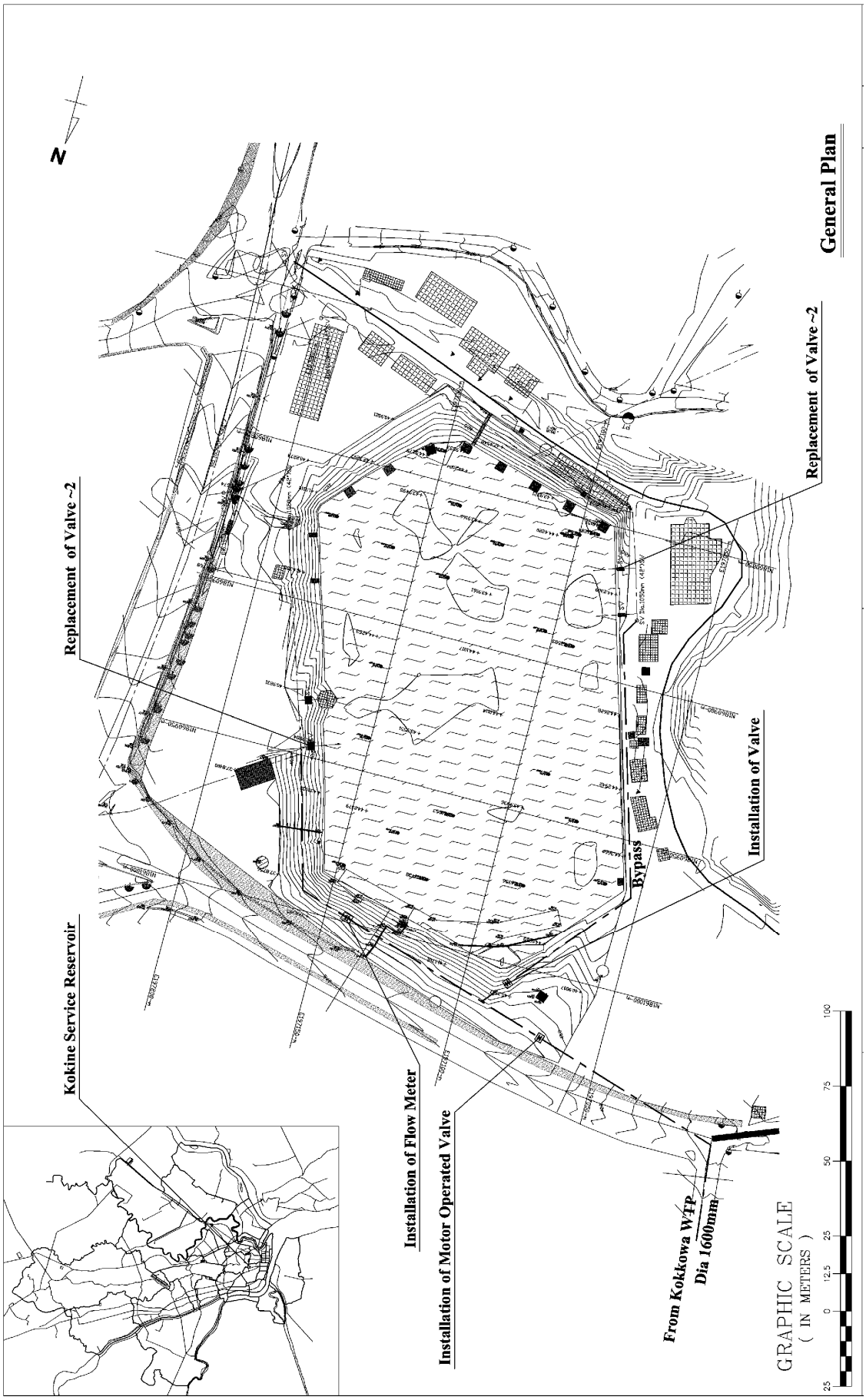
Source: JICA Study Team

In this plan it is considered that Kokine SR will be used for distribution of water to relatively low areas in Zone 1 through gravity in future. Retention time of Kokine SR considering the demand of Low subzone only is given below. The result indicates that retention time is more than normal required 8 hours.

Table 7-10 Retention Time of Kokine SR (considering Demand of Low Subzone of Zone 1)

Item	2025	2040
Daily Maximum Demand of Low Subzone of Zone 1	37 MGD	46 MGD
Retention Time*	13.0 hrs	10.4 hrs

*Retention time is calculated as 20 MG divided by daily maximum demand. In 2014, Kokine SR serves the high areas also which is proposed later to be served through pumped system.
Source: JICA Study Team


General Plan
N
Replacement of Valve -2
Replacement of Valve -2
Installation of Valve
Bypass
Kokine Service Reservoir
Installation of Flow Meter
Installation of Motor Operated Valve
From Kokkowa WTP
Dia 1600mm
GRAPHIC SCALE
(IN METERS)
25 0 12.5 25 50 75 100

7.2.2 Central SR with Distribution Pump

(1) Reconstruction of Central SR

The central SR should be reconstructed because of the unreliability of the existing structure. The reconstruction of this SR will have the following advantages:

- Increase retention time in the Zone 1 to the required 8 hours (Refer Table 7-3; if only Kokine SR is used, the minimum retention time of 8 hours cannot be maintained for demand of Zone 1 after 2030).
- It will serve water to pumped sub-Zone.
- Operation of Kokine SR can be interrupted, if required, for maintenance works such as cleaning, inspection and repair.

(2) Reconstruction Plan

Constraints and basic policy for the reconstruction is explained below.

【Constraints】

- High water level should be the same as that of the Kokine SR.
- Increase in the volume is rather difficult considering limitation in terms of structures surrounding the site.
- Therefore, new SR with storage capacity of 8.3 MG will be reconstructed.

【Basic Policy】

- Water to Central SR will be supplied from Yegu PS and pumps at Old Yegu PS will require replacement to supply water to Central SR.
- To be made of RC structure half-underground.
- Guiding walls will be provided to prevent short-circuit flow.
- Excavation area will be minimized because of the surrounding structures like a Pagoda.
- Demolishing works and construction works will be planned considering mitigation of noise and vibration.
- The existing wall will be utilized as a temporary retaining walls during construction.

(3) Facility Planning

Retention time of the Central SR for pumped High subzone is shown in the following Table.

Table 7-11 Retention Time of Central SR (for High Subzone)

Item	2025	2040
Daily Maximum Demand (MGD)	17	25
Retention Time*	11.7 hrs	8.0 hrs

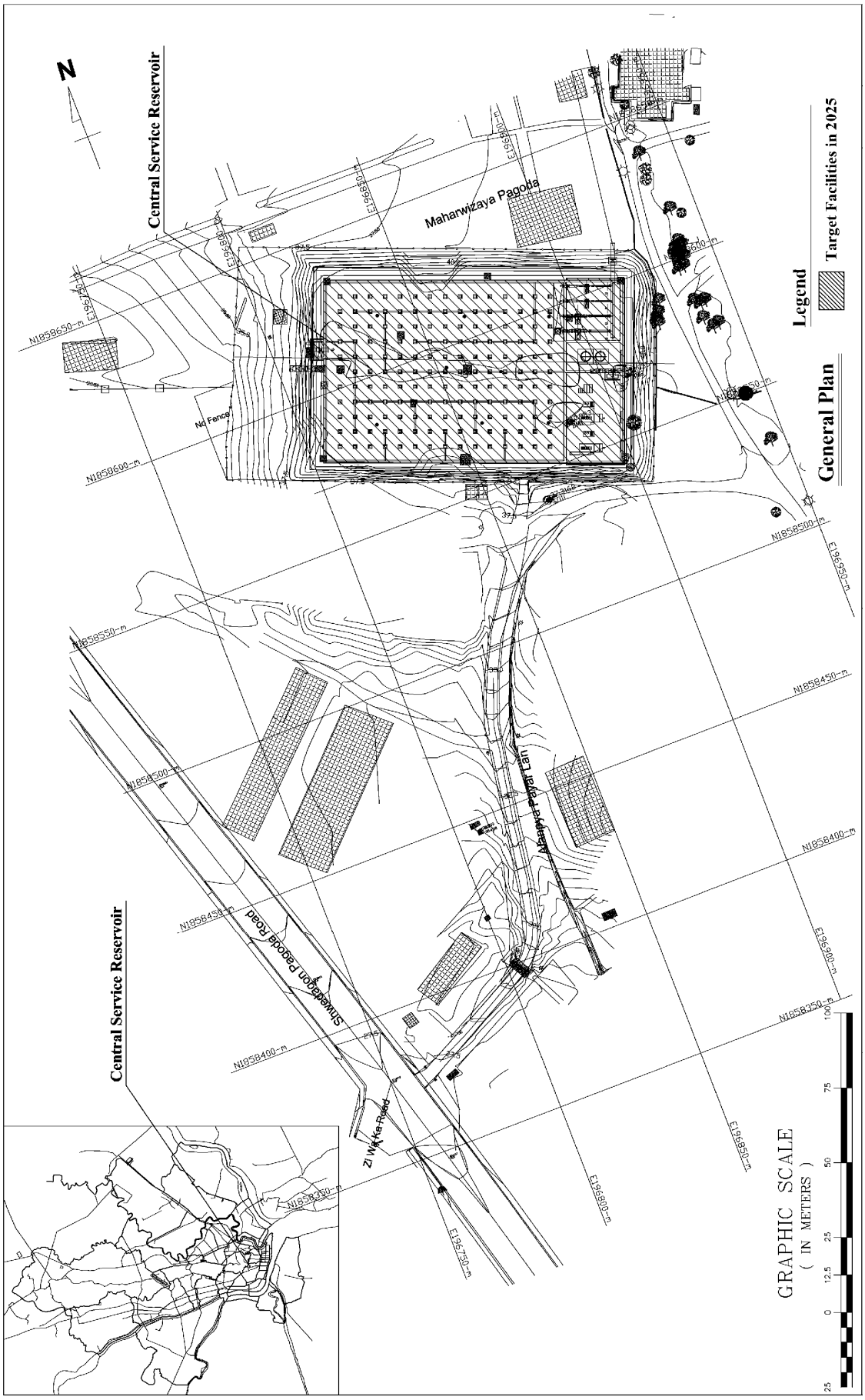
Note: *Retention time is calculated as 8.3 MG divided by daily maximum demand.
Demands are for pumped High subzone only.
Source: JICA Study Team

The distribution facilities consist of Central SR, inflow control valve and distribution pump (see the following Table). The inflow control valve is capable of controlling the inflow to set value. The distribution pump, horizontal double suction volute pump with VFD, is planned which is capable of controlling the pressure to set value. SCADA system will be introduced for these flow controls.

Table 7-12 Outline of Distribution Facilities at Central SR

No.	Facility	Specification	Quantity	
			Duty	Standby
1	Central SR	Reinforced Concrete Structure of 8.3MG	1 unit	-
2	Inflow control valve	Motorized Flow Control Valve	2 units	-
3	Outflow control valve	Motorized Flow Control Valve	2 units	-
3	Distribution Pump (large)	67 m^3/ min x 42 m x 660 kw, Horizontal Double Suction Volute Pump with VFD	1 unit	1 unit
4	Distribution Pump (small)	32 m^3/ min x 42 m x 375 kw, Horizontal Double Suction Volute Pump with VFD	1 unit	1 unit

Source: JICA Study Team


N
Central Service Reservoir
Maharwizaya Pagoda
Legend
Target Facilities in 2025
General Plan
Nd Fence
Central Service Reservoir
Shwedagon Pagoda Road
Zi Wa Ka Road
GRAPHIC SCALE
(IN METERS)
0
12.5
25
50
75
100
25

7.2.3 Electrical Facilities for Central SR with Pump

(1) General

Design parameters of the electrical facilities are shown below. Electricity supply situation is explained in 4.4.10 in Chapter 4.

Table 7-13 Design Parameters of Electrical Facilities for Zone 1

Design Parameters	
1) Receiving Voltage	33kV, 50Hz, 1 circuit
2) Receiving Transformer	3,000 kVA
3) Installed Capacity	2,400 kW
4) Operating Capacity	1,800 kW

Source: Phase 1 FS

(2) Power Receiving Circuit

The receiving capacity of pump station is 3 MVA, and the receiving voltage is 33 kV. A 33 kV cable shall be installed underground from the nearest YESC substation. The estimated length of the cable is less than 1 km.

Source: Phase 1 FS (YESB is now called as YESC)

Figure 7-8 Zone 1 PS and Expected 33 kV Cable Route

(3) Receiving Transformer and Distribution Equipment

Negotiations with YESC to obtain main power supply for Central SR will be under the scope of YCDC. Main power supply will be included under the scope of Japanese loan. Receiving transformer is not planned. Alternatively electricity is to be directly connected to the indoor closed-switchboard in the Central SR with PS.

7.2.4 SCADA

Refer to 4.4.11 in Chapter 4.

The flow and operation status to be monitored by SCADA at different locations are listed in the

following Table.

Table 7-14 Monitoring Items by SCADA for Zone 1

Item	Contents	Quantity
Central monitoring system	PS in Central SR	1 unit
Kokine SR	Water level meter Inlet flow meter Outlet flow meter Open rate of inlet valve Open rate of outlet valve Water pressure	1 unit 1 unit 1 unit 1 unit 1 unit 1 unit
Central SR	Water level meter Inlet flow meter Outlet flow meter Open rate of inlet valve Open rate of outlet valve Pump Status Water pressure	1 unit 1 unit 1 unit 1 unit 1 unit 1 set 1 unit
Inlet pipe of DMA	Flow meter, Water pressure	37 DMA

Source: JICA Study Team

7.3 Distribution Main Pipe

Zone 1 has been divided into 37 DMAs (See Figure 7-6). Distribution main routes are selected considering short route between SR to DMAs inlet and roads with less traffic intensity.

The distribution pipes will be aligned along the edges of the road within city. Most of the wide roads are 6 lane roads and of these the outermost lane on each side is often used for parking. These lanes will be used for distribution pipe installation to avoid traffic jam during construction. In the 2014 JICA Sewerage MP, sewers are planned to be installed in the middle of road at a depth of 3 m or below. Therefore, water supply distribution pipelines will be installed at 2-3 m depth.

Pipe sizes are determined through hydraulic analysis using EPANET2 which uses Hazen-Williams formula. Minimum water pressure at inlets of DMA is considered as 18 m. Ground elevation data is obtained from the available YCDC contour data in GIS and topographic survey data. Nodal demand is calculated as the demand of area served by a particular node.

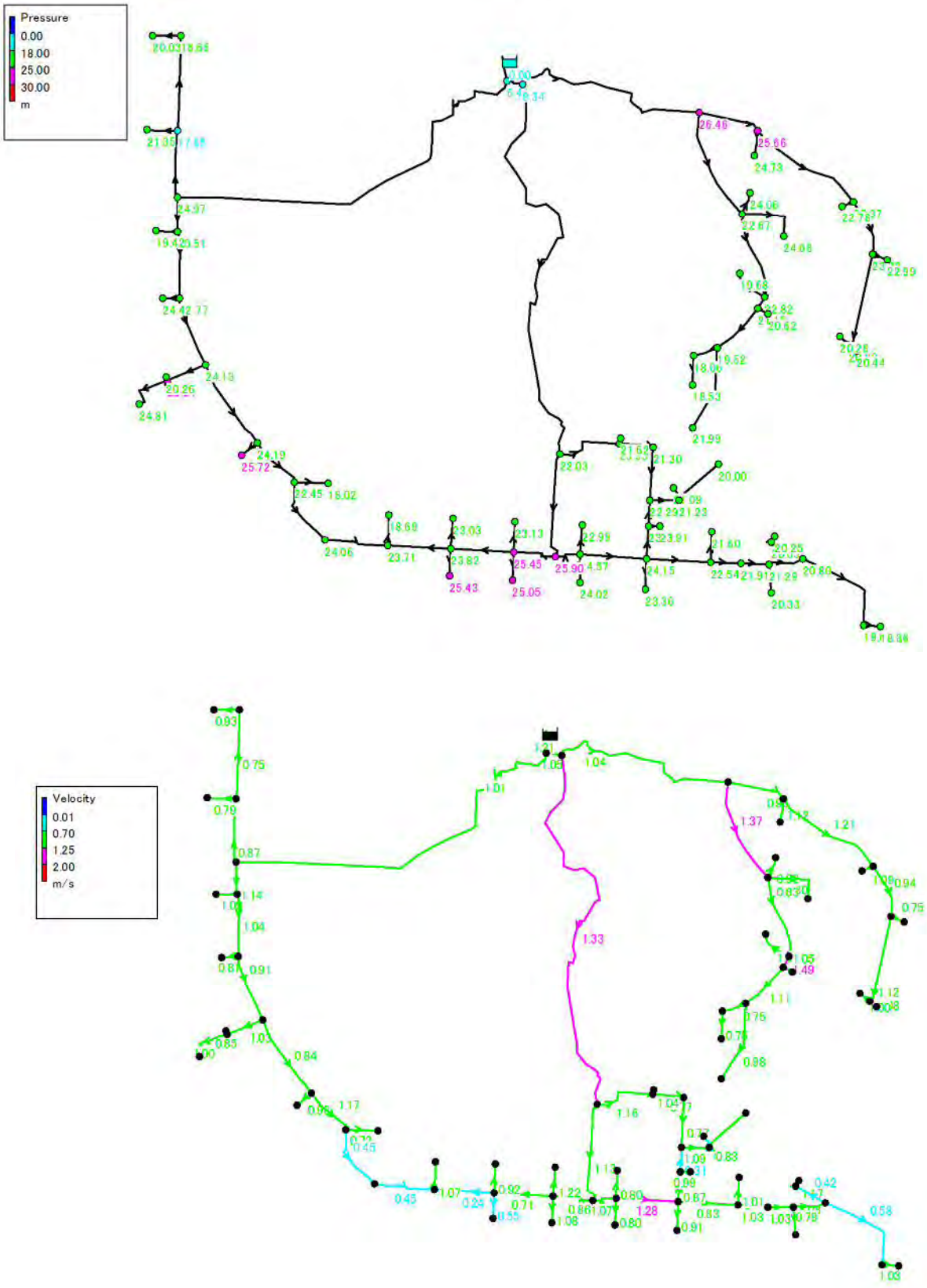
Network analysis has been carried out separately for Gravity system and Pump system of Zone 1. Results of network analysis for gravity system are shown in Figure 7-9 and results for pump system are shown in Figure 7-10.

The distribution main pipes (lengths, sizes and locations) proposed in this plan are as shown in the following Table and Figure 7-11. Very few sections of existing large size pipelines are new and have been considered to be used along with proposed distribution main pipelines.

Table 7-15 Length of Planned Distribution Main Pipe of Zone 1

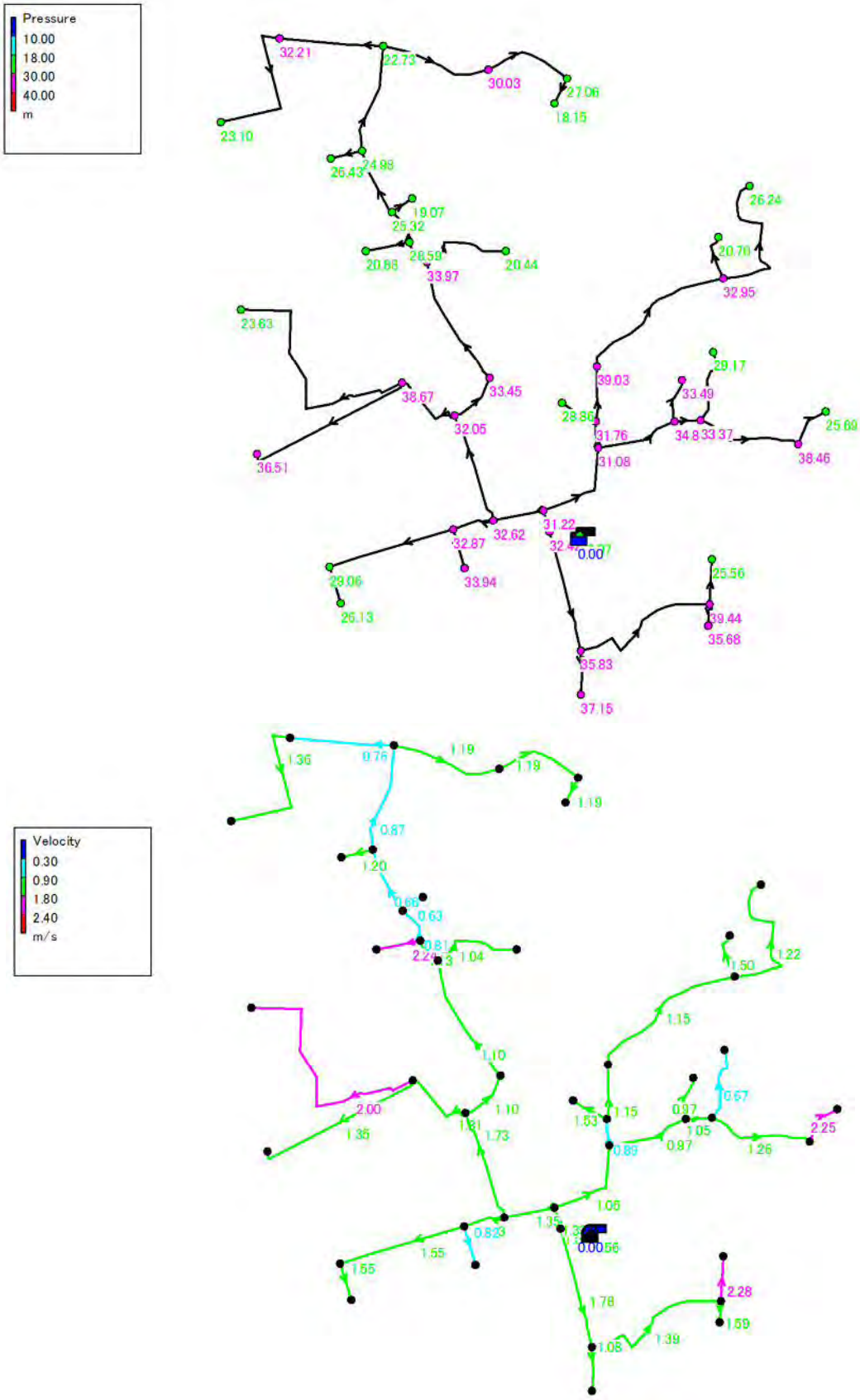
Pipe Diameter (mm)	Total Length of Existing Pipe to be Abandoned (m)	Length of Existing Pipe to be Used (m)	New Pipe Length Gravity (Low) Zone (m)	New Pipe Length Pump (High) Zone (m)	Total Length of Proposed Distribution Main (m)
	(1)	(2)	(3)	(4)	(2+3+4)
200				1,181	1,181
300	50,898		1,647	5,836	7,483
375	1,750				
400	1,439	2,368 (823 for Low + 1545 for High)	7,663	4,446	14,477
425	1,371				
450	3,357		252		252
500	546	893 (for High)	7,126	4,588	12,607
600	2,458		3,863	1,603	5,466
675	13,014				
750	5,154				
800			4,938	2,252	7,190
900	1,313			1,369	1,369
1,000			1,862	826	2,688
1,050	11,189				
1,200			10,738	377	11,115
1,400	1,408			455	455
1,800			156		156
2,000			223		223
Grand Total	93,897	3,261	38,468	22,933	64,662

Note: Most of the existing distribution pipelines are very old and is planned to be abandoned.
Source: JICA Study Team



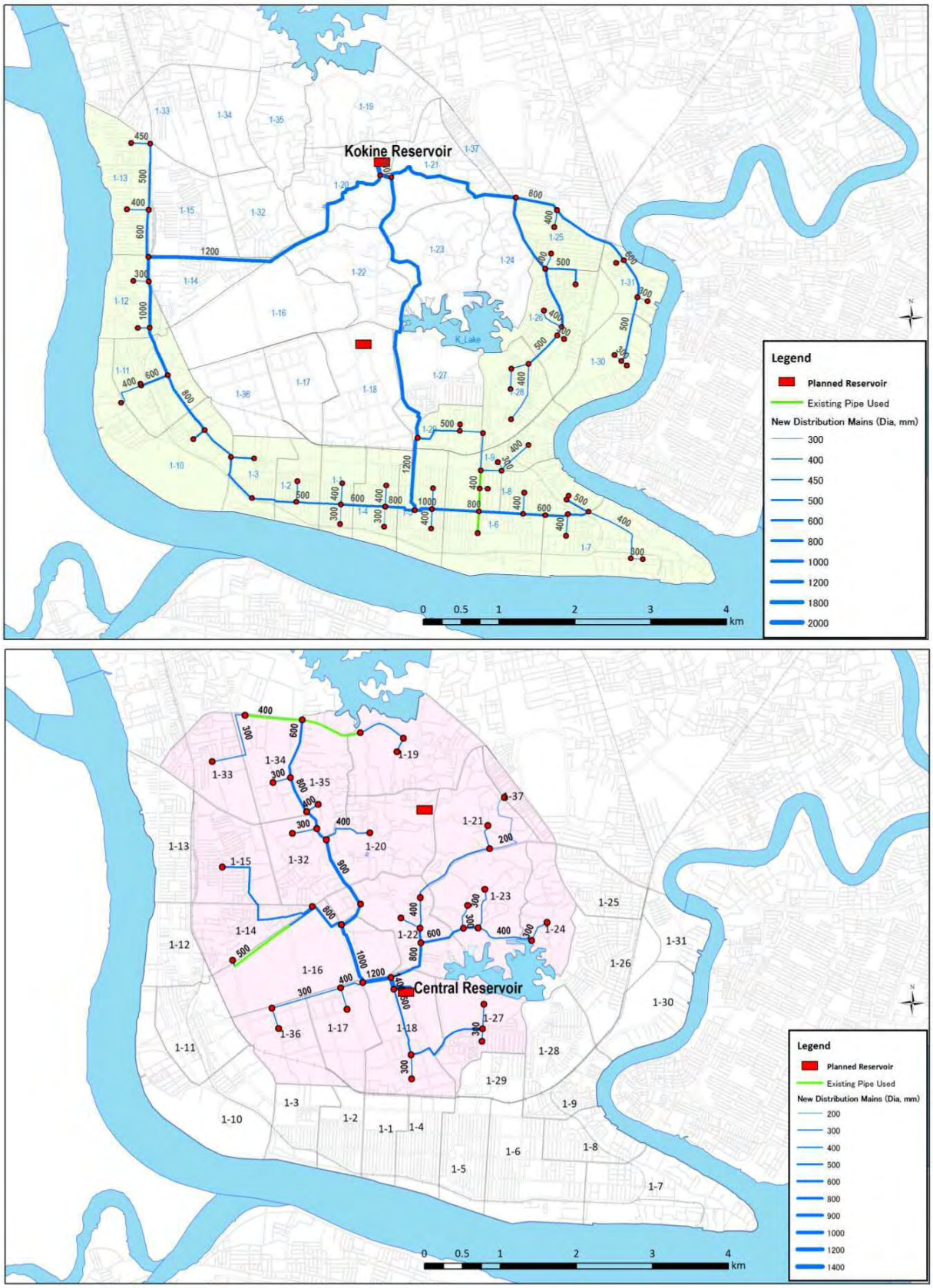
Source: JICA Study Team

Figure 7-9 Simulated Network Analysis Result for Gravity System (Kokine SR) of Zone 1



Source: JICA Study Team

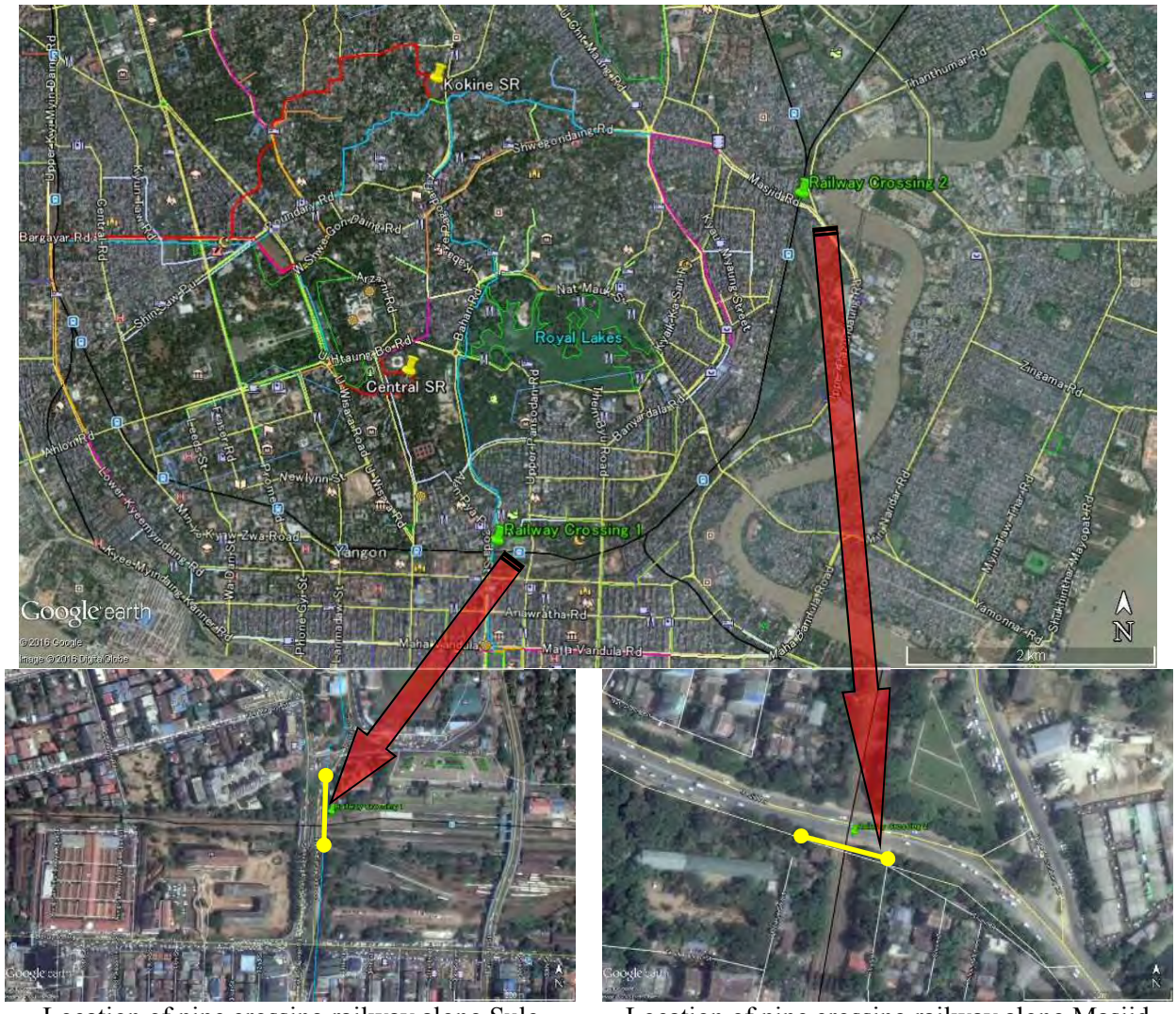
Figure 7-10 Simulated Network Analysis Result for Pump System (Central SR with PS) of Zone 1



Source: JICA Study Team

Figure 7-11 Distribution Main Pipes for Zone 1 of Gravity System from Kokine SR (upper figure) and Pump System from Central SR (lower figure)

For laying of distribution main pipes, trenchless method of pipe laying will be required at 2 locations where large diameter pipes are required to cross the existing railway lines (Figure below). Along the Sule Pagoda road, the pipe diameter is 1200 mm and for installation of shafts for pipe jacking, permission will be required from Railway authority. For pipe crossing of railway along Majid road also permission will be required from Railway authority. Space for shafts is available at both of these locations.



Location of pipe crossing railway along Sule Pagoda Road near Yangon central railway station
(ϕ 1200 mm, L=200m)

Location of pipe crossing railway along Masjid Road in Pazuntaung
(ϕ 600 mm, L=200m)

Source: JICA Study Team using background map of Google Earth

Figure 7-12 Distribution Main Crossing Railway

7.4 Distribution Pipes and DMA

7.4.1 Distribution Facilities

Currently, water is being distributed from groundwater wells also located in different spots in Zone 1 in addition to water from Yegu system. Eventually, it is considered that water distribution from wells will not be used when water supply starts from Kokkowa system. When Kokkowa system starts operation, it is considered that zones (Zone 1, 2 and 3) will be appropriately isolated using valves at the boundary.

7.4.2 DMA and Distribution Pipe

(1) DMA Plan

DMA is planned within Zone 1 for equitable water distribution by monitoring and controlling inflow to each DMA. The planned DMA can also be utilized to monitor NRW for each DMA by comparing inflow amount with total consumed amount. The smaller the DMA size, the more equal it water distribution to each DMA. However, for practical and ease of distribution operation, DMA size is enlarged. IWA recommends DMA size in the range of 500 to 3000 connections.

Boundaries of DMA are planned along backyards of the high-rise buildings, resulting in short lengths of distribution pipes for gravity flow area where high-rise buildings exist with high population density. On the contrary, areas with pump system distribution have mostly large sized bungalow-type housing. So roads constitute DMA boundaries. As a result, DMA is planned to have about 5,400 connections in Low subzone and about 2,700 connections in High subzone of Zone 1 which are shown in the following Table.

Table 7-16 DMA Planning for Low subzone of Zone 1

Demand in 2025 (m^3/d) and (MGD)	Service population in 2025 (1000 persons)	Estimated No. of Service connection *	No. of Connection/DMA
168,202 m^3/d (37 MGD)	452	103,200	5,432

Number of DMA	Bulk Meter(BM) with Chamber	Household survey & Data Handling	Replacement/Installation of Service Connection with Customer Meters
	Qty. (Nos.)	Qty. (Nos.)	Qty. (Nos.)
19	39	103,200	103,200

Note: * 4.38 person/connection
Source: JICA Study Team

Table 7-17 DMA Planning for High subzone of Zone 1

Demand in 2025 (m^3/d) and (MGD)	Service population in 2025 (1000 persons)	Estimated No. of Service connection *	No. of Connection/DMA
77,282 m^3/d (17 MGD)	215	49,100	2,728

Number of DMA	Bulk Meter(BM) Chamber	Household survey & Data Handling	Replacement/Installation of Service Connection with Customer Meter
	Qty. (Nos.)	Qty. (Nos.)	Qty. (Nos.)
18	20	49,100	49,100

Note: * 4.38 person/connection
Source: JICA Study Team

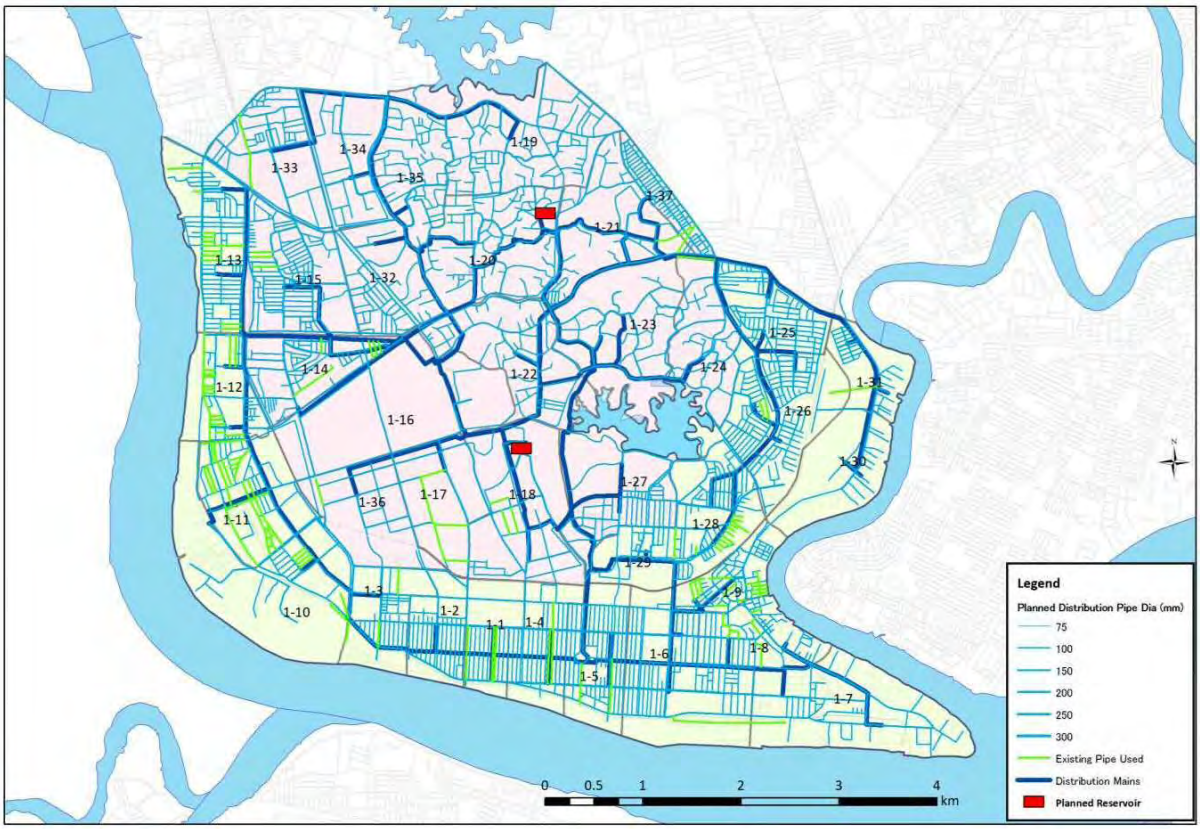
(2) Distribution Pipe within DMAs

Length of distribution pipe is planned as shown below based on the network analysis. Distribution pipe layout is shown below together with DMA. Use of existing pipes that are new is considered along with new pipes planned in this Study as indicated in the following Table and shown as green lines in the Figure below. Many existing distribution pipes are not suitable for required water pressure, because, re-use of overage pipe will trigger a huge number of water leakage by water pressure rising, and therefore are not used among the planned distribution pipes and hence new pipes are planned.

Table 7-18 Length of Planned Distribution Pipe for Zone 1

Pipe Diameter (mm)	Total Length of Existing Pipe (m)	Pipe Length Gravity from Kokine SR/Low Zone (m)			Pipe Length Pump from Central SR/High Zone (m)			Total Length of Proposed Distribution Pipe (m)
		Existing Pipe to be Used (m)	New Pipe (m)	Sub-Total Gravity (m)	Existing Pipe to be Used (m)	New Pipe (m)	Sub-Total Pump (m)	(4+7)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
40	2,284							
50	6,609							
75	13,675	2,123		2,123	151		151	**2,274**
100	71,146	7,127	153,278	160,405	3,734	123,986	127,720	**288,125**
110	1,435							
125	1,516							
150	220,792	14,838	42,968	57,806	2,632	67,754	70,386	**128,193**
160	3,672							
200	4,726		12,932	12,932		17,094	17094	**30,026**
225	19,181							
250	3,714		9,185	9,185		3,122	3,122	**12,307**
275	2,609							
300		473		473				**473**
Total	**351,359**	**24,561**	**218,363**	**242,924**	**6,517**	**211,956**	**218,473**	**461,397**

Source: JICA Study Team



Source: JICA Study Team

Figure 7-13 DMA and Distribution Pipe for Zone 1

(3) House Connection

In the existing condition, many households are using water from private wells and from piped supply after being mixed in their private reservoir or storage tank. In this Study, it is considered that the house connections will be directly connected to distribution pipes after achievement of 24 hrs supply.

In the existing condition, in the downtown area along the main roads, the customers are connected to the distribution pipes as shown in Figure below. On both sides of roads, drains are located which collects both rainwater and wastewater from neighboring houses. To connect the houses to the water supply distribution pipes, the house connections have to cross across the drains which can be a point of supplied water getting contaminated in case of leakage before reaching the user. To avoid this situation, the connection shall be through the backyard of the houses as shown in Figure below.

Figure 7-14 Existing House Connections

Source: JICA Study Team

Figure 7-15 Candidate of House Connection through Backyard

(4) Water Meters

Water meter is planned to be installed for 152,300 customers. The meters should be pressure tight and strong enough not to be tampered illegally. The meters should also be resistant to corrosion or elusion to have a high longevity. The material of meter should not be lead in any case. An example of water meter is given in Figure below.

Figure 7-16 Example of Flow Meter

7.5 Water Operation Plan during Construction Implementation

7.5.1 Change from The Existing Distribution System to New System (Additional Water from Kokkowa WTP)

In the existing distribution system (Figure 7-17), water comes to the new Zone 1 from the followings;

- directly from Yegu PS.
- from Kokine SR receiving water from Yegu PS.
- from Shwedagon SR receiving water from Kokine SR.

The zone 1 will be sub-divided into high and low. Change to the 2 sub-zones cannot be implemented instantly but should be implemented step-wise. The following key points need to be analyzed and confirmed before start of the implementation works:

1. Demands of the DMAs, and of high subzone and low subzone are almost matching as presented in this Study.
2. WTP and transmission pipe installation works to be implemented are already completed.
3. Yegu PS operates properly in order to convey sufficient amount of water to Central SR.
4. Kokine SR shall not be reconstructed, only cleaning shall be carried out and repair of SR, if needed, shall be implemented.

7.5.2 Step 1: Commencement of Water Supply from Kokkowa WTP

The salient features and necessary conditions of this step (Figure 7-18) are listed below:

- The construction of 40 MGD Kokkowa WTP will be implemented along with installation of transmission pumps, relay pumps in Zone 9, and transmission pipes from WTP to Zone 9 and from Zone 9 to Kokine SR in Zone 1.
- The transmission pipe from Zone 9 to Kokine SR will be connected to existing 56” (1400 mm) pipe at the inlet to Kokine SR.
- Kokine SR’s valves from Yegu will be closed to change water supply from Kokkowa.
- Using water from Kokine SR to Shwedagon SR, most of the areas in low subzone will be supplied Kokkowa water.
- Some parts of Pazuntaung, Botahtaung, Mingala Taungnyunt, Bahan and entire Tamway will be supplied Reservoir water from Hlawga PS using existing 42” (1050 mm) pipe.

【Required Pipe Laying Works】

- Laying of transmission pipe from WTP to Relay PS in Zone 9 and from Relay PS in Zone 9 to Kokine SR

7.5.3 Step 2: DMA Development in Low Subzone (1)

The salient features and necessary conditions of this step (Figure 7-19) are listed below:

- The distribution main pipes from Kokine SR to DMAs of Low subzone will be installed.
- Transmission from Zone 9 will be connected to newly constructed distribution mains at the outlet from Kokine reservoir along with installation of new valves.
- Transmission from Zone 9 will also be connected to existing pipe in the western part of Low subzone
- Subsequently, the distribution pipes will be installed and DMAs will be established in the western and southern townships of Low subzone of Zone 1.
- Yegu PS will convey Reservoir water to Shwedagon SR to supply water to Bahan and Dagon townships.
- Major areas of eastern part of Low subzone will still be supplied water directly from Hlawga PS.
- A new distribution main pipe from Kokine will be connected to existing main pipe of diameter 750 mm (30") on Bargayar Rd through tapping method without water supply suspension through existing pipe (Under pressure tapping method, Non-stoppable tapping method). Consequently, Kokkowa water will be continuously supplied through the existing main to high subzone in Zone 1 till the new distribution system is installed and becomes operational in this area.
- At this stage, leakage of Kokine SR can be tested upon confirmation that all the inlet and outlet valves are new and can be closed properly. If required, repair works of Kokine should also be undertaken.

【Required Pipe Laying Works】

- Laying of distribution main pipes in Low subzone (west and central)
- Laying of bypass pipe of dia.1000 mm at Kokine SR
- Non-stoppable tapping of dia.1400 mm x dia.1000 mm (Figure 7-22)
- Non-stoppable tapping of dia.1050 mm x dia.1000 mm (Figure 7-22)
- Connection work of new distribution main pipe from Kokine SR and existing main on Bargayar Rd. by non-stoppable tapping of dia. 750 mm (30") x dia. 700 mm (Figure 7-22)
- Installation of non-stoppable insert valve of dia. 750 mm (Figure 7-22) and Removal of existing main pipe from Kokine SR to Bargayar Rd
- Improvement of DMAs and pipe network in Low subzone (11 DMAs)

7.5.4 Step 3: DMA Development in Low Subzone (2)

The salient features and necessary conditions of this step (Figure 7-20) are listed below:

- Distribution pipes will be installed and DMAs will be established in the eastern townships of Low subzone of Zone 1. DMA establishment in Low subzone of Zone 1 will be completed.
- Yegu PS will continue conveying water to Shwedagon SR to supply water to Bahan and Dagon townships.

- Eastern townships of Tamway and some part of Mingala Taungnyunt of High subzone of Zone 1 will still be supplied water directly from Hlawga PS.

【Required Pipe Laying Works】

- Laying of distribution main pipes for Low subzone (east)
- Improvement of DMAs and pipe network in remaining part of Low subzone (8 DMAs)

7.5.5 Step 4: DMA Development in High Subzone

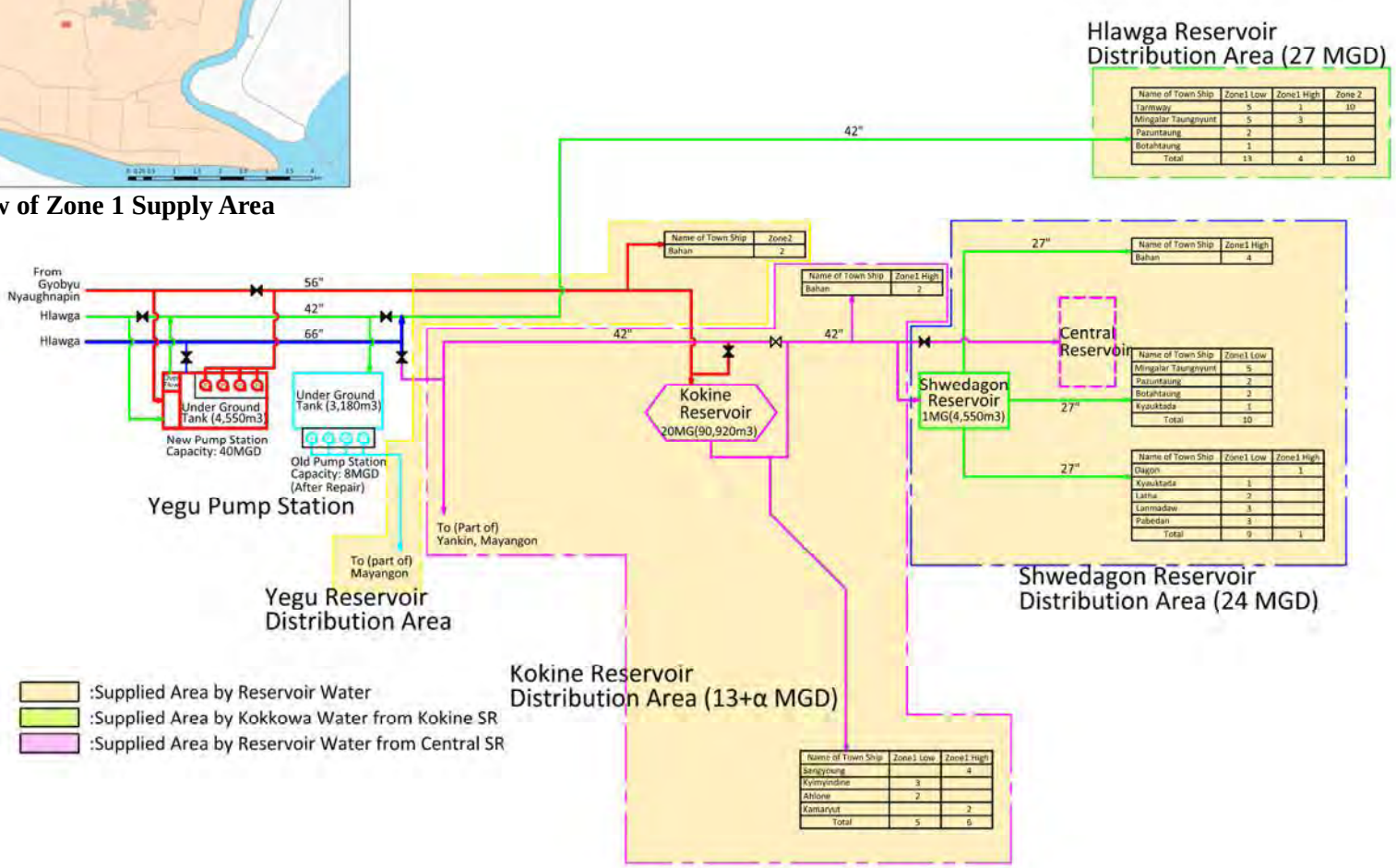
The salient features and necessary conditions of this step (Figure 7-21) are listed below:

- Central SR will be reconstructed.
- Water from Yegu PS will be conveyed to Central SR using 56" and 42" pipes.
- Distribution pipes will be installed and DMAs will be established in the townships of High subzone of Zone 1.
- Shwedagon SR and 27" pipes from Shwedagon SR will be abandoned.

【Required Pipe Laying Works】

- Laying of distribution main pipes for High subzone (All DMAs)
- Replacement of pumps in Yegu PS
- Improvement of DMAs and pipe network in High subzone (all 18 DMAs)

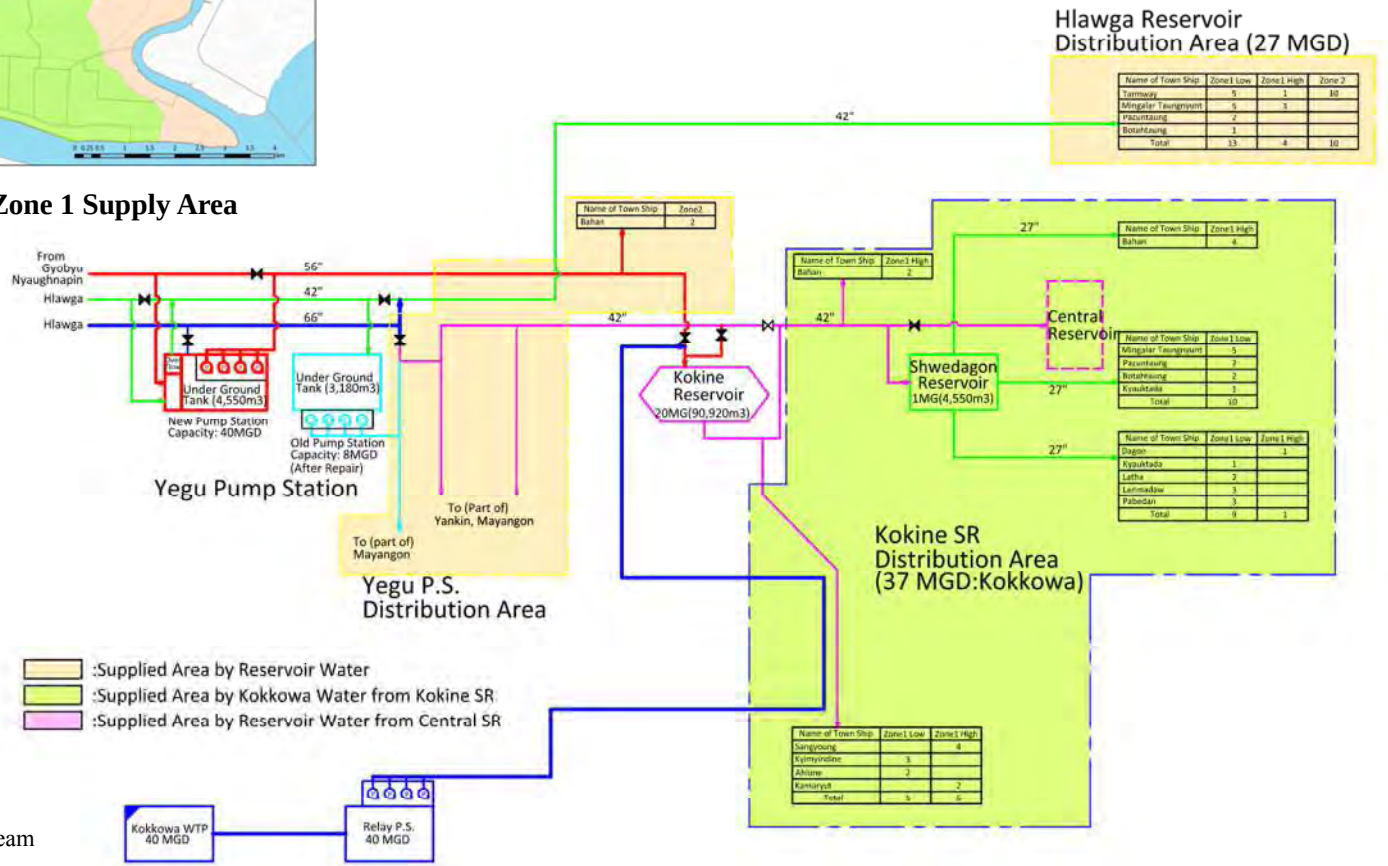
Over View of Zone 1 Supply Area



Source: JICA Study Team

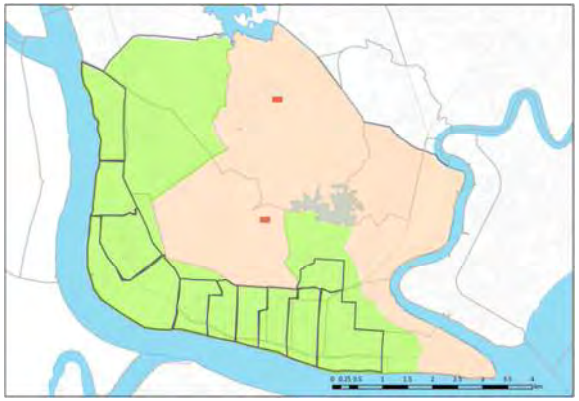
Figure 7-17 Schematic Diagram of Current Water Supply

Over View of Zone 1 Supply Area

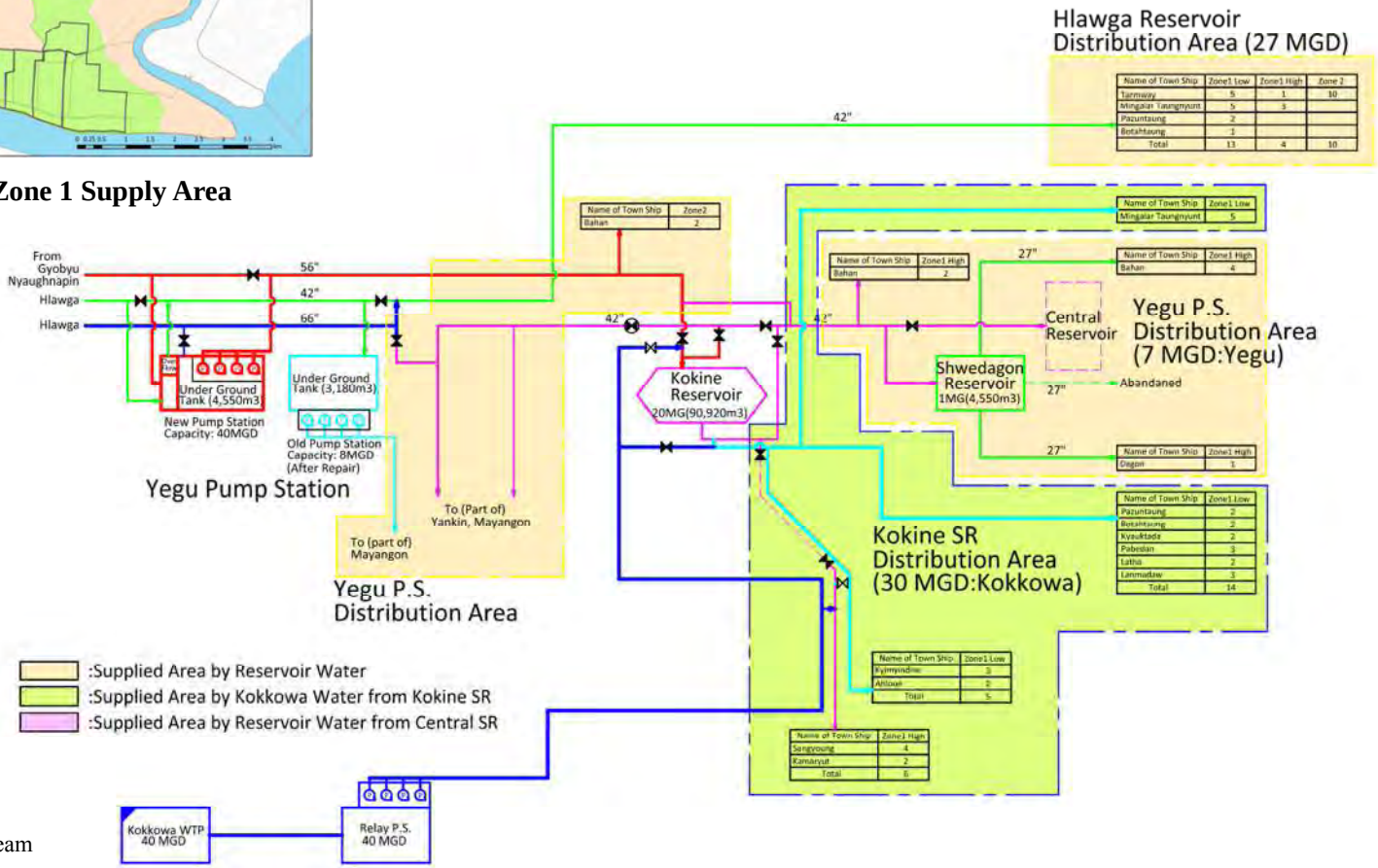


Source: JICA Study Team

Figure 7-18 Water Supply Changing Procedure [Step -1: Commencement of Water Supply from Kokkowa WTP]

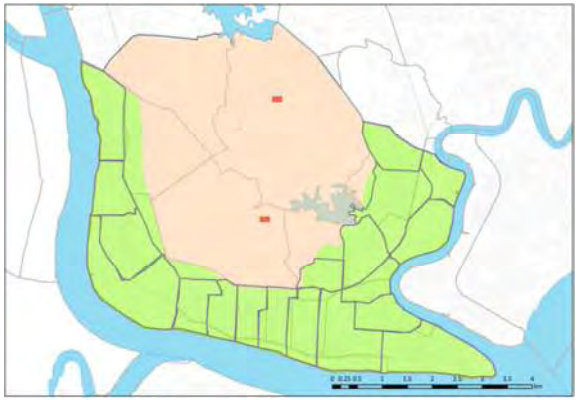


Over View of Zone 1 Supply Area

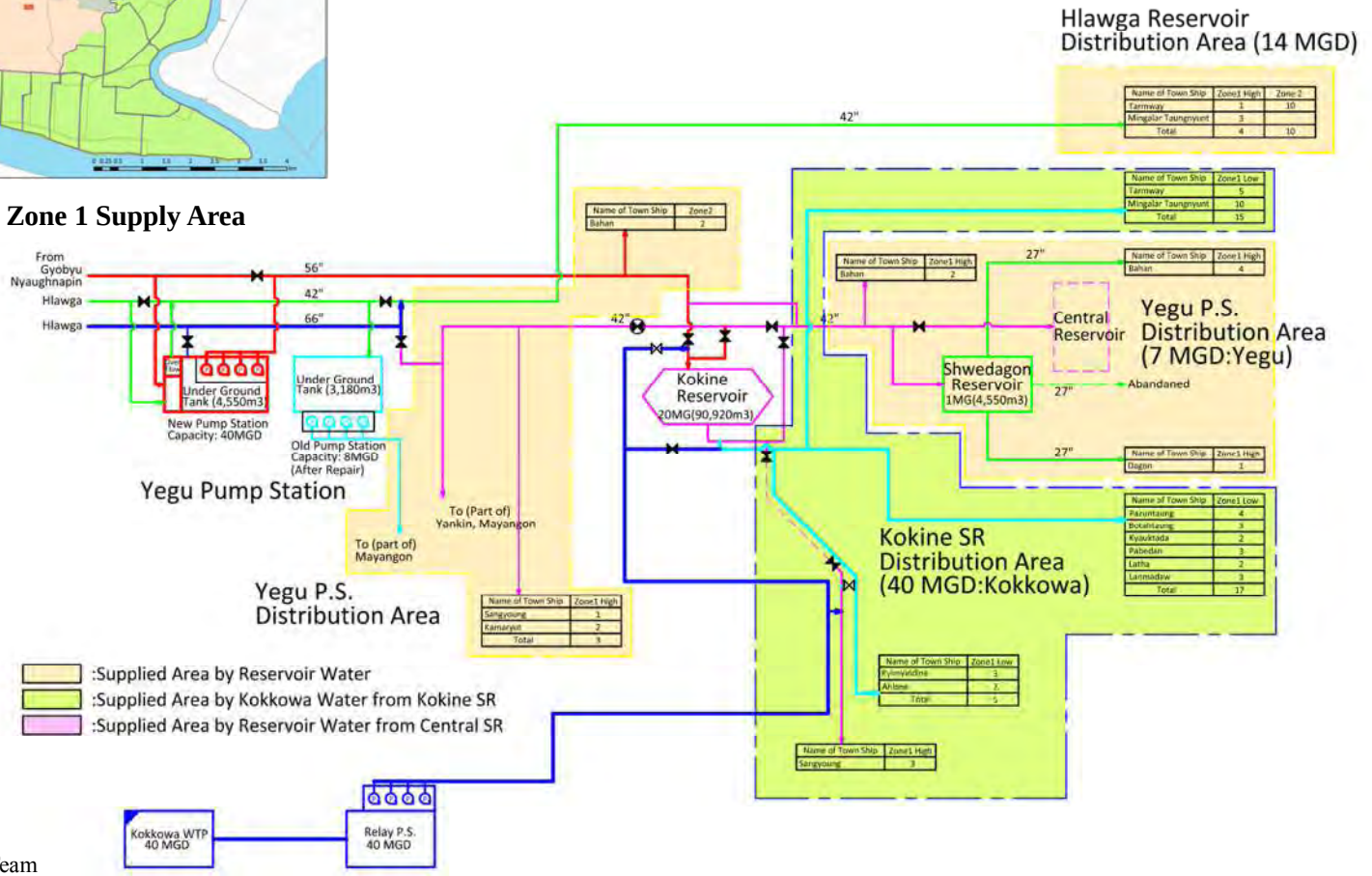


Source: JICA Study Team

Figure 7-19 Water Supply Changing Procedure [Step -2: DMA Development in Low Subzone (1)]

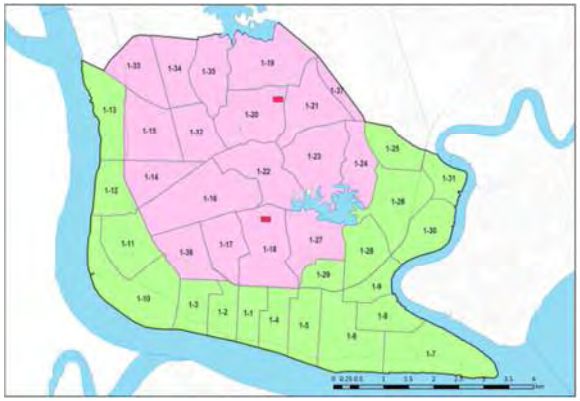


Over View of Zone 1 Supply Area

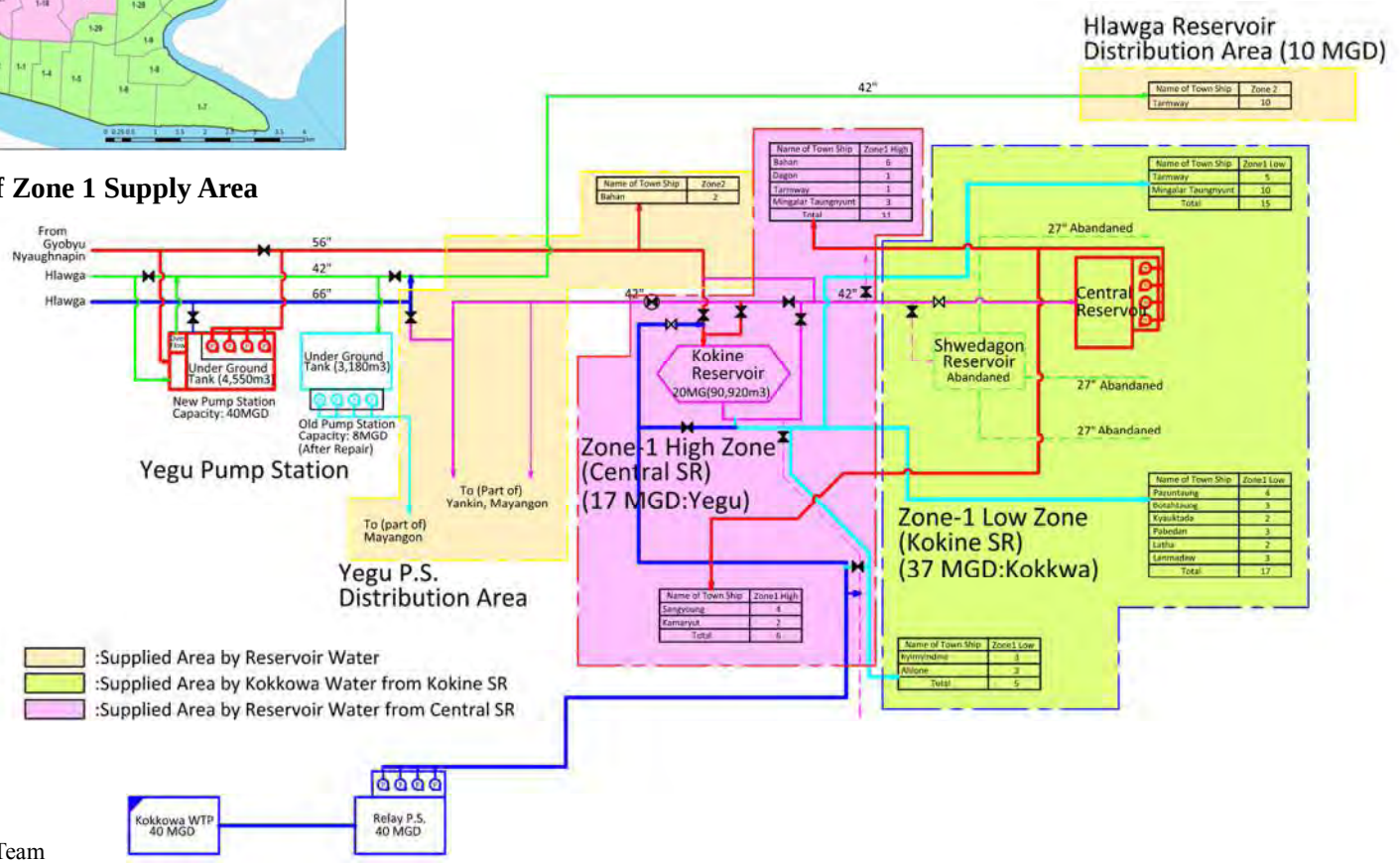


Source: JICA Study Team

Figure 7-20 Water Supply Changing Procedure [Step -3: DMA Development in Low Subzone (2)]

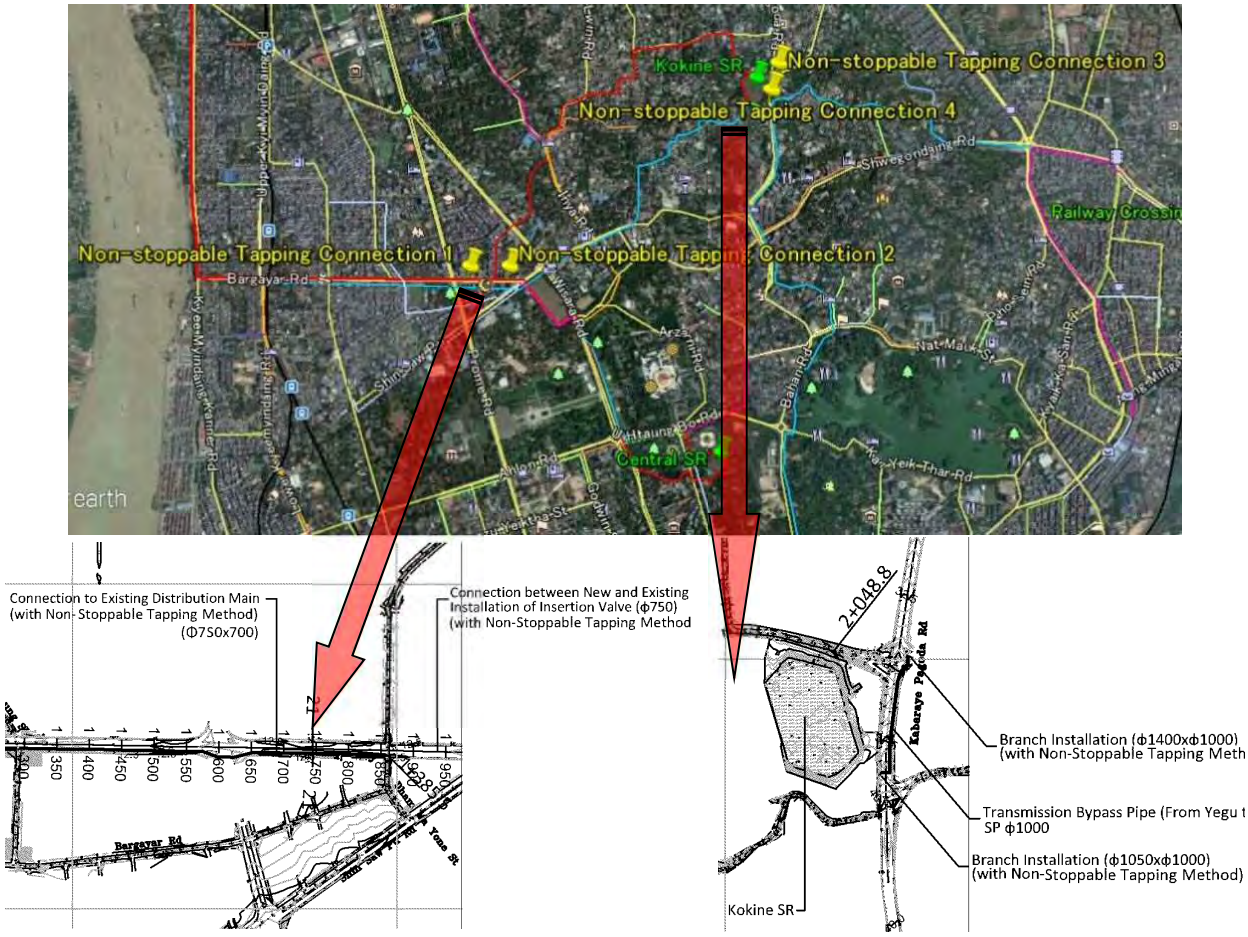


Over View of Zone 1 Supply Area



Source: JICA Study Team

Figure 7-21 Water Supply Changing Procedure [Step -4: DMA Development in High Subzone]



Location of connections to existing distribution pipe of ϕ 750 mm along Bargayar Road

Location of connections to existing distribution pipes of ϕ 1400 mm and ϕ 1050 mm along Kabar Aye Pagoda Road

Source: JICA Study Team using background map of Google Earth

Figure 7-22 Locations of Non-stoppable Tapping Connections

CHAPTER 8 OPERATION, MANAGEMENT AND CAPACITY

Issues to be considered for the proposed facilities are summarized considering the review of the current situation of management, system and capacity in the existing facilities as described in detail in Appendix-9.

8.1 Summary of Issues

8.1.1 Water Treatment Plant

(1) Maintenance

- Daily inspection and repair should be implemented and water quality and flow rate should be managed in order to purify water to the desired level.
- Washing process and quality management of filter media should be reconsidered in order to optimize washing cycle in case of filtration basin.
- Daily inspection and consumption of chemicals and electricity should be recorded in order to improve management of WTP.
- Documents of specifications and drawings of facilities and equipment should be managed in order to maintain them properly.
- Initial and operation cost including cost of spare parts should be considered and technical capacities of electrical and mechanical engineers should be developed in order to continue using the facilities properly for a long time.
- Equipment ledgers including data on installation year, manufacturer, item number and history of breakdown and repair/replacement should be prepared and updated in order to plan replacement effectively in the future.

(2) Equipment

- Intake flow meters should be installed in order to decide appropriate injection rate of coagulant.
- Coagulant injection point should be changed, coagulant should be added at required rates, inflow rate of water to each flocculation basin should be controlled by valves and outlets of flocculation basin should be renovated in order to improve coagulation and sedimentation.
- Chlorine injection equipment should be installed in order to remove algae of sedimentation and filtration basin and to disinfect treated water.
- Water quality monitoring equipment should be installed at the locations to monitor quality of raw water, water after sedimentation and treated water in order to optimize coagulant injection rate.
- Daily water quality test should be done by specific equipment for each indicator not by simple measurements, and reliability of the test should be improved by clarifying calibration process and frequency.

(3) Quality control

- Delivered products should be checked using the composition table provided by the suppliers to confirm if the products are meeting the ordered specifications.

(4) Structure

- Some portions in Nyaunghnapin WTP; including aged concrete structures, damaged and leaking gates, broken surface washing pipes, etc. should be renovated.

(5) Others

- Measures against inundation should be implemented in rooms of electrical equipment.

8.1.2 Transmission Pipe

(1) Equipment

- Flow meters should be installed on transmission pipes.

(2) Maintenance

- Transmission pipelines should be patrolled regularly in order to find leakages and unregistered connections.
- Leakages above ground should be repaired immediately and countermeasures should be implemented against unregistered connections.

8.1.3 Distribution Pipe

(1) Standardization of specification, regulation and procedure

- Specifications of materials and regulations of quality control and construction management should be standardized.
- Procedure of designing distribution pipe network should be established.

(2) Systematic facilities

- Distribution facilities such as service reservoirs and pipe network should be designed and constructed systematically.

(3) Maintenance

- Leak detection should be implemented after preparing leakage repair equipment.
- Old distribution pipes should be replaced effectively by using distribution pipeline maps, reports on repairing leakages and leakage history maps.

8.1.4 Water Supply Equipment

(1) Standardization of specifications, regulations and procedure

- Specifications of water meters and service equipment and regulations on service pipe connection with distribution pipe, quality control and construction management should be standardized.

- Plumbing models from distribution pipe to water meter should be defined.
- Procedure of defining meter size by calculating water head should be established.

(2) Meter owner

- Meter owner should be changed to YCDC from customers in order to facilitate easy maintenance.

8.1.5 Customer Management

(1) New customer registration

- New customers should be registered not at the township offices but at the head office in order to manage them uniformly.

(2) Water charge collection

- Individual water consumption should be compared with average consumption in case of each customer on the new system every month in order to find leakage and illegal connections effectively.

8.1.6 Measures

(1) Water treatment plant

- As for the issues of maintenance, equipment, quality management, structure and others related to existing water treatment facilities, it is expected that the activities of the JICA technical cooperation project, the JICA long term expert and the JICA training program in Japan will solve these issues. In addition, technical cooperation project should be continued to deal with the O&M issues related to the Kokkowa WTP that will treat river water, the first time experience for YCDC.

(2) Transmission and distribution pipe

- As for the issues of standardization of specifications, guidelines and procedures, systematic development and maintenance, it is expected that the activities of the JICA technical cooperation project, the JICA long term expert and the JICA training program in Japan will help solving these issues. Also, it is necessary to continue using the procedures and utilizing experiences that YCDC acquires from these activities to operate and manage the facilities constructed in this project.

(3) Water supply equipment

- As for the issues of standardization of specifications, guidelines and procedures related to water meters and meter owners, it is expected that the activities of the JICA technical cooperation project, the JICA long term expert and the JICA training program in Japan will help solving these issues. It is necessary to continue using the procedures and utilizing experiences that YCDC acquires from these activities to operate and manage the facilities constructed in this project.

(4) Customer management

- As for the issues of new customer registration and of water charge collection, it is expected that the activities of the JICA technical cooperation project, the JICA long term expert and the JICA training program in Japan will help solving these issues. It is necessary to continue using the procedures and utilizing experiences that YCDC acquires from these activities to operate and manage the facilities constructed in this project.

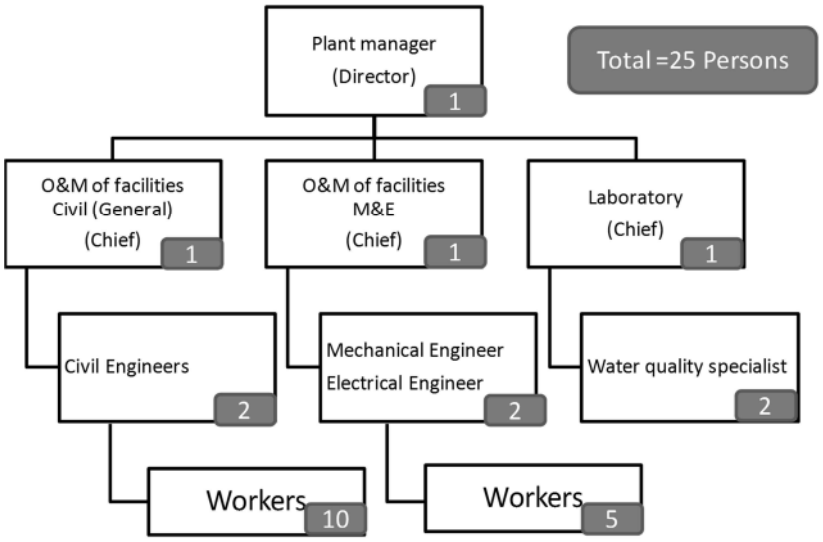
8.2 Required Organization Structure for Kokkowa Project

8.2.1 O&M Plan of The Kokkowa WTP

Considering that SCADA system will be installed at Kokkowa WTP, the operation and maintenance of Kokkowa WTP will be managed like WTPs in Japan and not like Nyaunghnapin WTP. Therefore, some information such as organization structure in case of WTP in Japan, proper maintenance of installed equipment in Myanmar and some manuals which are used in Fukuoka City Waterworks Bureau are described as reference. (Fukuoka City and Yangon City are friendship towns).

(1) Organization Structure in WTP

Organization chart of Kokkowa WTP is planned to be established under Reservoir division of EDWS. Since EDWS has a large number of civil engineers, including engineers/experts of 3 fields (such as civil, M&E and water quality) would be simple to begin operation of WTP. Mechanical and Electrical engineers should be placed at the WTP and their capacities should be developed in order to carry out operation and maintenance of facilities properly. This structure of WTP will be changed gradually in steps according to the capacity development of EDWS engineers. Therefore, a basic organization chart, duties of various staff-members, the number of staffs and their specialized field for the Kokkowa WTP is introduced and corresponding example data for WTPs in Japan is also included for future reference.



Source: JICA Study Team

Figure 8-1 Proposed Organization Chart of Kokkowa WTP

Table 8-1 Proposed Duties of Each Unit of Kokkowa WTP

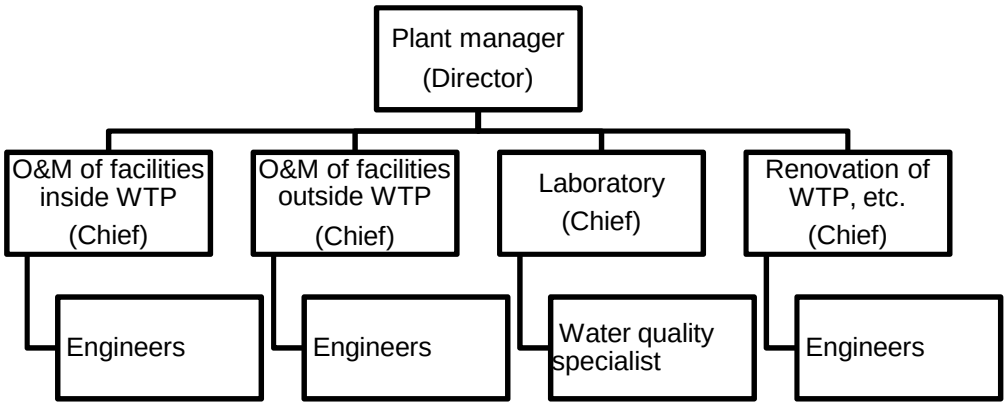
Unit	Duties
Plant Manager	To manage WTP
Civil Engineer	To operate and maintain WTP facilities including reservoir, intake, transmission
Mechanical and Electrical engineer	To operate and maintain mechanical and electrical components of WTP
Laboratory	To implement water quality test

Source: JICA Study Team

Table 8-2 Proposed Number of Staff in Various Technical Fields for Kokkowa WTP

Kokkowa WTP	Capacity	
Capacity (m^3/day)	273,000	
Number of staff	25	
Plant Manager	1	Civil, Mechanical and/or Electrical
Civil Engineer (Shift operations)	3	Civil
	10	Any Field
Mechanical and Electrical engineer	3	Mechanical and/or Electrical
	5	Mechanical and/or Electrical
Laboratory	3	Chemist

Source: JICA Study Team



Source: Fukuoka City

Figure 8-2 Reference of Basic Organization Chart of WTPs in Fukuoka

Table 8-3 Reference of Duties of Each Unit at WTPs in Fukuoka

Unit	Duties
Plant manager	To manage WTP
O&M of facilities inside WTP	To operate and maintain purification facilities inside WTP
O&M of facilities outside WTP	To operate and maintain facilities including reservoir, intake, and conveyance outside WTP
Laboratory	To implement water quality test
Renovation of WTP, etc.	To supervise construction works in WTP

Source: Fukuoka City

Table 8-4 Reference of Number of staffs at WTPs in Fukuoka

WTP	A		B		C		D		E	
Nominal capacity (m^3/day)	110,500		199,000		122,000		174,000		15,000	
Total number of staffs	22		27		24		24		19	
Plant manager	1	M	1	E	1	M	1	M	1	E
O&M inside WTP	6	E	7	E	6	E	8	E	7	E
	7	M	8	M	8	M	7	M	5	M
O&M outside WTP	2	E	3	E	2	E	3	E	2	E
	2	M	3	M	2	M	1	M	1	M
Laboratory	3	Q	3	Q	4	Q	3	Q	3	Q
Renovation of WTP, etc.	1	3	2	M	1	E	1	E	-	-

* E: Electrical Engineer, M: Mechanical engineer, H: Water Quality Specialist
Source: Fukuoka City

(2) Efficient Operation and Maintenance

1) Efficient operation

- Operation of WTP can be made more efficient by reduction in electricity cost through use of following measures.
- Gravity system of facilities planning
- Installation of rotation speed controlled pumps
- Optimization of operation time of washing pumps by checking head loss in filtration basin and by carrying out washing at proper intervals
- Automation of filtration basin washing
- Optimization of pump operation by monitoring flow rate at intake and transmission pumps
- Installation of high-efficiency motor and transformer installation of solar panels is also effective in future

2) The cost on chemicals can be reduced by use of following measures.

- Chemical injection at proper rate by implementing water quality test and jar test and deciding chemical injection rate based on the result of water quality test for samples of each purification stage
- Optimization of chemical injection rate by managing flow rate through each purification stage
- Reduction in unit cost of chemical by executing long-term contract with suppliers

(3) More efficient maintenance for future

1) Inspection

- Facilities and equipment are to be inspected using portable device and the record of the inspection should be managed on a master computer.
- Efficient daily inspection route is defined considering the locations of facilities and equipment.

2) Facility and equipment

- Sample water from location of each purification processes are pumped up to the water quality laboratory with pumps.
- Conditions of flocculation and filtration basins are monitored by surveillance camera in order to

purify efficiently.

- Equipment ledgers are prepared in order to consider replacement cycle and repair plan of equipment.

(4) Manual of Operation Management of Facilities

1) General

The main purpose of operation management is to achieve the function of the facility sufficiently. It is made possible through efficient operation and control of facilities including associated equipment. Operation and management of water treatment plant includes a wide range of facilities (e.g. Intake facilities, water treatment facilities, distribution facilities, chemical injection facilities, waste water treatment facilities, other treatment facilities, etc.). It is important to operate all these facilities satisfactorily to achieve the purpose of WTP.

In addition, it is most important to operate the entire plant as a water treatment system effectively and with integrity. Even if the water treatment conditions changes to some extent (e.g. raw water quality is worsened, emergency occurs, etc.), operation management must be performed considering buffer for such conditions. For this purpose, the collection of sufficient data is required (e.g. the situation of water sources, intake points, water distribution) for the operation and management of each facilities.

2) Intake facilities

It is important that intake facilities are operating in desired condition and is able to draw continuously high-quality raw water from the water source to cater to the demand. To intake raw water in better condition, it is important to carry out basic inspection and maintenance of facilities. If the gates, screen, water intake pump, etc., are not maintained adequately, it may have negative impact on water intake which subsequently will affect the treated water amount as a whole. By performing the daily inspection of water source, it is possible to find the abnormality in the water source quality at an early stage.

a) Water intake gate, solid waste removal machine

Water intake gate and solid waste removal machines are sometimes clogged due to deposition of floating objects and mud of the river, resulting into malfunctioning of intake facilities and poor raw water quality. The monitoring of these structures by daily visual inspection and performing regular cleaning is important to maintain the equipment in good condition.

b) Sand basin

Sand basin is a facility to remove pebbles and heavy sand that is present in the raw water by sedimentation. When there is excess deposition of the pebbles and sand in the sand basin, water intake function is reduced due to the following reasons.

- Insufficient sedimentation due to reduced residence time in the sand basin
- Clogging of the screen, etc.

It is important to keep the equipment in good condition by regular monitoring of sediment

deposition and removing sediments and cleaning screen whenever required.

c) Intake pump

Intake pump is a facility for feeding the raw water in stable amounts to water treatment facilities. Raw water contains sediments and suspended solids and in case of pumping surface water, reduction in amount of water is likely to occur due to suction of foreign matter and wearing of impeller resulting into low performance of pumps. Thus, during pumping operation in order to grasp the state of the pump, it is desirable to do the following.

- Regularly checking and recording pump electric current value
- Periodically performing the confirmation of the pumping amount

d) In addition to the inspection described above, to perform daily visual inspection and periodic inspections, and to carry out maintenance and upgrading based on analysis of inspection data, in order to maintain satisfactory level of pump operation.

3) Water treatment facility

a) Receiving well

Receiving well is used to stabilize the raw water and a facility for adjusting the raw water quantity. Also, receiving well can be used as an injection point for chemicals such as acid or alkaline agent used in the water purification process. Receiving well is initial location of WTP, and in order to perform the water purification process properly, the condition of raw water quality shall be understood accurately. Therefore, it is necessary to carry out the inspection of sampling pump and also visual inspections of the raw water quality.

b) Coagulation basin

i) Mixing basin

Mixing basin is a facility for uniformly diffusing the coagulant into the raw water after injecting through quick rapid agitation. In a typical flash mixer, mixing is achieved by rotating at a peripheral speed of more than 1.5m/s. It is also possible to adjust the injection intensity by monitoring and controlling water and injection volume.

ii) Flocculation basin

Flocculation basin is a facility for making agglomerates of small flocs and finally to large flocs by appropriate stirring to enable easy sedimentation. When the growth of the flocs is not sufficient, the outflow from sedimentation basin has higher turbidity, or due to reduction in the filtration duration, suspended matter flows out to the filtered water.

c) Coagulation sedimentation basin

Coagulation sedimentation basin is a facility to separate and remove majority of the flocs formed in flocculation basin by sedimentation through gravity. In managing the coagulation sedimentation basin, it is necessary to pay special attention to water quality of outflow from the sedimentation tank, and therefore it is important that a target turbidity level is set for outflow from sedimentation tank and water quality be monitored. When any abnormality is detected in

the outflow from sedimentation basin, the jar test should be carried out and appropriate chemical injection and equipment operation should be made based on result of the jar test. When excess amount of sludge is deposited in the sedimentation basin, the residence time is reduced and flocs do not settle sufficiently. To avoid this, sludge deposition in sedimentation basin should be monitored periodically and sludge should be removed whenever required. In addition, algae growth may occur in the sedimentation basin. If any adverse effect is expected on the treatment process, algae needs to be removed using chemicals (such as chlorine agent) or by cleaning the sedimentation basin after emptying. Also, once a year, it is desirable to perform cleaning of the inner surface of sedimentation basin, and inspect and carry out maintenance of the accessory equipment, after emptying it.

d) Filtration basin

Filtration basin is a facility to remove the contaminants from outflow of sedimentation basin by sieving action in the filter layer and through attachment to the filter media.

i) Washing of the filtration basin

Washing of the filtration basin is carried out when it reaches one of the following states.

- When turbidity of outflow from filtration basin exceeds the target value
- When the head loss reaches a set value

  The head loss is water head difference before and after filtration. Head loss is larger in case of clogging filter layer. When the head loss becomes excessive, it causes formation of air bubbles by the negative pressure in the filter layer, the filter layer surface contraction and cracking. In such case, filtered water quality is likely to be worsened.
- When the filtration duration reaches a set value

  A constant filtration duration is set such that the target value of the filtered water quality is maintained (approximately 24 hours to one week in normal condition), and when the filtration duration reaches to set value, washing will be required. It is effective for demand management contract.

  After stopping the operation of filtration basin for long-time, when the operation is planned to restart
- When a filtration basin is not operated for long time, it is possible that filtration may not be achieved due to growth of algae or microorganisms. Therefore, it is necessary to clean the filtration basin before restarting the operation.

ii) Washing method

Washing is performed by a combination of backwashing and surface washing or air washing. Washing through only backwashing is not appropriate as formation of mud ball is likely to occur. It is important to set the amount of washing water, washing pressure and time so that sufficient cleaning effect can be achieved. The washing duration of filter is decided based on the quality of washed water and considering economical washing method. The final washing effect is judged good or bad by comparing the degree of contamination of the filter media taken from the filter layer before and after washing. Since the washing effect will vary with the water temperature,

and the particle size and thickness of filter layer, the drainage after washing is required to be examined regularly and the washing time adjusted accordingly. When the washing method is not appropriate, in the long term the following disorders may occur, leading to deterioration in quality of filtered water, and increase in head loss.

- Mud ball formation
- Crack initiation on filter layer surface
- Generation of gap between the filtration basin side wall and filter layer
- Coarsening of the effective diameter of the filter medium
- Reduction in filter layer thickness
- The unevenness on the boundary surface of the gravel layer and the filter layer, filter bed

e) Clear water reservoir

Clear water reservoir is used to store treated water to take care of imbalance between the filtered water volume and water supply volume. Regular inspection of clear water reservoir is essentially required in terms of quality and hygiene. In particular, the residual chlorine level should be maintained in the range of target value. Moreover, water level in the clear water reservoir should be maintained in defined range in order to avoid cavitation in pumps. The entrance to water treatment plant should be locked appropriately. In addition, inspection and maintenance of the insect screen, ventilation facilities and rattle should be carried out periodically to prevent entry of rainwater, dust, insects and small animals from outside and to avoid water pollution.

4) Water transmission and distribution facilities

a) Transmission and Distribution pump

Water distribution amount varies with time and to carry out stable water distribution, it is important to control the pump operation appropriately. In case of change in distribution water amount, if the pipe flow rate increases rapidly, it may result in the generation of red water and also it is necessary to pay attention to occurrence of water hammer due to sudden stopping of the pump. In addition, as mentioned in the previous section (related to clear water tank), there is possibility of occurrence of cavitation in pump due to high drop in water level in clear water reservoir. Therefore, water level in the clear water reservoir should be monitored and maintained within defined range. Monitoring of pump operation should include continuous or scheduled measuring and record of data on suction and discharge pressure, water flow, voltage, electric current, and power. The pumps should include standby units and also spare parts such that each pump can be given rest at regular intervals and in case of breakdown without affecting the water supply services.

5) Chemical injection facility

- Chemical injection equipment for coagulation

Flocculants is used in treatment process to facilitate formation of flocs and easy sedimentation of colloidal particles present in raw water. It is important to ensure optimum injection rate and

injection volume considering the quality and quantity of the raw water. Therefore these parameters should be accurately measured, and maintenance of the chemical injection equipment is important. Also, inspection and cleaning of the injection pipe should be carried out regularly to avoid clogging of injection pipe due to coagulant. In order to achieve the optimum effect of the flocculants, it is important to carry out adjustment of the injection amount and agitation conditions. The processes are described below.

i) Injection rate

Factors affecting injection rate of flocculants are stirring, pH value, alkalinity, water temperature, etc. In order to determine the injection rate of the coagulant, basically the jar tests should be carried out regularly for raw water. The injection rate should be decided considering the result of jar test, based on the variation trend of raw water quality and actual mixing tank conditions. When the raw water quality changes suddenly (at the time of change of river water quality due to rainfall, etc.), the jar test should be carried out immediately. Also, it is important to monitor the situation of floc formation and sedimentation whether it is at desired level.

ii) pH value

pH value is an important factor for coagulation of colloids. The flocculants functions well in defined range of pH values, and if the pH level is outside this range, agglomeration effect is drastically deteriorated. Therefore, if the pH value of the raw water is too high or too low, it is necessary to adjust the pH value by addition of appropriate amount of acidic or alkaline agent. Incidentally, PAC is acidic, and when the injection rate is increased, the pH value is lowered. Therefore, it is necessary to add alkali in such case.

iii) Alkalinity

Alkalinity is an important factor affecting the flocculation process. To form good flocs, it is desirable that alkalinity after injecting the flocculant is at least about 20mg/L. If the alkalinity is low, there is need for addition of alkali in order to maintain the alkalinity within appropriate range.

iv) Water temperature

The water temperature is an important factor that affects the sedimentation, coagulating reaction and formation of floc. If the water temperature is higher, the growth of the floc is accelerated. If the water temperature is lower, the growth of the floc is slow. For poly aluminum chloride, the coagulating effect can be expected even at low water temperature. ()

v) Automatic injection of flocculant

Automatic injection rate of chemical can be executed by two ways. One is determining the injection rate by jar test. The other method uses an injection rate equation that has been determined based on the historical data of water quality or jar test. However, even in the case of using this method, it is required to confirm the injection rate using the data of regular jar test.

b) Disinfection equipment

Disinfection of tap water prevents contamination of water due to pathogenic organisms, and it is

carried out for the purpose of keeping the distributed water safe. Using chlorine as disinfectant, a large amount of water can be easily disinfected and there is an advantage that the effect remains. On the other hand, use of chlorine as disinfectant can result into generation of by-products such as trihalomethanes, strong odor by reacting with a specific substance and weakening the disinfecting effect by reacting with ammonia nitrogen. At high level of turbidity, the effect of chlorination is reduced. Injection rate of chlorine should be set considering the residence time and water quality such that the residual chlorine concentration of the faucet water is maintained at the specified level all times. Attention is needed toward level of residual chlorine which should not be excessively high.

i) Sodium hypochlorite

Sodium hypochlorite is a pale yellow liquid, and is characterized by strong alkalinity, and corrosiveness. It is rapidly decomposed by an acid, and releases chlorine gas. It is dangerous. Thus, care should be taken not to mix sodium hypochlorite with the acid solution. In addition, it is strongly alkaline, and care should be taken while handling it not to adhere to the skin and mucous membranes. In addition, sodium hypochlorite is unstable, and easily decomposes releasing oxygen during storage at room temperature, which is accelerated due to increasing temperature, sunlight, or ultraviolet radiation. For this reason, it is stored in a cool, dark place. Furthermore, since its effective chlorine content is reduced during storage, it is desirable to store it for only short period. Furthermore, when the sodium hypochlorite is exposed to water with high level of hardness, the scale may occur due to precipitation of calcium carbonate. Therefore, it is important to implement the inspection and cleaning near the injection point.

ii) Pre-chlorination

Pre-chlorination is carried out through injection of chlorine agent in the receiving well or mixing basin before sedimentation basin to ensure sufficient reaction time for the chlorine. . Pre-chlorination results into the biological killing and prevents algae breeding in the mixing basin and coagulation sedimentation basin. Moreover, it is also effective in case of raw water containing ammonia nitrogen. When pre-chlorination is used as countermeasure against ammonia nitrogen, the injection amount should be about 10 times the amount of ammonia nitrogen. However, if raw water contains trihalomethane precursor and musty odor producing blue-green algae, etc., there is a high possibility of formation of trihalomethane and generation of musty odor. So, care is required in this respect.

iii) Intermediate chlorination

Intermediate chlorination is carried out at a location between the sedimentation basin and filtration basin. In this method, chlorine is added after possible removal of the trihalomethane precursors or musty odor-producing cyanobacteria from raw water by coagulation and sedimentation, and therefore, it is effective countermeasure against trihalomethanes and musty odor producing materials.

iv) Post-chlorination

Post-chlorination is carried out in case when it is necessary to supplement the residual chlorine

consumed by filtration basin to bring it to desired level. Chlorine is added at a location between the filtration basin and clean water reservoir.

6) Wastewater treatment facility

Wastewater treatment facility is required to treat the sludge collected from sedimentation tank. The collected sludge is processed to separate liquid and solids. Separated liquid is either reused by returning to the raw water, or it is discharged into public water body. Separated solid can be used at landfill site after drying. In general, wastewater treatment includes processes of stabilization, thickening, dewatering, drying and disposal. The amount of generated sludge can be analyzed and estimated for the amount of treated water considering raw water condition for entire year and the data can be used for preparation of treatment plan for each season and each month. In addition, it is required to be careful because the sludge quality deteriorates due to long-term deposits in sedimentation tank and dewatering tank.

7) Power distribution equipment

In the operation management of the power distribution equipment, it is important to keep track of the normal operating condition of each device, and it is necessary to act quickly in case of any abnormality. In addition, it is necessary to understand the characteristics and operation interlock condition of the device. For early detection of abnormalities, it is necessary to carry out regular inspection of devices to measure and record values of current and voltage. If performance of the power distribution equipment is deteriorated, it will not only cause the failure or further reduction of efficiency of its own parts, but it may also cause disaster through other equipment failure, water supply interruption, electric shock and fire.

(5) Manual of maintenance inspection and repair

The purpose of maintenance inspection and repair is to supplement the deterioration of the function of the facility and to retain the original function. Main contents are described below.

1) Daily inspection

Daily inspection is based on the daily or weekly inspection of the equipment and includes activities of investigation, confirmation and recording of operating conditions of the equipment. At the time of inspection, it should be clearly recorded whether there is no change in data compared to the previous inspection and whether the value matches with the standard value using the check sheet. During the inspection the facilities are checked, data is measured and recorded and remarks are made in the check sheet. An example checklist is shown below for inspection of every facility.

- Main inspection contents: abnormal visual appearance, abnormal noise or offensive smell, reading of each instrument, etc.

Table 8-5 Daily Inspection Checklist (Example)

	Inspection Location	Inspection contents	Frequency (time/day)
Intake facilities	Water intake gate	The deposition of solid wastes and contaminants, etc. near intake gate	1～3
		Abnormality in the raw water quality of the river and in the gate Abnormal turbidity and chromaticity, oil contents, dead fishes	1～3
	Settling basin pump well	Abnormality in the raw water quality Abnormal turbidity and chromaticity, oil content, dead fishes	1～3
	Intake pump	Record of water flow rate, suction and discharge pressure, electric current value	1～3
		Abnormality in terms of noise, smell, vibration and temperature	1～3
Purification facilities	Receiving well	Abnormality in the raw water quality Abnormality in turbidity and chromaticity or presence of oil surface or carcasses of fish	1～3
	Mixing basin	Uniform spread of injected chemicals	1～3
		Abnormal sound, nasty smell, vibration, etc., in case of flashing mixer	1
	Flocculation	Floc formation	1～3
		Suspended solids and scum	1～3
	Sedimentation Basin	Floc settling	1～3
		Suspended solids and scum	1～3
	Filtration Basin	Suspended solids	1～3
		Condition of filter bed surface	1
		Abnormality in terms of turbidity and smell	1～3
	Clear water reservoir	Abnormality in terms of turbidity and smell	1
		Record of water level meter reading	1
		Presence of Insect	1
	Pump facility	Record of the current, suction and discharge pressure	1
		Abnormal sound, smell, extreme vibration	1
	Electrical facility	Record of the indicated value of each instrumentation indicator	1
		Abnormality in appearance	1
	Water quality Instrument	Dirt of degassing vessel and measuring tank	1
		Record of each measurement value	1
Others	Distribution Pump facility	Record of the current, suction and discharge pressure and pumping flow	1
		Abnormal sound, smell, extreme vibration	1
	PAC injection facility	Abnormal sound, nasty smell, leakage	1
		Record of injection flow rate and other data (opening and rotation speed, etc.)	1
		Record of storage amount	1
		Leakage from reservoir and piping, etc.	1
	Hypochlorous Acid injection facility	Abnormal sound, nasty smell, leakage	1
		Record of injection flow rate and other (opening and rotation speed, etc.)	1
		Record of storage amount	1
		Leakage from reservoir and piping, etc.	1
	Substation Equipment	Record of each measurement value	1
		Abnormality in appearance	1
		Others, abnormality or alarm	1

Source: Fukuoka City

2) Regular inspection

In general, regular inspection is carried out visually and focusses on the identification of any accidental damage and checking of maintenance status of the facilities. Main contents of this type of inspection are: refueling and cleaning of lubricant, damage in case of packing, checking operation and damage of the switch, adjustment of zero point and range, adjustment of input and output values, checking stock of consumables and spares, etc.

- Main Contents
  a) Machines: Refueling and cleaning of lubricant, adjustment of ground section, etc.
  b) Measuring equipment, etc.: Adjustment of input and output value by actual measurement, adjustment of span and zero, etc.

Table 8-6 Regular Inspection Checklist (Example)

	Inspection Location	Inspection contents	Frequency (time/Mon)
Intake facilities	Water intake gate	Check and clean situation of deposition	1
		Opening and closing operation check	1
	Pre-Settling pond	Record of the deposit amount	1
		Check clogging of the screen	1
	Intake pump	Check if adjustment of ground portion packing normal or not	1
		Inspection and refilling of lubricating oil	1
Purification facilities	Mixing basin	Inspection and refilling of lubricating oil	1
	Flocculation	Inflow into each floc formation tank or equivalent	1
		Removal of scum and other substance	1
		Check if deposited sediment amount normal or not	1
	Sedimentation Basin	Check clogging in sedimentation facilities	1
		Check for algae growth	1
		Record amount of deposition of sediment	1
	Filtration Basin	Abnormality such as formation of mud ball after washing	1
		Appropriate amount of wash water	1
		Confirmation of drainage water quality after washing	1
	Pump facility	Adjustment such as ground portion packing	1
		Inspection and refilling of lubricating oil, condition of the V-belt, etc.	1
	Electrical facility	Checking dust on the panel	1
	Water quality Instrument	Cleaning such as degassing vessel and measuring tank	1
		Implementation of the span adjustment by actual measurement	1
Others	Pump facility	Adjustment such as ground portion packing	1
		Inspection and refilling of lubricating oil	1
	PAC injection Facility	Formation of scale in the injection pipe and location	1
		Abnormality in the injection volume and the adjustment width	1
	Hypochlorous Acid injection facility	Formation of scale in the injection pipe and location	1
		Abnormality in the injection volume and the adjustment width	1
	Substation equipment	Check of dust on the panel	1
		Others, abnormal or alarm	1

Source: Fukuoka City

3) Consignment inspection

Normally, for the measuring equipment, the inspection is carried out through analysis and operation test. In case if any special equipment indicates error in its original function during ordinary and periodic inspection, precise inspection and maintenance should be carried out by skilled person with required expertise and knowledge. In particular, for large pumps and special equipment, the inspection should be carried out by the manufacturer or its agents because it requires specific expertise and knowledge to inspect.

Table 8-7 Consignment Inspection Item Description Example (Pump Facility)

	Inspection Location	Inspection contents	Frequency (time / year)
Ground pump	Ground portion	Check of the ground portion packing	1
		Other necessary inspection, test and record	1
	Lubricant	Condition of the lubricating oil	1
		Other necessary inspection	1
	Coupling	Condition of the shaft coupling	1
		Confirmation of centering	1
		Other necessary inspection	1
	Bolts, nuts	Tightening	1
		Other necessary inspection	1
	Meters and gauges	Condition of the pressure gauge	1
		Condition of the pressure switch	1
		Other necessary inspection	1
	Bearing temperature	Check of temperature	1
		Other necessary inspection	1
	Operation condition	Abnormality in terms of vibration, abnormal noise at the time of start and stop	1
		Normality of pressure for fully closed discharge valve	1
		Other necessary inspection	1
	Electric motor	Insulation resistance measurement	1
		Other necessary inspection	1
Pump control panel	Overall	Dirt in the inner surface	1
		Checking damage of board wiring and lose terminal	1
		Other necessary inspection	1
	Meters and gauges	Confirmation of the indicated value	1
		Other necessary inspection	1
	Electromagnetic conductor Auxiliary relays	Damage of electrical contact	1
		Other necessary inspection	1
	Protective relay timer	Movement examination	1
		Confirmation of setting value	1
		Other necessary inspection	1
	Measurement	Primary power supply voltage measurement	1
		Voltage measurement of control circuit	1
		Insulation resistance measurement	1
		Voltage and current measurement during pump operation	1
		Ground resistance measurement	1
		Other necessary inspection	1
	Linked examination	Operation in case of various type of control mode	1
		Other necessary inspection	1
er devic	Surface	Abnormality in vibration, abnormal noise, nasty smell and abnormal vibration	1

	Inspection Location	Inspection contents	Frequency (time / year)
		Operating condition of cooling fan	1
		Other necessary inspection	1
	Measurement	Main circuit voltage measurement	1
		Insulation resistance measurement	1
		Other necessary inspection	1

Source: Fukuoka City

Table 8-8 Consignment Inspection Item Description Example (Chlorine Injection Facility)

	Inspection points	Inspection contents	Frequency (time / year)
Control panel	Linked examination	Normally operating float switch and output signals from the devices	1
		Verification and adjustment of the operation range by proportional setter	1
		Other necessary inspection, examination, record	1
	Control panel	Damage and cracks in each part	1
		Damage of panel and wiring	1
		Other necessary inspection	1
Injection facility	Control unit	Normal operation of float switch and output signal from chlorine injection control panel	1
		Normal operation for various control mode in case of both manual or automatic	1
		Damage of panel and wiring	1
		Other necessary inspection	1
	Pump body	Damage, cracking and deformation in each part	1
		Leakage liquid	1
		Dirt in strainer and clogging	1
		Insulation resistance, current and voltage	1
		Discharge rate and discharge pressure	1
		Other necessary inspection	1
	Others	Leakage in siphon valve, damage, etc.	1
		Inspection of pipeline	1

Source: Fukuoka City

Table 8-9 Consignment Inspection Item Description Example (Electrical Instrumentation Facility)

	Inspection points	Inspection contents	Frequency (time / year)
Common facility	Inspection before maintenance, testing and data collection	Input and output Examination	1
		Record of setting Value	1
	Appearance inspection	Visual inspection and cleaning	1
		Inspection of installation condition	1
		Inspection of connecting parts	1
		Damage and corrosion	1
	Internal inspection	Visual inspection and cleaning	1
		Lubrication	1
		Inspection of mechanical parts (sliding part, link, rotation unit, etc.)	1
		Inspection of electrical parts (cable, connector, board, etc.)	1

	Inspection points	Inspection contents	Frequency (time / year)
		Insulation resistance measurement	1
		Damage and corrosion	1
		Other necessary inspection	1
	Preventive maintenance	Check and maintenance of deterioration, wear parts, consumable parts, etc.	1
Transmitter	Ultrasonic flowmeter	Input and output Examination	1
		Inspection of transmission and reception	1
		Inspection of power parts	1
		Insulation resistance measurement of coaxial cable	1
		Other necessary inspection	1
	Float-type water gauge	Input and output Examination	1
		Inspection and cleaning of wire float part	1
		Lubrication and cleaning of bearing and gear	1
		Other necessary inspection	1
	Immersion-type level gauge	Input and output Examination	1
		Transmitter input and output test	1
		Other necessary inspection	1
	Other transmitter	Input and output Examination	1
		Other necessary inspection	1
Computing unit	Acceleration calculator	Input and output Examination	1
		Calculation function inspection	1
		Power supply unit inspection	1
Setter	Alarm unit	Input and output Examination	1
		Setting function inspection	1
		Inspection of power parts	1
Recorder	Automatic equilibrium shape	Input and output Examination	1
		Alarm function inspection	1
		Motor part inspection	1
		Link and slide part inspection	1
		Inspection of power parts	1
		Other necessary inspection	1
Water quality instrument	Residual chlorine analyzer	Input and output Examination	1
		Cleaning of electrode	1
		Performance test and calibration	1
		Other necessary inspection	1
Controller	Sequencer	Confirmation of power and voltage	1
		Confirmation of memory backup battery	1
		Cooling fan cleaning	1
		Confirmation of operation indicator	1
		Other necessary inspection	1
Uninterruptible power system	Inverter	Confirmation of operating condition	1
		Insulation resistance measurement	1
		Calibration of indicating instrument	1
		Output voltage waveform measurement	1
		Alarm operation test	1
		Switching test	1
		Other necessary inspection	1
	Rectifier	Confirmation of operating condition	1
		Insulation resistance measurement	1
		Calibration of indicating instrument	1
		Output voltage waveform measurement	1
		Operation test	1
		Other necessary inspection	1

	Inspection points	Inspection contents	Frequency (time / year)
	Storage battery	Storage battery cleaning	1
		Inspection of catalyst stopper and liquid amount	1
		Battery voltage and electrolyte specific gravity measurement	1
		Other necessary inspection	1

Source: Fukuoka City

4) Routine repair

Routine maintenance should be carried out to prevent aging of the equipment and continue normal functioning even after passage of time. Once a few years (which should be about half of the service life), overhaul of the equipment should be carried out.

In order to take the expertise for the relevant equipment, it is appropriate to procure special part also from the manufacturer.

8.2.2 Priority Parameter of EDWS Laboratory for Water Quality Management

In Yangon, surface water has high turbidity and ground water has problem due to presence of Fe and salinity. To check the quality of distributed water, YCDC usually refers to the Myanmar National Drinking Water Quality (MNDWQ) Standard and WHO drinking water quality guidelines (4th). Priority parameters of present EDWS laboratory are given in Table below. Residual chlorine and alkalinity which are not included in the parameters currently should also be tested and monitored in order to check the operation conditions of WTP.

Table 8-10 Priority Parameters of EDWS Laboratory

Priority parameters	Current Standard value	Standard Value for Additional Parameters
pH	6.5 – 8.5	
Taste	Acceptable	
Odor	Acceptable	
Color	< 15 TCU	
Turbidity	< 5 NTU	
Total coliform	0 CFU/100ml	
Fecal coliform	0 CFU/100ml	
Residual chlorine	N/A	> 0.1 mg/l
Salinity	0 - 0.5 ppt	
Alkalinity	N/A	> 20 mg/l
Total Hardness	< 500 mg/l as $CaCO_3$	
TDS	< 1,000 mg/l	
Arsenic	< 0.001 mg/l	
Chloride	< 250 mg/l	
Iron	< 0.3 mg/l	
Lead	< 0.01 mg/l	
Nitrate	< 50 mg/l	
Manganese	< 0.4 mg/l	
Sulphate	< 250 mg/l	

Source: EDWS Laboratory and Additional parameters are added by JICA Study Team

8.2.3 Operation and Maintenance Plan for Pipelines

(1) Organization structure

Transmission pipeline will be maintained by existing transmission pipeline maintenance section, distribution pipeline by NRW control section which is to be established in cooperation with JICA technical assistance program and water supply equipment by township offices (see the Figure 8-3).

(2) Transmission pipeline

- Route Map of transmission pipeline should be prepared and updated.
- Transmission pipeline should be patrolled regularly in order to find any abnormality.

(3) Distribution pipeline

- To control leakage, it is important to control water pressure in distribution networks and to replace distribution pipes wherever required.
- Distribution pipeline maps should be updated regularly.
- Data on leakage repair and leakage history maps should be collected and managed properly for taking decision on effective pipe replacement in future.
- Water pressure and flow rate within DMA should be monitored by SCADA system.
- Leak detection should be implemented effectively by using information on water pressure and flow rate by SCADA system and data on water consumption from e-governance system.
- Valves should be inspected and maintained regularly in order to implement leak detection systematically.

(4) Water supply equipment

- Water supply equipment is installed based on the plumbing models in order to identify leakages easily in future.
- Meter readers should also collect information on meter condition, leakage and illegal connections at the time of meter reading.
- Leak detection should be implemented effectively by using leakage record maps and so on.

8.2.4 Improvement in Meter Reading, Billing and Collecting Water Charges

- New customers should be registered not in the township offices but in the head office in order to manage the database uniformly.
- Individual water consumption should be compared with usual one (of previous month) in case of each customer every month at the time of meter reading in order to find leakage and illegal connection effectively.
- Meter reading terminals should be utilized and direct debit from bank account should be introduced for payment of bills in order to reduce human errors in future.
- The e-governance system should be utilized for improving procedure of application for new connection, water charge collection and making decision on water suspension due to nonpayment.

8.2.5 Proper Maintenance Measures of Installed Equipment in Myanmar

(1) Asset management

- It is necessary to develop and replace facilities systematically and to secure funding to realize sustainable water utility management by drawing up the middle-long term facility development and replacement plans and to secure fiscal balance.
- It is necessary to consider equalizing annual budget with prolonging the lives of equipment and facilities by proper maintenance in the case of drawing up these plans.
- The asset management method is very useful for YCDC. The asset management on water supply management is a method for managing facilities effectively in terms of the life-cycle-cost on the middle-long term vision to realize projects developed in the Master Plan.
- As for the implementation of the asset management method, it is necessary to inspect and evaluate conditions and soundness of existing assets based on the technical knowledge, to estimate the middle-long term replacement quantity, and to consider securing the fund for replacement based on the fiscal balance, and to guarantee the feasibility of projects.

(2) Maintenance

- O&M manuals are provided and demonstrated by suppliers based on the provided manual at the time of delivery.
- It is difficult to inspect equipment that requires supplier's own techniques such as monitoring system and measurement equipment by third party, so contracts for maintenance should be made with suppliers in order to use such equipment properly for a long time.
- Existing facilities and equipment should also be maintained properly in order to prolong their life.

(3) Cost reduction

- Delivery countries of equipment should be selected such that that the transportation cost of repair parts is minimized.
- Spare, repair and accessory parts of equipment should be procured at the time of installation.

(4) Life of facility and equipment

- The life of all facilities and equipment should be prolonged through proper maintenance. For reference, the statutory durable years and target life duration of mechanical and electrical equipment in water utility in case of Japan is given below.

Table 8-11 Statutory Durable Years and Target Life for Mechanical Equipment

Name	Statutory durable years	Target life
Pump	15	30
Submersible pump	15	25
Automatic dust collector	17	25
Rapid mixing pump	15	30
Flocculator	17	30
Sludge scraper	17	30
Activated carbon injection equipment	15	20-25

Name	Statutory durable years	Target life
Coagulant injection equipment	15	20
Caustic soda injection	15	20-25
Sulfuric acid injection equipment	15	25
Sodium hypochlorite injection equipment	10	20
Desludging equipment	17	25

Source: Fukuoka City

Table 8-12 Statutory Durable Years and Target Life for Electrical Equipment

Name	Statutory durable years	Target life
Power receiving and transforming facility	20	23
DC power supply device	20	23
Power generation	15	25-27
Building and electrical equipment	20	23
Closed circuit television equipment	9	23
Central monitoring control facility	10	23
Multiplex radio equipment	9	20
Remote monitoring	9	15
Water quality measuring instrument	10	15

Source: Fukuoka City

8.2.6 Public Relations and Awareness

It is important to have a good relationship with customers, so activities related to enhancing public relations and awareness should be implemented. For reference, some of such activities are introduced below.

Homepage

Public relations paper

Visiting lecture in schools

Lecture for students during WTP visit

Source: Fukuoka City

8.3 Staffing and Capacity Development Plan

8.3.1 Organization Structure

(1) Kokkowa WTP

Refer to Section 8.2.1.(1)

(2) Pipelines

Refer to Section 8.2.3.(1)

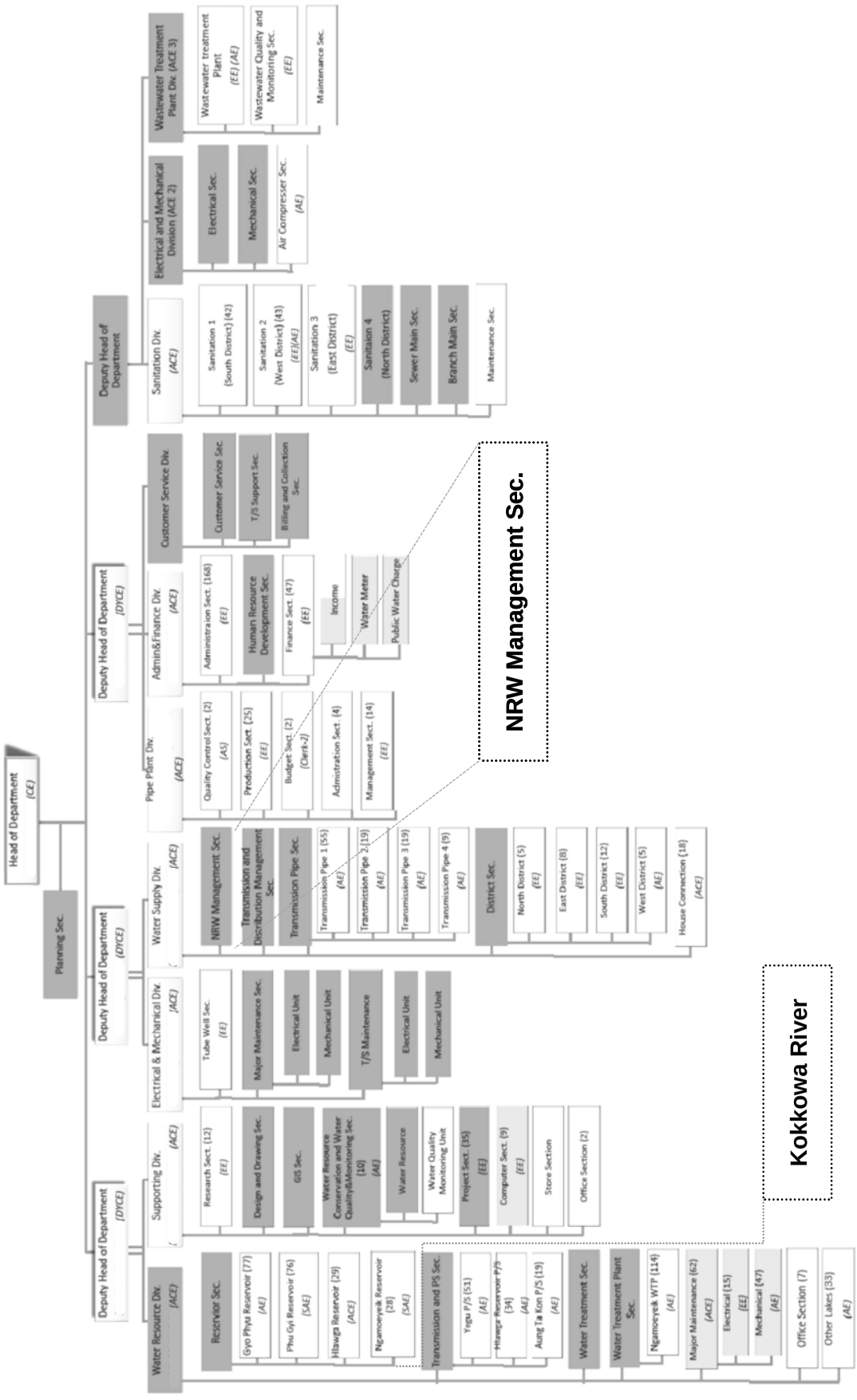


Figure 8-3 New Organization Chart of EDWS (Tentative)

8.3.2 Operation and Maintenance Cost

Refer to Section 9.5.

8.3.3 Capacity Development Plan

(1) Kokkowa WTP

For reference, the capacity development program in case of a WTP in Fukuoka in Japan is introduced below.

Table 8-13 Capacity Development Program in WTPs

Type	Contents
Lecture	General ・ Organization and duties of each section ・ Water purification and desludging processes ・ Facilities and equipment ・ Repair and construction plan for facilities and equipment in the fiscal year ・ Outsourcing contents
	Emergency response ・ Electricity suspension ・ Chemical leakage ・ Oils, ammonium and others
Practical training of O&M	General ・ Daily report ・ Daily inspection report
	Central monitoring system ・ Monitoring ・ Operation ・ Security system
	Sedimentation basin ・ Desludging ・ Cleaning of walls and plate settler in sedimentation basin ・ Measurement of sediment sludge
	Filtration basin ・ Surface and back washing
	Daily inspection ・ Electrical room ・ Water quality instrument room ・ Inspection gallery of sedimentation and filtration basin
	Chemical injection ・ Coagulant, sodium hypochlorite and caustic soda ・ Receipt/Stock of chemicals
	Water quality management ・ Outline of water quality test in the WTP ・ Water sampling ・ Daily water quality test ・ Jar test
Site visit	Facilities outside of the WTP ・ Reservoir, gaging basin and air pumping cylinder ・ Routes of conveyance and transmission ・ Distribution reservoir ・ Sludge disposal site

Source: Fukuoka City

(2) Pipelines

The capacity development program related to distribution management in Fukuoka in Japan is introduced below for reference.

Table 8-14 Capacity Development Program on Distribution Management

Type	Contents
Lecture & Practical training	General ・ Guidelines related to design of distribution pipe network ・ Guidelines on construction supervision
	Distribution pipes ・ Connection types ・ Flange types ・ Practical training on connection and disconnection
	Valves and fittings ・ Valves; line valves, air valves, stop valves, air valve and fire hydrants ・ Fittings types
	Water supply equipment ・ Plumbing; polyethylene, PVC and galvanized iron pipes ・ Ferrule with saddle
	Leakage ・ Method of leak detection ・ Leak detection equipment; acoustic bar, leak detector, leak sound correlator, and correlation method with multiple loggers ・ Methods of repairing leakages; wooden plug, stoppage service saddle and three pieces repair clamp ・ Examples of leakage accidents ・ Emergency response; water truck, emergency water taps and plastic water bags
	Water distribution control ・ Planning of water supply suspension

Source: Fukuoka City

8.4 Key Technical Fields of Capacity Development

Technical fields that are required to be focused during capacity development programs are as follows. For capacity strengthening of YCDC, the JICA technical assistance projects for other facilities (excluding operation of WTP) are being carried out in parallel from 2015.

(1) Water treatment plant

- Inspection and repair skills
- Management of water quality and flow rate
- Operation record, document management and equipment ledger
- Quality control of delivered products during procurement (equipment, materials, etc.)

(2) Distribution management

- Standardization of specification, regulation and working procedures
- Design of distribution pipeline network
- Construction supervision

- Leak detection and repair
- Old and damaged pipes replacement
- Patrol of main pipelines

(3) Water supply equipment

- Standardization of specifications, regulations and working procedures
- Calculation of proper meter size
- Construction supervision

(4) Customer management

- New customer registration
- Water charge collection

8.5 Technical Assistance Fields by JICA Technical Assistance Project and by This Project

8.5.1 JICA Technical Assistance Project

JICA technical assistance project is on-going since 2015, and the activities are mainly undertaken in the following fields.

- Improvement of water utility management: Establishment and reorganization of the Planning Division for strengthening of water supply management is planned.
- NRW reduction: Establishment of water leakage Control Division and implementation of pilot projects for the reduction of unaccounted water is to be carried out.
- Water quality management: Human resource development and capacity building related to water quality management in Yangon is to be carried out.

8.5.2 Proposal of New Technical Assistance Program for This Project and Cooperation with Japanese Local Governments

(1) Capacity development related to design and construction supervision of water distribution network of Zone 9

The design and construction of water distribution mains, distribution pipes and establishment of DMAs of Zone 9 are planned to be carried out by YCDC on its own. EDWS has no experience in design and construction of water distribution system applying establishment of DMA and SCADA, although it has experience of design and construction of distribution network. In order to carry out the works smoothly and to ensure the quality of works to the same level as in case of Zone 1, supporting activities will be provided through capacity development on design and construction supervision of distribution facilities of Zone 9.

For this purpose the following activities are expected to be carried out. Duration of activities will be

27 months, and will require about 30 MM of International experts input, 30 MM of local experts input. The components will include capacity development support in:

- Survey of water pipe routes and creation of GIS data of Zone 9,
- Basic planning and assistance of detailed design of distribution network and SCADA of Zone 9,
- Preparation of specification of SCADA equipment, and assistance in evaluation and procurement of Contractor,
- Assistance in construction supervision of distribution network and SCADA of Zone 9 (during 1 year).

(2) Capacity development related to operation and maintenance of 60 MGD facilities

A technical assistance program is proposed for 60 MGD facilities in which information on operation and maintenance will be shared by a local government or a maintenance company in Japan online and the organization will transfer skills of O&M to YCDC by analyzing the information and by preparing manuals of O&M for achieving proper O&M of new facilities by YCDC.

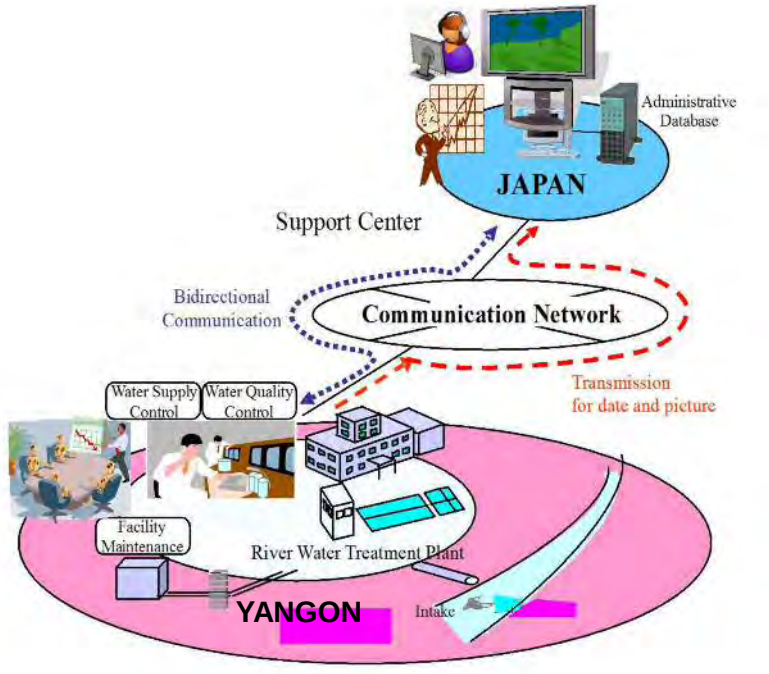
By using an on-line remote monitoring system, operation data on monitor screen and the situation of the central supervision room of WTP and/or PS can be obtained simultaneously, and the actual situation of operation can be understood by experts in Japan. Moreover, through use of such real time communication system, experts in Japan can discuss with relevant staff-members of YCDC in case of occurrence of specific problem in operation and management of WTP and technical assistance of Japan shall be provided effectively.

In addition, the organization should make a relationship of trust with YCDC because the information; status of purification process, water amount, water quality and daily inspection records, etc., have to be managed strictly. Security measures shall be implemented by installing authentication ID and access limits. The contents and schedule of technical assistance program are planned as follows.

Table 8-15 Proposal of New Technical Assistance Program

Program title	Capacity development program on O&M of new facilities constructed under ODA loan
Goal	YCDC can properly operate and maintain new facilities by itself.
Overview	Sharing information with an organization in Japan and transferring skills of O&M to YCDC
Shared information	Status of purification process, water amount, water quality and daily inspection records in the new facilities constructed under ODA loan
Shared organization	A Japanese local government and/or maintenance company which has a relationship of trust
Language	Burmese, Japanese and English
Schedule	
(First year)	Dispatching engineers to YCDC ・ To review O&M manuals prepared by loan consultant ・ To install data communication devices in the organization in Japan to receive information from YCDC's equipment
(Next 2 years)	Providing technical advices and Monitoring remotely from Japan ・ To transfer skills of O&M to YCDC regularly a few times a year ・ To revise the manuals of O&M
Remarks	Implementing security measures by installing authentication ID and access limits

Source: JICA Study Tem



Source: JICA Study Tem

Figure 8-4 Schematic Illustration of Support System by Remote Surveillance System

CHAPTER 9 COST ESTIMATION AND IMPLEMENTATION SCHEME OF THE PROJECT

Execution Scheme, Overall Project Cost, Preparation of Implementation Schedule, Financing Plan, Estimated Operation and Maintenance Cost, and Organizational Structure for Implementing the Project are described in this chapter.

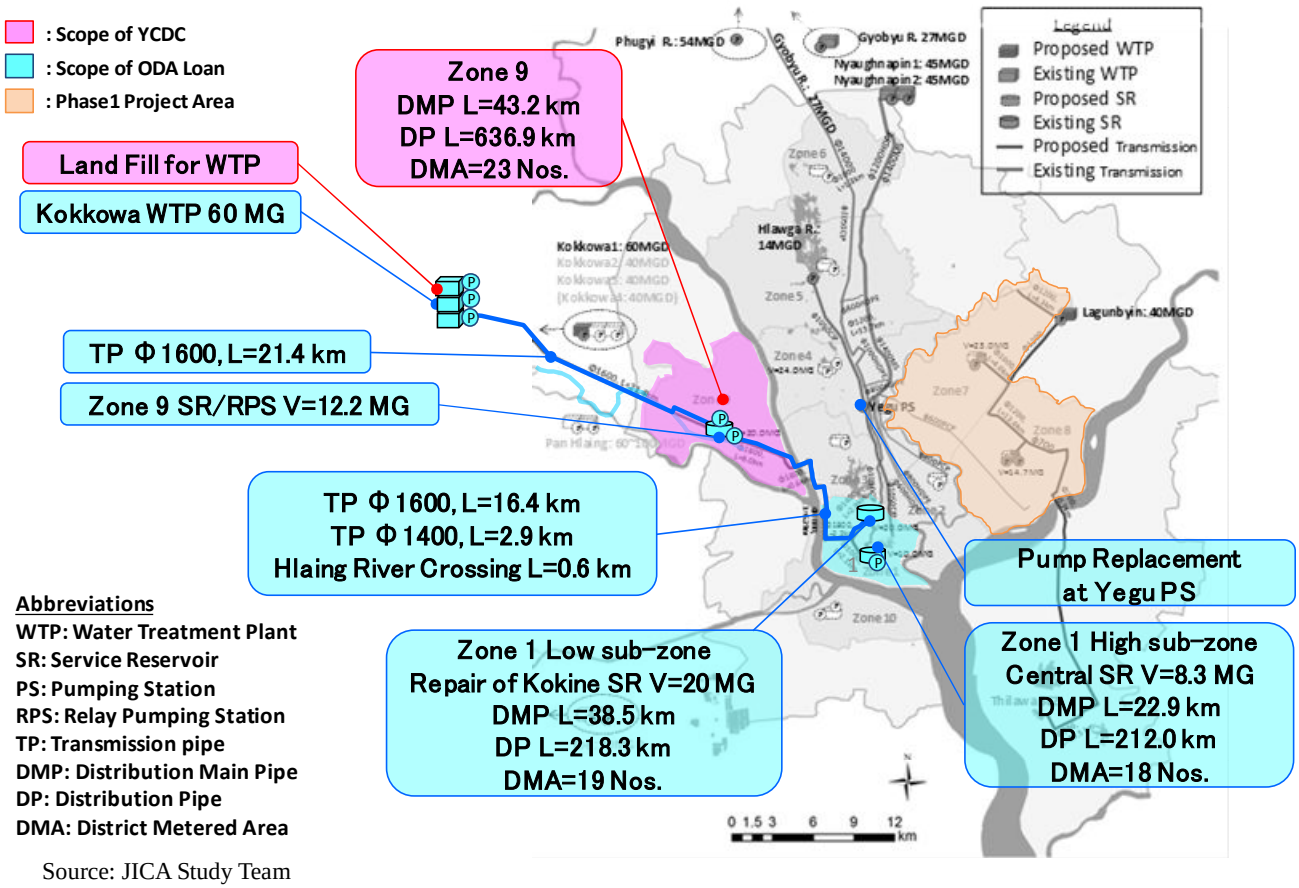
9.1 Execution Scheme

Execution scheme of project is formulated considering the situation of the present construction practices, market, and based on interviews of local constructors/ Japanese company undertaking business in Myanmar.

9.1.1 Scope of Works of Phase 2 Project

(1) Outline of the Scope of Project

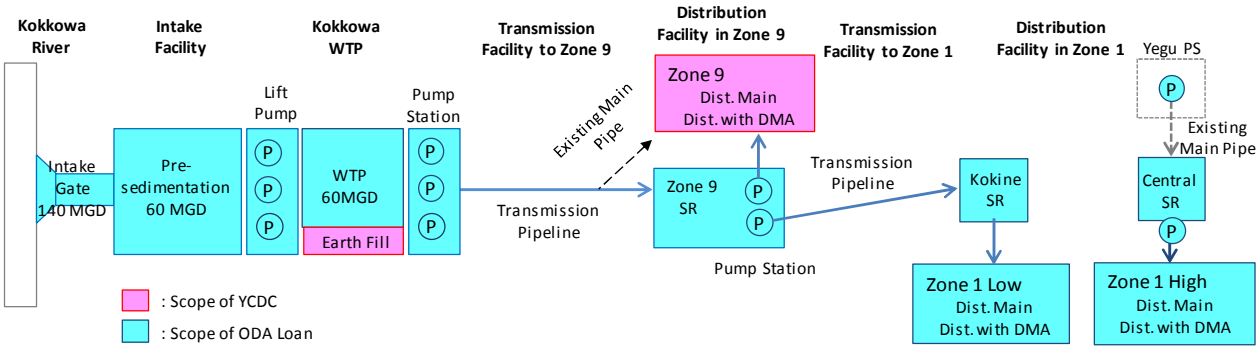
The outline of the scope of works of Phase 2project is summarized as below.



Source: JICA Study Team

Figure 9-1 The Scope of Works of Phase 2 Project

(2) Allocation of The Scope of Works of Phase 2 Project



Source: JICA Study Team

Figure 9-2 Schematic Diagram of The Scope of Works of Phase 2 Project

Table 9-1 Allocation of The Scope of Works of Phase 2 Project

ODA loan's Component	YCDC's Component
・Leading canal and Intake gate (140 MGD) ・Pre-sedimentation Pond (60 MGD)	・Earth fill for WTP site (60 MGD)
・Kokkowa WTP (60 MGD)	
・Transmission Pipe (41.3 km including 0.6 km river crossing ・Zone 9 SR (12.2 MG) ・Relay Pump Station (Transmission pump for Zone 1 and Distribution pump for Zone 9) ・Pump replacement at Yegu PS	
For Low subzone in Zone 1 ・Reservoir: Repair of existing Kokine SR (20 MG) ・Distribution Main Pipe (38.5 km) ・Distribution Pipe (218.3 km) with DMA (19 Nos.)	For Zone 9 ・Distribution Main Pipe (43.2 km) ・Distribution Pipe (636.9 km) with DMA (23 Nos.)
For High subzone in Zone 1 ・Re-construction of Central SR (8.3 MG) with Pumps ・Distribution Main Pipe (22.9 km) ・Distribution Pipe (212.0 km) with DMA (18 Nos.)	
Vehicle procurement (8 single four-wheel drive vehicles)	

Source: JICA Study Team

(3) Detailed Project Scope of Works of Phase 2 Project

The detailed project scope of works to be considered under Phase 2 project is given in the Table below.

Table 9-2 Detailed Project Scope of Works of Phase 2 Project

			Facility Name	Quantity	Capacity	Type Remarks
Eligible						
Scope1: Construction of Kokkowa WTP						
	A	1	Leading Canal with River Bank Protection, Intake Facilities	1 Unit	140 MGD	W 1500 mm x H 1500 mm of Square Gate with screen x 6 nos.
			Pre-Sedimentation pond	1 Unit	60 MGD	Surface Area: 100,000 m^2 Storage volume =812,000 m^3
		2a	Lift Pump House (Civil	1 Unit	60 MGD	Auto Screen x 2 nos.

			Facility Name	Quantity	Capacity	Type Remarks
			work)			
		2b	Lift Pump House (Mechanical and Electrical)	Pump Unit: 5 nos. (3 operation + 2 stand-by)	20 MGD x H 18m x Approx. 300 kW	Double suction volute pump by VFD control
		3	Receiving Well	1 Unit (3 Basins)	60 MGD	
		4	Rapid Mixing Basin	1 Unit (3 Basins)	60 MGD	Flash mixer, Overflow weir
			Flocculation Basin	1 Unit (3 Basins)	60 MGD	Horizontal and vertical zigzag flow
			Sedimentation Basin	1 Unit (6 Basins)	60 MGD	Upflow type with tube settler and Mechanical sludge collector
		5	Rapid Sand Filter	1 Unit (24 Filters)	60 MGD	Self-backwashing type
		6	Clear Water Tank	1 Unit (3 Lots)	V=4125 m^3 x3 Lots	
		7	Chemical Dosing Facilities	1 Unit (3 Lots)	60 MGD	Liquid ACH, Liquid Hypochlorite
		8a	Transmission Pump Station (Civil work)	1 Unit	60 MGD	
		8b	Transmission Pump (Mechanical and Electrical)	Pump Unit: 4 nos. (3 operation + 1 stand-by)	20 MGD x H 38m x Approx. 720kW	Double suction volute pump with Flywheel by ON-OFF control
		9	Wash Water Drainage Basin	1 Unit (3 Basins)	60 MGD	Discharge Pump x 9 nos.
		10	Sludge Basin	1 Unit (3 Basins)	60 MGD	Sludge Withdrawal Pump x 6 nos.
		11	Thickener	1 Unit (3 Basins)	60 MGD	
		12	Drying Bed	1 Unit (9 Basins)	60 MGD	
		13	Administration Facility, Laboratory, Accomodation Building for WTP staff, etc	1 Unit	60 MGD	Central Administration Building, Laboratory, SCADA Room, Warehouse, Road, Lighting, Drainage, Fence, Landscaping etc.
		14	Sub Power Station Facilities, Generator System	1 Unit	60 MGD	Diesel engine generator 6MVA, built-in radiator
		15	SCADA System of WTP	1 Unit	60 MGD	
Scope 2: Construction of Transmission Facilities from Kokkowa WTP to Zone 9 SR/RPS						
	B	1a	Transmission Pipe	Length: 21.4 km	Diameter: 1600 mm	Pipe Material: DCIP and/or MS
	C	a	Zone9 SR including Relay Tank (Civil work) including Administration Facility (Civil work)	1 Unit	12.2 MGD	
		b	Relay Pumps Station at Zone9 SR/RPS (Mechanical and Electrical) for Zone1	Pump Unit: 4 nos. (3 operation + 1 stand-by)	16.3 MGD x H 87 m x Approx. 1250 kW	Double suction volute pump with Flywheel by VFD control
			Sub Power Station Facilities, Generator System	1 Unit		Diesel engine generator 9 MVA, built-in radiator
			SCADA System of Transmission Flow	1 Unit		
	Z	1	Distribution Pumps Station for Zone 9 (Mechanical and Electrical)	Pump Unit: 2 nos. (1 operation + 1 stand-by)	Capacity: 76 m^3/ min x H 40 m x Approx. 720 kW	Double suction volute pump with Flywheel by VFD control
				Pump Unit: 2 nos.	Capacity: 32 m^3/	Double suction volute pump

			Facility Name	Quantity	Capacity	Type Remarks
				(1 operation + 1 stand-by)	min x H 40 m x Approx. 375 kW	with Flywheel by VFD control
Scope 3: Construction of Transmission Facilities from Zone 9 SR/RPS to Zone 1						
	B	1b	Transmission Pipe	Length: 16.4 km	Dia. 1600 mm	Pipe Material : DCIP and/or MS
				Length: 2.9 km	Dia. 1400 mm	Pipe Material : DCIP and/or MS
		2	Transmission Pipe Under Crossing Hlaing River by shield method	Length: 0.6 km	Shield Dia. 2400 mm Pipe Dia. 1600 mm	Pipe Material : DCIP and/or MS
		3	Tentative Connection pipe to Existing pipe by Non-stoppable Tapping method	4 locations	Dia. 1400 mm x 1000mm, Dia. 1050 mm x 1000mm, Dia. 750 mm x 700mm, and Dia. 700 mm Valve Insertion	
Scope 4: Modernization and Restructuring of Distribution Facilities of Zone 1 (Low subzone)						
	D	1	Repair of Kokine SR including Installation Infrow and Outflow Valves	1 Unit	20 MGD	
		2	Distribution Main Pipe (including Pipe Jacking method)	Length: 38.5 km	Dia. 300 ~2000 mm	Pipe Material: DCIP and/or MS Pipe jacking method (Railway crossing): 2 nos. ; Dia. 600 mm and Dia. 1200 mm
		3	Distribution Pipe with DMA	Length: 218.3 km	Dia. 100 ~250 mm	Pipe Material : HDPE and/or DCIP
			Service Connection Replacement	103,200 nos.		
			Customer Meter Replacement & Installation	103,200 nos.		
		4	SCADA System of DMA	19 nos.		
Scope 5: Modernization and Restructuring of Distribution Facilities of Zone 1 (High subzone)						
	D	5a	Reconstruction of Central SR (Civil work)	1 Unit	8.3 MGD	
		5b	Distribution Pumps for Zone 1 (High) (Mechanical and Electrical)	Pump Unit: 2 nos. (1 operation + 1 stand-by)	Capacity: 67 m^3/min x H 42 m x Approx. 660 kW	Type: Double suction volute pump with Flywheel by VFD control
				Pump Unit: 2 nos. (1 operation + 1 stand-by)	Capacity: 32 m^3/min x H 42 m x Approx. 375 kW	Type: Double suction volute pump with Flywheel by VFD control
		6	Power Line and Sub Power Station Facilities, Generator	1 Unit		Diesel engine generator 4MVA, built-in radiator
		7	Distribution Main Pipe	Length: 22.9 km	Dia. 200 ~1400 mm	Pipe Material : DCIP and/or MS
		8	Distribution Pipe with DMA	Length: 212.0 km	Dia. 100 ~250 mm	Pipe Material : HDPE and/or DCIP
			Service Connection Replacement	49,100 nos.		
			Customer Meter	49,100 nos.		

			Facility Name	Quantity	Capacity	Type Remarks
			Replacement & Installation			
		9	SCADA System of DMA	18 nos.		
		10	Replacement of Pump Equipment and Related Electrical Facilities at Yegu Pump Station	Pump Unit: 3 nos. (2 operation + 1 stand-by)	Capacity: 11 MGD x H 53 m x Approx. 450 kW	Type: Double suction volute pump by ON-OFF control
Scope 6: Procurement of vehicles						
			Purchasing 4WD Used Car for Consulting Service			
Non Eligible						
Scope 7: Landfill for WTP						
	Y	1	Landfill (Civil work) for WTP	Amount of earth fill soil: about 210,000 m^3		
Scope 8: Distribution Facilities of Zone 9						
	Z	2	Distribution Main Pipe	Length: 43.2 km	Dia. 300 ~2000 mm	Pipe Material : HDPE, DCIP and/or MS
		3	Distribution Pipe with DMA	Length: 636.9 km	Dia. 100 ~300 mm	Pipe Material : HDPE
		4	SCADA System of DMA	23 nos.		

Source: JICA Study Team

(4) Applications of Japanese Technology in Case of the WTP

Following facilities and equipment are considered for application of Japanese technology and for providing training during the technical trip to Japan in case of WTP.

Table 9-3 Applications of Japanese Technology to The WTP

Facility/ Equipment	Specifications
Mixing tank	Flush mixer
Sedimentation basin	Tube settler
Desludging equipment	Mechanical Sludge Collector
Back washing filtration basin	Self-washing type
Measure against water hammer	Pumps with flywheel
Monitoring and control system for WTP	SCADA system

Source: JICA Study Team

(5) Application of Japanese Technology to The Transmission and Distribution Facilities

Following materials and method are considered for application of Japanese technology and for providing training during the technical trip to Japan in case of transmission and distribution facilities.

Table 9-4 Applications of Japanese Technology to The Transmission and Distribution Facilities

Item/ Location	Specifications
Pumps with system for controlling flow	Rotation speed controlled pumps
Measure against water hammer	Pumps with flywheel
Monitoring and control facility in SR	Flow control valve
Monitoring and control system for PS	SCADA system
Transmission pipe	Steel Pipe/ Ductile Iron pipe

Item/ Location	Specifications
Connection to existing pipe (under pressure tapping method)	Non-stoppable tapping and/or insert valve
River crossing section	Trenchless construction; Shield Method
Railway crossing	Trenchless construction; Pipe Jacking
Monitoring and control system for DMAs	SCADA system

Source: JICA Study Team

9.1.2 Natural Conditions

Natural conditions have significant impact on construction period and cost. Therefore, understanding of natural conditions is important for planning of the execution scheme, and calculation of appropriate cost of construction. The natural conditions which should be taken into consideration are described below.

(1) Rainfall

Yangon belongs to Tropical monsoon climate, and is roughly divided into Summer season during March to mid-May, Rainy season during mid-May to October, and Dry season during October to February as described in "2.1.3 Meteorology".

Air temperature in summer season exceeds 35 degrees Celsius. However, particular measures against high air temperature may be unnecessary since construction works in the city are ordinary.

On the other hand, rainfall increases rapidly during rainy season (especially during July to August). Heavy rain occurs for long part of the day. During period of heavy rains, construction work needs attention, and working efficiency usually drops.

According to actual experiences during Japanese grant aid project (2014 - 2016), working days ratio is 60% (18 days/month) of annual average and on days of heavy rainfall during July – August working days ratio drops to 20% (6 days/month). Many excavation works will be carried out in this project. In consideration of safety measures, in conditions such as rising of groundwater level and collapsing of trench sides by heavy rainfall, large-scale works shall be avoided during rainy season.

(2) Geological Condition and Groundwater Level

Geological survey results of this study are shown in the Appendix-4.

a) Kokkowa WTP

At the site of Kokkowa WTP, geological formation includes weak silt/clay layers from ground surface to a depth of about GL-30-50m, and below that sand layer exists, which is the load-bearing layer. The average groundwater level is about GL-1 m and it is observed as stable in bore hole during surveyed period.

b) Zone 9 SR/Relay PS

Planned construction site of Zone 9 SR/RPS is located in the premises of YCDC garden. The present geological formation at this location comprises weak silt layer from surface to 4 m, and then sand layer continues to a depth of GL-20 m, which is the load-bearing layer. The average groundwater level is about GL-5 m and it is observed to rise in bore hole during surveyed period.

c) Zone 1 SRs

Planned construction sites of two SRs in Zone 1 are located in the YCDC's property. The present ground has sand layer from surface and it continues, the load-bearing layer starts at about GL-8 m as bearing layer. The average groundwater level is about GL-8 m.

d) Hlaing River Crossing

Planned construction sites of river crossing section are public road and MoAI's property along the riverside, respectively. The present geological formation consists of weak silt/clay layers from surface to about GL-25m, and then sand layer continues which is the load-bearing layer. The average groundwater level is about GL-3m and it is observed to rise in bore hole during surveyed period. Soil boring survey must be carried out on the river bed during detailed design stage.

e) Transmission and Distribution Pipe

Laying locations of transmission pipe from WTP is along drainage channel beside Route No. 5 towards the center of Yangon city. Moreover, most of the transmission and distribution pipes are proposed to be installed along city roads. The geological formation of these sites consists of clay layers.

(3) River Water Level

a) Kokkowa River for Intake and WTP construction

In order to install intake gates in the river, water level in river is expected to influence the construction work. Excavation works should be avoided during rainy season to avoid any negative impact of high water level on construction works.

b) Hlaing River Crossing

Departure/ Arrival shafts are to be installed near Hlaing River. Construction work should be avoided during rainy season to avoid any negative impact due to high water level.

9.1.3 Procurement of Construction Materials and Related Machines/Equipment

Materials required for construction that are procured in Yangon is basically conveyed to a temporary site by land transportation. Proposed locations of WTP/SRs in this project exist along main roads, and the access to these locations is good.

On the other hand, imported materials transported through ocean are unloaded at Yangon port, and conveyed from Yangon port to construction sites through land transportation. Heavy vehicles are restricted to pass through the city during daytime. To take care of this, heavy vehicles will require to be operated during nighttime.

(1) Construction Material

Main construction material is concrete, reinforcing bar, temporary material, etc. According to the interview of local contractors, most of the construction materials can be supplied without delay.

- Concrete: cement and aggregate can be readily procured in Yangon city. A ready-mixed concrete manufacturer which carries out adequate quality control exists in Yangon. The mentioned manufacturer has a supply capacity of 1,500 m^3/day.
- Reinforcing bar: BS standards made in China are available in the market.
- Temporary material: earth retaining material (such as steel sheet pile or bracing, etc.), shuttering material, scaffolding/ supporting material, heavy temporary material can be also procured in Yangon city.

(2) Pipe Material

Decision on using a steel pipe, a ductile iron pipe or a HDPE pipe is taken appropriately after taking into consideration pipe size, intended purpose and cost.

- Steel pipe and ductile iron pipe are not manufactured in Myanmar. Currently, most of steel and ductile iron pipes are imported from China. On the other hand, Japanese company has a steel fabrication factory in Yangon and has the possibility of steel pipe procurement in the future.
- The HDPE pipe is manufactured at the Yangon factory of Myanmar private companies, and its use is already being practiced in several projects of YCDC. Its quality is based on the ISO standard.
- In case of construction of pipeline crossing Hlaing River, the material should be water proof and leakage proof. Therefore, shield machine, segment of outer shell, materials and equipment, etc. should be imported from Japan.
- Jacking method is proposed to be applied for pipeline crossing railway and main road intersections in Yangon City. Based on the actual experiences of Japanese grant aid project, clay layer having sufficient cohesion exists predominantly on the surface in the city. Therefore, high strength shell is required for jacking method. All material should be imported from Japan.
- In addition, based on the experiences of Japanese grant aid project, material related to connection of new pipes with existing pipe through method of tapping pipe without suspension of water supply (Non-stoppable Tapping) should be also imported from Japan.

Table 9-5 Procurement of Pipe Material

Material	Suppliers	Notes
HDPE pipe	Yangon	- 150 mm
Ductile iron pipe	Japan or neighboring countries	200 – 1,600 mm
Steel pipe	Yangon, Japan or neighboring countries	1650 mm -
Shield tunneling method	Japan	River Crossing
Pipe jacking method	Japan	Railway crossing
Perforator	Japan	Non-stoppable Tapping

Source: JICA Study Team

(3) Mechanical and Electrical Equipment

Mechanical and electrical equipment is imported because of absence of related factory in Myanmar. These equipment are to be procured from Japan or neighboring countries. Reliable products are desirable in order to use equipment for a long duration. For this purpose, technical requirements for equipment are specified, and then, these equipment should be procured from reliable manufacturers who have experience of delivering good quality products for a long term.

Table 9-6 Procurement of Mechanical and Electrical Equipment

Equipment	Suppliers
Large size pump	Japan or neighboring countries
Chemical feed pump	ditto
Auto screen	ditto
Tube settler	ditto
Sludge collector	ditto
Perforated block type underdrain	ditto
Motor operated valve	ditto
Power receiving and transforming Equipment	ditto
Electrical distribution panel	ditto
VFD panel	ditto
Diesel power generation equipment	ditto
Instrumentation equipment (Flow meter, Water quality meter)	ditto
Monitor and control equipment (SCADA)	ditto

Source: JICA Study Team

(4) Construction Machine

WTP and SRs can be built by general machines that are used for construction of infrastructures. Presently, construction machines are widely used in construction works, such as hotel and housing complex in the Yangon city or in neighboring areas. Key machines and equipment used in construction works are listed below.

- Excavation and site preparation

  Backhoe, Shovel loader, Clamshell, Bulldozer,

  Dump truck, Vibration roller, Road roller, Grader

- Framework construction

  Crawler crane, Tower crane, Concrete pumping truck

- Piling work

Pile driver

- Earth retaining work

  Rough terrain crane, Truck with crane, Vibratory hammer

- Other construction machine

  Generator, Welding machine, Compressor, Submersible pump

(5) Local Workers and Constructors

In recent years, the construction market is very active in Myanmar. Movement and headhunt of capable workers and skillful technicians is on rise, and therefore rates are varying frequently.

Construction works of WTPs and SRs are not new to YCDC as they have experience of such works. However, since high water tightness is required in case of proposed facilities, experienced constructor should be selected.

EDWS has experience of only pipe installation works in Yangon City. However, in this project, sections of pipelines are also proposed to be installed through shield tunneling method and pipe jacking method. EDWS does not have any experience of these works, and there is also very few examples of similar work in Myanmar. Therefore, experienced constructor should be selected.

9.1.4 Outline of Execution Scheme

(1) WTP

The geological conditions mentioned above should be taken into consideration, and studies of construction method of landfill, land subsidence measures, foundation pile, the measures against groundwater level, etc., are required during the detailed design. Outline of execution scheme of this project is described below.

a) Access

The planned WTP site is near the Route No. 5, about 300 m north side of this road, which runs east-west in Zone 9, and access from Yangon city is also good. The access road from Route No. 5 to WTP has already been filled up by EDWS to level of +3.5 m as measures against inundation.

b) Earthwork

Backhoe, bulldozer and dump truck, etc., are used for excavation and backfilling.

c) Temporary works

Steel sheet pile method is adopted for stopping entry of water and earth-retaining when construction works is carried out near the river. On the other hand, main buildings will be built on the levelled

ground after landfill, and particular temporary works is unnecessary.

d) Earthwork and Landfill

The surroundings of planned WTP site are paddy field and damp area. The existing ground level of WTP was filled up to +3.5 m to avoid inundation by EDWS. YCDC will raise WTP site to +7.1 m level same as the existing embankment level as countermeasure against flood. The HHWL of Kokkowa River is about +6 m against planned ground level of WTP as +7.1 m.

Construction of landfill for WTP site is under YCDC's scope. The soil generated from excavation of pre-sedimentation pond can be used as landfill material for proposed WTP site. A large amount of unused soil should be used either for landfilling or should be disposed.

Amount of excavated soil of Pre-Sedimentation Pond: about 750,000 m^3

> Amount of earth fill soil: about 210,000 m^3

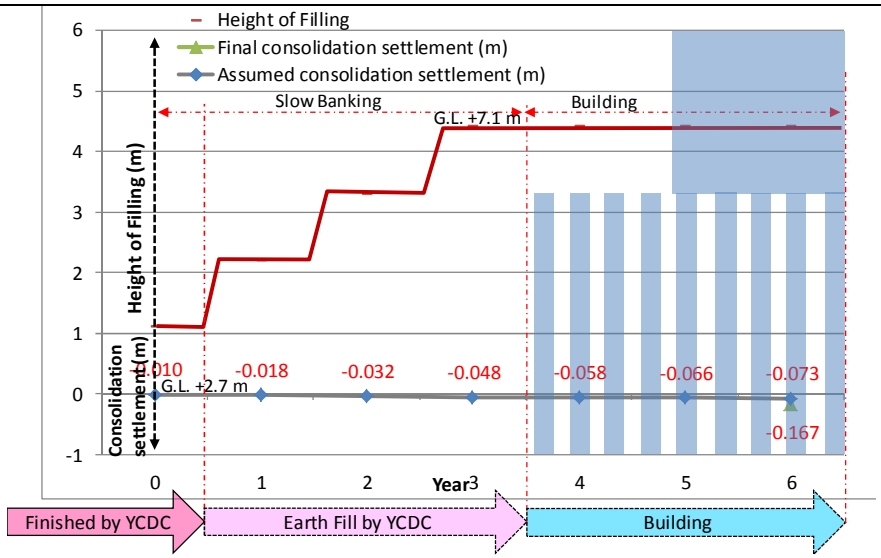
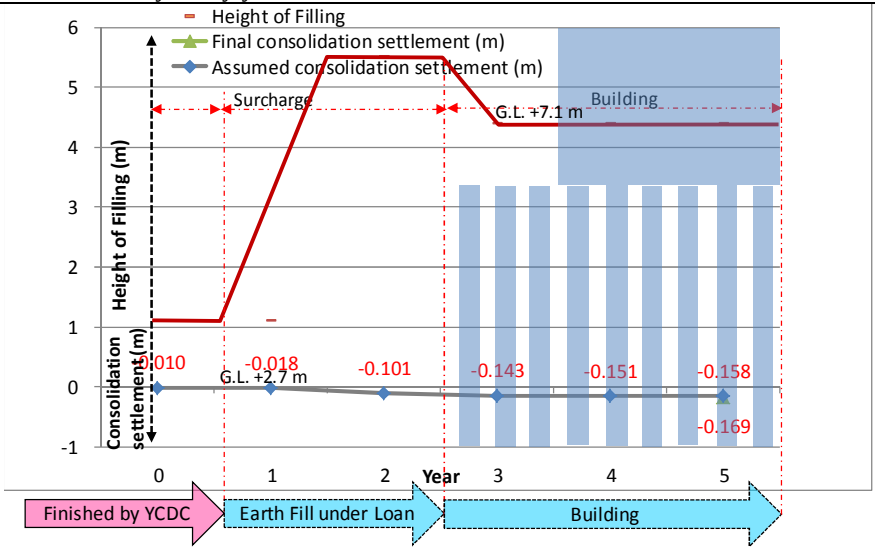
e) Settlement Level of Landfill

Settlement will start immediately after the landfill, because excavated soil is mainly clay. The settlement level is calculated using data of No. 7 bore hole, one of the worst conditions within the surveyed boring data. The comparison of land filling method is shown in the following Table. The consolidation settlement amounts are calculated by the following formula.

$$S = \sum \frac{C_c}{1+e_o} H \log \frac{\sigma_v + \Delta\sigma_v}{p_c}$$

where,
S: the consolidation settlement amount (m)
C_c: the compression index; 0.23 from data of No. 7 bore hole
e_0: the initial void ratio; 0.85 from data of No. 7 bore hole
H: the height of the compressible soil (m); 53.5 m from data of No. 7 bore hole
p_c: the initial vertical stress in the underground calculating point (kN/m^2); 454.8 kN/m^2 =53.5 x 8.5 (soil constant)
σ v: the vertical stress before a landfill (kN/m^2); $p_{c+} \Delta \sigma$ v
$\Delta \sigma$ v: the increased vertical stress by landfill (kN/m^2); calculated by the Boussinesq approximation

Table 9-7 Comparison of Land Filling Method

Slow Banking Method	 The height of landfill rises year by year.	
Surcharge Method	 In order to accelerate settlement, the height of initial landfill exceeds the planned ground level. Finally, the top soil is removed such that the level reduces to planned ground level.	
Items	【Slow Banking】	【Surcharge】
Construction Period	Total: **6 years** Landfill: 3 years + WTP: 3 years	Total: **5 years** Landfill: 2 years + WTP: 3 years
Direct Cost	1.9 Mil. USD	2.5 Mil. USD

Source: JICA Study Team

However, fortunately a time gap is available up to the start of ODA loan project work. For that reason, Slow Banking Method is applicable.

- Precondition: Structures shall be supported by foundation piles and shall not sink.
- Slow Banking Method: Estimated settlement amount is 16 cm as max.

f) Against settlement

Measures against settlement are:

1) Employment of Foundation pile for Structures,

2) Employment of flexible joint to pipelines,

3) Construction of roads is postponed to after 140 MGD completion (2040 year).

Especially the joints of structure and pipeline are weak point that may have negative impact due to settlement. Impact of settlement on structure can be prevented by foundation pile. However, pipeline sinks with settlement of the neighborhood ground, and a large difference occurs at the joints. Therefore, installation of flexible joint is recommended for pipe joints.

The overall development plan of Kokkowa WTP is to the capacity of 140 MGD, of which under this project only 60 MGD WTP is to be constructed as the first step. It is not necessary to hurry completion of landscaping work. Moreover, it requires a long period for settlement and stabilization of filled land. Therefore, it is better to postpone completion of landscaping work until after completion of 140 MGD facilities.

g) Piling Work

Foundation pile is needed in order to support a heavy mass, since planned construction site and surface layer are weak. In Yangon, cast-in-place concrete pile is commonly used as foundation pile. Following applicable scopes (length and diameter of pile) of foundation pile are taken into consideration, and cast-in-place concrete pile is adopted.

- Cast-in-place concrete pile (Dia.3,000 mm or less): applicable length ≧ 60 m
- Pre-stressed concrete pile (Dia.400-600 mm): applicable length ≦ 40 m
- Steel pile (Dia.400-600 mm): applicable length ≦ 60 m

Long foundation pile is required for thick weak layers of the planned ground. And negative frictional force by clay layer is produced by the pile surface. The study result is shown in the following Table as compared with the actual result of WTP till now. A bottom widening construction method is adopted for foundation pile.

Table 9-8 Comparison of Foundation Pile

Item	Nyaughnapin WTP	Lagunbyin WTP	Kokkowa WTP
Structure Type	Imported steel pile	Cast-in-place concrete pile	Cast-in-place concrete pile
Length	12 – 18 m	30 – 35 m	About 60 m
Model of Bore hall	----	----	No. 7
Diameter (reference only)	Φ400 mm	Φ800 mm	Φ1200 mm or φ800 mm with bottom widening to φ900 mm
Negative frictional force *	Low	Low	1290 kN/m x circumference

Notes: Negative friction causes on the circumferential surface of foundation pile by settlement.

* Negative frictional force is for reference only.

Source: JICA Study Team

h) Framework Construction

Although the amount of required concrete is huge, many ready-mixed concrete plants exist in Yangon, and required concrete will be supplied from a nearby plant.

i) Equipment installation

Mechanical/electrical equipment is to be installed after civil work, to avoid securing storage place for equipment, and prevention from degradation. However, if required, storage place should be arranged for such equipment.

j) Exterior Work

Completion of exterior work is postponed considering description of the measures against settlement in item f) above. However, fence should be installed on the site boundary in consideration of security. This work is included in the scope of YCDC.

k) Construction Schedule

The construction period is expected to be about 41 months from mobilization to completion of commissioning.

(2) Zone 9 SR/RPS

The geological conditions described above should be taken into consideration, and studies of construction method with respect to land subsidence measures, foundation pile, the measures against groundwater level, etc. are required during the detailed design. Outline of execution scheme of this project is described below.

a) Access

The planned site of Zone 9 SR/RPS, exist along Route No. 5, and access from Yangon city is good.

b) Earthwork

Backhoe, clamshell and dump truck, etc., are to be used for excavation and backfilling.

c) Temporary works

A Soil Mixing Wall method is adopted for stopping entry of water and earth-retaining of sand layers, because SR is underground type, and excavation is deep. The advantage of this construction method is that bracing and waling material is not needed and widely used for construction works in Yangon city.

d) Against Settlement

Measures against settlement are;

1) Use of Foundation pile for Structures,
2) Use of flexible joint in case of pipelines.

e) Foundation Pile

Foundation pile is needed in order to support a heavy mass, since planned construction site and surface layer are weak. In Yangon, cast-in-place concrete pile is commonly used as foundation pile. Length of foundation piles are about 20 m based on the existing soil condition.

f) Framework Construction

Although the amount of required concrete is huge, many ready-mixed concrete plants exist in Yangon, and required concrete will be supplied from a nearby plant.

g) Equipment Installation

Mechanical/electrical equipment is to be installed after civil work, to avoid securing storage place for equipment, and prevention from degradation. However, if needed, storage place should be arranged for such equipment.

h) Construction Schedule

The construction period is expected to be 24 months from mobilization to completion of commissioning.

(3) Kokine SR

Repair of existing Kokine SR based on the study result is planned as proposed in Chapter 7.

a) Access

Kokine SR is the existing distribution facility for downtown area. The aged SR is located beside Kaba Aye Pagoda Road which runs through north and south in city center, and access is good.

b) Working space

Some buildings are located in the surroundings of SR and working space has limitations.

c) Repair Procedure (Refer to Chapter 7)

The inside of Kokine SR shall be cleaned and inspected after new transmission pipe from Kokkowa and existing pipes are connected, and Kokkowa water is directly supplied by Relay PS using existing pipes.

d) Construction Schedule

For inspection of the Kokine SR, reduction of water level in the tank shall be monitored after

closing all newly installed inlet and outlet valves, and leakage points must be determined. Then, repair methods shall be studied and measures shall be implemented. 22 months are taken into consideration as construction period for inspection, study and repair.

(4) Central SR

Existing SR is to be demolished and SR be rebuilt.

a) Access

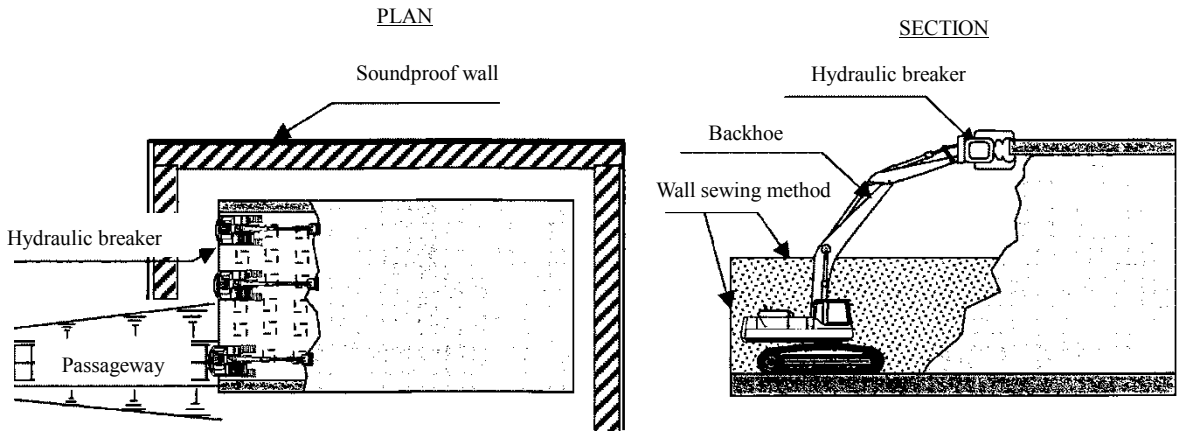
Central SR is abandoned currently. The aged SR is located beside Shwedagon Pagoda Road in city center, and access is good.

b) Working Space

Working permission must be obtained through YCDC, because SR is located in military area. Working space is limited and is surrounded by Pagodas and related structures on northern and western sides.

c) Removal Work

Effect on surrounding Pagodas may not be avoided with the removal work of entire existing SR. Therefore, lower part of the wall of the existing SR is to be left untouched, and these will be utilized as earth retaining walls. Demolishing work of the structures other than some parts of walls should be carried out with low-noise and low-vibration methods not to affect the adjacent pagodas and houses. The wall-sewing method using hydraulic breaker can meet this requirement as shown in following Figure. If relevant machines are not available in Yangon, these will be imported from Japan or neighboring countries.



Source: JICA Study Team

Figure 9-3 Outline of Removal Method of Existing Structure

d) Temporary Works

Bracing and waling material is applied for retaining wall and is widely used for construction work in Yangon city.

e) Foundation Type

The new foundation is to be constructed upon the existing floor. Spread foundation type will be adopted.

f) Framework Construction

Although the amount of required concrete is huge, many ready-mixed concrete plants exist in Yangon, and required concrete will be supplied from a nearby plant.

g) Equipment Installation

Mechanical/electrical equipment is to be installed after civil work, to avoid securing storage place for equipment, and prevention from degradation. However, if required, storage place should be arranged for such equipment.

h) Construction Schedule

The construction period is expected to be 24 months from mobilization to completion of commissioning.

(5) Transmission Pipeline along Route No. 5

a) Planning of Construction Season

This construction should be carried out during dry season to have low water level in ditch along which construction is to be carried out.

b) Buried Location of Pipe

Steel pipe or ductile iron pipe is to be laid underground of ditch along Route No. 5. Earth covering on pipe should be more than 1.5 m based on request of MoAI. An open space shall be set in a ditch, because some sections are used for irrigation canal.

c) Earthwork

Backhoe and dump truck, etc. are used for excavation and backfilling.

d) Temporary Works

In dry season, when water level in the ditch drops, partitions will be set in the ditch using earth wall to get rid of remaining water, and open cut method will be used. The same construction method is

adopted basically for pipe laying.

e) Pipe Laying

A crane will be employed for hanging, lowering in ditch, and installing pipe.

f) Construction Procedure

① Sandbags are placed along the ROW boundary to avoid water influx into excavated trench for pipe installation from the irrigation canal.

② Trench is excavated for pipe installation. Since depth of trench is around 3 meters, open-cut method is adopted. During the excavation, dewatering is conducted by drainage pump, and water is returned to irrigation canal.

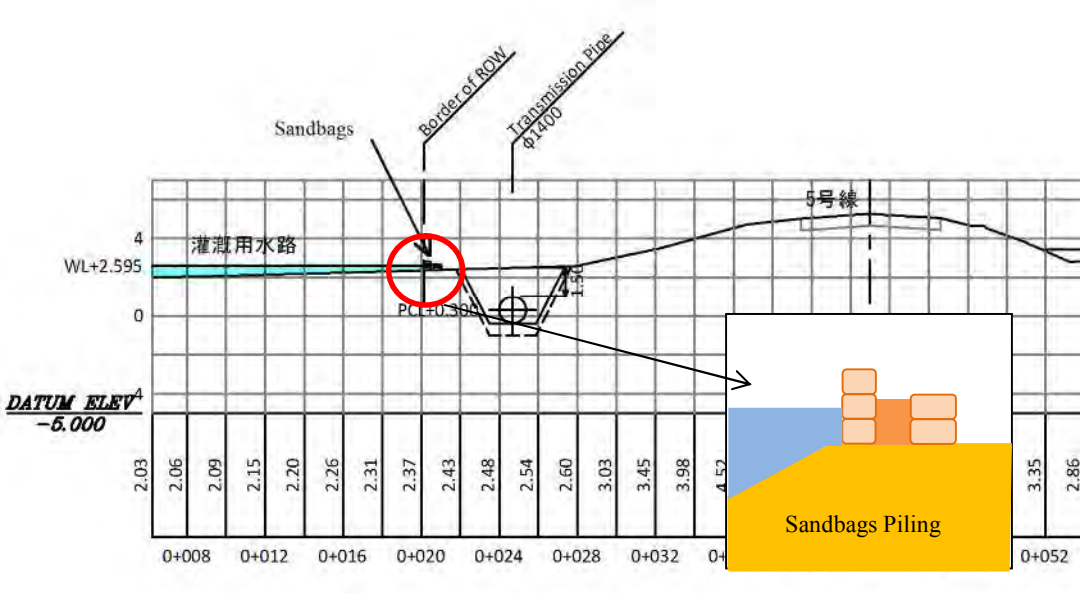
③ Hanging and placing of pipes and welding joint (in case of steel pipe) are conducted.

④ After the completion of joint connection, back fill is conducted.

⑤ Sandbags are relocated to move pipe installation site ahead.

⑥ After this, procedure ② to ⑤ is repeated.

In the place where is difficult to excavate by open-cut method due to the obstructions, earth retaining by sheet piles is used.



Source: JICA Study Team

Figure 9-4 Cross Section of Pipe Installation along Route 5

g) Construction Schedule

The construction is divided into 2 scopes, and the construction periods for these scopes are expected to be respectively 41 months and 42 months as 9 m length pipe is installed per day including procurement.

(6) Hlaing River Crossing

The geological conditions mentioned above should be taken into consideration, and studies of construction method with respect to the measures against groundwater level, etc. are required during the detailed design. Outline of execution scheme of this component is described below.

a) Planning of Construction Season

This construction should be carried out during dry season to have as low water level of river as possible.

b) River Crossing Method

Shield driving method is applicable to the section (Casing of Outside Dia. 2,350 mm, Dia. 1600 mm, L = 550 m) of Hlaing River crossing as described in Chapter 5. The constructors in neighboring countries have little working experience of the shield driving method of river crossing. Therefore, construction work material (tunnel machine/ mine mouth/ muddy water treatment equipment, etc.) is to be imported from Japan.

c) Buried Location of Pipe

The width of Hlaing River is about 400 m and the maximum depth of water is about -22.0 m. The top of casing pipe should be at least 6.0 m below the present river bed (see Chapter 5).

d) Temporary Works for Shafts

Depth of shaft bottom is around 30 m, and wall depth considering depth of embedment against boiling becomes about 43 m. From the views of water-stopping performance and stability against forces such as earth pressure, methods mentioned below are considerable. However, underground cast-in-site wall method and soil-cement-mixing wall method are applicable by the depth limitation of each method.

- Underground cast-in-site Wall Method (RC underground wall): applicable depth $\leqq$ 150 m
- Soil-cement-mixing Wall Method (SMW Method): applicable depth $\leqq$ 45 m
- Sheet Pile Method (Vibro-hammer Press Jack Method): applicable depth $\leqq$ 25 m

SMW Method is cheaper and commonly used in local. Thus, SMW Method is planned for shaft construction. In addition, dewatering will be carried out by pump during construction period to avoid accumulation of water.

e) Construction Schedule

The construction period is expected to be 24 months from mobilization to completion works.

(7) Transmission and Distribution Pipeline under City Road

a) Planning of Construction Season

In rainy season, the average rainfall in July - August is 500 mm/month. In order to avoid occurrence of any accident, excavation work shall be reduced during this season. Instead, operations during night time are planned during dry season.

b) Buried Location of Pipe

Steel pipe or ductile iron pipe is to be laid underground of Yangon roads. Although it depends on situations of other underground utilities, pipe depth should be 2 -3 m for big diameter pipe and about 1 - 1.5 m for small diameter pipes.

c) Earthwork

Backhoe and dump truck, etc., are used for excavation and backfilling.

d) Temporary Works

Trench and retaining wall is required for sections having deep excavation. The disadvantage of pitching type trench sheet plate and Liner plate used by Japanese grant aid project is that they require unnecessarily large machines and cause reduction of available road for traffic. In addition, dewatering should be carried out by pump during construction period.

e) Pipe Laying

A crane is to be employed for hanging and installing pipe.

f) Underground Utility of Other Organizations

Although buried cable certainly exists in the city area, there is little information on these utilities. When a buried cable would be found in a trench, solutions shall be discussed on-site upon discussion with representatives of power supply and telecommunication companies.

g) Railway Crossing

Railway crossing is planned at two locations in this project. Ductile pipe is adopted from the viewpoint of microcell/ macrocell corrosion. Subsidence limits and countermeasures in case of a railway shall be decided by discussion with the railway company during the detailed design. The level of railway profile should be measured during construction works.

h) Reduction in Traffic Congestion

Most of the pipe laying works is along roads with heavy traffic, therefore, the outline of construction work should be discussed with YCDC and traffic police in advance. The construction period and

location of affected road should be clarified. In order to alleviate the impact of traffic congestion, work outline including diversion if any should be informed to citizens in advance before pipe laying.

i) Safety Measures

Continuous barricade shall be set up on construction sites so that walker may not come into working space and construction equipment is not operated out of the working space. Moreover, exclusive flagman should be arranged for working time.

j) Reduction of the Effect of Suspension of Water Supply

In this project, large-scale suspension of water supply will not occur, because connection of the large pipe is planned by tapping pipe method without water supply suspension. However, short-time suspension of water supply is expected to occur, when connection of small size pipe changes. Therefore, connection works shall be carried out at night as much as possible and arrangement of water truck shall be made suitably as alternative water source.

k) Construction Schedule

The length of pipe of dia.1000 mm that can be installed in a day is 6 m/day during day and night work based on the actual result of grant aid project. In addition, the corresponding length of pipe in case of small pipe is 25m/day in daytime work. The construction period is expected to be 63 months for Low subzone and 62 months for High subzone including procurement.

(8) Study of Supplementary Facilities

Supplementary works to be carried out in this project include ①Exterior work in WTP, ② Gardening in relay pump station, ③ Exterior work in Zone 1 SRs, and ④Power supply.

① Exterior work in WTP: Completion of exterior is to be postponed until settlement of the landfill stabilizes as mentioned above. However, fence is to be set on the site boundary from the viewpoint of security. This work is included in the scope of YCDC.

② Gardening in Zone 9 SR: Gardening work in park is not included in this project for jurisdiction of park department of YCDC.

③ Exterior work in Zone 1 SRs: Some expenses are added.

④ Power supply: Installation of power line to WTP was completed by YCDC, and provision of Sub-station of WTP is included in this project. Power supply to Zone 9 SR and Central SR with sub-station are also included in this project.

9.1.5 Safety Control

The Study Team organized a seminar related to the safety control for YCDC in December, 2015. The contents are shown in the Appendix-10.

9.1.6 Risk Management

During implementation of this Project, the steps to mitigate or avoid risk shall be undertaken. Reference shall be made to the framework given in Appendix-14.

9.2 Overall Project Cost

9.2.1 Conditions of Cost Estimate

9.2.2 Proposed Package

Table 9-9 Candidate Packages of Eligible Portion for JICA ODA Loan Project

Non-disclosure

Table 9-10 Non-eligible portion for JICA ODA Loan (YCDC own budget)

Non-disclosure

9.2.3 Conditions of Construction Cost Estimate

Table 9-11 Breakdown of Construction cost

Non-disclosure

9.2.4 Estimated Overall Project Cost

Table 9-12 Estimated Overall Project Cost

Non-disclosure

9.3 Preparation of Implementation Schedule

9.3.1 Implementation Schedule

Table 9-13 Implementation Schedule for Each Package

Non-disclosure

Table 9-14 Detailed Implementation Schedule of Selection of Consultant

Non-disclosure

Table 9-15 Detailed Schedule of Selection of Contractor

Non-disclosure

Table 9-16 Breakdown Schedule of Construction Works

Non-disclosure

9.3.2 Disbursement Schedule

Table 9-17 Disbursement Schedule

Non-disclosure

9.4 Financing Plan

Table 9-18 Annual Fund Requirement

Non-disclosure

Table 9-19 Preliminary Funding Structure

Non-disclosure

Table 9-20 Breakdown of Cost

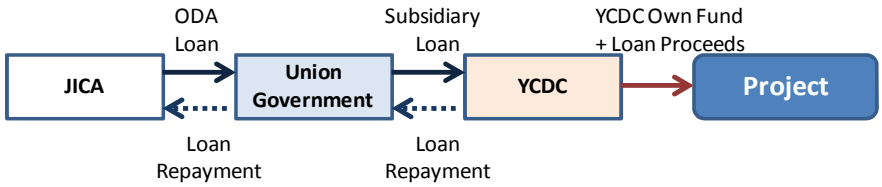
Non-disclosure

Table 9-21 Cost by Year (million Yen)

Non-disclosure

(3) Funding Sources

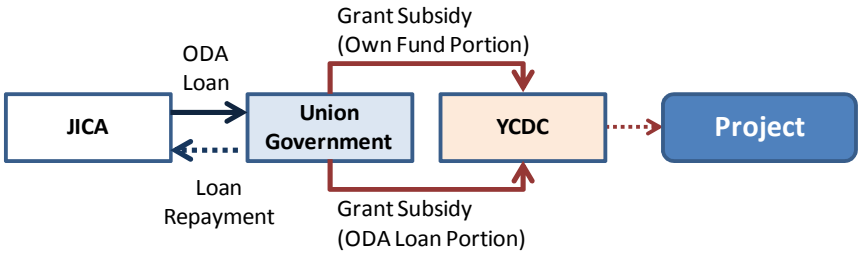
Eligible component will be financed by ODA loan. In accordance with the Phase 1 implementation and discussions with YCDC, the ODA loan proceeds will be on-lent to YCDC from the Union Government as a subsidiary loan. Its loan conditions will be the same as those of the original ODA loan and YCDC will be responsible to the repayments in full amount (See following Figure).



Source: JICA Study Team

Figure 9-5 Financing Structure of JICA ODA Loan

For YCDC own-fund portion, YCDC is primarily responsible to the budgeting for the investment; because usually YCDC does not receive subsidy for capital expenditure from Union Government or Yangon Region Government. However, due to the project's massive investment requirement and low profitability of water supply service, YCDC may need the subsidy from Union Government as grant assistance. In that case, both ODA loan obligation and own-fund portion (or either one) should be borne by the Union Government (See following Figure). The needs for grant subsidy from the Union Government will be further discussed in Chapter 10.



Source: JICA Study Team

Figure 9-6 Case of Grant Subsidy from Union Government

9.5 Estimated Operation and Maintenance Cost

Table 9-22 Quantity and Unit Cost

Non-disclosure

Table 9-23 OM Cost for Phase 2 Project

(Unit: USD/year)

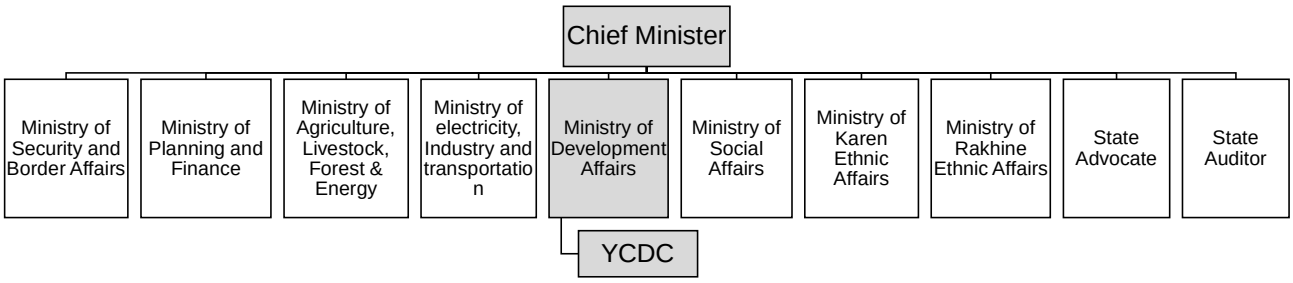
Non-disclosure

9.6 Organizational Structure for Implementing The Project

9.6.1 Administrative Organization on Water

(1) Yangon Region Government

Construction and operation/maintenance of irrigation canals and drainages are clearly defined in the Constitution as duties of the central and regional governments while the responsible agencies for construction of water supply, sewerage and urban drainage facilities is not explicitly defined under the Constitution. However, collection of water tax is defined as the regional government's responsibility. Department of Development Affairs in the regional government assumes the role of providing water supply systems. So it is not clear to us whether the regional government still assumes water supply sector in Yangon region.



Source: JICA Study Team

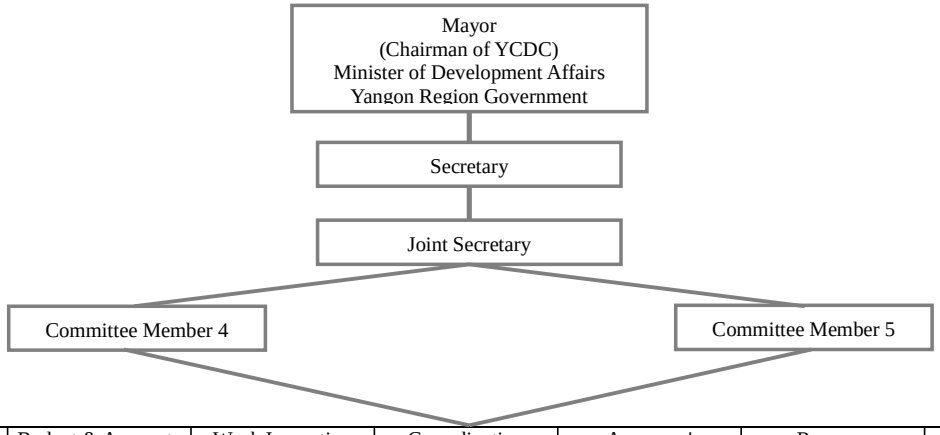
Figure 9-7 Yangon Regional Government Organogram

(2) Yangon City Development Committee

YCDC was established based on the "City of Yangon Development Act" aiming to foster development project in Yangon city independently. The law defined that YCDC is authorized to implement their own project by using their own funding resources. However, YCDC is not appropriately able to exercise their authority under current procedure, for instance, 1) YCDC needs to apply for permissions for implementation of projects to the central government, and 2) the funding sources of YCDC's activity are incorporated into the national budgetary system.

An organogram of overall YCDC is shown as the following Figure. YCDC is headed by the mayor, and supported by the secretary and the joint-secretary under the mayor. The committee members consist of mayor, secretary, joint-secretary, and other 2 members (committee 4 and 5). 20 departments in YCDC belong to these committees.

YCDC is responsible for water, sewerage and sanitation projects in 33 townships out of 45 townships of Yangon division. The law defines the role and the responsibility to establish policies, and to manage and implement them.



The Administration Department	Budget & Accounts Department	Work Inspection Department	Co-ordination Department	Assessors' Department	Revenue Department	Markets Department
Veterinary & Slaughter House Department	Pollution Control & Cleansing Department	Engineering Department (Roads & Bridges)	Engineering Department (Buildings)	Engineering Department (Water & Sanitation)	Motor Transport & Workshop Department	Central Stores Department
Playgrounds, Parks & Gardens Department	Security & Disciplinary Department	City Planning and Land Administration Department	Health Department	Public Relations and Information Department	Production Department	Committee Office

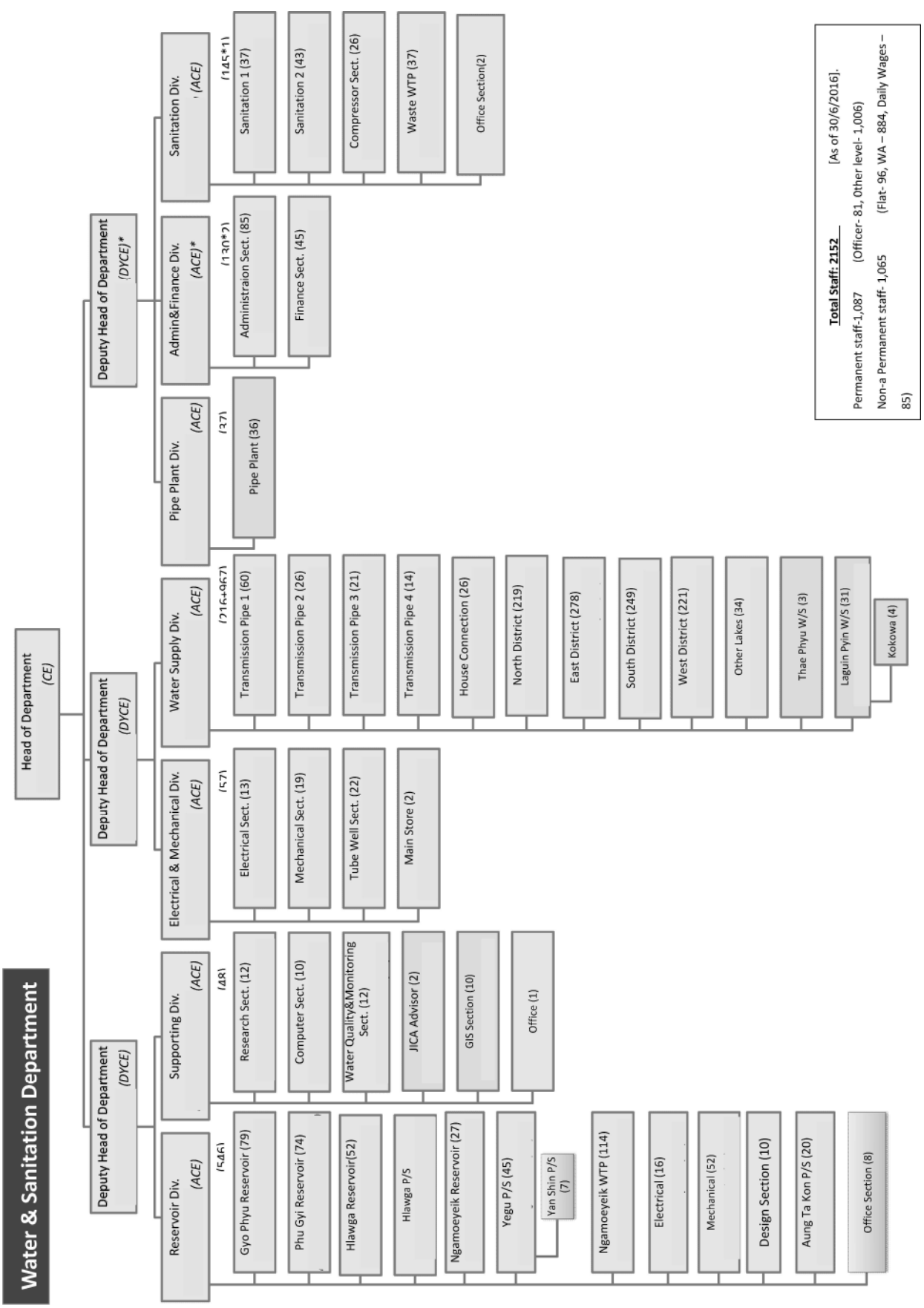
Source: YCDC

Figure 9-8 Overall YCDC Organogram

(3) Engineering Department (Water Supply and Sanitation)

Engineering Department (Water Supply and Sanitation) consists of 7 divisions under the Head of Department and Deputy Head of Department. Total number of staff members is 2,152 as of 30 June 2016 (refer to Appendix- 9 for details.).

A re-organization is under study currently by assistance of technical cooperation project as described in Chapter 8.



Source: EDWS

Figure 9-9 EDWS Organogram

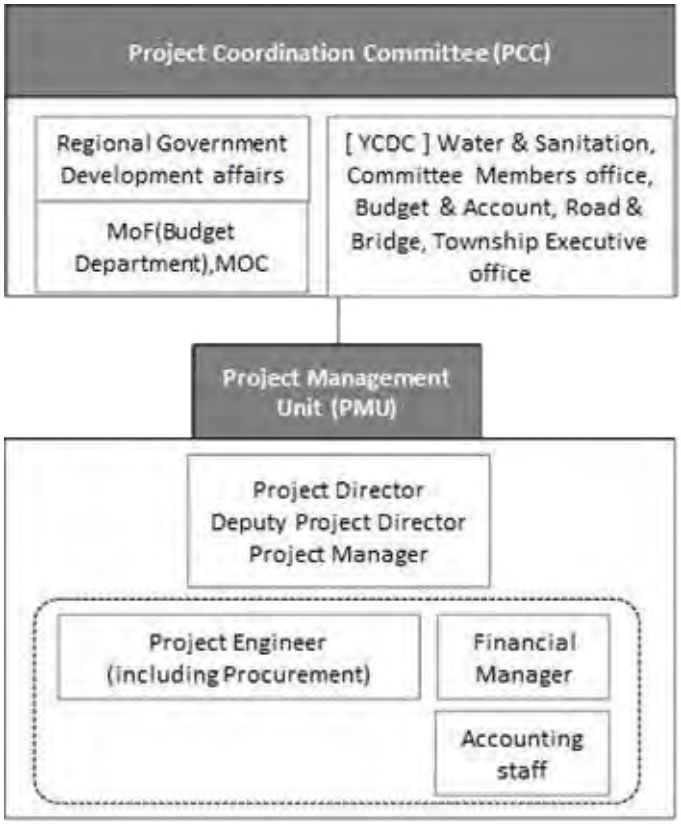
9.6.2 Organizational Structure for Implementing The Project

An organizational structure for the Project consists of Project Coordination Committee (PCC) and Project Management Unit (PMU).

Table 9-24 Roles and Responsibilities of Project Organizations

Project organization	Institutions responsible	Role and responsibility
Project Coordination Committee: PCC	Regional government, YCDC, Related ministries	• Project coordination for planning and implementation
Project Management Unit: PMU	EDWS	• Project management • Supervision • Monitoring and coordination • Allocation of budget

Source: JICA Study Team



Source: JICA Study Team

Figure 9-10 Proposed Organizational Arrangement for Project Implementation

9.6.3 Project Coordination Committee (PCC)

PCC is a supreme organization related to project implementation. The committee meeting will be held regularly, for instance quarterly in addition to the beginning and completion of the project. PCC shall be co-chaired by YCDC. PCC coordinates the necessary issues for agreement, discussion and cooperation on the project activities. It regularly reviews the progress of project activities and gives instruction and guidance for project implementation.

The key member of PCC will be development affairs of regional government, department of finance, accounting, road and bridge and township offices of YCDC and so on. The main functions of PCC will be as follows:

- Approving work plans and budgets for the project
- Monitoring and reviewing progress of activities of various concerned agencies
- Opening of regular meetings for committee
- Coordinating stakeholders relevant to the project activities of other institutions, dispute settlement, enhancing smooth project implementation
- Monitoring and reviewing the activity progress by the relevant institutions
- Identifying problems and bottlenecks in course of implementing various activities by the concerned agencies and suggest ways and means to solve the problems and bottlenecks
- Identifying issues which need to be considered, discussed, and coordinated
- Coordinating follow-up actions

9.6.4 Project Management Unit (PMU)

EDWS has the experience to establish PMU for Phase 1 project already.

(1) Role

PMU shall be established within EDWS and ad-hoc entity to be established for the project implementation. PMU is aimed at enhancing management and monitoring of the project, and be an independent organization to implement the specified project during the limited period. It will be headed and staffed by a full-time Project Director (PD), probably by the Chief Engineer, and the PMU shall establish the project office consisting of the staff members of technical and management section in the EDWS.

PMU shall be tasked with managing and monitoring the day-to-day activities of the project at the field level. The Project Director has the responsibility and authority for overall activities including coordination between sections and with construction companies to ensure the progress of the project within the implementation period. The main functions are listed as follows.

- To be comprehensively responsible for project implementation in accordance with the loan contract
- To coordinate and manage the Project activities
- To establish a monitoring and evaluation system that would track the progress of the Project
- Supervising and monitoring the day-to-day project activities
- Preparing project implementation and work plan and reporting the progress of the project with the assistance of the consultant
- Arranging and supervising construction works
- Arranging procurement of goods, works and services for the project

- Receiving and distributing funds for project activities
- Maintaining accounts of the project and arrange audit

(2) Staffing of PMU

The following staffing for PMU is recommended. The duty of Project Director may be undertaken by Chief Engineer supported by the Deputy Chief Engineers and that of project manager will be carried out by Assistant Chief Engineer. It is desirable that these personnel are appointed from EDWS from the viewpoint of capacity development of staff members and synergy effects.

The number of persons suggested in the following Table is just an indicative figure and shall not be necessarily limited to these numbers.

Table 9-25 Proposed Staffing of PMU

Areas	Position	Section	No.
Management			
1	Project Director	Chief Engineer	1
2	Deputy Project Director	Deputy Chief Engineer	2
3	Project Manager	Assistant Chief Engineer	1
Technical section (including manager)			
4	Engineer	Civil (EE) 2 Procurement (EE) 2	4
5	Assistant Engineer	Civil (AE or SAE) 2 Procurement (AE or SAE) 2 Water quality (AE or SAE) 1 Environment (AE or SAE) 1	6
Administration and Finance (including manager)			
6	Finance	Financial division	1
7	Accounting staff	Accounting division	1
Total			16

Source: JICA Study Team

9.6.5 Technical Level of Executing Agency and Relevant Experiences

EDWS has been conducting planning and design of water supply system in addition to maintenance of facilities. Various training is also organized and implemented by YCDC. Hence, it can be said that some knowledge and expertise on water supply system has been accumulated to a certain level by engineers in EDWS.

In terms of construction work and construction supervision experience, EDWS has dispatched some engineers for supervising the construction works of Nyaunghnapin WTP (phase 1 and 2) and Lagunbyin WTP and employed many daily labors. In this sense, EDWS has experiences of the construction and supervision of water infrastructure, consequently it can be said that EDWS has some experience of project management to a certain level.

9.6.6 Financial Management Capability of The Executing Agency

As for the financial management to implement the project, EDWS has limited but certain experience of ODA loan project implementation in Phase 1 project. However, overall financial management of EDWS as a water utility agency is still on a developing stage and requires significant capacity development. Analysis of financial management capacity of EDWS is summarized as follows:

- Budgeting: Budget decision is made by the union government based on YCDC's proposal. YCDC or EDWS does not have external funding/ financial sources for its project implementation and operation.
- Accounting: YCDC maintains government accounting system applying single-entry bookkeeping. Since its water tariff is very low and revenue and expenditure are separately budgeted and recorded, EDWS heavily relies on internal subsidy from revenue of other departments. EDWS is not managed as a financially independent entity.
- Water tariff: Issues such as lower rates for government agencies and inequality between fixed rate and metered rate customers are being solved by YCDC. However, Water tariff rate in general is set extremely low and far from the cost recovery level. There is no standardized procedure or guidelines to follow to establish an appropriate water tariff schedule to ensure financial soundness of EDWS.
- Meter reading, billing and bill collection: EDWS has not prepared a operational procedure/ manuals for consumer meter readers. Monitoring mechanism of water bill collection is uncertain.
- Asset management: Asset database has not been developed.

To cope with the challenges mentioned above, YCDC has launched the JICA technical cooperation project "Project for Improvement of Water Supply Management of YCDC" to enhance its financial management capacity in financial management, asset management, accounting, water tariff setting, etc. Further analysis of fiscal status of EDWS is presented in Appendix- 12.

9.6.7 Selection Policy for Consulting Firms

9.6.8 Consulting Services

Table 9-26 Consulting Services

Non-disclosure

9.6.9 Bidding Methods and Setting of Contract Conditions

9.6.10 Selection Policy for Contractors

CHAPTER 10 FINANCIAL AND ECONOMIC ANALYSIS

10.1 Financial Analysis

(1) Introduction

In the present section, financial evaluation of the proposed project is carried out to analyze its profitability, financial efficiency and sustainability from the point of view of the implementing agency i.e. YCDC through financial cash flow analysis.

Unless otherwise specified, the present analysis applies the general assumptions used in the cost estimation in Chapter 9, which are summarized in the Table below.

Table 10-1 General Assumptions for Financial Analysis

No.	Item	Assumption	Reference / Remarks
1	Exchange Rate	Kyat 1.00 = JPY 0.0923	See Chapter 9
2	Price Escalation	FC = 1.6% LC = 5.8%	See Chapter 9
3	Physical Contingency	Construction: 5% Consulting Services: 5%	See Chapter 9
4	Administration Cost	5%	See Chapter 9
5	VAT and Import Tax	VAT: 5% Import Tax: 2%	
6	Interest Rates (% p.a.)	- ODA Loan: 0.01% (40 years repayment period including 10 year grace period) - Front end fee: None (0%)	JICA ODA loan conditions for Low-Income Least Developed Countries as of July 2016
		- Exchange risk premium assumption: 6.0%	JICA Survey Team assumption based on the difference of average inflation rate estimates (percentage change in end-of-period consumer prices) for 2016-2020 period between G7 countries average (1.8%) and Myanmar (7.8%) referring to the estimates by IMF in World Economic Outlook Database, October 2015
7	Project Lifetime	40 years from 2016	JICA Survey Team assumption
8	Prices	All prices are expressed in constant price at July 2016 level excluding inflation.	JICA Survey Team assumption based on generally-accepted practice in similar analysis
9	Interest During Construction	Since the analysis aimed to calculate the project IRR of the total capital used, interest during construction is excluded from the calculation.	JICA Survey Team assumption based on generally-accepted practice in similar analysis

Source: JICA Study Team based on various sources

(2) Initial Investment Cost

Table 10-2 Initial Investment Cost

Non-disclosure

(3) Reinvestment Cost

Table 10-3 Reinvestment Cost

Non-disclosure

(4) O&M Cost

Incremental O&M cost as difference from the existing water supply facilities is calculated based on the estimation presented in Chapter 9 (See the following Table).

Table 10-4 O&M Cost

O&M Cost per year (million Kyat)	Kokkowa WTP and Trans. PS to Zone 9	Relay PS for Zone1	Dist. for Zone9	Central SR including Yegu PS	Kokine SR	Total
Salary	61	12	0	12	0	86
Electricity	1,924	2,125	712	1,972	11	6,744
Maintenance (Spare parts)	962	326	151	150	0	1,588
Sludge cake	380	0	0	0	0	380
Chemical Chlorine: Liquid Hypochlorite	801	0	0	0	0	801
Chemical Coagulant; ACH	2,474	0	0	0	0	2,474
Other cost	132	49	17	43	0	241
Total	6,733	2,513	879	2,177	11	12,314
Average daily demand (m^3)	229,118	151,382	77,737	69,554	151,382	298,672
Cost per m^3 (Kyat/m^3)	81	45	31	86	0	113

Source: JICA Study Team

(5) Water Tariff and Non-revenue Water Ratio

Water tariff applied in the projection is the currently applicable for YCDC water service customers, i.e. 88 Kyat/m^3 for domestic customers and 110 Kyat/m^3 for non-domestic customers. Non-revenue water ratio projection is assumed as per the following Table.

Table 10-5 Non-revenue Water Ratio Assumption

	2015	2020	2025	2030	2035	2040 ~
Non-revenue water ratio	60%	35%	10%	10%	10%	10%
Leakage ratio	55%	30%	5%	5%	5%	5%

Source: JICA Study Team

(6) Weighted Average Cost of Capital

As reviewed in Chapter 9, the initial investment is financed by the subsidiary loan from the Union Government (100% of ODA loan portion i.e. 100% of the eligible portion) and YCDC own fund (rest of the initial investment i.e. 100% of the non-eligible portion). Weighted Average Cost of Capital (WACC) as the threshold of financial viability is estimated as per the following Table.

Table 10-6 Weighted Average Cost of Capital

Non-disclosure

(7) Financial Cash Flow Projection

Following Table shows the financial cash flow projection based on the aforementioned assumptions and estimates. Since the project only produces negative cash flow during the entire project lifetime, it is impossible to calculate the financial internal rate of return (FIRR) unless the negative cost inclusion for the residual value of reinvestment. FIRR is estimated at -18.7% including the said negative cost. Net present value (NPV) of the project at 5.04% WACC is estimated as ■■Kyat. The project is deemed extremely unprofitable and financially not viable.

This is mainly because the current water tariff level is extremely low and cannot even cover the O&M cost (annual operational revenue amounts to ■■Kyat as compared to annual O&M cost of 12.3 billion Kyat). In order to cover the annual financial cost of 5.04% and achieve full-cost recovery of capital and O&M costs, the current water tariff level must be increased by +805% (9.1 times) in real terms excluding inflation.

Table 10-7 Financial Cash Flow Projection

Non-disclosure

(8) Combined Cash Flow Projection with Phase 1 Project

The present section evaluates the project's financial viability when combined with cash flow projection of the Phase 1 project. Construction cost of Phase 1 project is converted as given in following Table from the original estimates provided by JICA.

Table 10-8 Initial Investment Cost of Phase 1 Project

Non-disclosure

O&M cost of Phase 1 project is also converted as given in following Table. Out of Lagunbyin WTP's capacity of 40 MGD, it is assumed that 10 MGD is used to cover the demand of Thilawa SEZ (9 MGD or 40,900 m^3/day on average), where the water tariff for foreign non-domestic customers of 880 Kyat/m^3 is applied; whereas 30 MGD of the WTP capacity (average production of 124,000 m^3/day) covers the demand of Zone 7 and Zone 8 customers with the same NRW projection of Phase 2 (See following Table) and water tariff (88 Kyat/m^3 for domestic and 110 Kyat/m^3 for non-domestic customers).

Table 10-9 O&M Cost of Phase 1 Project

O&M Cost per year (million Kyat)	USD thousand	*million Kyat equivalent **
Manpower	278	*270*
Electricity	1,837	*1,784*
Replacement of Parts	400	*388*
Chemical Dosing	14,776	*14,346*
Others	359	*349*
Total	17,650	*17,136*

* Exchange rate applied: USD 1.00 = 970.9 Kyat

Source: JICA Study Team based on JICA information

Combined cash flow projection based on the aforementioned information is presented in Table 10-11. Even combined with the Phase 1 which has the Thilawa SEZ operation with favorable water tariff of 880 Kyat/m^3, the project generates only negative cash flow over the project life except for the residual value at the end due to heavy investment cost. FIRR is estimated at -18.8% showing no significant

difference from the case with Phase 2 alone. NPV is estimated as minus 793,395 million Kyat on the discount rate of 5.04%. Similar to the results of Phase 2 project, this is mainly because of the extremely low water tariff level to the general public (domestic and non-domestic customers except for Thilawa SEZ) which cannot even cover the O&M cost. In order to cover the annual financial cost of 5.04% and achieve full-cost recovery, the current water tariff level for the general public must be increased by +659% (7.6 times) in real terms excluding inflation.

However, since the combined project has the Thilawa SEZ, the project's O&M cost coverage is significantly improved as compared to that of the Phase 2 project (See following Table).

Table 10-10 Comparison of Average O&M Cost and Water Tariff Revenue (2035)

Average Cost and Revenue per Revenue Water (Kyat/m^3) in Year 2035	Phase 1	Phase 2	Phase 1 + Phase 2 Combined
O&M Cost	**308**	**164**	**225**
Water Tariff Revenue	**307**	**97**	**186**
O&M Cost Coverage	***100%***	***59%***	***83%***
Phase 1 (excluding Thilawa SEZ)	71	-	30
Phase 1 (Thilawa SEZ)	236	-	100
Phase 2	-	97	56

Source: JICA Study Team

(9) Further Analysis

Further financial analysis of the project on fiscal status of YCDC, water tariff setting and subsidiary loan conditions is presented in Section 10.3.

Table 10-11 Combined Cash Flow Projection

Non-disclosure

10.2 Economic Analysis

(1) Introduction

In the present section the quantifiable socio-economic impact and efficiency is evaluated in economic terms through the economic analysis. The economic evaluation applies cost-benefit analysis of cash flow projection to calculate an economic internal rate of return (EIRR) as the primary indicator of the analysis.

Unless otherwise noted, the present economic analysis applies the same assumptions as those of the financial analysis. Other assumptions particular to the economic analysis is summarized in Table below.

Table 10-12 General Assumptions for Economic Analysis

No.	Item	Assumption	Source / Reference
1	Prices	All prices are expressed in constant price at 2016 level excluding inflation.	JICA Survey Team assumption based on generally-accepted practice in similar analysis
2	Transfer Items in Estimated Costs	Transfer items such as tax (VAT and import tax) and interest during construction are excluded from the cash flow projection.	JICA Survey Team assumption based on generally-accepted practice in similar analysis
3	Standard Conversion Factor for Local Currency Cost	Standard Conversion Factor of 0.975 is applied to convert financial value of local currency costs into economic value.	JICA Study Team assumption based on the Report and Recommendation of the President on Mandalay Urban Services Improvement Project (ADB, October 2015)
4	Land Opportunity Cost	It is assumed that compensation cost for land acquisition represents opportunity cost of land	JICA Survey Team assumption
5	Social Discount Rate	10%	JICA Survey Team assumption based on generally-accepted practice in similar analysis

Source: JICA Study Team based on various sources

(2) Economic Cost

Table 10-13 Initial Investment Cost

Non-disclosure

Reinvestment cost is converted to economic value as given in the following Table.

Table 10-14 Reinvestment Cost

Non-disclosure

O&M cost is converted to economic value as given in the following Table.

Table 10-15 O&M Cost

O&M Cost per year (million Kyat)	WTP	Transmission PS	Distribution to Zone 9	Distribution to Zone 1 Central SR (including Yegu PS)	Distribution to Zone 1 Kokine SR	Total
Salary	60	12	0	12	0	84
Electricity	1,876	2,072	694	1,923	11	6,576
Maintenance (Spare parts)	938	318	147	146	0	1,548
Sludge cake	370	0	0	0	0	370
Chemical Chlorine: Liquid Hyp	781	0	0	0	0	781
Chemical Coagulant; ACH	2,412	0	0	0	0	2,412
Other cost	129	48	17	42	0	235
Total	6,565	2,450	857	2,123	11	12,006

Source: JICA Study Team

(3) Economic Benefit

In accordance with the generally-accepted practice of the economic analysis of water supply projects, economic benefit of the project is recognized as (i) non-incremental benefit and (ii) incremental benefit.

Non-incremental benefit

Non-incremental benefit of the water supply is estimated from the cost of alternative water sources. It is assumed that the beneficiaries of the project would use the alternative water sources in the without-project case; therefore, the project will reduce such costs that would be spent on those alternatives.

The Preparatory Study for Urban Development Programme in the Greater Yangon (JICA) conducted a household interview survey (2013 JICA-HIS) which contains questionnaire regarding water consumption among households who do not have access to piped water supply from YCDC. According to the survey results, majority of the households without access to YCDC water service uses bottled water for drinking and domestic tube wells for other purposes. Alternative water source costs are estimated based on the combination of those two sources.

Firstly, average water consumption is estimated based on the survey results. As shown in the following Table, a household without piped water service by YCDC consumes 90.9 gallons (413 liter) per day. Assuming the average household size of 4.4 persons, it is equivalent to 94 lpcd. It is assumed that an average household consumes 20 liter per day of purchased bottled water for drinking and cooking purposes, and the rest (393 liter per day) is provided from the domestic tube well for other purposes.

Table 10-16 Average Water Consumption without YCDC Water Service

To who answered not having connection with "Piped water supply system by YCDC"
Q49e: How much is the average water consumption in a day? (Gallon/day)

Water consumption per day (Gallon)	Less than 50	51 - 100	101 - 200	201 - 300	301 - 400	More than 400	No Answer	Answered	Total	
Number	1,813	3,190	1,198	277	110	74	41	6,662	6,703	
% to Total	27.0%	47.6%	17.9%	4.1%	1.6%	1.1%	0.6%	99.4%	100.0%	
% to Answered	**27.2%**	**47.9%**	**18.0%**	**4.2%**	**1.7%**	**1.1%**		**100.0%**		
Median value assumptin	25.0	75.0	150.0	250.0	350.0	450.0		**Gallon/day/HH**	**L/day/HH**	**LPCD**
Weighted Average	6.8	35.9	27.0	10.4	5.8	5.0		**90.9**	**413**	**94**

Source: JICA Study Team based on Phase 1 Study and 2013 JICA-HIS

Cost of the alternative water sources are estimated through JICA Study Team's assumptions based on interviews with local residents. The following Table shows the cost estimates of a domestic tube well consisting of capital cost of 1,420,000 Kyat and recurrent cost (electricity cost) of 6.17 Kyat/m^3.

Table 10-17 Domestic Tube Well Cost

Capital Cost (Kyat)		Recurrent Cost (Electricity Cost) Estimation		
Well Construction	1,000,000	Pump Capacity	2,100	L/hour
Electric Pump (0.5HP)	150,000	Pump Output	370	Wh
Water Tank	200,000	Electricity	0.176	kW/m^3
Piping	70,000	Unit Cost	35	Kyat/kWh
Total Capital Cost	**1,420,000**	**Electricity Cost**	**6.17**	**Kyat/m^3**

Source: JICA Study Team

The following Table illustrates the cash plow projection to estimate the average domestic tube well cost per water consumption. Assumed that replacement of electric pump is required every three years

during the economic lifetime of 20 years, average present value of tube well water is estimated as 1,380 Kyat /m^3 at the social discount rate of 10%.

Table 10-18 Average Cost of Domestic Tube Well Water

Year	1	2	3	4	5	6	7	8	9	10
Capital Cost	**1,420,000**	**0**	**150,000**	**0**	**0**	**150,000**	**0**	**0**	**150,000**	**0**
Well Construction	1,000,000									
Electric Pump (0.5HP)	150,000		150,000			150,000			150,000	
Water Tank	200,000									
Piping	70,000									
Electricity Cost	**917**	**917**	**917**	**917**	**917**	**917**	**917**	**917**	**917**	**917**
Total Cost (Kyat)	**1,420,917**	**917**	**150,917**	**917**	**917**	**150,917**	**917**	**917**	**150,917**	**917**
Water Consumption (m^3) (393 L per day)	**141.5**	**141.5**	**141.5**	**141.5**	**141.5**	**141.5**	**141.5**	**141.5**	**141.5**	**141.5**

Year	11	12	13	14	15	16	17	18	19	20
Capital Cost	**0**	**150,000**	**0**	**0**	**150,000**	**0**	**0**	**150,000**	**0**	**-50,000**
Well Construction										
Electric Pump (0.5HP)		150,000			150,000			150,000		-50,000
Water Tank										
Piping										
Electricity Cost	**917**	**917**	**917**	**917**	**917**	**917**	**917**	**917**	**917**	**917**
Total Cost (Kyat)	**917**	**150,917**	**917**	**917**	**150,917**	**917**	**917**	**150,917**	**917**	**-49,083**
Water Consumption (m^3) (393 L per day)	**141.5**	**141.5**	**141.5**	**141.5**	**141.5**	**141.5**	**141.5**	**141.5**	**141.5**	**141.5**

Present Value at 10% Social Discout Rate

Present Value of Cost	**1,662,949**	**Kyat**
Present Value of Water Consumption	**1,205**	**m^3**
Average Well Water Cost	**1,380**	**Kyat/m^3**

Source: JICA Study Team

As shown in the following Table, combined alternative water source cost is calculated based on the assumed price of bottled water of 500 Kyat per 20 liter bottle and the domestic tube well water cost estimated above (1,380 Kyat/m^3). Average alternative water cost per volume, non-incremental benefit of the project, is estimated as 2,524 Kyat/m^3.

Table 10-19 Alternative Water Cost (Combined)

Alternative Water Source	Consumption per day (L/HH)	Cost per day (Kyat)	Average watercost (Kyat/m^3)
Water for drinking and cooking: Bottled water	20	500	
Water for other use: Domestic tube well (1380Kyat/m^3)	393	543	
Total	**413**	**1,043**	**2,524**

Source: JICA Study Team

Incremental benefit

The project will not only substitute the beneficiaries' existing water consumption from other sources (non-incremental benefit), it will also increase the water consumption at the price of beneficiaries' willingness to pay for the new piped water service (incremental benefit). Incremental benefit is estimated from the willingness to pay for the piped water supply among residents surveyed in 2013 JICA-HIS. According to 2013 JICA-HIS, the average willingness to pay per household is estimated at 2,530 Kyat/month (See following Table).

Table 10-20 Willingness to Pay for Better Water Supply Services

For 24 hour drinkable water supply (Kyat/month)	Less than 500	501 - 1000	1001 - 2000	2001 - 3000	3001 - 5000	5001 - 7000	More than 7000	No Answer	Answered	Total
Number	2,279	2,191	1,557	1,221	1,040	264	1,516	1	10,068	10,069
% to Total	22.6%	21.8%	15.5%	12.1%	10.3%	2.6%	15.1%	0.0%		100.0%
% to Total Answered	22.6%	21.8%	15.5%	12.1%	10.3%	2.6%	15.1%		100.0%	
Median value assumption	250	750	1,500	2,500	4,000	6,000	8,000			Kyat/month
Weighted Average	**57**	**163**	**232**	**303**	**413**	**157**	**1,205**			**2,530**

Source: JICA Study Team based on 2013 JICA-HIS

Likewise, incremental water volume that the beneficiaries are willing to consume the better water supply is estimated at 1.23 times on average based on the 2013 JICA-HIS results (See following Table). This is equivalent to 116 lpcd or 15.26 m^3 per month for an average household of 4.4 persons. Based on the estimates above, the average willingness to pay per cubic meter is calculated at 166 Kyat/m^3 (2,530 Kyat/15.26 m^3).

Table 10-21 Water Consumption Volume of Better Water Supply

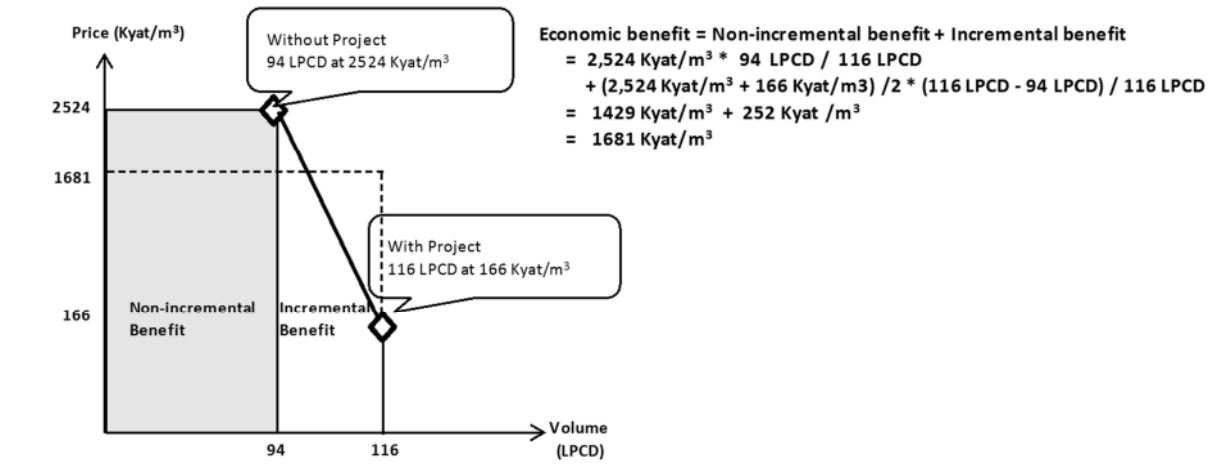
Q50: How many times do you want to consume more water comparing to the current cunsumption if possible?

Times to the current consumption	1	1.25	1.5	2	3	More than 3	No answer	Answered	Total
Number	7,432	778	424	1,125	131	178	1	**10,068**	**10,069**
% to Total	73.8%	7.7%	4.2%	11.2%	1.3%	1.8%	0.0%		100.0%
% to Total Answered	73.8%	7.7%	4.2%	11.2%	1.3%	1.8%		**100.0%**	
Median value assumptin	1	1.25	1.5	2	3	4		**Times**	**LPCD**
Weighted Average	0.74	0.10	0.06	0.22	0.04	0.07		**1.23**	**116**

Source: JICA Study Team

Economic benefit calculation

Based on the non-incremental and incremental benefits estimated above, the estimation of average economic benefit is calculated at 1,681 Kyat/m^3 (See following Figure).



	Water Consumption	Water Price
Without Project	94	2,524
With Project	116	166

Source: JICA Study Team

Figure 10-1 Economic Benefit Calculation

(4) Calculation of EIRR

Economic cash flow projection over the project life is presented in following Table based on the aforementioned assumptions and estimates. EIRR of the project is estimated as 14.3%. As compared to the social discount rate of 10%, the project is deemed economically viable.

Table 10-22 Calculation of EIRR

Non-disclosure

(5) Sensitivity Analysis

Sensitivity analysis has been carried out to see sensitivity of EIRR to decrease of water consumption volume (demand) and cost increase. Results show that the demand decrease is slightly more sensitive than increase in project cost (See following Table). Switching values to achieve 10% EIRR are 38% increase in cost and 27% decrease in water demand respectively.

Table 10-23 Sensitivity Analysis

EIRR		Water Consumption (Demand) Decrease						
		0%	-5%	-10%	-15%	-20%	-25%	-30%
Cost Increase	0%	14.3%	13.5%	12.8%	12.0%	11.2%	10.4%	9.6%
	5%	13.6%	12.9%	12.1%	11.4%	10.6%	9.8%	9.0%
	10%	12.9%	12.2%	11.5%	10.8%	10.0%	9.2%	8.4%
	15%	12.3%	11.6%	10.9%	10.2%	9.5%	8.7%	7.9%
	20%	11.8%	11.1%	10.4%	9.7%	9.0%	8.2%	7.4%
	25%	11.2%	10.6%	9.9%	9.2%	8.5%	7.7%	7.0%
	30%	10.7%	10.1%	9.4%	8.7%	8.0%	7.3%	6.5%

Source: JICA Study Team

10.3 YCDC Financial Projection for This Project

(1) Introduction

As seen in Section 10.1, the project is not financially viable mainly due to the extremely low water tariff. The financial analysis results show that, in case the subject customer base is limited to that of the project (Zone 1 and 9), the current water tariff level must be increased by 9.1 times in real terms except inflation (See 10.1(7)), which is very unlikely.

In the present section, the financial projection will be carried out to estimate (i) the project's tariff increase effect for the whole YCDC customer base; and (ii) subsidy and subsidiary loan conditions in order to enhance financial viability of the project.

The projection will follow the same assumptions made for the financial analysis in Section 10.1 except for the prices expressed in current value including inflation in the present projection, applying 1.6% inflation rate for FC and 5.8% for LC in the base case scenario, which are the same as the price escalation precondition applied in the cost estimates presented in Chapter 9. The subsidiary loan conditions for the base case are (i) interest rate (0.01% p.a.), loan amount and repayment period are the same as those of ODA loan; and (ii) exchange risk premium of 6.0% is assumed.

(2) Case Scenarios

Following case scenarios are envisaged for the analysis.

- Base Case: No subsidy from Central Government is provided to YCDC.
- Case 1: No subsidy from Central Government is provided to YCDC. Two equal-percentage tariff increases for all YCDC customers in 2019 (Phase 1 commissioning) and in 2023 (Phase 2 commissioning) are estimated to achieve a zero cumulative cash position at the end of project life.
- Case 2: 25% of ODA loan portion is given to YCDC as grant subsidy.
- Case 3: 50% of ODA loan portion is given to YCDC as grant subsidy.

(3) Financial Projection and Necessary Water Tariff Increase

Financial projection of Base Case scenario is shown in the following Figure. Since YCDC bears all the financial burden of ODA loan and own-fund portion of initial investment, net cash flow of the case is negative during the entire project period. Cumulative cash position at the end of project period is ■■ kyat. The Base Case is deemed financially not viable.

Non-disclosure

Figure 10-2 Financial Projection (Base Case)

In Case 1 (See the following Figure), water tariff increase for all YCDC customers (equal percentage in 2019 and 2023 each) is estimated to achieve a zero cumulative cash position at the end of project period. Necessary tariff increase is calculated at +62.1% in nominal terms each in 2019 and 2023, or 2.6 times in total which is much lower than the case of projections in 10.1 (7) in which necessary tariff increase (9.1 times in total) is applied only to Zone 1 and 9 customers. As shown in the following Figure, the tariff increase of entire YCDC customers significantly raises operational cash flow to surplus position in each year.

Non-disclosure

Figure 10-3 Financial Projection (Case 1)

In Case 2 and Case 3, grant subsidy from the central government is provided to YCDC to ease its financial burden that derives from subsidiary loan for initial investment. Grant subsidy accounts for 25% of ODA loan portion in Case 2 and 50% of ODA loan portion in Case 3 respectively. Results are shown in Figure 10-4 (Case 2) and Figure 10-5 (Case 3). Since YCDC's debt service payments are reduced by the grant subsidy, the water tariff increase requirements are lowered to 2.4 times (Case 2) and 2.3 times (Case 3) in total.

Figure 10-4 Financial Projection (Case 2)

Figure 10-5 Financial Projection (Case 3)

(4) Results of Financial Projection and Water Tariff for Poverty Group

Results of financial projection in respective case scenarios are summarized in the following Table and Figure. Cases with Central Government subsidy (Case 2 and Case 3) have lowered water tariff increase requirement. However, even with 50% subsidy for ODA loan portion in Case 3 the required tariff increase in 2019 and 2023 accounts for over 50% in nominal terms. As shown in the results, in order for the project to achieve financial viability, it is necessary to increase the current water tariff for all customers by 2.6 times (Case 1) to 2.3 times (Case 3) depending on the subsidy provided by Central Government.

On the assumption of 3 to 4% of household income affordability criteria (See Section 2.3 of Chapter 2), the increased water tariff level in all the four cases are lower than 3%, indicating the required tariff increase is considered affordable among the domestic customers.

Table 10-24 Results of Financial Projection

Figure 10-6 Required Tariff Increase in Four Cases

CHAPTER 11 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

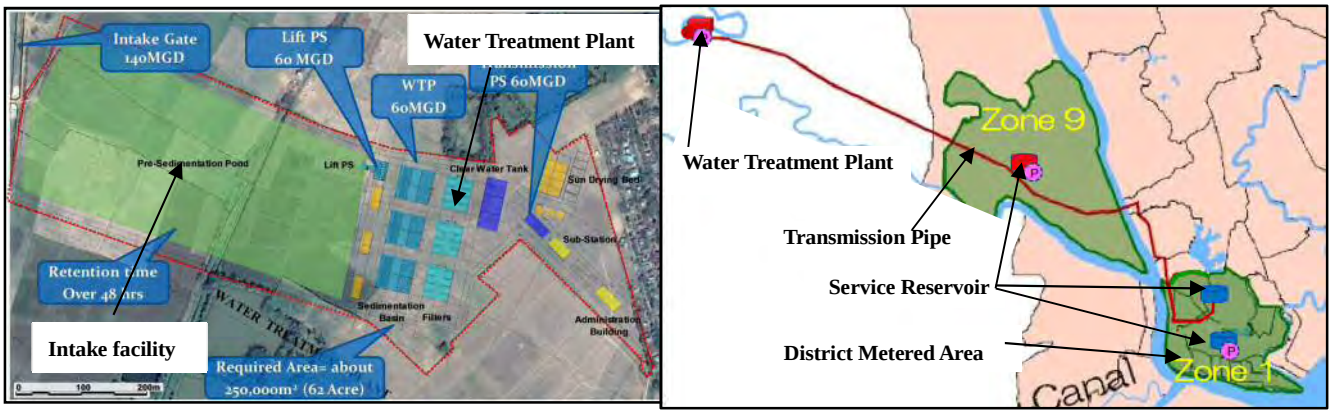
11.1 Outline of Project Component

The project aims at improving water supply services to meet the increasing water demand by using raw water from Kokkowa River and constructing WTP and associated transmission and distribution facilities, which will contribute to improve living environment and economic development in Yangon city. The outline of project component, scope of facilities and location of project area are shown as below.

Table 11-1 Outline of Phase 2 Project Component

Project Component	For Zone 9	For Zone 1	Area
Intake Gates	140 MGD		25 ha (62 Acre)
Pre-sedimentation Pond	60 MGD		
Water Treatment Plant	60 MGD		
Transmission Pipe	21.4 km (WTP→Zone 9 SR)	19.9 km (Zone 9 SR→Zone 1)	-
Service Reservoir	12.2 MG in 2025	20 MG (Kokine) 8.3 MG (Central) in 2025	Zone 9 SR 1.5 ha, Kokine SR 1.4 ha, Central SR 0.7 ha
Distribution Main Pipe	43.2 km	61.4 km	-
Distribution Pipe	636.9 km	430.3 km	-
DMAs	23 Nos.	37 Nos.	-

Source: JICA Study Team



Source: JICA Study Team

Figure 11-1 Location of Project Area

11.2 Environmental and Social Condition

11.2.1 Access to Urban Services

Following Table shows township-wise proportion of households which have access to urban services. Access to urban services especially in terms of electricity and toilet/sanitation facility is developed with high ratio in almost all townships. However, improvement related to services in the fields of telephone, piped water supply, and solid waste collection is not visible in some part of suburban areas such as Kyimyindine and Hlaing Tharyar.

Table 11-2 Access to Urban Services by Townships

Zone	No	Town Ship	Electricity (%)	Telephone (%)	Piped Water Supply (%)	Toilet/Sanitation Facility (%)	Solid Waste Collection (%)
Zone 1	1	Latha	88	93	87	100	99
	2	Lanmadaw	100	92	91	100	97
	3	Pabedan	100	92	86	98	95
	4	Kyauktada	99	93	82	100	92
	5	Botahtaung	100	79	84	100	91
	6	Pazuntaung	100	93	89	100	94
	7	Ahlon	100	92	67	100	93
	8	Kyimyindine	86	54	38	96.5	54
	9	Sangyoung	100	84	65	99.5	94
	10	Dagon	97	95	85	100	82
	11	Bahan	99	77	86	100	90
	12	Tamway	100	86	85	99.7	95
	13	Mingala Taungnyunt	100	81	91	98.9	95
	14	Seikkan	100	60	80	100	100
Zone 9	29	Hlaing Tharyar	88	42	3	100	69
Average			97	81	75	100	89

Source: 2013 JICA-HIS

11.2.2 Land Use

Following Table shows township-wise proportion of land use by different categories. The ratio of Build-up areas dominate with over 90 % in almost all townships. On the other hand, ratio of unbuild-up areas, which has potential to be developed in future, is significant mostly in some parts of suburban area such as in the townships of Kyimyindine, Dagon, Seikkan and Hlaing Tharyar.

Table 11-3 Land Use Ratio by Townships

Zone	No.	Town Ship	Build-up Area							Unbuild-up Area						
			Area (km^2)	Residential (%)	Business (%)	Commercial (%)	Industrial (%)	Public Facility (%)	Build-up Area Total (%)	Urban development (%)	Playground (%)	Agricultural (%)	Open space (%)	Green Area (%)	Water Surface (%)	Unbuild-up Area Total (%)
Zone 1	1	Latha	0.81	55	0	0	0	45	100	0	0	0	0	0	0	0
	2	Lanmadaw	1.41	65	10	0	0	25	100	0	0	0	0	0	0	0
	3	Pabedan	0.76	76	4	19	0	1	100	0	0	0	0	0	0	0
	4	Kyauktada	0.71	88	11	0	0	0	99	0	0	0	0	0	0	0
	5	Botahtaung	2.38	64	15	0	8	2	89	9	0	1	0	0	0	10
	6	Pazuntaung	1.01	78	3	0	8	0	89	10	0	0	0	0	1	11
	7	Ahlon	2.69	62	5	0	20	3	90	0	0	0	9	0	1	10
	8	Kyimyindine	10.77	44	0	0	4	3	51	0	0	45	2	0	1	48
	9	Sangyoung	2.47	92	0	0	0	7	99	0	0	0	1	0	0	1
	10	Dagon	11.65	48	4	0	0	3	55	0	2	0	41	3	0	46
	11	Bahan	8.84	79	1	0	1	1	82	1	0	0	6	5	6	18
	12	Tamway	4.79	71	0	0	0	17	88	0	4	1	3	2	1	11
	13	Mingala Taungnyunt	5.06	53	0	3	13	14	83	1	3	0	2	8	3	17
	14	Seikkan	0.13	3	9	0	50	0	62	9	0	0	0	0	30	39
Zone 9	29	Hlaing Tharyar	67.33	22	0	0	19	1	42	24	2	19	3	1	8	57
Average			-	60	4	1	8	8	82	4	1	4	4	1	3	18

Source: 2013 JICA-HIS

11.2.3 Status of Sanitation and Hygiene

Following Table shows the existing status of sewage treatment in Yangon City. The population covered with sewerage system is only 7.3 % of the entire population, and more than 90 % of the population depends on individual treatment system.

Table 11-4 Status of Sewage Treatment in Yangon City

Treatment facility	Percentage of population (%)
Sewerage system	7.3
Septic tank	18.4
Pour-flush toilet	28.0
Fly-prevention toilet	18.0
Unsanitary toilet	28.0
No toilet	0.3

Source: Water Supply Improvement Project Study for Yangon City and Pathein City, 2014

Following Table shows the number of patients suffering from waterborne diseases and mortality rate in Yangon District. Number of deaths are much lower compared to number of patients but exist in case of each disease. Some residents, excluding those receiving piped water supply, have been using water that is not subjected to appropriate water quality controls as drinking water, and these residents are exposed to the risk of waterborne infectious disease.

Table 11-5 Number of Patients Suffering from Waterborne Diseases and Mortality Rate in Yangon District

Sickness	2007		2008		2009		2010		2011	
	No. of patients	No. of deaths	No. of patients	No. of deaths	No. of patients	No. of deaths	No. of patients	No. of deaths	No. of patients	No. of deaths
Cholera	4	0	49	0	191	7	22	1	37	0
Diarrhea	17,322	7	17,462	9	13,166	10	11,851	2	10,969	4
Dysentery	8,507	0	9,489	0	6,135	0	6,361	0	4,436	0
Food poisoning	244	7	259	3	435	7	255	0	395	0
Typhoid & Para typhoid	103	1	71	1	55	0	98	0	47	0
Viral hepatitis	188	6	251	1	14	4	271	3	205	2

Source: Water Supply Improvement Project Study for Yangon City and Pathein City, 2014

Following Table shows death rate during child birth, number of hospitals, and number of doctors by townships. Average of death rate during child birth in the townships of Zones 1 and 9 is 7.1, and it is much lower than the corresponding value of 41 in case of whole of Myanmar and 16 in case of whole of world according to the WHO statistic value.

On the other hand, number of hospitals and doctors are extremely low. Number of hospital is greater than the number of doctors due to multiple jobs by poorly paid doctor in public hospital.

Table 11-6 Death Rate During Child Birth, Number of Hospitals, and Number of Doctors by Townships

Zone	No.	Town Ship	Death Rate During Child Birth per 1000	No. of Hospitals per 1000	No. of Doctors per 1000
Zone 1	1	Latha	5	0.91	0.03
	2	Lanmadaw	5	1.9	0.09
	3	Pabedan	6	2.13	0.08
	4	Kyauktada	5	1.21	2.56
	5	Botahtaung	8	0.77	0.1
	6	Pazuntaung	8	0.89	1.6
	7	Ahlon	9	0.67	0.05
	8	Kyimyindine	10	0.59	0.85
	9	Sangyoung	0.1	1.02	0.04
	10	Dagon	7	0.65	0.04
	11	Bahan	3	0.43	0.03
	12	Tamway	5	0.72	0.62
	13	Mingala Taungnyunt	9	0.55	0.04
	14	Seikkan	20	0.45	0.89
Zone 9	29	Hlaing Tharyar	6	0.01	0.02
Average			7.1	0.9	0.5

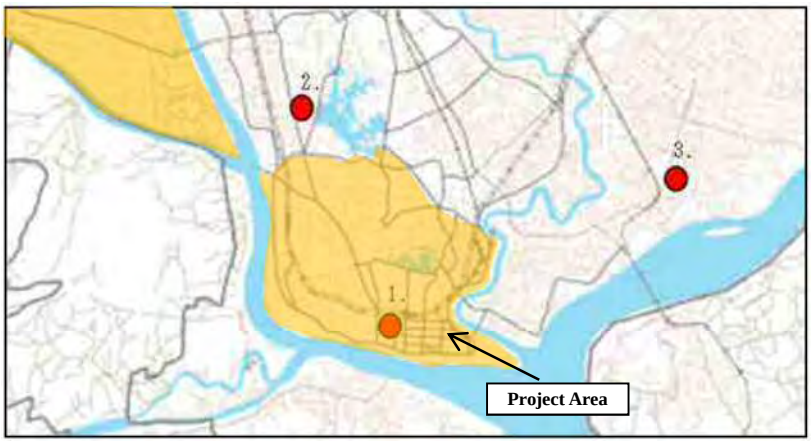
Source：2013 JICA-HIS

11.2.4 Air Quality

Periodic observation of air quality has not been conducted in Yangon City but spot observation was conducted in April 2007 and January 2008 by YCDC. Observed values of TSP and PM_{10} is over the recommended limit in WHO standard.

Environmental Conservation Department is newly created by MoNREC as the organization responsible for establishment of environmental standard, but specific environmental standard for air quality has not been established yet in Myanmar.

Until the domestic environmental standard is established in Myanmar, appropriate management of construction equipment, idling stop, and muffler installation shall be executed during construction period following WHO environmental standards.



Source：2014 JICA Water MP

Figure 11-2 Location of Spot Observation for Air Quality

Table 11-7 Result of Spot Observation for Air Quality

Site	Observational Month	TSP ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	NO_2 ($\mu g/m^3$)
1. Commercial site (Traders Hotel)	April, 2007	342.58	177.69	-	-
	Jan., 2008	143.21	71.75	-	-
2. Residential site (IBC)	April, 2007	168.61	68.59	1.14	23.22
	Jan., 2008	118.70	65.3	1.24	22.28
3. Surrounding site near to industrial zone (Forest Department Head Quarter)	April, 2007	127.37	66.95	0.37	28.36
	Jan., 2008	188.66	136.92	0.25	25.42
WHO Standard		100	50	20	40

Source：2014 JICA Water MP

11.2.5 Water Quality and Adaptation to Climate Change

1) Water Quality

Discharges of process wastewater from utility operations to surface water should not result in contaminant concentrations in excess of local ambient water quality criteria or, in the absence of local criteria, other sources of ambient water quality, like EHS guideline standard as shown below.

Table 11-8 Water Quality Guidelines Value as per EHS Guidelines

Pollutant	Guideline Value (mg/l)
pH	6-9
BOD	30
COD	125
Total nitrogen	10
Total phosphorus	2
Oil and grease	10
Total Suspended solids	50
Total coliform bacteria	400 MPN/ 100ml
Acrolein, Aldrin, alpha-Endosulfan, Aluminum, Arsenicbeta-Endosulfan, Carbaryl Cadmium, Chlordane, Chloride, Chlorine, Chloropyrifos, Chromium (III), Chromium (VI), Cyanide, Diazinon Dieldrin, Endrin, gamma-BHC, 4,4'-DDT, Heptachlor, Heptachlor Epoxide, Lead, Mercury, Methylmercury, Nickel, Parathion Pentachlorophenol, Silver, Toxaphene, Tributyltin, Zinc	Ultra-low level

Source：EHS Guidelines 2007, World Bank Group

2) Adaptation to climate change

In general, the impact of climate change on water supply sector is adverse in terms of water volume and quality due to decrease in rainfall amount and concentrated heavy rain, respectively. Therefore, it could lead to the destabilization of water supply project.

In terms of water volume, according to 2012 JICA Water MP, the probable lowest flow amount of Kokkowa River for ten years is approximately 20,000 MGD, and available intake amount is estimated as 10,000 MGD. On the other hand, the intake facility is designed with intake capacity of 140 MGD, which is equal to 1.4 % of available intake amount in this study.

In terms of water quality, while the turbidity of raw water is expected to instantaneously exceed 1,000 NTU for several hours after concentrated heavy rain, the facilities planning is carried out considering increase in coagulant amount in sedimentation basin and maintenance of 12 to 48 hours retention time in pre-sedimentation pond in such cases.

Based on the above description, the vulnerability of water sources in this project to climate change is not expected due to considerably large amount of river flow and low proportion of intake amount and high capacity design of the facilities for inflow of high turbidity raw water. Therefore, the project is considered to possess sufficient adaptability to climate change.

11.2.6 Waste Disposal

Specific environmental standard value for waste disposal such as sludge and construction waste has not been established in Myanmar and EHS standard. Waste control is managed by Department of Pollution Control and Cleansing in YCDC based on the Pollution Control and Cleansing Rules 2001. There are two final disposal sites and five interim disposal sites in Yangon City that accept disposal of solid wastes on twenty-four hour basis using open dumping method.

Excavation soil and excess sludge will be generated during construction and operation period. It will be disposed at existing disposal site as construction waste and general waste, respectively.

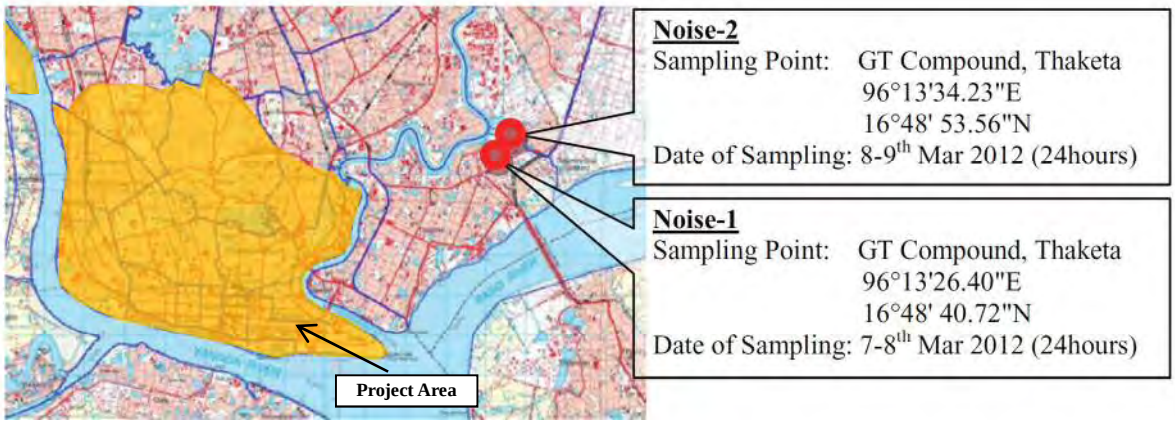
Source：2014 JICA Water MP

Figure 11-3 Location of Disposal Site in Yangon City

11.2.7 Noise

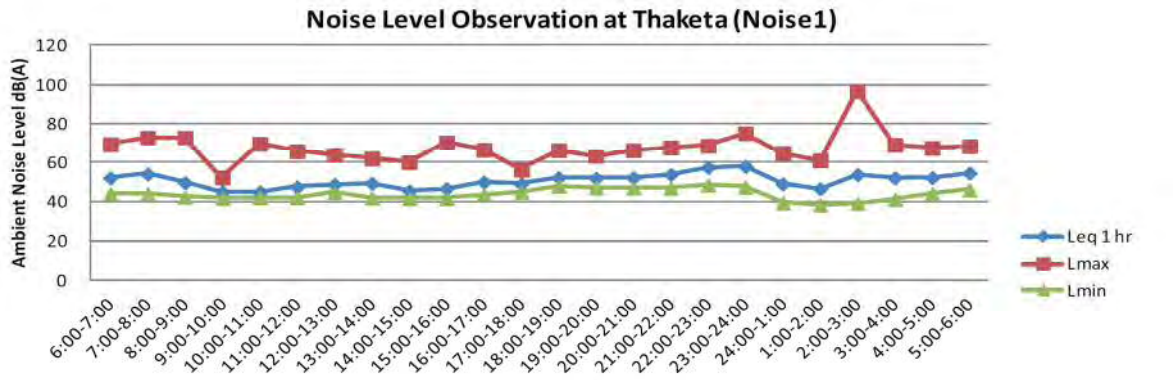
There is no typical data showing the noise assessment in the project area. However, the noise level were measured at the two locations in eastern part of Yangon City, the area adjacent to project area, during 2013-JICA Urban Development Plan. The survey area is located in a residential area that has limited traffic. The noise levels were recorded for 24 hours in March 2012. Figure 11-5 and 11-6 show the result of noise level observation at sampling point Noise-1 and Noise-2, respectively as the general information about the noise assessment. The L_{eq} 1hr values varied in the range of 45.06 – 58.16 dB and 42.88 – 54.53 dB at Noise-1 and Noise-2, respectively. The L_{eq} 24hr values were 50.81 dB and 49.25 dB, respectively.

As there is no available noise level standard established in Myanmar yet, referring to the WHO guideline value, the L_{eq} 24hr values at the two locations are not different compared to the values indicated in WHO guideline for outdoor living area, i.e., 50 or 55 dB.



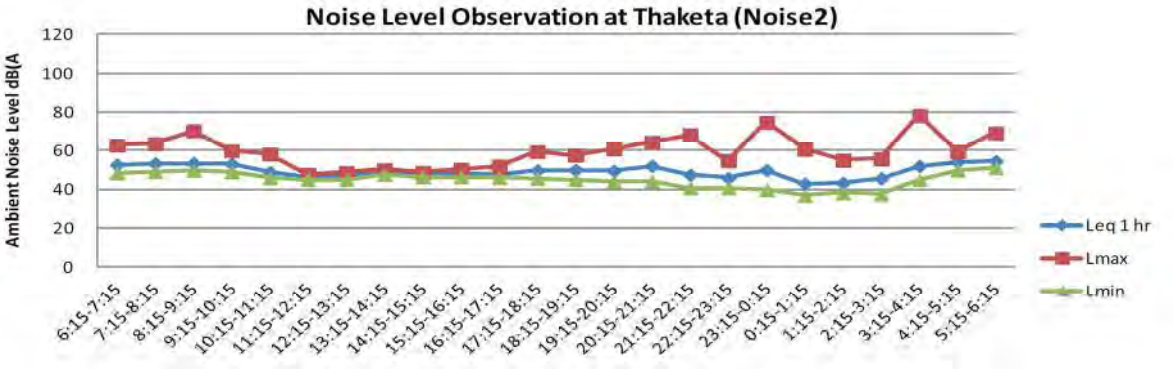
Source : 2013-JICA Urban Development Plan

Figure 11-4 Location of Noise Level Samples



Source : 2013-JICA Urban Development Plan

Figure 11-5 Noise Level Observation (Noise-1, Measurement Date: 7-8th March, 2012)



Source : 2013-JICA Urban Development Plan

Figure 11-6 Noise Level Observation (Noise-2, Measurement Date: 8-9th March, 2012)

Table 11-9 Noise Levels as per WHO Guidelines

Specific Environment	Critical Health Effect	L_{Aeq} (dB)	L_{Amax} (dB)
Outdoor living area	Serious annoyance	55	-
	Moderate annoyance	50	-

Source: WHO Guideline for specific noise

As mentioned in Chapter 7, low-noise and low-vibration method will be planned considering mitigation of noise and vibration not to affect the adjacent pagodas and houses.

11.2.8 Ground Settlement

The ground settlement by overuse of ground water and own weight of facilities will not occur by this project with surface water intake and pile foundation.

On the other hand, settlement will start immediately after the landfill in the construction site of water treatment plant, because excavated soil is mainly clay. However, slow banking method will be adopted and the small settlement amount is estimated. Therefore, the ground settlement will not affect the adverse impact to the surrounding environment.

11.2.9 Cultural Heritage

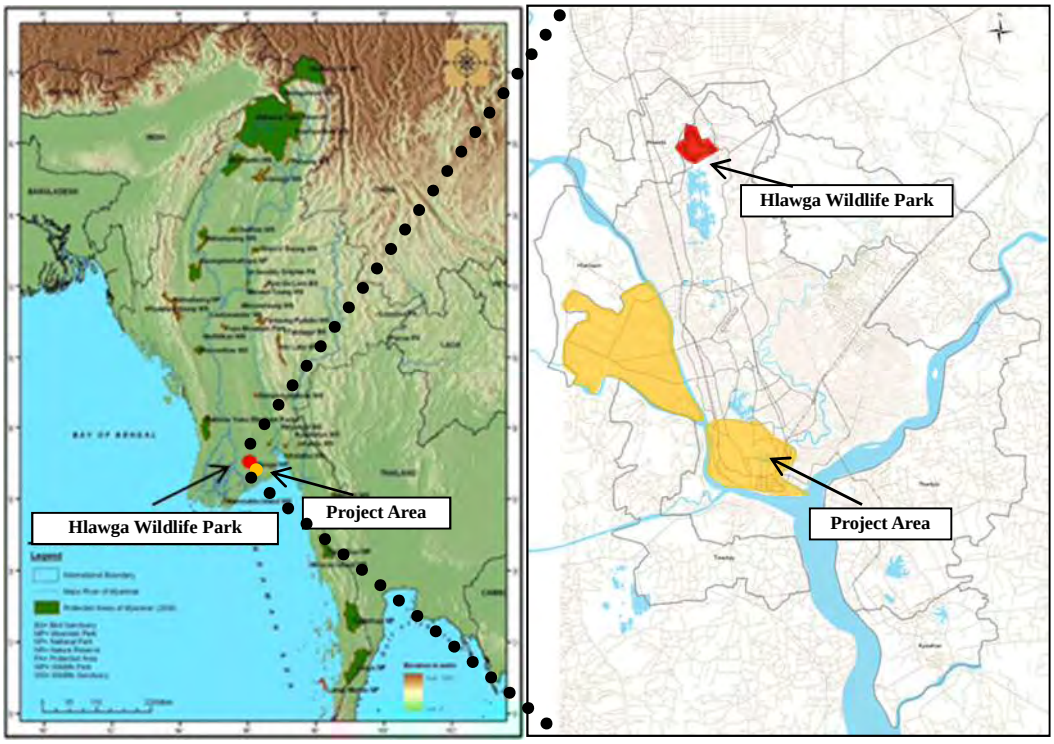
189 buildings which were constructed before 1950 are registered as cultural heritage buildings by YCDC in 1996. Most of the heritage buildings are located in the southern part of the Yangon City. There are no cultural heritage building in the proposed construction site and project affected area.

11.2.10 Ecosystem

There are 153 endangered species including mammal, bird, reptile, invertebrate, and plant in Yangon City, but not in the proposed construction site and project affected area.

11.2.11 Protected area

The protected areas of Myanmar (wildlife park, wildlife sanctuary, bird sanctuary, etc.) are shown in the following Figure. The protected area is located in Hlawga Wildlife Park. The Hlawga Wildlife Park is located the north of Yangon There is no protected area in the proposed construction site and project affected area (see the Figure below).



Source: 2014 JICA Water MP

Figure 11-7 Protected Area

11.2.12 Ethnic Minority

Following Table shows township-wise proportion of ethnic group population composition. The ethnic groups in others category include Kachin, Kayar, Mon, Shan, and Foreign nationals. The proportion of others is much high in some part of CBD area in Latha, Lanmadaw, and Pabedan. On the other hand, Barmar is in majority ethnic group in most township.

There is no traditional settlement of indigenous ethnic minority groups mentioned in World Bank OP 4.10 at the proposed construction site and project affected area.

Table 11-10 Proportion of Ethnic Composition by Townships

Zone	No.	Town Ship	Barmar	Karin	Rakhine	Others
Zone 1	1	Latha	24.2	0.5	2.0	73.3
	2	Lanmadaw	61.7	0.9	2.7	34.7
	3	Pabedan	31.6	2.0	1.0	65.4
	4	Kyauktada	73.7	1.5	1.8	23.0
	5	Botahtaung	72.4	2.5	1.9	23.2
	6	Pazuntaung	81.1	1.9	1.1	15.9
	7	Ahlon	78.0	1.3	6.0	14.7
	8	Kyimyindine	97.0	0.7	2.1	0.2
	9	Sangyoung	84.3	1.7	1.4	12.6
	10	Dagon	64.5	1.1	2.9	31.5
	11	Bahan	88.4	3.4	2.5	5.7
	12	Tamway	80.0	4.1	1.1	14.8
	13	Mingala Taungnyunt	93.1	1.5	0.9	4.5
	14	Seikkan	95.0	3.4	0.4	1.2
Zone 9	29	Hlaing Tharyar	92.9	1.4	1.6	4.1
Average			74.5	1.9	2.0	21.7

Source：2013 JICA-HIS

11.2.13 HIV Prevention Measurement

HIV infection spread is a serious problem that needs immediate attention in Myanmar. Principal route of HIV infection is unprotected sexual contact in sex industries and drug injection using contaminated needles. According to the UNAIDS report "AIDS Epidemic Update 2004" and "2014 JICA Phase-I FS", HIV infection rate is 1.2 % in case of whole Myanmar and 0.55 % in Yangon Region in 2005. The rate in Yangon Region is reported to be decreasing to 0.25 % in 2010 and 0.15 % in 2011.

HIV prevention measures shall be followed during construction period and this is proposed to be stipulated in the tender document prior to the contract with the construction contractor.

The proposed basic program which is generally stipulated in the tender document includes: 1) promotion of condom use, 2) test and treatment of sexually transmitted infection, 3) HIV education through peer education, and 4) volunteer counseling and testing. The tender document also stipulates the service provider which means a person or entity approved by the employer of the project and the National HIV authority to provide the HIV awareness prevention program.

11.2.14 Encouragement of Gender and Handicapped Person Equality

The project will contribute to the encouragement of gender and handicapped person equality and be managed with gender consideration as described below.

1) Reduction in Hardship of Women and Handicapped Person Life

The project will improve the capacity, reliability, and efficiency of the existing water supply systems with better quality and services by providing direct and indirect gender benefits to large numbers of women.

Outside of YCDC water supply area, drinking water is generally delivered by venders in 20 L bottle and water for other purposes is obtained from well or storage reservoir. The housewife is generally obliged to engage in the work of fetching water required for daily activities such as bathing, cleaning (excluding drinking water), which usually takes few dozen minutes per day. It consumes significant time of daily life and causes mental and physical hardship on women.

Therefore, as a primary user and manager of water in the households, women and handicapped person will benefit from the convenience and availability of water for daily needs, reduced physical labor and drudgery, time savings in water collection and improved family health which ultimately reduces poverty by use of YCDC piped water supply.

2) Women Placement Program

Women's social advancement have been promoted in Myanmar and appropriate occupational choice is fully recognized except for some specialty work such as laborer in coalmine, front line work in armed force, and Buddhist monk in religious group, etc.

The project creates employment opportunities for women as listed below.

- Promote the creation of job and livelihood opportunities for women during construction phase of project.
- Create employment opportunities for interested women during operation and maintenance.
- Provide training in administrative procedures and relevant skill development opportunities for female members.

3) Project Management with Gender Consideration

The project shall be managed with gender consideration as listed below.

- Separate toilets for women and men labors at construction sites as necessary
- Provide awareness rising sessions on HIV and sexual harassment and women's safety for contractors and construction workers
- Employment of the female staff for water quality management
- Carry out public education for health, hygiene and behavior change

11.3 Legal Framework for Environmental and Social Considerations

(1) Regulation and Law for Environmental and Social Considerations

Environmental Conservation Law (2012) and Environmental Conservation Rules (2014) have been instituted as regulation and law for environmental and social considerations in Myanmar.

- Environmental Conservation Law (2012)

  Environmental Conservation Law have been instituted by MoNREC in March 2012. It is the fundamental law for environmental conservation and the contents of this Law is shown below.

Chapter		Sections
1	Title and Definition	1-2
2	Objectives	3
3	Formation of the Environmental Conservation Committee	4-6
4	Duties and Powers relating to the Environmental Conservation of the Ministry	7-8
5	Environmental Emergency	9
6	Environmental Quality Standard	10-12
7	Environmental Conservation	13-16
8	Management of Urban Environment	17
9	Conservation of Natural Resources and Cultural Heritages	18-20
10	Prior Permission	21-25
11	Insurance	26-27
12	Prohibitions	28-30
13	Offences and Penalties	31-34
14	Miscellaneous	35-42

- Environmental Conservation Rules (2014)

  Environmental Conservation Rules have been instituted by MoNREC in April 2014. It is the fundamental law for conservation of cultural heritage and protected area, and the contents of this Law is shown below.

Chapter		Sections
1	Title and Definition	1-2
2	Adaptation Policy Relating to Environmental Conservation	3-6
3	Environmental Conservation	7-26
4	International, Regional and Bi-lateral Cooperation Relating to Environmental Conservation	27-28
5	Environmental Management Fund	29-35
6	Environmental Emergency	36-37
7	Environmental Quality Standards	38-39
8	Management of Urban Environment	40
9	Waste Management	41-46
10	Conservation of Natural Resources and Cultural Heritages	47-50
11	Environmental Impact Assessment	51-61
12	Prior Permission	62-68
13	Prohibitions	69
14	Miscellaneous	70-74

In the Environmental Conservation Rules, the basic policy for the project development is mentioned as below.

- EIA report including environmental management plan shall be submitted to MoNREC.
- Environmental management plan shall be executed within a specified period and implementation status be reported to MoNREC.

(2) Approval Procedure for Environmental Impact Assessment

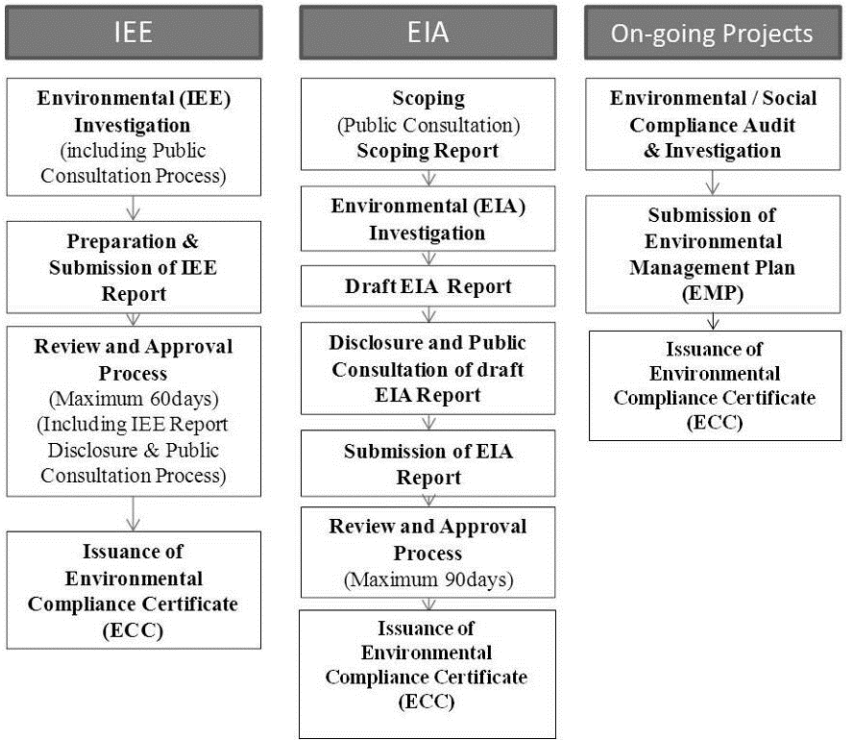
As there is rapid progress of infrastructure development in recent years, and realization of improvement of environmental impact assessment (EIA) procedure, the EIA procedure has been approved in Cabinet Office, and published in January 2016. The EIA Procedure includes the screening, public consultation, and monitoring as listed below.

Chapter		Sections
1	Title and Definition	1-5
2	Establishment of Environmental Impact Assessment Process	5-10
3	Screening	10-12
4	Initial Environmental Examination	12-14
5	Environmental Impact Assessment	15-22
6	Appeal Process	22-23
7	Environmental Management Plan	23
8	Environmental Consideration in Project Approval	24-28
9	Monitoring	28-31
10	Administrative Punishment	31-32
Annex 1	Categorization of Economic Activities for Assessment Purposes	
Annex 2	Environmental Assessment Procedure Flowchart.	
Annex 3	Prescribed Penalties Under Procedure	

Outline of the EIA Procedure is described below.

- The EIA shall be executed for the project with negative effect on the project area and Environmental Compliance Certificate (ECC) be acquired.
- Response to resettlement issue is not mentioned in the EIA procedure. Therefore these issues shall be responded following the policy and guidelines published by other international organization.
- Environmental management plan shall be executed within a specified period even for on-going project before the development of the EIA procedure.

Required process and schedule for IEE, EIA, and on-going project are mentioned in the EIA procedure as given below.



Source: The EIA Procedure (2016)

Figure 11-8 Required Process and Date for IEE, EIA and On-going Project

Projects which require IEE/EIA practice is categorized into 142 type of economic activities in EIA procedure. However, water supply project aiming groundwater development is only subjected to IEE/EIA procedure and project with surface water intake is not included in the list of project requiring IEE/EIA procedure.

Table 11-11 Required IEE/EIA Procedure for Water Supply Project

Water Supply			
No.	Type of Economic Activity	Criteria for IEE Type Economic Activities	Criteria for EIA Type Economic Activities
111	Groundwater Development for Industrial, Agricultural or Urban Water Supply	< 4,500 m^3/day	≧4,500 m^3/day

(3) Other Regulation and Law

The following regulation and law also covers a part of environmental and social considerations.

- The Water Power Act 1927 (Burma Act 11, 1927)
- The Underground Water Act (1930)
- Public Health Law (1972)
- Territorial Sea and Maritime Zone Law (1977)
- Irrigation Laws and Regulations (1982)
- Law on Aquaculture (1989)
- Marine Fisheries Law (1990)
- The Forest Law (1992)
- The Protection of Preservation of Cultural Heritage Region Law (1994)
- The Protection of Wildlife, Wild Plant and Conservation of Natural Area Law (1994)
- National Environmental Policy (1994)
- Mines Law (1994)
- Myanmar Agenda 21 (1997)
- The Conservation of Water Resources and River Law (2006)
- National Sustainable Development Strategy NSDS (2009)
- Myanmar Investment Law (2011)
- Farmland Law (2012)
- Farmland Rules (2012)
- Vacant, Fallow and Virgin Lands Management Law (2012)
- Vacant, Fallow and Virgin Lands Management Rules (2012)
- Myanmar Investment Rule (2013)
- Investment Notification (2013)
- The Standard Performance and Specification Law (2014)

11.4 Assessment of Alternatives

(1) With/Without Project

Refer to the Section 10.2 (3) in the Chapter 10.

(2) Alternatives of WTP site

Refer to the Section 4.1.4 in the Chapter 4.

(3) Alternatives of Transmission Pipeline Route

Since Route 5 is the only road connecting the locations of WTP and Zone 9 SR and Hlaing River, there are no alternatives for the alignment of transmission pipeline.

11.5 Scoping of Environmental and Social Impact

In order to identify the issues that are likely to be of great importance during EIA and eliminate those that are of little concern, scoping was carried out. Following Table shows the matrix of the potential project impacts, rating, description, survey item, and TOR.

Table 11-12 Scoping of Environmental Impacts

Category	Item	Rating		Description	Survey Item	TOR
		P/C	O			
Pollution	Air Quality	B-	D	P/C: Some negative impacts on air quality are expected due to operation of heavy equipment/vehicles. O: Expected impacts will be temporary only during the construction stage.	・Air quality standard ・Review of expected impacts during construction period	・Literature search, interview survey with related organization ・Data collection of construction method and equipment
	Water Quality	D	D	The impact is negligible.	-	-
	Waste Disposal	B-	B-	P/C: Construction works will generate excavated soil. O: Improper management of sludge could contaminate soil and surface/underground water.	・Legal framework of waste disposal ・Disposal method in existing waste disposal site ・Current condition of existing waste disposal site	・Literature search, interview survey with related organization
	Noise	B-	D	P/C: Temporary impacts of noise due to operation of heavy equipment and vehicles during construction are expected. O: Negative impact of noise due to operation of pump and generator will be reduced by sound proof wall and physical isolation from boundary.	・Environmental standard for noise regulation ・Review of expected impacts during construction period	・Literature search, interview survey with related organization ・Data collection of construction method and equipment
	Ground Settlement	D	D	The risk of ground settlement in the planned construction site will be closely examined by geotechnical survey during this study.	-	-
Natural Environment	Protected Area	D	D	There is no protected area around the project site.	-	-
	Ecosystem	D	D	There is no endangered species around project area.	-	-
	Hydrometeor	D	D	Negative impact is not expected due to the big amount of river flow and low proportion of intake amount on flow amount.	-	-
Social Environment	Involuntary Resettlement	B-	D	There are 7 involuntary resettlements in the proposed construction site along national road.	/Confirmation of current situation of illegal occupation	・Site Survey
	Local Economy	D	D	Negative impact is not expected.	-	-
	Cultural Heritage	D	D	No cultural heritage is located in/near the project site.	-	-
	Landscape	D	D	The impact is negligible.	-	-
	Ethnic Minority	D	D	No ethnic minority groups live around the project site.	-	-
	Hazards	B-	D	Increase in risks of hazard is probably expected among the construction workforce.	・Work safety measurement	・Similar case examination

A+/-: Significant positive/negative impact is expected.
B+/-: Positive/negative impact is expected to some extent.
C+/-: Extent of positive/negative impact is unknown.
(A further examination is needed, and the impact could be clarified as the study progresses)
D: No impact is expected.
P/C: Planning/Construction
O: Operation
Source：JICA Study Team

11.5.1 Mitigation Measures for Potential Project Impact

Following Table shows matrix of mitigation measures, responsible organization, and financial source.

Table 11-13 Mitigation Measures for Potential Project Impact

Category	Item	Rating		Description	Mitigation Measures	Responsible Organization	Financial Source
		P/C	O				
Pollution	Air Quality	B-	D	P/C: Some negative impacts on air quality are expected due to operation of heavy equipment/vehicles. O: Expected impacts will be temporary only during the construction stage.	Vehicles shall be covered tightly when transporting construction materials. Spray water to reduce dust in the construction site during the dry season. Idling stop, muffler installation shall be executed in construction period	Contractor, YCDC	Contract amount with contractor
	Waste Disposal	B-	B-	P/C: Construction works will generate excavated soil. O: Improper management of sludge could contaminate soil and surface/underground water.	Excavated soil and sludge will be disposed in existing disposal site as construction waste and general waste, respectively.	Contractor, YCDC	Contract amount with contractor
	Noise	B-	D	P/C: Temporary impacts of noise due to operation of heavy equipment and vehicles during construction are expected. O: Negative impact of noise due to operation of pump and generator will be reduced by sound proof wall and physical isolation from boundary.	Construction noise shall be reduced to the regulation value of WHO standard by the appropriate management of construction equipment/vehicles. Construction plan, period, negative effect shall be opened to the residents in the construction period.	Contractor, YCDC	Contract amount with contractor
Social Environment	Involuntary Resettlement	B-	D	There are 7 involuntary resettlements in the proposed construction site along national road.	Resettlement action plan shall be prepared following JICA guideline. Enough compensation and support shall be given to the target household.	YCDC	Yen loan amount
	Hazards	B-	D	Increase in risks of hazard is probably expected among the construction period.	Provide protective equipment and uniform to workers including masks, gloves and boots by contractor. Regular monitoring of construction site and safety education shall be executed by contractor.	Contractor, YCDC	Contract amount with contractor

A+/-: Significant positive/negative impact is expected.
B+/-: Positive/negative impact is expected to some extent.
C+/-: Extent of positive/negative impact is unknown.
(A further examination is needed, and the impact could be clarified as the study progresses)
D: No impact is expected.
P/C: Planning/Construction
O: Operation
Source: JICA Study Team

11.5.2 Environmental Monitoring Plan

Following Table shows environmental monitoring plan including monitoring item, point, frequency, and responsible organization.

Table 11-14 Environmental Monitoring Plan

Item	Monitoring Item	Monitoring Point	Frequency	Responsible Organization	Financial Source
Air Quality	PM_{10}, TSP, CO, NOx, SOx	Construction site	Monthly	Contractor、YCDC	Contract amount with contractor
Waste Disposal	Construction waste, Sludge waste	Construction site	Monthly	Contractor、YCDC	Contract amount with contractor
Noise	Noise volume	Construction site	Monthly	Contractor、YCDC	Contract amount with contractor
Involuntary Resettlement	Resettlement state	Transmission Pipeline Route	Resettlement period	YCDC	Yen loan amount
Hazards	Protective equipment use, presence of dangerous work, observance of traffic regulations	Construction site	Monthly and as needed by the designated security chief	Contractor、YCDC	Contract amount with contractor

Source：JICA Study Team

The following monitoring form will be used for the environmental monitoring.

The latest result of the below items shall be submitted to the lenders as part of Quarterly Progress Report throughout the construction phase.

Monitoring Form

1. Response/Actions to Comments and Guidance from Government Authorities and the Public

Monitoring Item	Monitoring Results
Number and contents of formal comments made by the public	
Number and contents of responses from Government agencies	

2. Pollution

Air Quality (Ambient Air Quality)

Item	Unit	Measured Value (Mean)	Measured Value (Max)	Referred International Standards	Measurement Point	Frequency
PM10						
TSP						
CO						
NOx						
SOx						

Garbage

Item	Unit	Measured Value (Mean)	Measured Value (Max)	Referred International Standards
Construction garbage amount				
Sludge amount				

3. Natural Environment

Noise

Item	Unit	Measured Value (Mean)	Measured Value (Max)	Referred International Standards
Noise level				

4. Social Environment

Working Condition

Monitoring Item	Monitoring Results
Safety gear use, Workplace hazards, Compliance of traffic law	

11.5.3 Environmental Check List

Following Table show the environmental check list for this study.

Table 11-15 Environmental Check List for This Study

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
1 Permits and Explanation	(1) EIA and Environmental Permits	(a) Have EIA reports been already prepared in official process? (b) Have EIA reports been approved by authorities of the host country's government? (c) Have EIA reports been unconditionally approved? If conditions are imposed on the approval of EIA reports, are the conditions satisfied? (d) In addition to the above approvals, have other required environmental permits been obtained from the appropriate regulatory authorities of the host country's government?	(a) - (b) - (c) - (d) -	(a) While the water supply project with surface water is not subject for EIA procedure in Myanmar, environmental and social consideration survey was carried out in this survey. (b) － (c) － (d) －
	(2) Explanation to the Local Stakeholders	(a) Have contents of the project and the potential impacts been adequately explained to the Local stakeholders based on appropriate procedures, including information disclosure? Is understanding obtained from the Local stakeholders? (b) Have the comment from the stakeholders (such as local residents) been reflected to the project design?	(a) Y (b) Y	(a) SHM and Social and economic interview were conducted in this study (Refer to Section 11.8).. (b) The same as.(a)
	(3) Examination of Alternatives	(a) Have alternative plans of the project been examined with social and environmental considerations?	(a) Y	(a) Assessment of alternative plans for transmission pipeline was conducted, and the pipeline laying under the secured public land next to the right of way is recommended with social and environmental considerations.
2 Pollution Control	(1) Air Quality	(a) Is there a possibility that chlorine from chlorine storage facilities and chlorine injection facilities will cause air pollution? Are any mitigating measures taken? (b) Do chlorine concentrations within the working environments comply with the country's occupational health and safety standards?	(a) N (b) Y	(a) Due to prevention of leakage accident of chlorination agents, liquid hypochlorite is recommended as safest agent with simple devices. In addition, construction of barrier is proposed to prevent overflow. (b) Health and safety standards for working environments have not been enacted in Myanmar. Safety measures with safety gear and enough air ventilation is recommended following ILO standards.
	(2) Water Quality	(a) Do pollutants, such as SS, BOD, COD contained in effluents discharged by the facility operations comply with the country's effluent standards?	(a) Y	(a) Effluent standards have not been enacted in Myanmar and high concentration of contaminants is not expected in water treatment plant.
	(3) Wastes	(a) Are wastes, such as sludge generated by the facility operations properly treated and disposed in accordance with the country's regulations?	(a) Y	(a) Regulations for waste disposal have not been enacted in Myanmar. Excavation soil and excess sludge will be disposed in existing disposal site.
	(4) Noise and Vibration	(a) Do noise and vibrations generated from the facilities, such as pumping stations comply with the country's standards?	(a) Y	(a) Standards for noise and vibrations have not been enacted in Myanmar. Noise and vibrations in construction phase will be controlled by management of construction equipment/vehicles following WHO standard.
	(5)	(a) In the case of extraction of a large volume of	(a) N	(a) Extraction of a large volume of ground

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
	Subsidence	groundwater, is there a possibility that the extraction of groundwater will cause subsidence?		water is not expected in this project.
3 Natural Environment	(1) Protected Areas	(a) Is the project site or discharge area located in protected areas designated by the country's laws or international treaties and conventions? Is there a possibility that the project will affect the protected areas?	(a) N	(a) There is no protected area in project site.
3 Natural Environment	(2) Ecosystem	(a) Does the project site encompass primeval forests, tropical rain forests, ecologically valuable habitats (e.g., coral reefs, mangroves, or tidal flats)? (b) Does the project site or discharge area encompass the protected habitats of endangered species designated by the country's laws or international treaties and conventions? (c) If significant ecological impacts are anticipated, are adequate protection measures taken to reduce the impacts on the ecosystem? (d) Is there a possibility that the amount of water used (e.g., surface water, groundwater) by project will adversely affect aquatic environments, such as rivers? Are adequate measures taken to reduce the impacts on aquatic environments, such as aquatic organisms?	(a) N (b) N (c) N (d) N	(a) There is no primeval forests, tropical rain forests, ecologically valuable habitats in project site. (b)There is no endangered species in project site. (c) Significant ecological impacts are not anticipated in project site. (d) There is no adverse effect to aquatic environment by low amount of water used.
	(3) Hydrology	(a) Is there a possibility that the amount of water used (e.g., surface water, groundwater) by the project will adversely affect surface water and groundwater flows?	(a) N	(a) There is no adverse effect to surface water and ground water flows by low amount of water used.
4 Social Environment	(1) Resettlement	(a) Is involuntary resettlement caused by project implementation? If involuntary resettlement is caused, are efforts made to minimize the impacts caused by the resettlement? (b) Is adequate explanation on compensation and resettlement assistance given to affected people prior to resettlement? (c) Is the resettlement plan, including compensation with full replacement costs, restoration of livelihoods and living standards developed based on socioeconomic studies on resettlement? (d) Is the compensations going to be paid prior to the resettlement? (e) Is the compensation policies prepared in document? (f) Does the resettlement plan pay particular attention to vulnerable groups or people, including women, children, the elderly, people below the poverty line, ethnic minorities, and indigenous peoples? (g) Are agreements with the affected people obtained prior to resettlement? (h) Is the organizational framework established to properly implement resettlement? Are the capacity and budget secured to implement the plan? (i) Are any plans developed to monitor the impacts of resettlement? (j) Is the grievance redress mechanism established?	(a) Y (b) Y (c) Y (d) Y (e) Y (f) Y (g) Y (h) Y (i) Y (j) Y	(a) To minimize the impact caused by the resettlement, assessment of alternative of transmission pipeline was conducted. (b) Social and economic interview were conducted in this study (Refer to Sub-section 11.8.2). (c) Socioeconomic study will be conducted on May 2016. (d) It will be paid prior to the resettlement. (e) Resettlement policy framework with compensation policy have been already prepared. (f) Resettlement policy framework pay particular attention to vulnerable groups. (g) Social and economic interview were conducted in this study (Refer to Sub-section 11.8.2). (h) Engineering Department (Water & Sanitation) in YCDC will be responsible organization and secure the capacity and budget. (i) Monitoring will be carried out on resettlement period. (j) Redress mechanism will be established following resettlement policy framework.

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
4 Social Environment	(2) Living and Livelihood	(a) Is there a possibility that the project will adversely affect the living conditions of inhabitants? Are adequate measures considered to reduce the impacts, if necessary? (b) Is there a possibility that the amount of water used (e.g., surface water, groundwater) by the project will adversely affect the existing water uses and water area uses?	(a) Y (b) N	(a) Adequate measures is considered by compensation and income restoration program. (b) Adversely effect to the existing water uses is not expected by this project.
	(3) Heritage	(a) Is there a possibility that the project will damage the local archeological, historical, cultural, and religious heritage? Are adequate measures considered to protect these sites in accordance with the country's laws?	(a) N	(a) There is no heritage in project site.
	(4) Landscape	(a) Is there a possibility that the project will adversely affect the local landscape? Are necessary measures taken?	(a) N	(a) There is no adverse effect to local landscape.
	(5) Ethnic Minorities and Indigenous Peoples	(a) Are considerations given to reduce impacts on the culture and lifestyle of ethnic minorities and indigenous peoples? (b) Are all of the rights of ethnic minorities and indigenous peoples in relation to land and resources respected?	(a) N (b) N	(a) There is no ethnic minorities and indigenous peoples in the project site. (b) There is no ethnic minorities and indigenous peoples in the project site.
	(6) Working Conditions	(a) Is the project proponent not violating any laws and ordinances associated with the working conditions of the country which the project proponent should observe in the project? (b) Are tangible safety considerations in place for individuals involved in the project, such as the installation of safety equipment which prevents industrial accidents, and management of hazardous materials? (c) Are intangible measures being planned and implemented for individuals involved in the project, such as the establishment of a safety and health program, and safety training (including traffic safety and public health) for workers etc.? (d) Are appropriate measures taken to ensure that security guards involved in the project not to violate safety of other individuals involved, or local residents?	(a) Y (b) Y (c) Y (d) Y	(a) The laws for working conditions have not been enacted in Myanmar. (b) Tangible safety considerations will be considered by the contractor. Safety measures based on ILO standard is proposed to be mentioned in the contract. (c) Safety program and training including wearing of safety gear and compliance of road traffic law will be considered by the contractor. (d) Appropriate instruction to security guards including grievance adjustment and work attitude correction will be considered by the contractor.
5 Others	(1) Impacts during Construction	(a) Are adequate measures considered to reduce impacts during construction (e.g., noise, vibrations, turbid water, dust, exhaust gases, and wastes)? (b) If construction activities adversely affect the natural environment (ecosystem), are adequate measures considered to reduce impacts? (c) If construction activities adversely affect the social environment, are adequate measures considered to reduce impacts? (d) If the construction activities might cause traffic congestion, are adequate measures considered to reduce such impacts?	(a) Y (b) N (c) Y (d) Y	(a) Adequate measures to reduce the impact will be conducted by the appropriate management of construction equipment/vehicles. The construction waste will be disposed to the existing disposal site. (b) There is no adverse effect to ecosystem in the project site. (c) There is no adverse effect to social environment. (d) Due to reduce the traffic congestion in construction site for transmission and distribution pipeline, the mitigation measures including construction time shift, advance notice, and instruction of other route will be conducted.
5 Others	(2) Monitoring	(a) Does the proponent develop and implement monitoring program for the environmental items that are considered to have potential impacts?	(a) Y (b) Y (c) Y (d) N	(a) Monitoring program will be carried out by YCDC. (b) Specific monitoring item is included in resettlement policy framework.

Category	Environmental Item	Main Check Items	Yes: Y No: N	Confirmation of Environmental Considerations (Reasons, Mitigation Measures)
		(b) What are the items, methods and frequencies of the monitoring program? (c) Does the proponent establish an adequate monitoring framework (organization, personnel, equipment, and adequate budget to sustain the monitoring framework)? (d) Are any regulatory requirements pertaining to the monitoring report system identified, such as the format and frequency of reports from the proponent to the regulatory authorities?		(c) Specific monitoring framework is included in resettlement policy framework. (d) Regulation for monitoring system have not been enacted in Myanmar. Monitoring result will be reported to YCDC.
6 Note	Reference to Checklist of Other Sectors	(a) Where necessary, pertinent items described in the Dam and River Projects checklist should also be checked.	(a)-	(a)-
	Note on Using Environmental Checklist	(a) If necessary, the impacts to transboundary or global issues should be confirmed (e.g., the project includes factors that may cause problems, such as transboundary waste treatment, acid rain, destruction of the ozone layer, or global warming).	(a)-	(a)-

1) Regarding the term "Country's Standards" mentioned in the above table, in the event that environmental standards in the country where the project is located diverge significantly from international standards, appropriate environmental, considerations are required to be made.
In cases where local environmental regulations are yet to be established in some areas, considerations should be made based on comparisons with appropriate standards of other countries (including Japan's experience).
2) Environmental checklist provides general environmental items to be checked. It may be necessary to add or delete an item taking into account the characteristics of the project and the particular circumstances of the country and locality in which the project is located.
Source: JICA Study Team

11.6 Land Acquisition and Resettlement Issue

11.6.1 Necessity of Land Acquisition and Resettlement

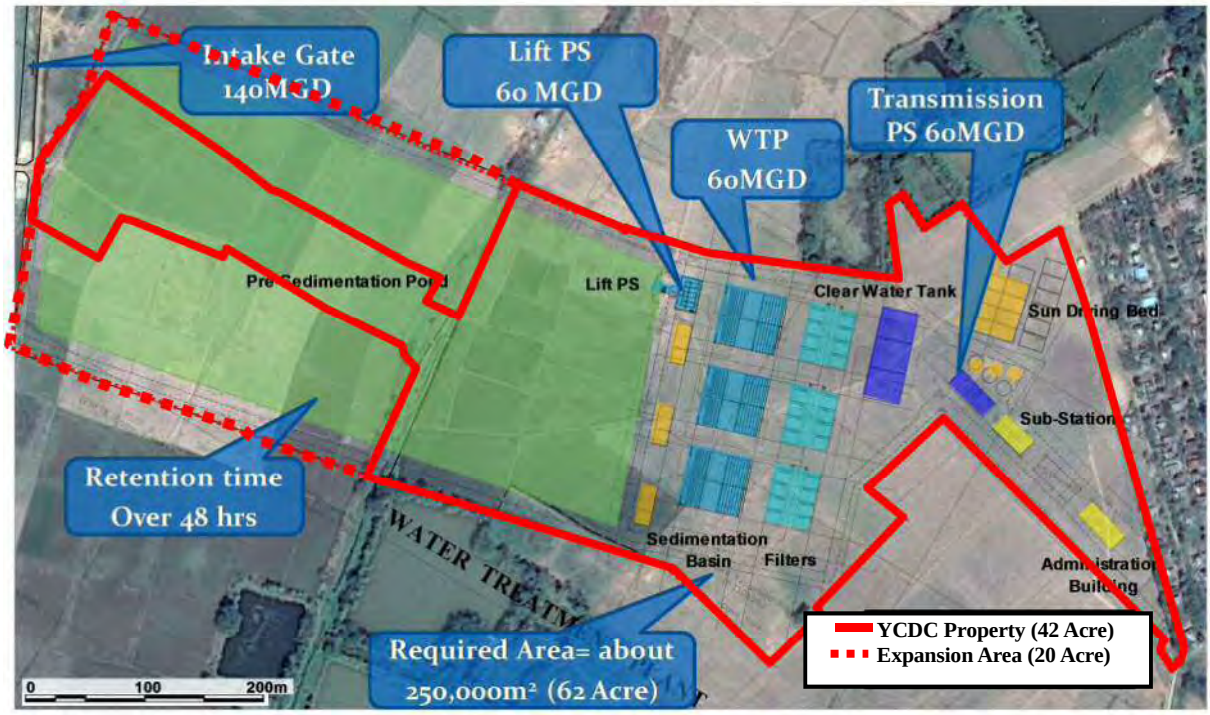
The current condition of land acquisition and resettlement are described below.

(1) Water Treatment Plant Construction Site

For the land acquisition of WTP, YCDC requested Yangon Regional Government to approve for land acquisition and then Yangon Regional Government ordered Township Land Record Department to provide the land ledger. Then, YCDC determined the 12 land owner based on the land ledger and negotiated with these land owners who depend mainly on rice farming on condition of the land price of 5 million kyats/acre. The total area is 41.7 acre (168,972 m^2) which is sufficient for 60 MGD WTP facilities. There are no illegal house occupancy in the site and no involuntary resettlement is required.

After reaching consensus with the land owners, land contract was concluded between land owner and YCDC. As the rice is annual plant, the construction of facilities can be started after harvesting of the crop. Considering this, the compensation against the lost assets was not required.

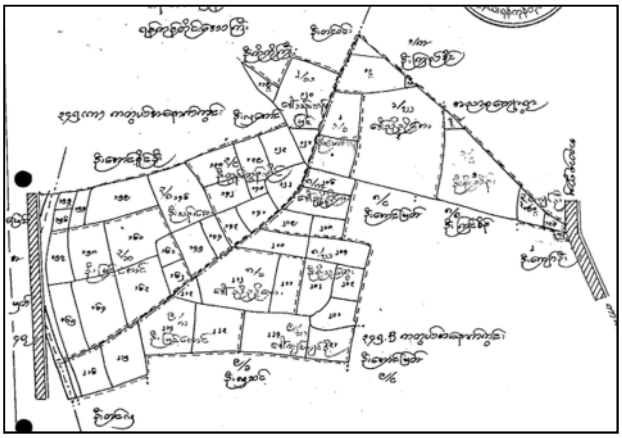
As shown in the following Figure and photo, there is naturally generated drainage canal in the north-south direction. The outlet of drainage is planned to be changed to surrounding drainage canal. The new drainage canal is planned to be constructed along with site development by YCDC and the review of the progress will be executed in detailed design stage.



Source: JICA Study Team

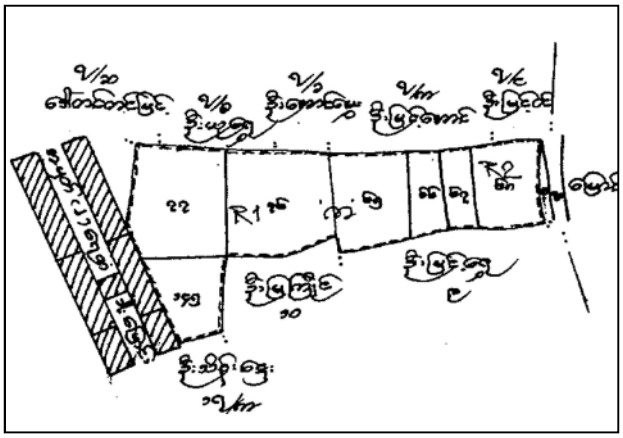
Figure 11-9 Expected Land Acquisition Area

Site for Water Treatment Plant



Land Ledger for Water Treatment Plant

Site for Pre-sedimentation Pond



Land Ledger for Pre-sedimentation Pond

Existing Drainage

Surrounding Site of Existing Drainage

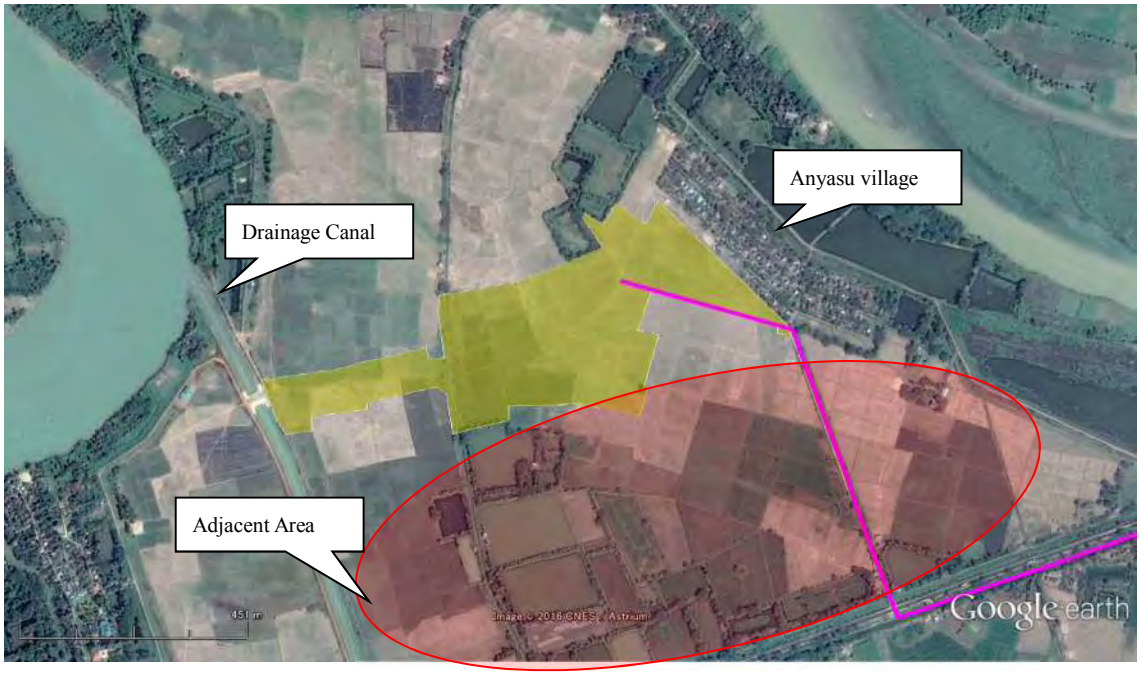
Source: JICA Study Team

Figure 11-10 Proposed Construction Site for Water Treatment Plant

However, the land acquisition of proposed construction site for pre-sedimentation pond is not sufficient and can provide only 12 hours storage time in case of 60 MGD capacity. The required land acquisition for expansion of pre-sedimentation pond which provide 48 hours is 20 Acre (80,940 m^2) and have not been completed yet. Land acquisition will be carried out in the same manner as described earlier, and YCDC will determine the land owner based on the land ledger and negotiate with them on condition of the land price per acre. After consensus formation, land contract will be concluded between land owner and YCDC. There are no illegal house occupations in the site and no involuntary resettlement will be required.

- Replacement Cost Survey

Replacement cost survey was conducted to make sure that land price of 5 million kyats/acre paid by YCDC was replacement cost. Interview of resident in nearby Anyasu village was executed due to the lack of real estate company around.



Source: JICA Study Team using background map of Google Earth

Figure 11-11 Location of Replacement Cost Survey

As result of interview by farmer living for 50 years in Anyasu village, the average land price in adjacent area of the Route No. 5 was approximately 7 million kyat/acre in June 2016. The land price of WTP construction site is assumed to be 20-30% lower than average price by the physical disadvantage of location nearby river and far from national road. Therefore, land price of 5 million kyat/acre paid by YCDC in 2015 is considered as replacement cost for land owner. Also, market land price is becoming high in surrounding area of Yangon City for recent years, and YCDC have been negotiated with land owner in expansion area by replacement cost considering increase of land price.

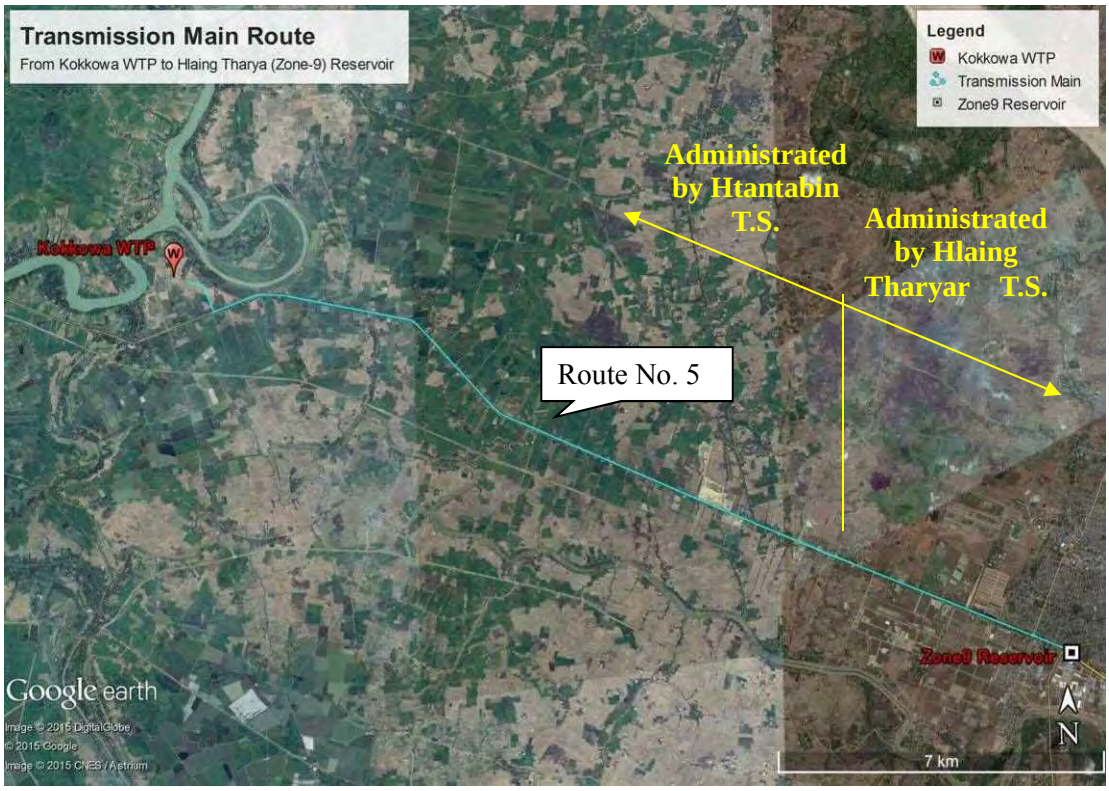
(2) Transmission and Distribution Pipe Construction Site

- National Road (Route No. 5)

The proposed transmission pipelines will be installed along the national road Route No. 5 and city road. Currently, Route No. 5 is paved on 4-lane and 2-lane in Hlaing Tharyar TS and Htantabin TS, respectively. ROW of Route No. 5 is decided by MOC as approximately 45 m wide and Route No. 5 has the potential to be expanded up to ROW due to future increase in population and transportation. The transmission pipe along Route No. 5 will be installed in the ditch out of the extent of ROW. In the case of 60 MGD of Kokkowa WTP development by 2025, following large diameter pipelines are planned to be laid along the Route No. 5;

- Transmission pipeline from WTP to Zone 9 SR/RPS (φ1600mm)
- Transmission pipeline from Zone 9 SR/RPS to Zone 1 SRs (φ1600mm)
- Distribution main from Zone 9 SR to Zone 9 area (constructed by YCDC)

Since Route No. 5 is the only road connecting the WTP and Zone 9 SR, pipelines mentioned above are planned to be laid along the Route No. 5.



Source: JICA Study Team using background map of Google Earth

Figure 11-12 Transmission Pipeline Alignment along Route No.5

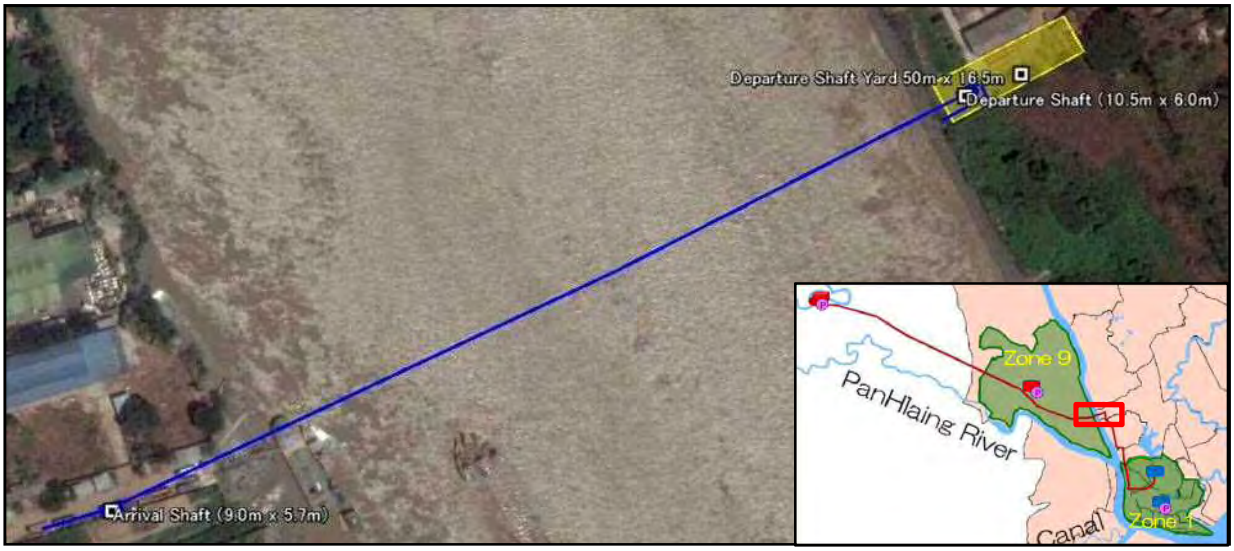
In the Minutes of Meeting on Follow up mission between JICA and YCDC on 30 November 2015, JICA and YCDC agreed concerning transmission facility as below;

- Transmission pipe will be installed along National Route No. 5. The subject area is within jurisdiction of MoC, Yangon Regional Government and YCDC. JICA and YCDC agreed that YCDC will exchange letters with relevant authorities to inform pipe laying position.
- Gas pipe line is installed along National Route No. 5. JICA and YCDC agreed to confirm the location of gas pipeline to avoid any conflict related to the installation site.
- There are electric transmission towers beside the lying site. JICA and YCDC agreed that YCDC will exchange letters with MoEE and YESC to inform pipe lying position.

The census and socio-economic survey on project affected persons (PAPs) living in the construction site of transmission pipe were conducted for valuation of assets to be compensated and for explaining the project contents. As a result of these interviews, seven (7) illegal occupants are on the proposed alignment of transmission pipeline from WTP in Htantabin TS to Zone 9 SR in Hlaing Tharyar TS along the Route No. 5. Detailed is described below in the Sub section 11.8.2.

(3) River Crossing Site

Installation of the transmission pipeline from Zone 9 SR to Zone 1 area will necessarily require crossing of Hlaing River. Shield tunnel method is recommended as the result of the comparison of construction method. Enough space is required for the construction of departure shaft and yard. Departure shaft and yard will be constructed in the MOAI land and arrival shaft will be constructed in city road. Therefore, no land acquisition and no involuntary resettlement.



Source: JICA Study Team using background map of Google Earth

Figure 11-13 Proposed Location of River Crossing

Site for Departure Shaft and Yard

Site for Arrival Shaft

Source: JICA Study Team

Photo 11-1 Proposed Construction Site for River Crossing

There is no rigid legal procedure for the permission of tentative occupation in public land and the permission for construction of departure shaft yard was already obtained after discussion between MoAI and YCDC. Request letter will be submitted by YCDC to MoAI to obtain approval document on construction works in MoAI land.

(4) City Road

The transmission pipe along city road will be installed under the existing road owned by YCDC. Therefore, there is no negative environmental impact including land acquisition and involuntary resettlement.

Existing City Road in Downtown Area

Existing City Road near Central SR in Zone 1

Source: JICA Study Team

Photo 11-2 Proposed Construction Site for Pipelines along City Road

(5) Service Reservoir Construction Site

- Zone 9 SR

The proposed construction site for Zone 9 SR is located in City Park owned by YCDC. Therefore, no land acquisition or involuntary resettlement is required.

Construction Site for Zone 9 SR

Construction Site for Zone 9 SR

Source: JICA Study Team

Photo 11-3 Proposed Construction Site for Zone 9 SR

- Kokine SR Construction Site in Zone 1

Kokine SR will be constructed in the existing SR construction site owned by YCDC. Therefore, land acquisition and involuntary resettlement is not required.


Source: JICA Study Team

Photo 11-4 Proposed Construction Site for Existing Kokine SR in Zone1

- Central SR Construction Site in Zone 1

Central SR will be constructed in the existing SR construction site owned by YCDC. Therefore, land acquisition and involuntary resettlement is not required.


Existing Zone 1 Central SR **Existing Zone 1 Central SR**

Source: JICA Study Team

Photo 11-5 Proposed Construction Site for Existing Central SR in Zone1

(6) Distribution Pipeline Construction Site in Water Supply Zone

The distribution pipe along city road will be installed under the existing road owned by YCDC. Therefore, there is no negative environmental impact including land acquisition and involuntary resettlement.

11.6.2 Major Laws for Land Acquisition/ Resettlement

(1) Summary of Laws and Regulatory Framework

Currently there is no law in Myanmar, comprehensively stipulating on land acquisition and resettlement regulations. The Land Acquisition Act, enacted in 1894, is still serves as the legal basis for land acquisition in current Myanmar.

Resettlement related issues are described in some existing laws and regulations. However, in most of cases, details such as procedures and conditions related to resettlement issues are yet to be determined. Following Table indicates relevant Myanmar laws and regulations for land acquisition and resettlement which are applicable to Myanmar where the project site is located.

Myanmar Laws and Regulations for Land Acquisition and Resettlement

- Farmland Law, 2012
- Farmland Rules, 2012
- Vacant, Fallow and Virgin Lands Management Law, 2012
- Vacant, Fallow and Virgin Lands Management Rules, 2012
- Constitution of the Republic of the Union of Myanmar, 2008
- Forest Law, 1992
- Transfer of Immovable Property Restriction Law, 1987
- The Law Amending the Disposal of Tenancies Law, 1965
- The Lower Burma Town and Village Land Act, 1899
- Land Acquisition Act, 1879 (Amended in 1937 (Adaptation of Laws Orders), and 1940 (Burma Act 27)
- The Land and Revenue Act 1876 (Amended in 1945 (Burma Act No 12), 1946 (Burma Act No 64), and 1947 (Burma Act No 6)
- The Lower Burma Land Revenue Manual, 1876
- Development Committee Law, 1993

(2) Principles on JICA Resettlement Policy

The key principle of JICA policies on involuntary resettlement is summarized in the final page of Sub section 11.7.9.

(3) Comparison between the Government's Laws/ Regulations and JICA Guidelines

The comparison between the Government's laws/regulations and JICA Guidelines are shown in the Table below.

Table 11-16 Comparison between The Government's Laws/ Regulations and JICA Guidelines

No.	JICA Guidelines	Law in Myanmar	Gap Between Laws in Myanmar and JICA Guidelines	Measures to Filling Gap
1	Involuntary resettlement and loss of means of livelihood are to be avoided when feasible by exploring all viable alternatives. (JICA Guidelines: JICA GL)	Not applicable	There is no regulation which mentions or requests to avoid or minimize involuntary resettlement and loss of livelihood means.	The project examines alternatives to avoid or minimize resettlement impact.
2	When population displacement is unavoidable, effective measures to minimize impact and to	Compensation or indemnity is provided for farmland acquisition for the interest of	There is no difference.	-

No.	JICA Guidelines	Law in Myanmar	Gap Between Laws in Myanmar and JICA Guidelines	Measures to Filling Gap
	compensate for losses should be taken. (JICA GL)	the State or public. (Farmland Law (2012) Art. 26, Farmland Rules (2012) Art. 64)		
3	People who must be resettled involuntarily and people whose means of livelihood will be hindered or lost must be sufficiently compensated and supported, so that they can improve or at least restore their standard of living, income opportunities and production levels to pre-project levels. (JICA GL)	Damages to standing crops/trees, lands, movable/immovable properties, relocation cost, economic activities are requested to compensate. (Land Acquisition Act (1894) Art. 23, Farmland Rules (2012) Art. 67)	There is no stipulation of improving or at least restoring living standard, income opportunities and production levels to pre-project levels in the Myanmar legal framework.	Assistance for improving or restoring livelihood at least to pre-project level is provided.
4	Compensation must be based on the full replacement cost as much as possible. (JICA GL)	Compensation at three times of the value calculated based on the average production of crops in the current market price of that area is provided. (Farmland Rules (2012) Art. 67)	There is no significant difference.	-
5	Compensation and other kinds of assistance must be provided prior to displacement. (JICA GL)	When compensation is not paid on or before land acquisition, compensation amount awarded with interest rate must be paid.	There is no clear indication about timing of compensation payment in the Myanmar legal framework.	Assistance is planned to be provided by all amount payment before displacement.
6	When consultations are held, explanations must be given in a form, manner, and language that are understandable to the Affected people. (JICA GL)	Not applicable	Ditto	Consultations with PAPs have been organized using Understandable explanation methods.
7	Appropriate and accessible grievance mechanisms must be established for the affected people and their communities. (JICA GL)	1) Notice of compensation amount to PAPs directly: appeal to the court within 6 weeks from the date of compensation award 2) Notice of compensation amount to representatives of PAPs: i) within 6 weeks of receipt of compensation notice, or ii) within 6 months from the date of compensation award (Land Acquisition Act (1894) Art. 18)	The procedure of grievance in the Myanmar context is direct settlement at the court, which is not necessarily easy or accessible to PAPs.	The project establishes the grievance redressal mechanism by utilizing the existing administration system to be convenient for PAPs.
8	Affected people are to be identified and recorded as early as possible in order to establish their eligibility through an initial baseline survey (including population census that serves as an eligibility cut-off date, asset inventory, and socioeconomic survey), preferably at the project identification stage, to prevent a subsequent influx of encroachers of others who wish to take advance of such benefits. (WB OP4.12 Para.6)	A notification of land acquisition or public purposes is published in the gazette, which is also published at the convenient place in the concerned municipality. (Land Acquisition Act (1894) Article 4)	There is no specific description of identifying affected people as early as possible in the national law.	Census survey will be conducted in May 2016 for identifying number of affected households as well as their socio-economic condition.
9	Eligibility of benefits includes, the PAPs who have formal legal rights to land (including customary and traditional land	Occupiers/stakeholders of lands to be acquired are explained about acquisition and claims to compensations.	Detail procedures as well as eligibility criteria are not clearly defined. Also there is no specific	The project establishes eligibility for assistance to all households whose

No.	JICA Guidelines	Law in Myanmar	Gap Between Laws in Myanmar and JICA Guidelines	Measures to Filling Gap
	rights recognized under law), the PAPs who don't have formal legal rights to land at the time of census but have a claim to such land or assets and the PAPs who have no recognizable legal right to the land they are occupying.(WB OP4.12 Para.15)	(Land Acquisition Act (1894) Article 9)	indication about displaced persons without titles.	income sources or assets are confirmed as affected due to project implementation.
10	Provide support for the transition period (between displacement and livelihood restoration). (WB OP4.12 Para.6)	Not Applicable	There is no regulation stipulating to provide support for the transition period.	Sufficient support for the transition period is provided.
11	Particular attention must be paid to the needs of the vulnerable groups among those displaced, especially those below the poverty line, landless, elderly, women and children, ethnic minorities etc. (WB OP4.12 Para.8)	Not Applicable	There is no regulation stipulating to provide particular attention to the vulnerable groups.	The support for the vulnerable groups is provided.
12	For projects that entail land acquisition or involuntary resettlement of fewer than 200 people, abbreviated resettlement plan is to be prepared. (WB OP4.12 Para.25)	Not Applicable	There is no regulation stipulating to provide resettlement plan.	The project does not request more than 200 people of displacement, and Prepares abbreviated resettlement plan accordingly.

Source: JICA Study Team

11.7 Principles of Resettlement Policy

11.7.1 Resettlement Policy

In the projects, YCDC is expected to take all necessary measures to mitigate adverse social impacts, including those associated with construction of pre-sedimentation basin and transmission pipe. For the PAPs, the principal objective of the draft Resettlement Policy Framework (RPF) is to ensure that all persons displaced economically and/or physically are compensated for all lost assets at full replacement cost at market value.

JICA has policies on resettlement, which are stipulated in JICA Guidelines. The key principle of JICA policies on involuntary resettlement is summarized below:

a) Involuntary resettlement and loss of means of livelihood are to be avoided when feasible by exploring all viable alternatives.

b) When population displacement is unavoidable, effective measures to minimize the impact and to compensate for losses should be taken.

c) People who must be resettled involuntary and people whose measures of livelihood will be hindered or involve losses must be sufficiently compensated and supported, so that they can improve or at least restore their standard of living, income opportunities and production levels to pre-project levels.

d) Compensation must be based on the full replacement cost as much as possible.

e) Compensation and other kinds of assistance must be provided prior to displacement.

f) In preparing a resettlement action plan, consultations must be prompted in the planning, implementation, and monitoring of resettlement action plans.

g) Appropriate and accessible grievance mechanisms must be established for the affected people and their communities.

In addition to the above policies, JICA also applies for the following policies stipulated in WB OP 4.12.

a) Affected people are to be identified and recorded as early as possible in order to establish their eligibility through an initial baseline survey (including population census that serves as an eligibility cut-off date, asset inventory, and socioeconomic survey) to prevent a subsequent influx of encroachers of others who wish to take advance of such benefit.

b) Provide support for the transition period (between displacement and livelihood restoration).

c) Particular attention must be paid to the needs of vulnerable people among those displaced, especially those below the poverty line, elderly, women and children, ethnic minorities etc.

d) For projects that entail land acquisition or involuntary resettlement of fewer than 200 people, abbreviated resettlement plan (ARAP) is to be prepared.

"PAPs of the project" refers to all the people who, on account of project activities, would have their (i) standard of living adversely affected; or (ii) right, title, interest in any house, or any other fixed or movable asset acquired or possessed temporarily or permanently; or (iii) business, occupation, work or place of residence or habitat adversely affected.

"Replacement cost" is defined as follows:

- For houses and other structures, it is the market cost of the materials to build a replacement structure with an area and quality similar to those of the affected structure, or to repair a partially affected structure, plus the cost of transporting building materials to the construction site, plus the cost of any labor and contractors' fees, plus the cost of any registration and transfer taxes.
- In determining the replacement cost, depreciation of the asset and the salvage values are not taken into account, nor is the value of benefits to be derived from the project deducted from the valuation of an affected asset.

11.7.2 Scope of Resettlement Impact

A census and socio-economic survey will be carried out to identify PAPs and prepare the inventory of the assets to be compensated. The census and socio-economic survey must cover all of the PAPs and identify all of their assets affected. At the beginning of census, the cut-off date is disclosed to public in order to avoid influx of additional population into the project area just to receive assistance, and persons who occupy the project area after cut-off date are not eligible for compensation. The PAPs living or doing income generation activities in the project site on the cut-off date are eligible for compensation. The cut-off date of this project will be declared on the day census begins and will be announced by YCDC through the public consultation meeting and notice displayed in the public area.

11.7.3 Eligibility Criteria and Income Restoration Program

(1) Eligibility Criteria

The purpose of resettlement planning is to ensure that PAPs have sufficient opportunity to replace assets they will lose, and to improve or at least restore their incomes and living standards. To achieve these objectives, it is essential to ensure that all PAPs are identified, and to ensure that all PAPs are deemed eligible for appropriate mitigation measures in the resettlement action plan (RAP). The PAPs of the project are normally eligible for compensation at replacement cost for any fixed assets or movable assets that will not be able to be used after resettlement, and the estimated future value of productive trees.

The PAPs of the project have no recognizable legal right or claim to the land they are occupying, so they may not be entitled to land compensation, but are compensated at replacement cost for productive trees, and other assets or improvements they have established on the land they use.
The following generic Entitlement Matrix provides the principles that will be used during implementation.

Table 11-17 Entitlement Matrix

Type of Losses	Entitled Person	Entitlements	Responsibility & Procedures
Loss of Private Land	Land owners of private land	Cash compensation at replacement cost which is equivalent to the market value	Responsibility for each procedures is shared as follows: 1. Confirmation of Assets - Implementing Consultant 2. Calculation of compensation cost- Implementing Consultant 3. Agreement of compensation cost- YCDC 4. Provision of compensation cost to PAPs -YCDC 5. Payment Procedure - YCDC
Loss of Land-based Income	Land owners of private	Cash compensation at replacement cost which is equivalent to the market value	
Loss of Fixed Assets	Owners of affected assets (living structures or stores)	Cash compensation at replacement cost which is equivalent to the market value	
	Person planted trees to be cut	Cash compensation at the current market price of the materials such as fruits obtained from the trees	
Loss of Movable Assets	Owners of movable assets	Cash compensation at the current market price if they are not able to be used after resettlement	
	Livestock		
Loss of income source	Contracted worker and self-employed person	Cash assistance for non-working period due to resettlement. Rehabilitation assistance to achieve the policy objective to improve or restore their livelihoods and standards of living in real terms.	Responsibility for each procedures is shared as follows: 1. Confirmation of livelihood - Implementing Consultant 2. Preparation of Income Restoration Program – YCDC, NGO 3. Monitoring – YCDC

Source: JICA Study Team

(2) Income Restoration Program (IRP)

Income Restoration Program (IRP) will be planned to restore and stabilize livelihood of displaced PAPs to at least pre-project level after resettlement, depending on its necessity, based on the results of

survey for the needs of measures for livelihood rehabilitation.
Summary of survey for the needs of measures for livelihood rehabilitation is shown below.

1. Objective
   Based on the result of census and socio-economic survey, the needs of measures for livelihood rehabilitation are determined.
2. Survey Target
   The Survey Target shall be the households along the Route No.5 on the proposed construction site of transmission pipe.
3. Survey Contents
   The item to be confirmed is shown below.
   - Loss of assets and job opportunities
   - Needs of livelihood rehabilitation including financial assistance, work training, and job placement
4. Survey Method
   The needs of livelihood rehabilitation and loss of assets will be determined based on the result of census and socio-economic survey. All data and summary report will be attached in ARAP, and Income Restoration Program (IRP) is developed after the confirmation of the above item.
5. Schedule
   Analysis of census and socio-economic survey: Social and economic interview were conducted in this Study (Refer to Sub-section 11.8.2).
   Summarization of the needs of measures for livelihood rehabilitation:
   To be conducted by Yangon Regional Government

IRP is proposed to be composed of support for restoration of economic conditions through the activities for enhancement of income earning opportunities. The PAPs who need to alter income earning activity from current to another activity and unemployed people who desire to have skill for finding job opportunity are entitled to participate in IRP. IRP will be implemented not only for men but also women of working age. In supports for income earning opportunities, a series of technical support for improvement of work-skill are to be included. The activity of the series of technical support will provide vocational trainings to PAPs in order to improve their skills for enhancing job opportunities. Since some ministries provide several types of vocational training, which could be utilized as part of IRP, cooperation with these concerned ministries will be taken into consideration.

Although IRP will be finalized based on needs analysis of PAPs through consultation with PAPs, it is planned to consist of three main activities: i) technical support for improvement of work skill, ii) technical support for livelihood management, and iii) assistance for finding the income earning opportunities. In addition to these three main activities, follow-up will also be implemented by using

internal and external monitoring results. In order to implement IRP effectively, a horizontal unit among several administrative level will be established.

i) Technical Support for Improvement of Work Skill

This is an activity to provide vocational trainings to PAPs in order to improve their skills for enhancing job opportunities. Ministries currently provide several vocational trainings as shown in some examples in the following Table, which can be utilized as a part of IRP by cooperating with the concerned ministries.

Table 11-18 Example of Technical Support for Income Earning Activity in IRP

No.	Economic Restoration activity	Sub-activities	Implementing institution	Type of technical support	Duration of technical training	Approximate Cost (MNK /Person)	Location
1	Construction activity	Construction work (road construction, carpentry, masonry, electricity, plumbing, etc.)	YCDC	Vocational training in theory and practice, on the job training, technical advice as needed, advice for job opportunity	6 weeks	125,000	Specified Training Center
		Mechanical work (earthmoving, heavy equipment, pump & machine operator, etc.)			6 weeks	38,000	
2	Small scale industry activity	Wood based carpentry	YCDC, NGO (Capacity Building Initiative, PACT in Myanmar. etc.)	Vocational training in theory and practice, on the job training, technical advice as needed, advice for job opportunity	30 days	180,000	Specified Training Center
		Food processing			7 days	55,000	
		Tailoring, dress making			3 months	150,000	
3	Small scale livestock and horticulture	Small scale livestock, poultry	YCDC, NGO (Capacity Building Initiative, PACT in Myanmar. etc.)	Technical training on site, study tour, technical advice as needed	5-15 days	-	On site
		Small scale horticulture (vegetable, cash crops, fruit tress)			5-15 days	-	

Source: JICA Study Team

ii) Technical Support for Livelihood Management

This activity supports households to improve their current physical living condition by providing technical training and/or education. Tentatively, formulation of religious and social groups (e.g. how to organize a stable community including establishing necessary rules and system), management of income and expenditure (e.g. support to open bank accounts, deliberated plan of saving and expenditure after receiving assistance amount and regular income from jobs) and hygiene education (e.g. awareness for health) are planned to be provided as technical supports.

iii) Support for Finding Income Earning Opportunities

Supports to find job opportunities during construction and after operation of WTP are provided for

PAPs by facilitating capability of PAPs and a job vacancy in cooperation with Department of Labor under Ministry of Labor, Immigration and Population, and also by giving preference of job opportunities to PAPs

iv) Follow-up Activities

In the monitoring, situations of restoration of PAP's livelihood and community formulation will be monitored. Further appropriate measures will be examined and conducted with PAPs if necessary.

IRP commences with participatory workshop with PAPs after resettlement of PAPs.

11.7.4 Grievance Procedures

To ensure that PAPs have avenues for raising complaints relating to compensation payment, construction-related damages, or other aspects of project implementation, a multi-step grievance procedure will be established in the ARAP. YCDC will assess in more detail appropriate grievance redressal mechanisms for the project and the ARAP will detail the procedures for that particular project activity. Necessary elements of the grievance procedures include:

a) An initial stage, within the local village or town level, in which any person aggrieved by any aspect of the compensation process can lodge an oral or written grievance to local authorities who are involved in project implementation. If the complaint cannot be resolved within 30 days of receipt, it advances to the second step of the process.
b) At the Stage 2, if the aggrieved person is not satisfied with the outcome of initial stage consideration, or if local level review is unable to reach a proposed solution, the aggrieved person can refer the issue to a grievance committee established by YCDC. The grievance committee, which is chaired by YCDC, reviews issues raised in the initial complaint and any actions for resolution suggested at the lower level and makes recommendations for resolution within 30 days.
c) At the Stage 3, if the aggrieved person is still dissatisfied following review by the grievance committee, the case may be referred to legal proceedings in accordance with the government of Myanmar's laws and procedures.

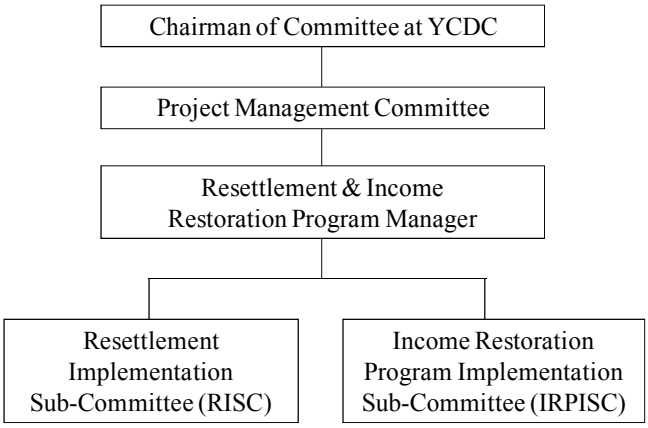
YCDC and implementing partner keep a record of all complaints referred to the grievance committee, including the description of issues raised and the outcome of the review process.

11.7.5 Implementation Arrangement

YCDC is the responsible body for implementation of ARAP, and sub-committee will be established chaired by Resettlement & Income Restoration Program Manager. Project Management Committee is coordinating agencies in supporting YCDC, RISC, and IRPISC for smooth implementation of ARAP including resettlement and IRP. The image of implementation structure of ARAP is presented in the

following Figure.

- One of the sub-committees is Resettlement Implementation Sub-Committee (RISC) which manages to coordinate and communicate with PAPs and all related organization in resettlement, manages the disbursement of assistance to PAPs, and coordinates with PAPs for implementation of grievance procedure, monitoring system, and resettlement as a whole.
- Other sub-committee is Income Restoration Program Implementation Sub-Committee (IRPSC) which manages to facilitate the integration of PAPs in the host community, finalizes IRP through consultation with PAPs, implements the series of activities of IRP, and follows up the activities of IRP.



Source: JICA Study Team

Figure 11-14 Organization Chart for Implementation of ARAP

Responsible organization for implementation of these activities will be EDWS/YCDC and Resettlement & Income Restoration Program will be chaired by the Chief Engineer of EDWS.

11.7.6 Implementation Schedule

The provisional schedule of the resettlement works is shown in following Table. It is provisional because the sequence or schedule may change due to circumstances, and accordingly the time will be adjusted for the implementation of the resettlement works.

Table 11-19 Provisional Schedule of The Resettlement Works

Items	Months	0	1	2	3	4	5	6
Completion of Detailed Design		▼						
Preparation and agreement of detail payment plan (amount and mode)	1M							
Award of assistances	3.5M							
Relocation of PAPs	1M							
Organization of IRP Implementation Committee	1M							
Registration for IRP	1M							
Implementation of IRP	3M							
Monitoring and evaluation	3M+α							

Source: JICA Study Team

11.7.7 Funding Arrangement

The compensation cost includes the compensation for house construction cost, moving fee, asset, and land calculated after census and socio-economic survey. The calculation basis of compensation for house construction cost, moving fee, and asset is based on unit material and labor cost published by MOC and market price. Also, compensation cost for land is based on the contract price upon consultation with land owners.

YCDC bears responsibility for paying all costs associated with compensation. The ARAP prepared in accordance with this draft ARAP requires a budget with estimated costs for all aspects of ARAP implementation. All persons adversely affected by the project are entitled to compensation or other appropriate mitigation measures. Compensation rates included in the ARAP provide the basis for calculating compensation amounts due to displacement of persons. Compensation must be paid in full to the PAPs losing their assets. No deductions from compensation will occur due to any reason. The resource of compensation, income restoration program and related operation will be included in the budget of EDWS/YCDC.

11.7.8 Monitoring Procedures

YCDC will monitor the implementation of the ARAP and report the monitoring results to JICA on a regular basis.

The objectives of the monitoring during project implementation phase are i) to monitor progress of IRP, ii) to monitor settlement status, and iii) to examine further measures if necessary.

The principal items to be checked by internal monitoring include the following:

- Effectiveness of grievance mechanism and raised issues
- Status of implementing IRP
- Issues for implementing IRP (i.e. implementation schedule, budget or personnel, personnel capacity, facilitation among relevant parties) and proposed remedial measures

IRPISC submits internal monitoring reports to YCDC after the resettlement phase including the following:

- Course of IRP and number of participants
- Status/progress of IRP
- Settlement status at the relocation site
- Issues raised at the grievance mechanism and measures taken

The methodology of evaluation is based mainly on comparison of socio-economic status of PAHs prior to and following displacement and level of satisfaction taking into consideration of external conditions. Socio-economic status and level of satisfaction will be examined through interview with PAPs at each period of external monitoring. If the findings would indicate that the objectives of ARAP or IRP have not been achieved, RISC and IRPISC and other concerned parties would propose appropriate additional measures to support PAPs to rehabilitate themselves to at least their pre-project situation.

11.7.9 Consultations and Disclosure Arrangements

The PAPs will be consulted during the preparation of the ARAP. The draft ARAP should be consulted with affected people and their inputs should be incorporated in the final ARAP. It should be prepared in Burmese. Consultation should be conducted in a local language and sufficient lead time (minimum 1 week) should be given to ensure all PAPs are able to participate in consultations and be fully informed of the ARAP.

The ARAP must describe measures taken to consult with displaced persons regarding proposed arrangements, and it summarizes the results of those consultations. YCDC also ensures public disclosure of the ARAP, in draft and final stages, to the PAPs and the general public in the project area, in a language and location accessible to them.

In the public consultation meeting, YCDC will explain the following items.

- General project information
- Result of census and socio-economic survey
- Compensation policy and contents

Reference: Principle of JICA Policies on Involuntary Resettlement

The key principle of JICA policies on involuntary resettlement is summarized below.
Involuntary resettlement and loss of means of livelihood are to be avoided when feasible by exploring all viable alternatives.

When, population displacement is unavoidable, effective measures to minimize the impact and to compensate for losses should be taken.

People who must be resettled involuntarily and people whose means of livelihood will be hindered or lost must be sufficiently compensated and supported, so that they can improve or at least restore their standard of living, income opportunities and production levels to pre-project levels.

Compensation must be based on the full replacement cost [8] as much as possible.

Compensation and other kinds of assistance must be provided prior to displacement.

For projects that entail large-scale involuntary resettlement, resettlement action plans must be prepared and made available to the public. It is desirable that the resettlement action plan include elements laid out in the World Bank Safeguard Policy, OP 4.12, Annex A.

In preparing a resettlement action plan, consultations must be held with the affected people and their communities based on sufficient information made available to them in advance. When consultations are held, explanations must be given in a form, manner, and language that are understandable to the affected people.

Appropriate participation of affected people must be promoted in planning, implementation, and monitoring of resettlement action plans.
Appropriate and accessible grievance mechanisms must be established for the affected people and their communities.
Above principles are complemented by World Bank OP 4.12, since it is stated in JICA Guideline that "JICA confirms that projects do not deviate significantly from the World Bank's Safeguard Policies". Additional key principle based on World Bank OP 4.12 is as follows.

Affected people are to be identified and recorded as early as possible in order to establish their eligibility through an initial baseline survey (including population census that serves as an eligibility of cut-off date, asset inventory, and socioeconomic survey), preferably at the project identification stage, to prevent a subsequent influx of encroachers who wish to take advance of such benefits.

Eligibility of Benefits include, the PAPs who have formal legal rights to land (including customary and traditional land rights recognized under law), the PAPs who don't have formal legal rights to land at the time of census but have a claim to such land or assets and the PAPs who have no recognizable legal right to the land they are occupying.

Preference should be given to land-based resettlement strategies for displaced persons whose livelihoods are land-based.

[8] Description of "replacement cost" is as follows.

Land	Agricultural Land	The pre-project or pre-displacement, whichever is higher, market value of land of equal productive potential or use located in the vicinity of the affected land, plus the cost of preparing the land to levels similar to those of the affected land, plus the cost of any registration and transfer taxes.
	Land in Urban Areas	The pre-displacement market value of land of equal size and use, with similar or improved public infrastructure facilities and services and located in the vicinity of the affected land, plus the cost of any registration and transfer taxes.
Structure	Houses and Other Structures	The market cost of the materials to build a replacement structure with an area and quality similar or better than those of the affected structure, or to repair a partially affected structure, plus the cost of transporting building materials to the construction site, plus the cost of any labor and contractors' fees, plus the cost of any registration and transfer taxes.

Provide support for the transition period (between displacement and livelihood restoration.

Particular attention must be paid to the needs of the vulnerable groups among those displaced, especially those below the poverty line, landless, elderly, women and children, ethnic minorities etc.

For projects that entail land acquisition or involuntary resettlement of fewer than 200 people, abbreviated resettlement plan is to be prepared.

In addition to the above core principles on the JICA policy, it also laid emphasis on a detailed resettlement policy inclusive of all the above points; project specific resettlement plan; institutional framework for implementation; monitoring and evaluation mechanism; time schedule for implementation; and, detailed Financial Plan etc.

11.8 Meeting with Stakeholders and Interviews

11.8.1 Meetings with Stakeholders for the Project Site of WTP

With regard to the meetings with stakeholders for the project site of Kokkowa WTP, a total of two (2) meetings were held by the initiative of YCDC as summarized below.

(1) Explanatory Meeting held in April 2015

In April 2015, an explanatory meeting for the WTP construction was held for two (2) days in the adjacent Anyasu Village, the details of which are given in the following Table.

Table 11-20 YCDC Explanatory Meeting on the Project at Anyasu Village Monastery

Item	Description	
1. Date	11th and 12th April 2015	
2. Venue	Anyasu Village Monastery	
3. Participants	Organization/Position	Total
	YCDC (EDWS): Chief Engineer, Deputy Chief Engineer (total 3), Executive Engineer, Assistant Chief Engineer, Assistant Engineer, other YCDC staff	Approximately 150 participants
	Community Leader, Htan Tapin Township Village Tract Leader, Htan Tapin Township	
	Anyasu Village Monastery religious figures	
	Anyasu Village inhabitants Pandaing Village inhabitants	
4. Agenda	- Project Components and its advantages - Some religious ceremony for the project	


Source: YCDC

According to YCDC, the explanatory meeting was held based on the local traditional custom including some religious ceremony for praying for the success of the WTP construction by inviting local high monks as well as local people. Therefore, any written records and documents on the meeting had not been prepared.

(2) Stakeholder Meeting for the Project held in January 2017

In January 2017, a stakeholder meeting (SHM) for the Project was held by YCDC for explaining the project components including additional land acquisition of 20 acres for the WTP, JICA policy (described below) on land acquisitions with entitlement, cut- off date and so on as summarized in the following Table.

Table 11-21 Stakeholder Meeting on the Project at Site Office in WTP

Item	Description	
1. Date & Time	11th January 2017 (9:00 am -10:45 am)	
2. Venue	The project Site Office in the WTP	
3. Participants	Organization/Position	Total
	YCDC (EDWS)	18
	YCDC (City Planning & Land Administration Department (Northern District)	1
	Road Department, Ministry of Construction	1
	Land Record Department (Htantabin Township)	1
	General Administration Department (Htantabin Township)	1
	General Administration Department (Northern District)	1
	General Administration Department (Hlaing Tharyar Township.)	1
	Religious Leader (Anyasu Village)	1
	Religious Leader (Ka Twel Village)	1
	Village Administrator (Ka Twel Village)	1
	Village Sub-administrator (Pandaing Village)	1
	Village Sub-administrator (Anyasu Village)	1
	Villager (Pandaing Village)	16
	Villager (Htantabin Village)	1
	Villager (Anyasu Village)	1
	JICA Study Team (Local Staff)	1
	Total	48
4. Agenda	- Project history, Components and Schedule - Possible Environmental and Social Impacts and the Proposed Countermeasures	

	- JICA Policy on compensations and entitlements for the Project, Cut-off date - Questions/Discussions/Comments




Source: JICA Study Team

1) Possible Environmental and Social Impacts and the Proposed Countermeasures

Based on the results of "Scoping of Environmental Impacts (See Table 11-12)" and "Mitigation Measures for Potential Project Impact (See Table 11-13)", possible environmental and social impacts and the Proposed countermeasures were explained in the SHM. In addition, some positive impacts such as social contributions to the people of Yangon Region by the Project as well as possibility of local people employments during the construction and operation of the Project were described by YCDC to the participants.

2) JICA Policy on Compensation and Entitlement for Land Acquisition

As per "Major Laws for Land Acquisition/ Resettlement (see Sub-section 11.6.2)" and "Principles of Resettlement Policy (See Section 11.7)", key points of JICA's policy on compensation and entitlement of the land acquisition were explained in the SHM.

3) Cut-off Date

In the SHM, cut-off date for the land acquisitions was explained as follows.

- ✓ YCDC held the explanatory meeting with stakeholders on 11th and 12th April 2015 at Anyasu Village Monastery (See Table 11-20).
- ✓ Therefore, 11th April 2015 can be recognized as de facto cut-off date for the first land acquisition.

- ✓ In addition, the SHM held on 11th January 2017 (See Table 11-21) can be recognized as second cut-off date for all land acquisitions for the Project especially additional land for 20 acres.

4) Discussions

At the last stage of SHM, questions, discussions and comments were made among the stakeholders and YCDC as specified in the following Table.

Table 11-22 Discussions in the Stakeholder Meeting

Questions, Discussions, Comments	Answers, countermeasures
(a) When the project is started, YCDC should consider for job opportunities of the people who live near by the project area.	(a)As presented in the SHM, YCDC will consider on the job opportunities.
(b) Land owner should accept the fair land price which will be decided appropriately by Yangon Regional Government as per entitlement matrix and JICA policy on replacement cost. (Monk)	(b) Speech by Monk
(c) How does YCDC evaluate for the price of land per acre? (A land owner)	It will be appraised by Yangon Regional Government depends on current price and unit price without abasing to the land owner. However, proof of land ownership is necessary to be compensated. (Htantabin Township Administrator)
(d) Warmly welcome and thanks to the government because their village have to be developed due to this kind of big project. (Pandaing Village Leader)	Comments
(e) They said that they will cooperate and perform for this project to be implemented successfully as it's the government level project and there are a lot of positive impacts and benefits to the people of the project area. (Government Administration Department (Northern District), General Administration Department (Hlaing Tharyar Township), Htantabin Land Record Department Road Department (MOC)	Comments
(f) This project is a beneficial project not only for villagers but also for the Yangon Region people, so he wants the success of it and to negotiate between land owner and concerned departments for required land acquisition. (Ka Twel Village Administrator)	Comments
(g) To submit concerned department for the additional land acquisitions (20Acre is for the Project) which is required for project with appropriate price as per JICA policy.(Deputy Chief Engineer, YCDC(EDWS))	Action to be taken by YCDC
(h) To recognize as 2nd cut-off date for the date of this SHM for land acquisition. (Deputy Chief Engineer, YCDC(EDWS))	Action to be taken by YCDC
(i) To negotiate for fair price with Katwe Village, Pandaing Village, Anyasu Village land owners and farm owners not to abase them. (Deputy. Chief Engineer)	Action to be taken by YCDC

Source: JICA Study Team

For details of SHM, two Minutes of Meetings prepared by YCDC and JICA Study Team are attached in the Appendix 15, and 16.

11.8.2 Social and Economic Interview Survey on the Proposed Alignment of Transmission Pipeline

In January 2017, a social and economic interview survey was conducted on the illegal occupancies on at the proposed alignment of transmission pipeline along the national Route No. 5 was conducted by local surveyors of JICA Study Team, the details of which are presented as follows.

(1) Purposes

- ✓ To identify present situations of illegal occupations on the proposed alignment of transmission pipeline
- ✓ To explain the Project component, possible environmental and social impacts and the countersues, JICA policy of resettlement and entitlements for illegal occupations, cut-off date and project schedule and others to the occupants
- ✓ To survey social and economic status of those illegal occupants
- ✓ To ask opinions and comments from the illegal occupants

(2) Survey Methods

1) Identification of the Pipeline Alignment

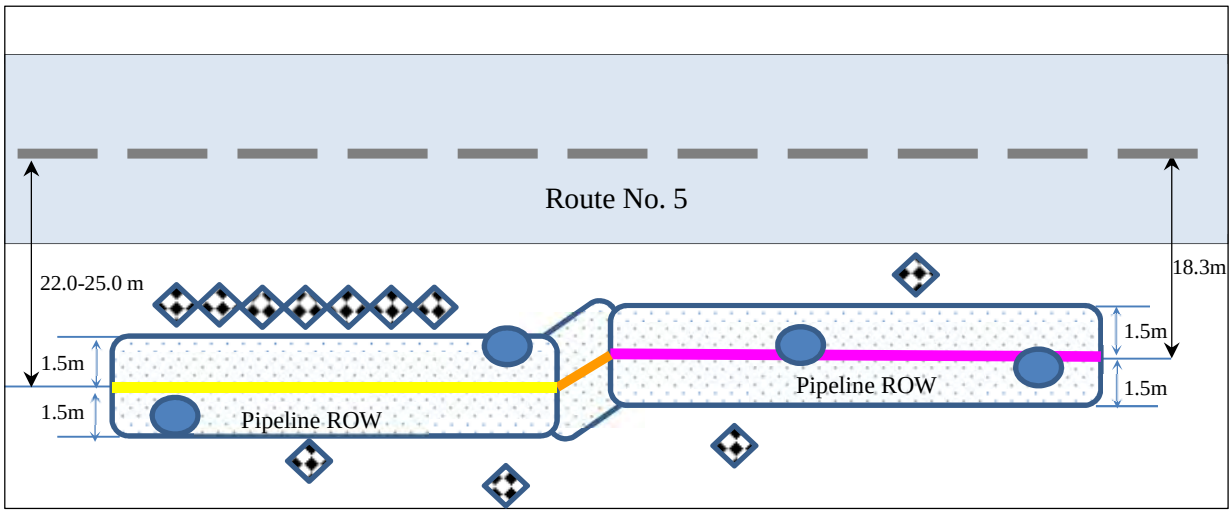
With consideration of the Route No. 5 situations and pipeline alignment of this Study at the F/S stage, the pipeline alignments were identified by the following concept of JICA Study Team (See the following Figure).

a. The pipeline alignment on the Route No. 5 is set as a location of 18.3 m from the road center line (See Pink line in the following Figure)
b. If an illegal house and an obstacle exit on the alignment of 1, a pipe alignment will be shifted to a location 22-25m away from the road center line (See yellow line in the following Figure)
c. Since pipe alignment on the north side of Route No. 5 is in YCDC road, there are no illegal house.

2) Definition and Configuration of Pipeline ROW

Based on the discussions with YCDC, Social-economic interview surveyors and technical instruction from the JICA Study Team, the pipeline ROW was considered as follows (See following Figure).

- ✓ The proposed diameter of transmission pipe to be installed is 1.6 m.
- ✓ Consideration of buffer and safety areas for the pipeline installations, the pipeline ROW were defined in the survey to be measured +/- 1.5 m from the proposed alignment of transmission pipeline in this Study .



Illegal occupancies on ROW identified in the Survey

Surrounding Illegal occupancies out of the ROW identified in the Survey (not interviewed)

Source: JICA Study Team

Figure 11-15 Image of Pipeline Alignment with Pipeline ROW and Illegal Occupants

3) Identification of Illegal Occupants

Due to the fact that the transmission pipeline is proposed to be installed in Htantabin and Hlaing Tharyar Townships, a survey was conducted both townships on 16th and 17th January 2017 in both townships.

As a result of the survey, a total of 41 illegal occupancies were scattered around the pipeline ROW, and then six (6) illegal occupancies (houses/shops) and one (1) local religious facility situated on the pipeline ROW as summarized in the following Figure and Table. For details of interview survey is attached in the Appendix 17.

Source: JICA Study Team using background map of Google Earth

Figure 11-16 Location of Affected Household on the Pipeline ROW

Table 11-23 Seven (7) Illegal Occupants on the Pipeline ROW

Illegal Occupant	Township	GPS coordinates		Household/Business
1	Htantabin	16º53’9.35"N	96º0’14.75"E	Rice Storage/Mill
2	Htantabin	16º53’11.17"N	96º0’10.61"E	Bamboo shop
3	Htantabin	16º54’56.32"N	95º56’2.33"E	Noodle Shop
4	Htantabin	16º54’56.02"N	95º56’2.52"E	General Shop
5	Htantabin	16º54’56.62"N	95º56’2.02"E	Shop (Closed)
6	Htantabin	16º55’58.7"N	95º54’47.64"E	House/ Restaurant
7	Htantabin	16°56'29.70"N	95°53'13.64"E	Local religious (Buddhism) facility

Source: JICA Study Team

(3) Explanation before questionnaire interview

At the opening of the social and economic interviews, project components, legal status, possible impacts, resettlement policy and entitlements and so on was explained orally to those illegal occupants by the surveyors as summarized in the following Table.

Table 11-24 Explanations on the Project and Policy on Involuntary Resettlement

No.	Expiatory Item	Description Orally Explained
1.	Project and construction of the transmission pipeline on ROW of the Route No. 5.	・ This project can support and improve the distribution of water in the Greater Yangon by YCDC in corporation with JICA. ・ The Project includes a WTP at Kokkowa and about 1.6 m diameter of transmission pipeline. ・ This line will be passed through the Htantabin and Hlaing Tharyar townships. ・ Generally, the pipe alignment is about 18.3 m from the center of the Route No.5. ・ The pipeline ROW of pipe line is about 3 m width. ・ So the affected area is in 16.8 m (55 ft) and 19.8 m (65 ft) for the center of the Route No.5.
2.	Necessity of involuntary resettlement for the Project and the legal status of the occupation	・ The transmission pipeline is planned to be constructed the pipeline ROW in which your households/shops are situated. ・ Your occupation status on the pipeline ROW is illegal because the land owner is the government. ・ Therefore, you are requested to involuntary remove your household/shop by the project.
3.	Possible environment and social impacts by the Project (mitigation measures)	・ The possible environment and social impacts by this project are air, noise and water pollution and soil degradation during the pipe line construction. Temporary distributing the transportation because of the heavy machines and cutting the private entrances. ・ Air pollution will be engaged at the construction period due to the transportation the heavy machines and power generators, and exhaust emission and dusting. The mitigation plans are: (a) altering work practices to avoid or minimize the generation of dust, (b) Spraying water on roads and tracks, (c) Dust limit vehicle speed on unsealed private road to less than 40 km/hr. ・ The noise will be generated from the transportation of the heavy machines and pipes during construction stage. ・ Mitigation plan will be carried out: (a) Turn equipment off when not in use, (b) Perform regular inspection and maintenance of construction vehicles and equipment to ensure that they have good quality mufflers installed and worn parts are replaced, (c) Avoid operations at night, where possible. ・ Soil degradation by removing the vegetation or trees, trenching for the pipeline and muddy soil will be come out from these operation.
4.	Project policy and the Entitlements of the involuntary resettlement for the illegal occupation	・ All the policies, processes, procedures and implementation arrangements are fully consistent with the JICA guidelines and JICA policy as well as relevant laws and regulations of Myanmar. ・ Namely loss of fixed and movable assets will be compensated in the replacement cost and for loss of income source will be achieve the rehabilitation assistance to restore their livelihoods.

No.	Expiatory Item	Description Orally Explained
		・ However, the compensation for land is not eligible due to the illegal occupation.
5.	Setting up of Cut-off Date	・ A cut-off date can be defined as the first date of the interview survey to the Project Affected Persons (PAPs) on the pipeline ROW. ・ Namely, any persons who occupy or insist the ownership for the project affected areas (lands are subject to acquisition, namely pipeline ROW) after the cut-off date are not eligible for any compensation and consultation.
6.	Possible resettlement schedule	・ According to the implementation schedule, the possible resettlement schedule will be started at end of 2018 or at the middle of 2019.
7.	Contact persons of YCDC for the resettlement	・ U Zaw Min, Executive Engineer, YCDC (water & sanitation).

Source: JICA Study Team

(3) Outcomes from Social-Economic Survey along the pipeline ROW

During the social-economic survey, it has been identified that a total of 6 households with 24 people and one local religious facility were affected in Htantabin Township, the details of which are summarized as follows.

1) Affected Illegal Occupants

The following Table shows detailed information of project affected persons and family members.

Table 11-25 The information of Affected Persons

Illegal Occupant	HH head Sex	HH head Age	HH Business	Business Permission	HH head Education	Religious	Ethnicity	Living years	HH Members
1	F	58	Rice storage of rice mill	Yes	Primary	Buddhist	Bamar	40	3
2	M	51	Bamboo shop	Yes	Primary	Buddhist	Bamar	51	5
3	F	40	Noodle Shop	No	Cannot read and write	Buddhist	Bamar	11	4
4	F	48	General Shop	No	Primary	Buddhist	Bamar	14	2
5	M	31	Shop (Closed)	No	Secondary	Buddhist	Bamar	13	5
6	M	37	House/ Restaurant	No	Primary	Buddhist	Bamar	7	5
Total	M 3 F 3	-	All Self-employed	Yes:2 No:4	Primary 4 Secondary 1 Other 1	All Buddhist	All Bamar	-	24
Min	-	31	-	-		-	-	7	2
Max	-	58	-	-		-	-	51	5
Average	-	44	-	-		-	-	23	4
Median	-	44	-	-		-	-	14	5

Source: JICA Study Team

2) Household Expenditure

The following Table shows average expenditures of project affected households.

Table 11-26 Average Affected Household Expenditure (MMK/Month)

Illegal Occupant	Food	Utilities (water, power, telephone)	Taxes	Transport	Education	Health	Clothing	Cooking Fuel
1	200,000	900,000	79,000	100,000	0	100,000	50,000	0
2	200,000	5,000	1,250	0	100,000	50,000	50,000	150,000
3	150,000	0	0	22,500	0	0	20,000	72,000
4	150,000	0	0	60,000	150,000	0	30,000	30,000
5	150,000	0	0	75,000	3,000	10,000	15,000	10,000
6	150,000	0	125,000	100,000	100,000	30,000	50,000	100,000
Min	150,000	0	0	0	0	0	15,000	0
Max	200,000	900,000	125,000	100,000	150,000	100,000	50,000	150,000
Average	166,667	150,833	34,208	59,583	58,833	31,667	35,833	60,333
Median	150,000	0	1,250	60,000	58,833	30,000	35,833	60,333

Source: JICA Study Team

3) Household/Shop Structure

The following Table shows project affected household/shop structures.

Table 11-27 Affected Household/Shop Structures

Illegal Occupant	Outside dimensions: (m x m)	Built year	Building permit	General condition		Materials		
				Outside:	Inside:	Walls	Roof	Floor inside
1	30mx1-1.7m	2014	No	fair	fair	-	Zinc	-
2	9.14mx11m	2014	No	fair	fair	-	Nipa	-
3	3.96mx3.04m	2013	No	poor	poor	-	Nipa	Bamboo
4	4.87mx4.57m	2015	No	poor	poor	-	Nipa	-
5	3.9mx3.96m	2015	No	poor	poor	-	Nipa	Bamboo
6	21.9mx8.2m	2015	No	fair	fair	Bamboo	Nipa	Concrete

Note: Nipa = stitched Nipa leaves, -: No wall/ No Floor

Source: JICA Study Team

In accordance with the interview data, the project affected person, families, households/shops and structures can be summarized as follows.

A. Affected Business

- ✓ One partially affected rice storage of rice mill (rice mill, the rice storage's sunshade, fence and some will be affected but the business can be continued to run)
- ✓ One partially affected bamboo shop (bamboos can be moved inside of the fence)
- ✓ Three totally affected small shops
- ✓ One partially affected house and restaurant (Some portions of the restaurant will be affected)
- ✓ One partially affected local religious facility

B. Vulnerability Issues,

- ✓ Three (3) households are woman headed households and one man headed household has a mental handicap daughter.
- ✓ Some portion of the rice storage of rice mill is constructed in village land and the others are in the

ROW of Route No. 5.

- ✓ The rice mill and the bamboo shop have the appropriated licenses.
- ✓ However, the other four shops do not have any licenses.
- ✓ All these six (6) affected structures and one religious facility constructed without building permits.

C. Religious and Ethnicity Conditions, and Others

- ✓ All of the member of households are Buddhist and Bamar.
- ✓ All affected households' livelihood depend on their own business from their shops and mill which are affected by this project.
- ✓ Basically all of the occupancies are willing to implement this project.

(4) Opinions, Requests and Responses from YCDC

Some opinions and requests are summarized in the following Table.

Table 11-28 Opinion, Questions, comments and Responses by YCDC

Illegal Occupant No.	Interviewee	Opinions/Questions/Comments from Occupant	Responses and Countermeasures expressed by YCDC
1	Owner	The owner requested to shift the pipe alignment if possible.	EE, YCDC, replied that YCDC will try to find other alternative ways to shift the alignment. So, the change of the alignment route will be considered at the detailed design stage.
2	Owner	The owner requested that YCDC to make quick action while in construction stage. Because pipe line alignment passes through his house entrance. So, if possible pipe line installation should be finished in short time.	EE, YCDC, replied that it will be quick because good heavy machines and vehicles will be used for this systematically. As explained before the interview, the impacts during construction phase are small and limited time and necessary countermeasures against the impacts are proposed.
3	Owner	The owner said that she will resettle her shop during construction into another place stage due to this project is for the public water supply. But after construction of pipe line, she wants to reopen her shop here.	As explained before the interview, this structure is located on the ROW of Route No. 5 as illegal occupation, for the involuntary resettlement, the JICA policy and entitlement for the resettlement were explained to the owner. In addition, EE replied that there'll needed to maintain after construction (operation stage). Therefore, her shop cannot be re-opened on the pipeline ROW.
4	Owner	The owner commented, this project is for the public water supply, so she will remove her shop during construction stage. But after construction of pipeline, she wants to reopen the shop right here.	As explained before the interview, this structure is located on the ROW of Route No. 5 as illegal occupation, for the involuntary resettlement, the JICA policy and entitlement for the resettlement were explained to the owner. In addition, EE replied that there will needed to maintain after construction (operation stage). Therefore, her shop cannot be re-opened on the pipeline ROW.
5	Owner	The owner has neither complained nor comments on this project, because his shop has been abandoned since last year. He will remove his shop from the	EE said that they will consider for replacement cost based on JICA entitlement matrix though he has not belonged to this shop anymore.

Illegal Occupant No.	Interviewee	Opinions/Questions/Comments from Occupant	Responses and Countermeasures expressed by YCDC
		pipeline alignment if necessary.	
6	Owner	The restaurant owner said that he will dissolve his shop by the time construction is started. And only this business is their livelihood. Therefore, he requested that he would like to dissolve his shop partially.	As explained before the interview, this structure is located on the ROW of Route No. 5 as illegal occupation, for the involuntary resettlement, the JICA policy and entitlement for the resettlement were explained to the owner. EE replied that partially dissolved might have to be decided after the detail design stage.
7	Benefactor	The benefactor said that this chapel was constructed by the instruction of his dream. So he is not willing to remove and resettle to another place. He has no another place to reconstruct.	As explained before the interview, this structure is located on the ROW of Route No. 5 as illegal occupation, for the involuntary resettlement, the JICA policy and entitlement for the resettlement were explained to the benefactor.

Source: JICA Study Team

CHAPTER 12 PROJECT EFFECTS

12.1 Quantitative Effects

The direct effects by implementation of Phase 2 project, same as Phase 1 project, are expected as listed below.

1. The service population with treated safe water will be increased.
2. The water consumption per capita will be increased.
3. The quality of supplied water will be improved.
4. The duration of water supply will be increased.

The following Table shows the proposed evaluation and performance indicators and their target values for the project.

Table 12-1 Evaluation and Performance Indicators

Indicator	Original (Yr 2015)	Target (Yr 2026)
Indicators for Zone 1 and Zone 9		
Operation Indicator		
Served Population (thousand)	546	1,040
- Zone 1 (Low subzone)	369	457
- Zone 1 (High subzone)	142	219
- Zone 9	36	364
Maximum Amount of Water Supply (MGD)	46	75
- Zone 1 (Low subzone)	32	37
- Zone 1 (High subzone)	12	18
- Zone 9	2	20
Rate of Facility Utilization (%) (Kokkowa WTP) *1	-	95
Water Pressure in Distribution Network (MPa) *2*3	0.075	0.15
Non-revenue Water Ratio (%) *2*4	66	20
Rate of Continuous Dosing of Disinfection Facility (%) *3	0	100
Minimum Amount of Residual Chlorine (mg/L) *3	0	0.1
Effect Indicator		
Served Coverage Rate (%)	36	63
Indicators for Yangon City (for reference)		
Served Population (thousand)	1,991	3,789
Maximum Amount of Water Supply (MGD)	162	274
Served Coverage Rate (%)	37	58

Notes:
*1: Rate of Facility Utilization = Max Amount of Water Supply in Zone 1 (Low) and Zone 9 / Capacity of Kokkowa WTP
*2: Base value is set from the average value of Yangon city in 2011
*3: Target value is set from the target service level of 2014 Water MP
*4: Target value is set same as the average value of other cities in the Southeast Asian countries.
Others: Values are set from the water demand of this Study (2016 Phase 2 FS)
2 years after the completion of the implementation works as Yr 2024
Source: JICA Study Team

Monitoring of projects effects are proposed to be implemented as per the following Table.

Table 12-2 Monitoring of Operation and Effect Indicators

Indicator for Zone 1 and Zone9	In charge of monitoring	Means of Verification	Monitoring Frequency
Served Population	YCDC	Calculation formula = number of water supply connections × average number members per household	Yearly
Maximum amount of water supply	YCDC	Amount of distributed water from each service reservoir (Zone 9, Kokine and Central SR)	Yearly
Rate of facility utilization of Kokkowa WTP	YCDC	Calculation formula = Volume of water produced annually at Kokkowa WTP / 365 days / WTP capacity	Yearly
Water pressure in distribution network	YCDC	Measurement at location where the pressure is expected to be the lowest among the distribution pipe network (the end of distribution pipe network or the location where the altitude is high)	Quarterly
NRW ratio	YCDC	Calculation formula = Amount of water consumed annually by users / Amount of water distributed annually (from Zone 9, Kokine and Central SR)	Yearly
Rate of continuous dosing of disinfection	YCDC	Measured at Kokkowa WTP	Quarterly
Free residual chlorine concentration	YCDC	Measured at the location where residual chlorine concentration is expected to be the lowest in distribution network (the end of distribution pipe network)	Quarterly
Served Coverage Rate	YCDC	Calculation formula = Number of water supply connection / (population ÷ average number of members per household)	Yearly

Source: JICA Study Team

12.2 Qualitative Effects

Qualitative effects envisaged by the project implementation are as follows:

- Improvement of the living environment of Yangon City residents
  - Improvement in water supply conditions mentioned above shall contribute to reduction in occurrence of water related diseases such as cholera, typhoid and diarrhea, and skin & eye diseases and is expected to improve health conditions of the people, which will contribute to reduction in medical expenditure of household.
  - The current cost for obtaining water will be reduced and the household expenditure on water will be reduced, which will indirectly contribute to improvement in the livelihood of the people.
  - Water use will be more convenient, i.e., whenever required, water will be supplied.
  - Water fetching time and efforts will be reduced and mitigated. As a result, working and education opportunity for women and children will be enhanced.

- Establishment of an environment for investment through water supply in Yangon City
  - Working opportunities will be created during construction and operation & maintenance of water supply facilities

- It will contribute to the stabilization of people's livelihood in the area and political stability.
- The industry and business that are now affected by dirty water supply will be activated and contribute to the development of the country.
- Occurrence of land subsidence and salinization of ground water is expected to be reduced due to reduction in groundwater withdrawal.

CHAPTER 13 RECOMMENDATIONS

Major problems of water supply conditions are low service coverage, low water pressure and short duration of water supply and undrinkable water supply. Major problems related to water supply facilities are limited water production, old facilities, and absence of disinfection in water supply system. Major problems related to management of water works include high NRW ratio and inefficiency of business management basis for waterworks. To tackle these problems, the proposed priority projects for infrastructure development and capacity building shall be implemented as soon as possible as a first step.

In addition, the assistance to enhance the capacity of YCDC on waterworks management shall be obtained from the countries with high technology and management skills such as Japan for effective and quick transfer of technology and management skills. For this purpose, Phase 1 project, JICA technical cooperation project and other capacity enhancement projects are being carried out in parallel currently and are expected to be very beneficial for YCDC.

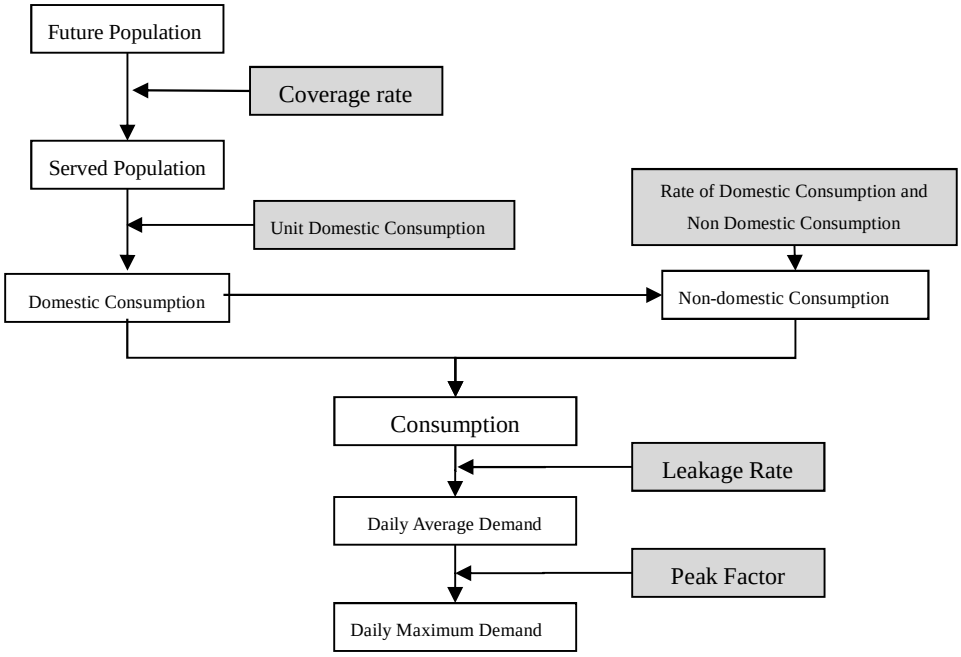
For long time, investment in infrastructure has been deferred and the service level of public water supply is at low level. Therefore, development of water supply facilities to improve water supply services requires input of a large amount of fund. To meet this requirement, the most favorable loan, soft loan of donor at low interest rate, shall be utilized to reduce financial burden of YCDC, or the country as a whole. However, due to the project's massive investment requirement and low profitability of water supply services sector, YCDC may need subsidy from Union Government as grant assistance. In such case, both ODA loan obligation and own-fund portion (or either one) should be borne by the Union Government.

In addition, to improve water supply services on sustainable basis through development of infrastructure, it is inevitable to raise water tariff level and optimize the system to carry out operation and maintenance without any subsidy. For this purpose, YCDC has to work with the public through public awareness activities and consider poor people in tariff setting.

APPENDICES

Table Review of Water Demand and Estimation Procedures

Item	Procedure of Water Demand Estimation	Sections	Remarks
Population of Yangon			
Township Population	A	3.2.3 Population Allocation	Township populations are revised using the 2014 census.
Water Demand by Township			
Service Coverage Ratio by Township	B	3.2.4(2) Service Coverage Ratio	Township service coverage ratio in 2014 is based on the census data
Served Population by Township	C = A x B	3.2.4(3) Served Population	Revised
Per Capita Consumption	D	3.2.4(4) Per Capita Consumption	Same as the MP
Leakage Ratio	E	3.2.4(5) NRW ratio and Leakage Ratio	Same as the MP, the targeted values of YCDC
Peak Factor	110%	3.2.4(6) Peak Factor	Same as the MP
Maximum Water demand	F = (C x D) / (1 – E) x 110%	3.2.4(7) Water Demand Estimation	Revised
Water Demand by Supply Zone			
	Converting township water demand into supply zone demand.	3.2.5 Water Demand by Water Supply Zone	Revised



Source: 2014 JICA Water MP

Figure Flow Chart of Water Demand Estimation

Population

				Source Census				→ Projected								
No	Township	District	WS Zone	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
1	Latha	West	1	25,057	25,057	25,057	25,057	25,057	25,057	25,057	25,057	25,057	25,057	25,057	25,057	25,057
2	Lanmadaw	West	1	47,160	47,160	47,160	47,160	47,160	47,160	47,160	47,160	47,160	47,160	47,160	47,160	47,160
3	Pabedan	West	1	33,336	33,336	33,336	33,336	33,336	33,336	33,336	33,336	33,336	33,336	33,336	33,336	33,336
4	Kyauktada	West	1	29,853	29,853	29,853	29,853	29,853	29,853	29,853	29,853	29,853	29,853	29,853	29,853	29,853
5	Botahtaung	East	1	40,995	40,995	40,995	40,995	40,995	40,995	40,995	40,995	40,995	40,995	40,995	40,995	40,995
6	Pazuntaung	East	1	48,455	48,455	48,455	48,455	48,455	48,455	48,455	48,455	48,455	48,455	48,455	48,455	48,455
	CBD			**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**
7	Ahlon	West	1	55,482	58,122	60,763	63,403	66,044	66,129	66,215	66,308	66,402	66,496	66,590	66,684	66,790
8	Kyimyindine	West	1,10	111,514	114,065	116,616	119,167	121,718	122,659	123,600	124,630	125,660	126,690	127,720	128,751	129,922
9	Sangyoung	West	1,3	99,619	101,149	102,680	104,211	105,742	105,827	105,913	106,006	106,100	106,194	106,288	106,382	106,488
10	Dagon	West	1	25,082	25,082	25,082	25,082	25,082	25,082	25,082	25,082	25,082	25,082	25,082	25,082	25,082
11	Bahan	West	1,2	96,732	96,807	96,882	96,957	97,032	97,244	97,456	97,533	97,611	97,689	97,766	97,844	97,936
12	Tamway	East	1,2	165,313	172,030	178,747	185,464	192,182	192,353	192,525	192,712	192,899	193,086	193,273	193,461	193,674
13	Mingala Taungnyunt	East	1	132,494	138,713	144,932	151,151	157,370	157,626	157,883	158,164	158,445	158,726	159,007	159,288	159,607
14	Seikkan	West	1	2,826	2,826	2,826	2,826	2,826	2,826	2,826	2,826	2,826	2,826	2,826	2,826	2,826
15	Dawbon	East	2	75,325	75,325	75,325	75,325	75,325	75,325	75,325	75,325	75,325	75,325	75,325	75,325	75,325
	Inner Urban Ring			**764,387**	**784,119**	**803,853**	**823,586**	**843,321**	**845,071**	**846,825**	**848,586**	**850,350**	**852,114**	**853,877**	**855,643**	**857,650**
16	Kamayut	West	1,3	84,569	86,064	87,560	89,056	90,552	90,980	91,408	91,876	92,344	92,812	93,280	93,749	94,281
17	Hline	West	3	160,307	160,307	160,307	160,307	160,307	160,307	160,307	160,307	160,307	160,307	160,307	160,307	160,307
18	Yankin	East	2,3	70,946	70,946	70,946	70,946	70,946	70,946	70,946	70,946	70,946	70,946	70,946	70,946	70,946
19	Thingangyun	East	2	209,486	209,486	209,486	209,486	209,486	209,486	209,486	209,486	209,486	209,486	209,486	209,486	209,486
	Outer Ring Zone			**525,308**	**526,803**	**528,299**	**529,795**	**531,291**	**531,719**	**532,147**	**532,615**	**533,083**	**533,551**	**534,019**	**534,488**	**535,020**
20	Mayangon	West	3,4	198,113	199,607	201,102	202,597	204,092	205,383	206,675	207,037	207,399	207,762	208,124	208,487	209,416
21	Insein	North	3,4	305,283	309,700	314,118	318,535	322,953	324,835	326,718	328,778	330,838	332,898	334,958	337,019	339,361
22	Mingaladon	North	4,5,6	331,586	344,660	357,735	370,810	383,885	405,638	427,392	457,079	486,766	516,453	546,140	575,828	601,419
	Northern Suburbs			**834,982**	**853,967**	**872,955**	**891,942**	**910,930**	**935,856**	**960,785**	**992,894**	**1,025,003**	**1,057,113**	**1,089,222**	**1,121,333**	**1,150,196**
23	North Okkalapa	East	4	333,293	337,347	341,402	345,456	349,511	352,077	354,644	357,453	360,263	363,072	365,882	368,692	371,886
24	South Okkalapa	East	2,3	161,126	161,126	161,126	161,126	161,126	161,126	161,126	161,126	161,126	161,126	161,126	161,126	161,126
25	Thakayta	East	2	220,556	220,556	220,556	220,556	220,556	220,556	220,556	220,556	220,556	220,556	220,556	220,556	220,556
	Older Suburbs Zone			**714,975**	**719,029**	**723,084**	**727,138**	**731,193**	**733,759**	**736,326**	**739,135**	**741,945**	**744,754**	**747,564**	**750,374**	**753,568**
26	Dala	South	10	172,857	188,670	204,484	220,298	236,112	244,924	253,737	263,383	273,029	282,675	292,321	301,968	312,935
27	Seikkyi/ Khanaungto	South	10	34,003	36,711	39,419	42,127	44,836	45,862	46,889	48,012	49,136	50,260	51,384	52,508	53,785
	South of CBD			**206,860**	**225,381**	**243,903**	**262,425**	**280,948**	**290,786**	**300,626**	**311,395**	**322,165**	**332,935**	**343,705**	**354,476**	**366,720**
28	Shwepyitha	North	5	343,526	348,537	353,549	358,560	363,573	366,207	368,842	372,003	375,164	378,326	381,487	384,649	397,295
29	Hlaing Tharyar	North	9	687,867	696,350	704,833	713,317	721,801	731,502	741,204	746,791	752,380	757,968	763,556	769,145	774,111
30	Dagon North	East	7	203,948	211,199	218,450	225,701	232,953	234,835	236,718	238,778	240,838	242,898	244,958	247,019	249,361
31	Dagon South	East	8	371,646	379,348	387,051	394,754	402,457	407,590	412,724	418,343	423,962	429,581	435,200	440,819	447,207
32	Dagon East	East	7	165,628	206,808	247,988	289,168	330,348	359,950	389,553	421,957	454,361	486,765	519,169	551,573	588,414
33	Dagon Seikkan	East	8	167,448	168,047	168,646	169,245	169,844	177,801	185,758	194,467	203,177	211,886	220,596	229,306	239,208
	New Suburbs Zone			**1,940,063**	**2,010,289**	**2,080,517**	**2,150,745**	**2,220,975**	**2,277,885**	**2,334,799**	**2,392,339**	**2,449,882**	**2,507,424**	**2,564,966**	**2,622,511**	**2,695,596**
	Total (Yangon city)			**5,211,431**	**5,344,444**	**5,477,467**	**5,610,487**	**5,743,514**	**5,839,932**	**5,936,364**	**6,041,820**	**6,147,284**	**6,252,747**	**6,358,209**	**6,463,681**	**6,583,606**
34	Kyauktan	South		N/A				N/A		N/A					N/A	
35	Thanlyin	South		N/A				N/A		N/A					N/A	
36	Hlegu	North		N/A				N/A		N/A					N/A	
37	Hmawby	North		N/A				N/A		N/A					N/A	
38	Htantabin	North		N/A				N/A		N/A					N/A	
39	Twantay	South		N/A				N/A		N/A					N/A	
	a part of 6 suburban TSs			**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**

	Total of Greter Yangon			**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
34	Kyauktan	South		123,565												
35	Thanlyin	South		204,486												
36	Hlegu	North		213,754												
37	Hmawby	North		192,270												
38	Htantabin	North		125,220												
39	Twantay	South		212,763												
	All 6 suburban TSs			**1,072,058**												

Note:
Constant : 2014 Census population is used for population in 2014 which is lower than the projected population in the Urban Development Study.
D: The projected population in the Urban Development Study is employed for future population.
Re-allocated: Population is re-allocated upward in Shwepyitha and Hlaing Tharyar townships while re-allocated downward in Mayangon township,

Population

No	Township	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Note
1	Latha	25,057	25,057	25,057	25,057	25,057	25,057	25,057	25,057	25,057	25,057	25,057	25,057	25,057	25,057	Constant
2	Lanmadaw	47,160	47,160	47,160	47,160	47,160	47,160	47,160	47,160	47,160	47,160	47,160	47,160	47,160	47,160	Constant
3	Pabedan	33,336	33,336	33,336	33,336	33,336	33,336	33,336	33,336	33,336	33,336	33,336	33,336	33,336	33,336	Constant
4	Kyauktada	29,853	29,853	29,853	29,853	29,853	29,853	29,853	29,853	29,853	29,853	29,853	29,853	29,853	29,853	Constant
5	Botahtaung	40,995	40,995	40,995	40,995	40,995	40,995	40,995	40,995	40,995	40,995	40,995	40,995	40,995	40,995	Constant
6	Pazuntaung	48,455	48,455	48,455	48,455	48,455	48,455	48,455	48,455	48,455	48,455	48,455	48,455	48,455	48,455	Constant
	CBD	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	
7	Ahlon	66,896	67,003	67,109	67,216	67,337	67,458	67,579	67,700	67,821	67,958	68,096	68,233	68,371	68,509	D
8	Kyimyindine	131,093	132,264	133,435	134,607	135,938	137,270	138,601	139,933	141,265	142,779	144,293	145,807	147,321	148,835	D
9	Sangyoung	106,594	106,701	106,807	106,914	107,035	107,156	107,277	107,398	107,519	107,656	107,794	107,931	108,069	108,207	D
10	Dagon	25,082	25,082	25,082	25,082	25,082	25,082	25,082	25,082	25,082	25,082	25,082	25,082	25,082	25,082	Constant
11	Bahan	98,028	98,119	98,211	98,304	98,473	98,642	98,812	98,981	99,151	99,193	99,235	99,277	99,319	99,361	D
12	Tamway	193,887	194,100	194,313	194,526	194,768	195,010	195,252	195,494	195,737	196,012	196,287	196,562	196,837	197,113	D
13	Mingala Taungnyunt	159,926	160,246	160,565	160,885	161,248	161,611	161,974	162,337	162,701	163,113	163,526	163,939	164,352	164,765	D
14	Seikkan	2,826	2,826	2,826	2,826	2,826	2,826	2,826	2,826	2,826	2,826	2,826	2,826	2,826	2,826	Constant
15	Dawbon	75,325	75,325	75,325	75,325	75,325	75,325	75,325	75,325	75,325	75,325	75,325	75,325	75,325	75,325	Constant
	Inner Urban Ring	**859,657**	**861,666**	**863,673**	**865,685**	**868,032**	**870,380**	**872,728**	**875,076**	**877,427**	**879,944**	**882,464**	**884,982**	**887,502**	**890,023**	
16	Kamayut	94,813	95,346	95,878	96,411	97,016	97,621	98,226	98,831	99,437	100,125	100,813	101,501	102,189	102,878	D
17	Hline	160,307	160,307	160,307	160,307	160,307	160,307	160,307	160,307	160,307	160,307	160,307	160,307	160,307	160,307	Constant
18	Yankin	70,946	70,946	70,946	70,946	70,946	70,946	70,946	70,946	70,946	70,946	70,946	70,946	70,946	70,946	Constant
19	Thingangyun	209,486	209,486	209,486	209,486	209,486	209,486	209,486	209,486	209,486	209,486	209,486	209,486	209,486	209,486	Constant
	Outer Ring Zone	**535,552**	**536,085**	**536,617**	**537,150**	**537,755**	**538,360**	**538,965**	**539,570**	**540,176**	**540,864**	**541,552**	**542,240**	**542,928**	**543,617**	
20	Mayangon	210,345	211,275	212,204	213,134	214,012	214,890	215,768	216,647	217,526	218,547	219,568	220,589	221,611	222,633	Re-allocated
21	Insein	341,704	344,046	346,389	348,732	351,395	354,058	356,721	359,384	362,048	365,076	368,104	371,132	374,160	377,188	D
22	Mingaladon	627,012	652,604	678,196	703,789	729,381	754,973	780,566	806,158	831,751	846,750	861,749	876,749	891,748	906,748	D
	Northern Suburbs	**1,179,061**	**1,207,925**	**1,236,789**	**1,265,655**	**1,294,788**	**1,323,921**	**1,353,055**	**1,382,189**	**1,411,325**	**1,430,373**	**1,449,421**	**1,468,470**	**1,487,519**	**1,506,569**	
23	North Okkalapa	375,080	378,275	381,469	384,664	388,295	391,927	395,559	399,191	402,823	406,952	411,081	415,210	419,339	423,468	D
24	South Okkalapa	161,126	161,126	161,126	161,126	161,126	161,126	161,126	161,126	161,126	161,126	161,126	161,126	161,126	161,126	Constant
25	Thakayta	220,556	220,556	220,556	220,556	220,556	220,556	220,556	220,556	220,556	220,556	220,556	220,556	220,556	220,556	Constant
	Older Suburbs Zone	**756,762**	**759,957**	**763,151**	**766,346**	**769,977**	**773,609**	**777,241**	**780,873**	**784,505**	**788,634**	**792,763**	**796,892**	**801,021**	**805,150**	
26	Dala	323,902	334,869	345,836	356,804	369,273	381,742	394,211	406,680	419,150	433,326	447,502	461,679	475,855	490,032	D
27	Seikkyi/ Khanaungto	55,063	56,341	57,619	58,897	60,349	61,802	63,254	64,707	66,160	67,811	69,463	71,115	72,767	74,419	D
	South of CBD	**378,965**	**391,210**	**403,455**	**415,701**	**429,622**	**443,544**	**457,465**	**471,387**	**485,310**	**501,137**	**516,965**	**532,794**	**548,622**	**564,451**	
28	Shwepyitha	409,941	422,587	435,233	447,879	459,471	471,063	482,655	494,247	505,840	525,125	544,410	563,695	582,980	602,266	Re-allocated
29	Hlaing Tharyar	779,078	784,046	789,013	793,981	805,933	817,885	829,837	841,790	853,743	875,474	897,205	918,937	940,669	962,401	Re-allocated
30	Dagon North	251,704	254,046	256,389	258,732	261,395	264,058	266,721	269,384	272,048	275,076	278,104	281,132	284,160	287,188	D
31	Dagon South	453,596	459,985	466,374	472,763	480,026	487,289	494,553	501,816	509,080	517,338	525,596	533,854	542,112	550,371	D
32	Dagon East	625,255	662,096	698,937	735,779	777,665	819,551	861,437	903,323	945,210	992,832	1,040,454	1,088,076	1,135,698	1,183,320	D
33	Dagon Seikkan	249,110	259,013	268,915	278,818	290,076	301,335	312,593	323,852	335,111	347,911	360,711	373,511	386,311	399,111	D
	New Suburbs Zone	**2,768,684**	**2,841,773**	**2,914,861**	**2,987,952**	**3,074,566**	**3,161,181**	**3,247,796**	**3,334,412**	**3,421,032**	**3,533,756**	**3,646,480**	**3,759,205**	**3,871,930**	**3,984,657**	
	Total (Yangon city)	**6,703,537**	**6,823,472**	**6,943,402**	**7,063,345**	**7,199,596**	**7,335,851**	**7,472,106**	**7,608,363**	**7,744,630**	**7,899,564**	**8,054,501**	**8,209,439**	**8,364,378**	**8,519,323**	as same as MP
34	Kyauktan				N/A					N/A					N/A	
35	Thanlyin				N/A					N/A					N/A	
36	Hlegu				N/A					N/A					N/A	
37	Hmawby				N/A					N/A					N/A	
38	Htantabin				N/A					N/A					N/A	
39	Twantay				N/A					N/A					N/A	
	a part of 6 suburban TSs	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	

	Total of Greter Yangon	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	

34	Kyauktan															
35	Thanlyin															
36	Hlegu															
37	Hmawby															
38	Htantabin															
39	Twantay															
	All 6 suburban TSs															

Note:
Constant : 2014 Census population is used for population in 2014 which is lower than the projected population in the Urban Development Study.
D: The projected population in the Urban Development Study is employed for future population.
Re-allocated: Population is re-allocated upward in Shwepyitha and Hlaing Tharyar townships while re-allocated downward in Mayangon township,

Served Population

Source: Census → Projected

No	Township	District	WS Zone	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
1	Latha	West	1	21,382	21,862	22,342	22,822	23,303	23,804	24,305	24,455	24,605	24,756	24,906	25,057	25,057
2	Lanmadaw	West	1	32,884	33,859	34,834	35,809	36,784	37,727	38,671	39,614	40,557	41,500	42,443	43,387	44,141
3	Pabedan	West	1	29,277	29,958	30,639	31,320	32,002	32,669	33,336	33,336	33,336	33,336	33,336	33,336	33,336
4	Kyauktada	West	1	28,599	28,912	29,226	29,539	29,853	29,853	29,853	29,853	29,853	29,853	29,853	29,853	29,853
5	Botahtaung	East	1	40,165	40,372	40,580	40,787	40,995	40,995	40,995	40,995	40,995	40,995	40,995	40,995	40,995
6	Pazuntaung	East	1	47,777	47,946	48,116	48,285	48,455	48,455	48,455	48,455	48,455	48,455	48,455	48,455	48,455
	CBD			**200,084**	**202,909**	**205,737**	**208,562**	**211,392**	**213,503**	**215,615**	**216,708**	**217,801**	**218,895**	**219,988**	**221,083**	**221,837**
7	Ahlon	West	1	11,057	12,915	14,774	16,633	18,492	19,840	21,188	22,951	24,715	26,479	28,243	30,007	31,399
8	Kyimyindine	West	1,10	4,395	6,947	9,500	12,053	14,606	17,191	19,776	22,515	25,255	27,995	30,735	33,475	36,471
9	Sangyoung	West	1,3	14,231	16,489	18,747	21,005	23,263	25,400	27,537	31,603	35,670	39,737	43,804	47,871	50,057
10	Dagon	West	1	11,735	12,250	12,765	13,280	13,795	14,296	14,798	15,299	15,801	16,302	16,804	17,306	17,807
11	Bahan	West	1,2	83,442	85,384	87,326	89,268	91,210	93,358	95,507	95,974	96,441	96,909	97,376	97,844	97,935
12	Tamway	East	1,2	144,069	153,694	163,320	172,946	182,572	186,585	190,599	191,171	191,743	192,316	192,888	193,461	193,674
13	Mingala Taungnyunt	East	1	127,571	135,020	142,470	149,920	157,370	157,626	157,883	158,164	158,445	158,726	159,007	159,288	159,607
14	Seikkan	West	1	1,867	1,923	1,979	2,035	2,091	2,147	2,204	2,260	2,316	2,373	2,429	2,486	2,542
15	Dawbon	East	2	21,924	23,410	24,897	26,383	27,870	29,376	30,883	32,389	33,895	35,402	36,908	38,415	39,921
	Inner Urban Ring			**420,291**	**448,032**	**475,778**	**503,523**	**531,269**	**545,819**	**560,375**	**572,326**	**584,281**	**596,239**	**608,194**	**620,153**	**629,413**
16	Kamayut	West	1,3	6,672	8,626	10,580	12,534	14,488	16,384	18,281	23,062	27,843	32,624	37,405	42,187	44,354
17	Hline	West	3	42,780	46,111	49,443	52,775	56,107	59,313	62,519	65,725	68,931	72,137	75,343	78,550	81,756
18	Yankin	East	2,3	63,292	64,673	66,054	67,435	68,817	69,881	70,946	70,946	70,946	70,946	70,946	70,946	70,946
19	Thingangyun	East	2	100,942	105,034	109,127	113,219	117,312	121,501	125,691	129,880	134,070	138,260	142,450	146,640	150,829
	Outer Ring Zone			**213,686**	**224,444**	**235,204**	**245,963**	**256,724**	**267,079**	**277,437**	**289,613**	**301,790**	**313,967**	**326,144**	**338,323**	**347,885**
20	Mayangon	West	3,4	95,853	100,462	105,072	109,681	114,291	119,148	124,005	128,392	132,779	137,166	141,553	145,940	150,853
21	Insein	North	3,4	78,934	86,651	94,369	102,086	109,804	116,978	124,152	131,675	139,198	146,722	154,245	161,769	169,868
22	Mingaladon	North	4,5,6	98,186	110,108	122,031	133,953	145,876	162,690	179,504	203,489	227,474	251,459	275,444	299,430	326,813
	Northern Suburbs			**272,973**	**297,221**	**321,472**	**345,720**	**369,971**	**398,816**	**427,661**	**463,556**	**499,451**	**535,347**	**571,242**	**607,139**	**647,534**
23	North Okkalapa	East	4	286,487	297,000	307,513	318,026	328,540	338,045	347,551	351,779	356,007	360,235	364,463	368,692	371,886
24	South Okkalapa	East	2,3	110,186	113,253	116,320	119,387	122,455	125,677	128,900	132,122	135,345	138,567	141,790	145,013	148,235
25	Thakayta	East	2	61,339	65,854	70,369	74,884	79,400	83,811	88,222	92,633	97,044	101,455	105,866	110,278	114,689
	Older Suburbs Zone			**458,012**	**476,107**	**494,202**	**512,297**	**530,395**	**547,533**	**564,673**	**576,534**	**588,396**	**600,257**	**612,119**	**623,983**	**634,810**
26	Dala	South	10	17,644	23,858	30,072	36,286	42,500	49,161	55,822	63,983	72,144	80,306	88,467	96,629	107,274
27	Seikkyi/ Khanaungto	South	10	21	912	1,803	2,694	3,586	4,606	5,626	6,811	7,996	9,181	10,366	11,551	13,010
	South of CBD			**17,665**	**24,770**	**31,875**	**38,980**	**46,086**	**53,767**	**61,448**	**70,794**	**80,140**	**89,487**	**98,833**	**108,180**	**120,284**
28	Shwepyitha	North	5	28,511	35,926	43,341	50,756	58,171	65,969	73,768	82,093	90,418	98,743	107,068	115,394	128,145
29	Hlaing Tharyar	North	9	21,023	35,616	50,210	64,804	79,398	95,289	111,180	158,167	205,154	252,141	299,128	346,115	364,229
30	Dagon North	East	7	69,770	76,787	83,805	90,822	97,840	103,365	108,890	114,778	120,666	126,554	132,442	138,330	144,816
31	Dagon South	East	8	93,288	103,168	113,049	122,929	132,810	142,758	152,707	163,602	174,497	185,393	196,288	207,184	219,642
32	Dagon East	East	7	26,397	39,618	52,840	66,061	79,283	94,178	109,074	129,178	149,283	169,387	189,492	209,597	238,312
33	Dagon Seikkan	East	8	23,245	26,775	30,305	33,835	37,365	42,831	48,297	55,147	61,998	68,848	75,699	82,550	91,691
	New Suburbs Zone			**262,234**	**317,890**	**373,550**	**429,207**	**484,867**	**544,390**	**603,916**	**702,965**	**802,016**	**901,066**	**1,000,117**	**1,099,170**	**1,186,835**
	Total (Yangon city)			**1,844,945**	**1,991,373**	**2,137,818**	**2,284,252**	**2,430,704**	**2,570,907**	**2,711,125**	**2,892,496**	**3,073,875**	**3,255,258**	**3,436,637**	**3,618,031**	**3,788,598**

* Served Population = Population x Coverage Rate

Served Population

Source:

No	Township	WS Zone	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
1	Latha	1	25,057	25,057	25,057	25,057	25,057	25,057	25,057	25,057	25,057	25,057	25,057	25,057	25,057	25,057
2	Lanmadaw	1	44,896	45,650	46,405	47,160	47,160	47,160	47,160	47,160	47,160	47,160	47,160	47,160	47,160	47,160
3	Pabedan	1	33,336	33,336	33,336	33,336	33,336	33,336	33,336	33,336	33,336	33,336	33,336	33,336	33,336	33,336
4	Kyauktada	1	29,853	29,853	29,853	29,853	29,853	29,853	29,853	29,853	29,853	29,853	29,853	29,853	29,853	29,853
5	Botahtaung	1	40,995	40,995	40,995	40,995	40,995	40,995	40,995	40,995	40,995	40,995	40,995	40,995	40,995	40,995
6	Pazuntaung	1	48,455	48,455	48,455	48,455	48,455	48,455	48,455	48,455	48,455	48,455	48,455	48,455	48,455	48,455
	CBD		**222,592**	**223,346**	**224,101**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**	**224,856**
7	Ahlon	1	32,791	34,183	35,575	36,968	38,391	39,814	41,237	42,660	44,083	45,542	47,002	48,461	49,921	51,381
8	Kyimyindine	1,10	39,468	42,464	45,461	48,458	51,762	55,067	58,371	61,676	64,981	68,654	72,327	76,000	79,673	83,347
9	Sangyoung	1,3	52,243	54,429	56,615	58,802	61,019	63,236	65,453	67,670	69,887	72,140	74,394	76,647	78,901	81,155
10	Dagon	1	18,309	18,810	19,312	19,814	20,315	20,817	21,318	21,820	22,322	22,823	23,325	23,827	24,329	24,831
11	Bahan	1,2	98,027	98,119	98,211	98,303	98,472	98,642	98,811	98,981	99,151	99,193	99,235	99,277	99,319	99,361
12	Tamway	1,2	193,887	194,100	194,313	194,526	194,768	195,010	195,252	195,494	195,737	196,012	196,287	196,562	196,837	197,113
13	Mingala Taungnyunt	1	159,926	160,246	160,565	160,885	161,248	161,611	161,974	162,337	162,701	163,113	163,526	163,939	164,352	164,765
14	Seikkan	1	2,599	2,655	2,712	2,769	2,780	2,791	2,803	2,814	2,826	2,826	2,826	2,826	2,826	2,826
15	Dawbon	2	41,428	42,934	44,441	45,948	47,454	48,960	50,467	51,973	53,480	54,986	56,493	57,999	59,506	61,013
	Inner Urban Ring		**638,678**	**647,940**	**657,205**	**666,473**	**676,209**	**685,948**	**695,686**	**705,425**	**715,168**	**725,289**	**735,415**	**745,538**	**755,664**	**765,792**
16	Kamayut	1,3	46,522	48,690	50,858	53,026	55,347	57,669	59,990	62,312	64,634	67,138	69,643	72,148	74,653	77,158
17	Hline	3	84,962	88,168	91,374	94,581	97,787	100,993	104,199	107,405	110,611	113,817	117,023	120,229	123,435	126,642
18	Yankin	2,3	70,946	70,946	70,946	70,946	70,946	70,946	70,946	70,946	70,946	70,946	70,946	70,946	70,946	70,946
19	Thingangyun	2	155,019	159,208	163,398	167,588	171,777	175,967	180,157	184,347	188,537	192,726	196,916	201,106	205,296	209,486
	Outer Ring Zone		**357,449**	**367,012**	**376,576**	**386,141**	**395,857**	**405,575**	**415,292**	**425,010**	**434,728**	**444,627**	**454,528**	**464,429**	**474,330**	**484,232**
20	Mayangon	3,4	155,766	160,680	165,593	170,507	175,560	180,613	185,666	190,719	195,773	201,144	206,516	211,888	217,260	222,632
21	Insein	3,4	177,967	186,066	194,165	202,264	211,049	219,835	228,620	237,406	246,192	255,794	265,397	275,000	284,603	294,206
22	Mingaladon	4,5,6	354,197	381,581	408,965	436,349	468,851	501,353	533,855	566,357	598,860	627,794	656,729	685,663	714,598	743,533
	Northern Suburbs		**687,930**	**728,327**	**768,723**	**809,120**	**855,460**	**901,801**	**948,141**	**994,482**	**1,040,825**	**1,084,732**	**1,128,642**	**1,172,551**	**1,216,461**	**1,260,371**
23	North Okkalapa	4	375,080	378,275	381,469	384,664	388,295	391,927	395,559	399,191	402,823	406,952	411,081	415,210	419,339	423,468
24	South Okkalapa	2,3	151,458	154,680	157,903	161,126	161,126	161,126	161,126	161,126	161,126	161,126	161,126	161,126	161,126	161,126
25	Thakayta	2	119,100	123,511	127,922	132,333	136,744	141,155	145,566	149,977	154,389	158,800	163,211	167,622	172,033	176,444
	Older Suburbs Zone		**645,638**	**656,466**	**667,294**	**678,123**	**686,165**	**694,208**	**702,251**	**710,294**	**718,338**	**726,878**	**735,418**	**743,958**	**752,498**	**761,038**
26	Dala	10	117,920	128,565	139,211	149,857	163,477	177,097	190,717	204,337	217,958	235,130	252,302	269,474	286,646	303,819
27	Seikkyi/ Khanaungto	10	14,469	15,928	17,387	18,847	20,635	22,423	24,211	25,999	27,787	29,969	32,151	34,333	36,515	38,697
	South of CBD		**132,389**	**144,493**	**156,598**	**168,704**	**184,112**	**199,520**	**214,928**	**230,336**	**245,745**	**265,099**	**284,453**	**303,807**	**323,161**	**342,516**
28	Shwepyitha	5	140,896	153,648	166,399	179,151	193,904	208,658	223,412	238,166	252,920	274,607	296,295	317,983	339,671	361,359
29	Hlaing Tharyar	9	382,344	400,459	418,574	436,689	460,337	483,986	507,634	531,283	554,932	588,305	621,679	655,052	688,426	721,800
30	Dagon North	7	151,303	157,789	164,276	170,763	177,961	185,160	192,358	199,557	206,756	214,801	222,846	230,891	238,936	246,981
31	Dagon South	8	232,100	244,558	257,016	269,474	283,795	298,117	312,439	326,761	341,083	357,623	374,163	390,704	407,244	423,785
32	Dagon East	7	267,027	295,742	324,457	353,173	392,182	431,192	470,201	509,211	548,221	599,508	650,795	702,082	753,369	804,657
33	Dagon Seikkan	8	100,832	109,973	119,114	128,256	140,137	152,018	163,899	175,780	187,662	202,812	217,962	233,112	248,262	263,413
	New Suburbs Zone		**1,274,502**	**1,362,169**	**1,449,836**	**1,537,506**	**1,648,316**	**1,759,131**	**1,869,943**	**1,980,758**	**2,091,574**	**2,237,656**	**2,383,740**	**2,529,824**	**2,675,908**	**2,821,995**
	Total (Yangon city)		**3,959,178**	**4,129,753**	**4,300,333**	**4,470,923**	**4,670,975**	**4,871,039**	**5,071,097**	**5,271,161**	**5,471,234**	**5,709,137**	**5,947,052**	**6,184,963**	**6,422,878**	**6,660,800**

* Served Population = Population x Coverage Rate

Coverage Rate

Source: MP Census → Projected

No	Township	District	WS Zone	2011	2014	2018	2020	2025	2030	2035	2040	Note
1	Latha	West	1	93.0	85.3	93.0	97.0	100.0	100.0	100.0	100.0	
2	Lanmadaw	West	1	86.0	69.7	78.0	82.0	92.0	100.0	100.0	100.0	
3	Pabedan	West	1	94.0	87.8	96.0	100.0	100.0	100.0	100.0	100.0	
4	Kyauktada	West	1	96.0	95.8	100.0	100.0	100.0	100.0	100.0	100.0	
5	Botahtaung	East	1	92.0	98.0	100.0	100.0	100.0	100.0	100.0	100.0	
6	Pazuntaung	East	1	99.0	98.6	100.0	100.0	100.0	100.0	100.0	100.0	
	CBD			**93.4**	**89.0**	**94.0**	**95.9**	**98.3**	**100.0**	**100.0**	**100.0**	
7	Ahlon	West	1	47.0	19.9	28.0	32.0	45.0	55.0	65.0	75.0	**
8	Kyimyindine	West	1,10	17.0	3.9	12.0	16.0	26.0	36.0	46.0	56.0	
9	Sangyoung	West	1,3	43.0	14.3	22.0	26.0	45.0	55.0	65.0	75.0	**
10	Dagon	West	1	59.0	46.8	55.0	59.0	69.0	79.0	89.0	99.0	
11	Bahan	West	1,2	82.0	86.3	94.0	98.0	100.0	100.0	100.0	100.0	
12	Tamway	East	1,2	88.0	87.1	95.0	99.0	100.0	100.0	100.0	100.0	
13	Mingala Taungnyunt	East	1	96.0	96.3	100.0	100.0	100.0	100.0	100.0	100.0	
14	Seikkan	West	1	60.0	66.1	74.0	78.0	88.0	98.0	100.0	100.0	
15	Dawbon	East	2	26.0	29.1	37.0	41.0	51.0	61.0	71.0	81.0	
	Inner Urban Ring			**63.0**	**55.0**	**63.0**	**66.2**	**72.5**	**77.0**	**81.5**	**86.0**	
16	Kamayut	West	1,3	24.0	7.9	16.0	20.0	45.0	55.0	65.0	75.0	**
17	Hline	West	3	18.0	26.7	35.0	39.0	49.0	59.0	69.0	79.0	
18	Yankin	East	2,3	85.0	89.2	97.0	100.0	100.0	100.0	100.0	100.0	
19	Thingangyun	East	2	50.0	48.2	56.0	60.0	70.0	80.0	90.0	100.0	
	Outer Ring Zone			**45.5**	**40.7**	**48.3**	**52.1**	**63.3**	**71.9**	**80.5**	**89.1**	
20	Mayangon	West	3,4	39.0	48.4	56.0	60.0	70.0	80.0	90.0	100.0	
21	Insein	North	3,4	26.0	25.9	34.0	38.0	48.0	58.0	68.0	78.0	
22	Mingaladon	North	4,5,6	16.0	29.6	38.0	42.0	52.0	62.0	72.0	82.0	
	Northern Suburbs			**25.7**	**32.7**	**40.6**	**44.5**	**54.1**	**63.9**	**73.7**	**83.7**	
23	North Okkalapa	East	4	84.0	86.0	94.0	98.0	100.0	100.0	100.0	100.0	
24	South Okkalapa	East	2,3	66.0	68.4	76.0	80.0	90.0	100.0	100.0	100.0	
25	Thakayta	East	2	14.0	27.8	36.0	40.0	50.0	60.0	70.0	80.0	
	Older Suburbs Zone			**56.8**	**64.1**	**72.5**	**76.7**	**83.2**	**88.5**	**91.6**	**94.5**	
26	Dala	South	10	5.0	10.2	18.0	22.0	32.0	42.0	52.0	62.0	
27	Seikkyi/ Khanaungto	South	10	0.0	0.1	8.0	12.0	22.0	32.0	42.0	52.0	
	South of CBD			**4.1**	**8.5**	**16.4**	**20.4**	**30.5**	**40.6**	**50.6**	**60.7**	
28	Shwepyitha	North	5	7.0	8.3	16.0	20.0	30.0	40.0	50.0	60.0	
29	Hlaing Tharyar	North	9	2.0	3.1	11.0	15.0	45.0	55.0	65.0	75.0	**
30	Dagon North	East	7	26.0	34.2	42.0	46.0	56.0	66.0	76.0	86.0	
31	Dagon South	East	8	28.0	25.1	33.0	37.0	47.0	57.0	67.0	77.0	
32	Dagon East	East	7	20.0	15.9	24.0	28.0	38.0	48.0	58.0	68.0	
33	Dagon Seikkan	East	8	0.0	13.9	22.0	26.0	36.0	46.0	56.0	66.0	
	New Suburbs Zone			**13.4**	**13.5**	**21.8**	**25.9**	**41.9**	**51.5**	**61.1**	**70.8**	
	Total (Yangon city)			**37.3**	**35.4**	**42.3**	**45.7**	**56.0**	**63.3**	**70.6**	**78.2**	

* Increase in 2%/year from 2014

** Low rate TSs in Zone1 & 9 are set to 45%

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LPCD of Domestic

Source: → as same as MP

No	Township	District	WS Zone	2014	2018	2020	2025	2030	2035	2040	Note
1	Latha	West	1	111	126	133	150	167	183	200	
2	Lanmadaw	West	1	111	126	133	150	167	183	200	
3	Pabedan	West	1	111	126	133	150	167	183	200	
4	Kyauktada	West	1	111	126	133	150	167	183	200	
5	Botahtaung	East	1	111	126	133	150	167	183	200	
6	Pazuntaung	East	1	111	126	133	150	167	183	200	
	CBD			**111**	**126**	**133**	**150**	**167**	**183**	**200**	
7	Ahlon	West	1	111	126	133	150	167	183	200	
8	Kyimyindine	West	1,10	111	126	133	150	167	183	200	
9	Sangyoung	West	1,3	111	126	133	150	167	183	200	
10	Dagon	West	1	111	126	133	150	167	183	200	
11	Bahan	West	1,2	111	126	133	150	167	183	200	
12	Tamway	East	1,2	111	126	133	150	167	183	200	
13	Mingala Taungnyunt	East	1	111	126	133	150	167	183	200	
14	Seikkan	West	1	111	126	133	150	167	183	200	
15	Dawbon	East	2	111	126	133	150	167	183	200	
	Inner Urban Ring			**111**	**126**	**133**	**150**	**167**	**183**	**200**	
16	Kamayut	West	1,3	111	126	133	150	167	183	200	
17	Hline	West	3	111	126	133	150	167	183	200	
18	Yankin	East	2,3	111	126	133	150	167	183	200	
19	Thingangyun	East	2	111	126	133	150	167	183	200	
	Outer Ring Zone			**111**	**126**	**133**	**150**	**167**	**183**	**200**	
20	Mayangon	West	3,4	111	126	133	150	167	183	200	
21	Insein	North	3,4	111	126	133	150	167	183	200	
22	Mingaladon	North	4,5,6	111	126	133	150	167	183	200	
	Northern Suburbs			**111**	**126**	**133**	**150**	**167**	**183**	**200**	
23	North Okkalapa	East	4	111	126	133	150	167	183	200	
24	South Okkalapa	East	2,3	111	126	133	150	167	183	200	
25	Thakayta	East	2	111	126	133	150	167	183	200	
	Older Suburbs Zone			**111**	**126**	**133**	**150**	**167**	**183**	**200**	
26	Dala	South	10	69	80	86	100	117	133	150	
27	Seikkyi/ Khanaungto	South	10	69	80	86	100	117	133	150	
	South of CBD			**69**	**80**	**86**	**100**	**117**	**133**	**150**	
28	Shwepyitha	North	5	69	80	86	100	117	133	150	
29	Hlaing Tharyar	North	9	69	80	86	100	117	133	150	
30	Dagon North	East	7	69	80	86	100	117	133	150	
31	Dagon South	East	8	69	80	86	100	117	133	150	
32	Dagon East	East	7	69	80	86	100	117	133	150	
33	Dagon Seikkan	East	8	69	80	86	100	117	133	150	
	New Suburbs Zone			**69**	**80**	**86**	**100**	**117**	**133**	**150**	
	Total (Yangon city)										

LPCD (Dom. + Non dome.)

Source: → as same as MP

No	Township	District	WS Zone	2014	2018	2020	2025	2030	2035	2040	Note
1	Latha	West	1	185	210	222	250	278	305	333	
2	Lanmadaw	West	1	185	210	222	250	278	305	333	
3	Pabedan	West	1	185	210	222	250	278	305	333	
4	Kyauktada	West	1	185	210	222	250	278	305	333	
5	Botahtaung	East	1	185	210	222	250	278	305	333	
6	Pazuntaung	East	1	185	210	222	250	278	305	333	
	CBD			**185**	**210**	**222**	**250**	**278**	**305**	**333**	
7	Ahlon	West	1	185	210	222	250	278	305	333	
8	Kyimyindine	West	1,10	185	210	222	250	278	305	333	
9	Sangyoung	West	1,3	185	210	222	250	278	305	333	
10	Dagon	West	1	185	210	222	250	278	305	333	
11	Bahan	West	1,2	185	210	222	250	278	305	333	
12	Tamway	East	1,2	185	210	222	250	278	305	333	
13	Mingala Taungnyunt	East	1	185	210	222	250	278	305	333	
14	Seikkan	West	1	185	210	222	250	278	305	333	
15	Dawbon	East	2	185	210	222	250	278	305	333	
	Inner Urban Ring			**185**	**210**	**222**	**250**	**278**	**305**	**333**	
16	Kamayut	West	1,3	185	210	222	250	278	305	333	
17	Hline	West	3	185	210	222	250	278	305	333	
18	Yankin	East	2,3	185	210	222	250	278	305	333	
19	Thingangyun	East	2	185	210	222	250	278	305	333	
	Outer Ring Zone			**185**	**210**	**222**	**250**	**278**	**305**	**333**	
20	Mayangon	West	3,4	185	210	222	250	278	305	333	
21	Insein	North	3,4	185	210	222	250	278	305	333	
22	Mingaladon	North	4,5,6	185	210	222	250	278	305	333	
	Northern Suburbs			**185**	**210**	**222**	**250**	**278**	**305**	**333**	
23	North Okkalapa	East	4	185	210	222	250	278	305	333	
24	South Okkalapa	East	2,3	185	210	222	250	278	305	333	
25	Thakayta	East	2	185	210	222	250	278	305	333	
	Older Suburbs Zone			**185**	**210**	**222**	**250**	**278**	**305**	**333**	
26	Dala	South	10	115	133	143	167	195	222	250	
27	Seikkyi/ Khanaungto	South	10	115	133	143	167	195	222	250	
	South of CBD			**115**	**133**	**143**	**167**	**195**	**222**	**250**	
28	Shwepyitha	North	5	115	133	143	167	195	222	250	
29	Hlaing Tharyar	North	9	115	133	143	167	195	222	250	
30	Dagon North	East	7	115	133	143	167	195	222	250	
31	Dagon South	East	8	115	133	143	167	195	222	250	
32	Dagon East	East	7	115	133	143	167	195	222	250	
33	Dagon Seikkan	East	8	115	133	143	167	195	222	250	
	New Suburbs Zone			**115**	**133**	**143**	**167**	**195**	**222**	**250**	
	Total (Yangon city)										

* LPCD (Dom. + Non dome.) = LPCD (Domestic) ÷ 60%

Daily Average Demand

Source: → Projected

No	Township	District	WS Zone	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
1	Latha	West	1	7,911	7,875	7,839	7,803	7,767	7,904	8,041	8,103	8,165	8,227	8,289	8,352	8,425
2	Lanmadaw	West	1	12,167	12,190	12,214	12,237	12,261	12,527	12,794	13,127	13,461	13,794	14,128	14,462	14,851
3	Pabedan	West	1	10,832	10,790	10,749	10,708	10,667	10,848	11,029	11,045	11,062	11,078	11,095	11,112	11,209
4	Kyauktada	West	1	10,581	10,423	10,266	10,108	9,951	9,913	9,876	9,891	9,906	9,921	9,936	9,951	10,038
5	Botahtaung	East	1	14,861	14,562	14,263	13,964	13,665	13,614	13,563	13,583	13,603	13,624	13,644	13,665	13,784
6	Pazuntaung	East	1	17,677	17,295	16,914	16,532	16,151	16,091	16,031	16,055	16,079	16,103	16,127	16,151	16,292
	CBD			**74,029**	**73,135**	**72,245**	**71,352**	**70,462**	**70,897**	**71,334**	**71,804**	**72,276**	**72,747**	**73,219**	**73,693**	**74,599**
7	Ahlon	West	1	4,091	4,609	5,127	5,645	6,164	6,586	7,009	7,607	8,206	8,804	9,403	10,002	10,573
8	Kyimyindine	West	1,10	1,626	2,436	3,247	4,057	4,868	5,705	6,542	7,465	8,388	9,311	10,234	11,158	12,298
9	Sangyoung	West	1,3	5,265	5,887	6,509	7,131	7,754	8,432	9,110	10,479	11,848	13,218	14,587	15,957	16,857
10	Dagon	West	1	4,341	4,405	4,469	4,533	4,598	4,746	4,895	5,069	5,244	5,418	5,593	5,768	5,993
11	Bahan	West	1,2	30,873	30,755	30,638	30,520	30,403	31,000	31,598	31,801	32,004	32,207	32,410	32,614	32,931
12	Tamway	East	1,2	53,305	55,193	57,081	58,969	60,857	61,957	63,058	63,343	63,629	63,915	64,201	64,487	65,125
13	Mingala Taungnyunt	East	1	47,201	48,514	49,828	51,142	52,456	52,345	52,234	52,406	52,578	52,751	52,923	53,096	53,671
14	Seikkan	West	1	690	691	693	695	697	713	729	748	768	788	808	828	855
15	Dawbon	East	2	8,111	8,405	8,700	8,995	9,290	9,753	10,217	10,734	11,252	11,769	12,287	12,805	13,441
	Inner Urban Ring			**155,503**	**160,895**	**166,292**	**171,687**	**177,087**	**181,237**	**185,392**	**189,652**	**193,917**	**198,181**	**202,446**	**206,715**	**211,744**
16	Kamayut	West	1,3	2,468	3,058	3,648	4,238	4,829	5,438	6,048	7,650	9,253	10,856	12,459	14,062	14,939
17	Hline	West	3	15,828	16,546	17,265	17,983	18,702	19,693	20,684	21,783	22,883	23,983	25,083	26,183	27,527
18	Yankin	East	2,3	23,418	23,298	23,178	23,058	22,939	23,205	23,472	23,507	23,542	23,577	23,612	23,648	23,855
19	Thingangyun	East	2	37,348	37,787	38,226	38,665	39,104	40,344	41,584	43,043	44,502	45,961	47,420	48,880	50,765
	Outer Ring Zone			**79,062**	**80,689**	**82,317**	**83,944**	**85,574**	**88,680**	**91,788**	**95,983**	**100,180**	**104,377**	**108,574**	**112,773**	**117,086**
20	Mayangon	West	3,4	35,465	36,123	36,781	37,439	38,097	39,561	41,026	42,550	44,074	45,598	47,122	48,646	50,781
21	Insein	North	3,4	29,205	31,054	32,903	34,752	36,601	38,838	41,075	43,644	46,214	48,783	51,353	53,923	57,212
22	Mingaladon	North	4,5,6	36,328	39,402	42,476	45,550	48,625	54,006	59,388	67,472	75,556	83,641	91,725	99,810	110,210
	Northern Suburbs			**100,998**	**106,579**	**112,160**	**117,741**	**123,323**	**132,405**	**141,489**	**153,666**	**165,844**	**178,022**	**190,200**	**202,379**	**218,203**
23	North Okkalapa	East	4	106,000	106,878	107,756	108,634	109,513	112,249	114,985	116,567	118,149	119,732	121,314	122,897	125,083
24	South Okkalapa	East	2,3	40,768	40,780	40,793	40,805	40,818	41,732	42,646	43,784	44,922	46,060	47,198	48,337	49,881
25	Thakayta	East	2	22,695	23,637	24,580	25,523	26,466	27,826	29,187	30,701	32,215	33,730	35,244	36,759	38,615
	Older Suburbs Zone			**169,463**	**171,295**	**173,129**	**174,962**	**176,797**	**181,807**	**186,818**	**191,052**	**195,286**	**199,522**	**203,756**	**207,993**	**213,579**
26	Dala	South	10	4,058	5,292	6,526	7,760	8,994	10,468	11,942	13,848	15,754	17,660	19,566	21,473	24,483
27	Seikkyi/ Khanaungto	South	10	4	192	381	569	758	980	1,203	1,475	1,748	2,020	2,293	2,566	2,971
	South of CBD			**4,062**	**5,484**	**6,907**	**8,329**	**9,752**	**11,448**	**13,145**	**15,323**	**17,502**	**19,680**	**21,859**	**24,039**	**27,454**
28	Shwepyitha	North	5	6,557	7,995	9,434	10,872	12,311	14,046	15,781	17,753	19,725	21,698	23,670	25,643	29,248
29	Hlaing Tharyar	North	9	4,835	7,827	10,819	13,811	16,803	20,293	23,784	34,410	45,036	55,662	66,288	76,914	82,819
30	Dagon North	East	7	16,047	17,211	18,376	19,541	20,706	22,000	23,294	24,783	26,272	27,761	29,250	30,740	32,916
31	Dagon South	East	8	21,456	23,118	24,781	26,444	28,107	30,387	32,668	35,342	38,016	40,691	43,365	46,040	49,968
32	Dagon East	East	7	6,071	8,748	11,425	14,102	16,779	20,056	23,334	27,982	32,631	37,279	41,928	46,577	54,478
33	Dagon Seikkan	East	8	5,346	5,986	6,626	7,266	7,907	9,119	10,332	11,934	13,536	15,139	16,741	18,344	20,927
	New Suburbs Zone			**60,312**	**70,885**	**81,461**	**92,036**	**102,613**	**115,901**	**129,193**	**152,204**	**175,216**	**198,230**	**221,242**	**244,258**	**270,356**
	Total (Yangon city)			**643,429**	**668,962**	**694,511**	**720,051**	**745,608**	**782,375**	**819,159**	**869,684**	**920,221**	**970,759**	**1,021,296**	**1,071,850**	**1,133,021**

Leakage Ratio (%)	**50%**	**37%**	**33%**	**25%**
1- Leakage Ratio (%)	**50%**	**63%**	**67%**	**75%**

* Daily Average Demand = (Served Population x LPCD (Dom. + Non dome.)/1000) ÷(1- Leakage Ratio (%))

Daily Average Demand

Source:

Mld

No	Township	WS Zone	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
1	Latha	1	8,498	8,571	8,644	8,717	8,771	8,826	8,881	8,936	8,991	9,048	9,106	9,164	9,222	9,280
2	Lanmadaw	1	15,240	15,629	16,018	16,407	16,510	16,613	16,716	16,819	16,922	17,030	17,139	17,248	17,357	17,466
3	Pabedan	1	11,306	11,403	11,500	11,598	11,670	11,743	11,815	11,888	11,961	12,038	12,115	12,192	12,269	12,346
4	Kyauktada	1	10,125	10,212	10,299	10,386	10,451	10,516	10,581	10,646	10,711	10,780	10,849	10,918	10,987	11,056
5	Botahtaung	1	13,903	14,023	14,142	14,262	14,351	14,440	14,530	14,619	14,709	14,803	14,898	14,993	15,088	15,183
6	Pazuntaung	1	16,433	16,575	16,716	16,858	16,963	17,069	17,174	17,280	17,386	17,498	17,610	17,722	17,834	17,946
	CBD		**75,505**	**76,413**	**77,319**	**78,228**	**78,716**	**79,207**	**79,697**	**80,188**	**80,680**	**81,197**	**81,717**	**82,237**	**82,757**	**83,277**
7	Ahlon	1	11,145	11,717	12,289	12,861	13,452	14,043	14,635	15,226	15,818	16,460	17,102	17,745	18,387	19,030
8	Kyimyindine	1,10	13,438	14,578	15,718	16,859	18,150	19,441	20,733	22,024	23,316	24,826	26,337	27,847	29,358	30,869
9	Sangyoung	1,3	17,757	18,657	19,557	20,458	21,381	22,305	23,229	24,153	25,077	26,073	27,069	28,065	29,061	30,057
10	Dagon	1	6,218	6,443	6,668	6,893	7,116	7,339	7,562	7,785	8,009	8,246	8,483	8,721	8,958	9,196
11	Bahan	1,2	33,248	33,566	33,883	34,201	34,476	34,751	35,026	35,301	35,577	35,821	36,066	36,310	36,555	36,800
12	Tamway	1,2	65,763	66,401	67,039	67,678	68,189	68,700	69,212	69,723	70,235	70,788	71,342	71,896	72,450	73,004
13	Mingala Taungnyunt	1	54,247	54,822	55,398	55,974	56,455	56,936	57,417	57,898	58,380	58,908	59,437	59,966	60,495	61,024
14	Seikkan	1	882	909	936	963	973	983	993	1,003	1,014	1,020	1,026	1,033	1,039	1,046
15	Dawbon	2	14,077	14,713	15,349	15,986	16,626	17,267	17,907	18,548	19,189	19,870	20,552	21,233	21,915	22,597
	Inner Urban Ring		**216,775**	**221,806**	**226,837**	**231,873**	**236,818**	**241,765**	**246,714**	**251,661**	**256,615**	**262,012**	**267,414**	**272,816**	**278,218**	**283,623**
16	Kamayut	1,3	15,816	16,693	17,570	18,448	19,396	20,345	21,294	22,243	23,192	24,269	25,346	26,423	27,500	28,577
17	Hline	3	28,872	30,216	31,561	32,906	34,262	35,619	36,975	38,332	39,689	41,132	42,575	44,018	45,461	46,904
18	Yankin	2,3	24,062	24,269	24,476	24,683	24,837	24,992	25,147	25,302	25,457	25,620	25,784	25,948	26,112	26,276
19	Thingangyun	2	52,650	54,535	56,420	58,306	60,175	62,044	63,913	65,782	67,651	69,638	71,625	73,612	75,599	77,587
	Outer Ring Zone		**121,400**	**125,713**	**130,027**	**134,343**	**138,670**	**143,000**	**147,329**	**151,659**	**155,989**	**160,659**	**165,330**	**170,001**	**174,672**	**179,344**
20	Mayangon	3,4	52,916	55,051	57,186	59,322	61,507	63,692	65,877	68,062	70,247	72,688	75,130	77,572	80,014	82,456
21	Insein	3,4	60,502	63,791	67,081	70,371	73,964	77,558	81,151	84,745	88,339	92,464	96,589	100,714	104,839	108,965
22	Mingaladon	4,5,6	120,611	131,011	141,412	151,813	164,427	177,041	189,656	202,270	214,885	226,984	239,083	251,183	263,282	275,382
	Northern Suburbs		**234,029**	**249,853**	**265,679**	**281,506**	**299,898**	**318,291**	**336,684**	**355,077**	**373,471**	**392,136**	**410,802**	**429,469**	**448,135**	**466,803**
23	North Okkalapa	4	127,270	129,457	131,644	133,831	135,973	138,115	140,257	142,399	144,542	147,001	149,461	151,920	154,380	156,840
24	South Okkalapa	2,3	51,425	52,969	54,513	56,058	56,409	56,760	57,112	57,463	57,815	58,187	58,559	58,931	59,303	59,676
25	Thakayta	2	40,471	42,327	44,183	46,040	47,911	49,783	51,654	53,526	55,398	57,388	59,378	61,368	63,358	65,349
	Older Suburbs Zone		**219,166**	**224,753**	**230,340**	**235,929**	**240,293**	**244,658**	**249,023**	**253,388**	**257,755**	**262,576**	**267,398**	**272,219**	**277,041**	**281,865**
26	Dala	10	27,494	30,505	33,516	36,527	40,589	44,652	48,714	52,777	56,840	62,350	67,861	73,372	78,883	84,394
27	Seikkyi/ Khanaungto	10	3,376	3,782	4,187	4,593	5,123	5,654	6,184	6,715	7,246	7,946	8,647	9,347	10,048	10,749
	South of CBD		**30,870**	**34,287**	**37,703**	**41,120**	**45,712**	**50,306**	**54,898**	**59,492**	**64,086**	**70,296**	**76,508**	**82,719**	**88,931**	**95,143**
28	Shwepyitha	5	32,853	36,458	40,063	43,668	48,125	52,583	57,041	61,499	65,957	72,841	79,725	86,609	93,493	100,377
29	Hlaing Tharyar	9	88,725	94,630	100,536	106,442	114,097	121,752	129,407	137,062	144,717	155,873	167,030	178,186	189,343	200,500
30	Dagon North	7	35,093	37,269	39,446	41,623	44,082	46,541	49,000	51,459	53,918	56,855	59,792	62,730	65,667	68,605
31	Dagon South	8	53,897	57,826	61,755	65,684	70,337	74,990	79,643	84,296	88,949	94,702	100,456	106,210	111,964	117,718
32	Dagon East	7	62,380	70,281	78,183	86,085	97,461	108,837	120,214	131,590	142,967	159,076	175,186	191,295	207,405	223,515
33	Dagon Seikkan	8	23,511	26,094	28,678	31,262	34,797	38,332	41,868	45,403	48,939	53,785	58,631	63,477	68,323	73,170
	New Suburbs Zone		**296,459**	**322,558**	**348,661**	**374,764**	**408,899**	**443,035**	**477,173**	**511,309**	**545,447**	**593,132**	**640,820**	**688,507**	**736,195**	**783,885**
	Total (Yangon city)		**1,194,204**	**1,255,383**	**1,316,566**	**1,377,763**	**1,449,006**	**1,520,262**	**1,591,518**	**1,662,774**	**1,734,043**	**1,822,008**	**1,909,989**	**1,997,968**	**2,085,949**	**2,173,940**
	Leakage Ratio (%)					**80%**					**15%**					**10%**
	1- Leakage Ratio (%)					**80%**					**85%**					**90%**

* Daily Average Demand = (Served Population x LPCD (Dom. + Non dome.)/1000) ÷(1- Leakage Ratio (%))

Daily Maximum Demand

Source: → Projected

No	Township	District	WS Zone	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
1	Latha	West	1	2	2	2	2	2	2	2	2	2	2	2	2	2
2	Lanmadaw	West	1	3	3	3	3	3	3	3	3	3	3	3	3	4
3	Pabedan	West	1	3	3	3	3	3	3	3	3	3	3	3	3	3
4	Kyauktada	West	1	3	3	2	2	2	2	2	2	2	2	2	2	2
5	Botahtaung	East	1	4	4	3	3	3	3	3	3	3	3	3	3	3
6	Pazuntaung	East	1	4	4	4	4	4	4	4	4	4	4	4	4	4
	CBD			**19**	**19**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**18**
7	Ahlon	West	1	1	1	1	1	1	2	2	2	2	2	2	2	3
8	Kyimyindine	West	1,10	0	1	1	1	1	1	2	2	2	2	2	3	3
9	Sangyoung	West	1,3	1	1	2	2	2	2	2	3	3	3	4	4	4
10	Dagon	West	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	Bahan	West	1,2	7	7	7	7	7	8	8	8	8	8	8	8	8
12	Tamway	East	1,2	13	13	14	14	15	15	15	15	15	15	16	16	16
13	Mingala Taungnyunt	East	1	11	12	12	12	13	13	13	13	13	13	13	13	13
14	Seikkan	West	1	0	0	0	0	0	0	0	0	0	0	0	0	0
15	Dawbon	East	2	2	2	2	2	2	2	2	3	3	3	3	3	3
	Inner Urban Ring			**36**	**38**	**40**	**40**	**42**	**44**	**45**	**47**	**47**	**47**	**49**	**50**	**51**
16	Kamayut	West	1,3	1	1	1	1	1	1	1	2	2	3	3	3	4
17	Hline	West	3	4	4	4	4	5	5	5	5	6	6	6	6	7
18	Yankin	East	2,3	6	6	6	6	6	6	6	6	6	6	6	6	6
19	Thingangyun	East	2	9	9	9	9	9	10	10	10	11	11	11	12	12
	Outer Ring Zone			**20**	**20**	**20**	**20**	**21**	**22**	**22**	**23**	**25**	**26**	**26**	**27**	**29**
20	Mayangon	West	3,4	9	9	9	9	9	10	10	10	11	11	11	12	12
21	Insein	North	3,4	7	8	8	8	9	9	10	11	11	12	12	13	14
22	Mingaladon	North	4,5,6	9	10	10	11	12	13	14	16	18	20	22	24	27
	Northern Suburbs			**25**	**27**	**27**	**28**	**30**	**32**	**34**	**37**	**40**	**43**	**45**	**49**	**53**
23	North Okkalapa	East	4	26	26	26	26	26	27	28	28	29	29	29	30	30
24	South Okkalapa	East	2,3	10	10	10	10	10	10	10	11	11	11	11	12	12
25	Thakayta	East	2	5	6	6	6	6	7	7	7	8	8	9	9	9
	Older Suburbs Zone			**41**	**42**	**42**	**42**	**42**	**44**	**45**	**46**	**48**	**48**	**49**	**51**	**51**
26	Dala	South	10	1	1	2	2	2	3	3	3	4	4	5	5	6
27	Seikkyi/ Khanaungto	South	10	0	0	0	0	0	0	0	0	0	0	1	1	1
	South of CBD			**1**	**1**	**2**	**2**	**2**	**3**	**3**	**3**	**4**	**4**	**6**	**6**	**7**
28	Shwepyitha	North	5	2	2	2	3	3	3	4	4	5	5	6	6	7
29	Hlaing Tharyar	North	9	1	2	3	3	4	5	6	8	11	13	16	19	20
30	Dagon North	East	7	4	4	4	5	5	5	6	6	6	7	7	7	8
31	Dagon South	East	8	5	6	6	6	7	7	8	9	9	10	10	11	12
32	Dagon East	East	7	1	2	3	3	4	5	6	7	8	9	10	11	13
33	Dagon Seikkan	East	8	1	1	2	2	2	2	3	3	3	4	4	4	5
	New Suburbs Zone			**14**	**17**	**20**	**22**	**25**	**27**	**33**	**37**	**42**	**48**	**53**	**58**	**65**
	Total (Yangon city)			**156**	**164**	**168**	**171**	**179**	**189**	**199**	**210**	**223**	**233**	**245**	**258**	**274**

* Daily Maximum Demand (MGD) = Daily Average Demand (Mld) x 1.1 ÷4,546

Daily Maximum Demand

Source:

MGD

No	Township	WS Zone	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
1	Latha	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2	Lanmadaw	1	4	4	4	4	4	4	4	4	4	4	4	4	4	4
3	Pabedan	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3
4	Kyauktada	1	2	2	2	3	3	3	3	3	3	3	3	3	3	3
5	Botahtaung	1	3	3	3	3	3	3	4	4	4	4	4	4	4	4
6	Pazuntaung	1	4	4	4	4	4	4	4	4	4	4	4	4	4	4
	CBD		**18**	**18**	**18**	**19**	**19**	**19**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**
7	Ahlon	1	3	3	3	3	3	3	4	4	4	4	4	4	4	5
8	Kyimyindine	1,10	3	4	4	4	4	5	5	5	6	6	6	7	7	7
9	Sangyoung	1,3	4	5	5	5	5	5	6	6	6	6	7	7	7	7
10	Dagon	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
11	Bahan	1,2	8	8	8	8	8	8	8	9	9	9	9	9	9	9
12	Tamway	1,2	16	16	16	16	16	17	17	17	17	17	17	17	18	18
13	Mingala Taungnyunt	1	13	13	13	14	14	14	14	14	14	14	14	15	15	15
14	Seikkan	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	Dawbon	2	3	4	4	4	4	4	4	4	5	5	5	5	5	5
	Inner Urban Ring		**52**	**55**	**55**	**56**	**56**	**58**	**60**	**61**	**63**	**63**	**64**	**66**	**67**	**68**
16	Kamayut	1,3	4	4	4	4	5	5	5	5	6	6	6	6	7	7
17	Hline	3	7	7	8	8	8	9	9	9	10	10	10	11	11	11
18	Yankin	2,3	6	6	6	6	6	6	6	6	6	6	6	6	6	6
19	Thingangyun	2	13	13	14	14	15	15	15	16	16	17	17	18	18	19
	Outer Ring Zone		**30**	**30**	**32**	**32**	**34**	**35**	**35**	**36**	**38**	**39**	**39**	**41**	**42**	**43**
20	Mayangon	3,4	13	13	14	14	15	15	16	16	17	18	18	19	19	20
21	Insein	3,4	15	15	16	17	18	19	20	21	21	22	23	24	25	26
22	Mingaladon	4,5,6	29	32	34	37	40	43	46	49	52	55	58	61	64	67
	Northern Suburbs		**57**	**60**	**64**	**68**	**73**	**77**	**82**	**86**	**90**	**95**	**99**	**104**	**108**	**113**
23	North Okkalapa	4	31	31	32	32	33	33	34	34	35	36	36	37	37	38
24	South Okkalapa	2,3	12	13	13	14	14	14	14	14	14	14	14	14	14	14
25	Thakayta	2	10	10	11	11	12	12	12	13	13	14	14	15	15	16
	Older Suburbs Zone		**53**	**54**	**56**	**57**	**59**	**59**	**60**	**61**	**62**	**64**	**64**	**66**	**66**	**68**
26	Dala	10	7	7	8	9	10	11	12	13	14	15	16	18	19	20
27	Seikkyi/ Khanaungto	10	1	1	1	1	1	1	1	2	2	2	2	2	2	3
	South of CBD		**8**	**8**	**9**	**10**	**11**	**12**	**13**	**15**	**16**	**17**	**18**	**20**	**21**	**23**
28	Shwepyitha	5	8	9	10	11	12	13	14	15	16	18	19	21	23	24
29	Hlaing Tharyar	9	21	23	24	26	28	29	31	33	35	38	40	43	46	49
30	Dagon North	7	8	9	10	10	11	11	12	12	13	14	14	15	16	17
31	Dagon South	8	13	14	15	16	17	18	19	20	22	23	24	26	27	28
32	Dagon East	7	15	17	19	21	24	26	29	32	35	38	42	46	50	54
33	Dagon Seikkan	8	6	6	7	8	8	9	10	11	12	13	14	15	17	18
	New Suburbs Zone		**71**	**78**	**85**	**92**	**100**	**106**	**115**	**123**	**133**	**144**	**153**	**166**	**179**	**190**
	Total (Yangon city)		**289**	**303**	**319**	**334**	**352**	**366**	**385**	**402**	**422**	**442**	**457**	**483**	**503**	**525**

* Daily Maximum Demand (MGD) = Daily Average Demand (Mld) x 1.1 ÷4,546

By Zone

Actual -> estimate

Population	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Zone1	793,619	808,977	824,335	839,693	855,051	856,561	858,072	859,608	861,144	862,680	864,216	865,752	867,501
Low	505,645	516,638	527,631	538,624	549,617	550,579	551,542	552,595	553,648	554,701	555,755	556,809	558,006
High	287,974	292,339	296,704	301,069	305,434	305,982	306,530	307,013	307,496	307,979	308,461	308,944	309,495
Zone2	636,790	641,130	645,470	649,810	654,150	654,312	654,474	654,614	654,754	654,895	655,035	655,176	655,336
Zone3	653,154	656,011	658,868	661,725	664,583	666,217	667,852	668,814	669,778	670,741	671,705	672,669	674,170
Zone4	653,434	662,841	672,249	681,657	691,065	698,039	705,015	713,144	721,274	729,404	737,533	745,664	754,016
Zone5	501,245	512,476	523,706	534,937	546,168	559,149	572,131	589,413	606,695	623,978	641,260	658,542	683,361
Zone6	133,165	138,415	143,666	148,917	154,168	162,904	171,641	183,563	195,485	207,407	219,330	231,253	241,530
Zone7	369,576	418,007	466,438	514,869	563,301	594,786	626,271	660,735	695,199	729,663	764,127	798,592	837,775
Zone8	539,094	547,395	555,697	563,999	572,301	585,391	598,482	612,810	627,139	641,467	655,796	670,125	686,416
Zone9	687,867	696,350	704,833	713,317	721,801	731,502	741,204	746,791	752,380	757,968	763,556	769,145	774,111
Zone10	243,487	262,846	282,206	301,566	320,926	331,074	341,222	352,330	363,439	374,547	385,655	396,764	409,393
Total	5,211,431	5,344,448	5,477,468	5,610,490	5,743,514	5,839,935	5,936,364	6,041,822	6,147,287	6,252,750	6,358,213	6,463,681	6,583,609

Served Population	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Zone1	488,174	510,833	533,493	556,153	578,814	591,094	603,375	616,106	628,838	641,570	654,302	667,034	675,564
Low	353,891	368,737	383,583	398,429	413,276	419,835	426,396	431,523	436,651	441,779	446,908	452,036	456,556
High	134,283	142,096	149,910	157,724	165,537	171,259	176,980	184,583	192,187	199,791	207,394	214,998	219,008
Zone2	298,747	315,522	332,298	349,073	365,849	379,037	392,226	402,808	413,392	423,975	434,558	445,142	455,409
Zone3	310,157	324,145	338,133	352,121	366,110	379,867	393,625	407,400	421,176	434,951	448,727	462,503	475,609
Zone4	380,391	399,345	418,300	437,255	456,211	474,390	492,570	506,522	520,474	534,426	548,379	562,331	576,226
Zone5	75,213	88,299	101,385	114,471	127,557	143,353	159,149	178,883	198,616	218,350	238,084	257,818	283,594
Zone6	39,432	44,219	49,007	53,795	58,584	65,336	72,089	81,721	91,353	100,986	110,618	120,251	131,248
Zone7	96,167	116,406	136,645	156,884	177,123	197,543	217,964	243,956	269,949	295,941	321,934	347,927	383,128
Zone8	116,533	129,943	143,354	156,764	170,175	185,589	201,004	218,750	236,496	254,242	271,988	289,734	311,333
Zone9	21,023	35,616	50,210	64,804	79,398	95,289	111,180	158,167	205,154	252,141	299,128	346,115	364,229
Zone10	19,109	27,052	34,995	42,939	50,883	59,413	67,943	78,189	88,435	98,682	108,928	119,175	132,263
Total	1,844,945	1,991,380	2,137,820	2,284,259	2,430,704	2,570,911	2,711,125	2,892,502	3,073,883	3,255,264	3,436,646	3,618,031	3,788,603

Coverage (%)	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Zone1	61.5%	63.1%	64.7%	66.2%	67.7%	69.0%	70.3%	71.7%	73.0%	74.4%	75.7%	77.0%	77.9%
Low	70.0%	71.4%	72.7%	74.0%	75.2%	76.3%	77.3%	78.1%	78.9%	79.6%	80.4%	81.2%	81.8%
High	46.6%	48.6%	50.5%	52.4%	54.2%	56.0%	57.7%	60.1%	62.5%	64.9%	67.2%	69.6%	70.8%
Zone2	46.9%	49.2%	51.5%	53.7%	55.9%	57.9%	59.9%	61.5%	63.1%	64.7%	66.3%	67.9%	69.5%
Zone3	47.5%	49.4%	51.3%	53.2%	55.1%	57.0%	58.9%	60.9%	62.9%	64.8%	66.8%	68.8%	70.5%
Zone4	58.2%	60.2%	62.2%	64.1%	66.0%	68.0%	69.9%	71.0%	72.2%	73.3%	74.4%	75.4%	76.4%
Zone5	15.0%	17.2%	19.4%	21.4%	23.4%	25.6%	27.8%	30.3%	32.7%	35.0%	37.1%	39.1%	41.5%
Zone6	29.6%	31.9%	34.1%	36.1%	38.0%	40.1%	42.0%	44.5%	46.7%	48.7%	50.4%	52.0%	54.3%
Zone7	26.0%	27.8%	29.3%	30.5%	31.4%	33.2%	34.8%	36.9%	38.8%	40.6%	42.1%	43.6%	45.7%
Zone8	21.6%	23.7%	25.8%	27.8%	29.7%	31.7%	33.6%	35.7%	37.7%	39.6%	41.5%	43.2%	45.4%
Zone9	3.1%	5.1%	7.1%	9.1%	11.0%	13.0%	15.0%	21.2%	27.3%	33.3%	39.2%	45.0%	47.1%
Zone10	7.8%	10.3%	12.4%	14.2%	15.9%	17.9%	19.9%	22.2%	24.3%	26.3%	28.2%	30.0%	32.3%
Total	35.4%	37.3%	39.0%	40.7%	42.3%	44.0%	45.7%	47.9%	50.0%	52.1%	54.1%	56.0%	57.5%

PerCapita (Lpcd)	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Zone1	111	115	119	123	126	130	133	137	140	144	147	150	154
Low	111	115	119	123	126	130	133	137	140	143	147	150	154
High	111	115	119	123	126	130	133	137	141	144	147	150	154
Zone2	111	115	119	123	126	130	133	137	140	144	147	150	154
Zone3	111	115	119	123	126	130	133	137	140	144	147	150	154
Zone4	111	115	119	123	126	130	133	137	140	144	147	150	154
Zone5	95	99	101	103	105	108	111	116	120	123	125	128	132
Zone6	111	116	120	123	126	130	133	138	142	145	148	150	155
Zone7	69	73	76	78	80	83	86	90	93	96	98	100	105
Zone8	69	73	76	78	80	83	86	90	93	96	98	100	104
Zone9	69	75	78	79	80	83	86	92	95	98	99	100	104
Zone10	72	78	81	83	84	88	90	95	98	101	103	105	109
Total	105	108	111	114	116	119	121	124	127	129	131	133	137

Daily Max. MGD	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Zone1	200,024	200,024	204,570	204,570	209,116	213,662	218,208	222,754	227,300	231,846	236,392	245,484	250,030
Low	145,472	145,472	145,472	145,472	150,018	150,018	154,564	154,564	159,110	159,110	163,656	168,202	168,202
High	54,552	54,552	59,098	59,098	59,098	63,644	63,644	68,190	68,190	72,736	72,736	77,282	81,828
Zone2	122,742	122,742	127,288	127,288	131,834	136,380	140,926	145,472	150,018	154,564	159,110	163,656	168,202
Zone3	127,288	127,288	127,288	127,288	131,834	136,380	145,472	150,018	154,564	159,110	163,656	168,202	172,748
Zone4	154,564	154,564	159,110	163,656	168,202	172,748	177,294	181,840	186,386	190,932	195,478	204,570	209,116
Zone5	27,276	27,276	31,822	36,368	40,914	45,460	50,006	54,552	59,098	68,190	72,736	81,828	90,920
Zone6	18,184	18,184	18,184	18,184	22,730	22,730	27,276	27,276	31,822	36,368	40,914	45,460	50,006
Zone7	22,730	27,276	31,822	36,368	40,914	45,460	50,006	54,552	59,098	68,190	72,736	81,828	90,920
Zone8	27,276	27,276	31,822	36,368	40,914	45,460	50,006	50,006	54,552	59,098	63,644	68,190	72,736
Zone9	4,546	4,546	9,092	13,638	18,184	22,730	27,276	36,368	50,006	59,098	72,736	86,374	90,920
Zone10	4,546	4,546	4,546	4,546	9,092	13,638	18,184	18,184	18,184	22,730	22,730	27,276	31,822
Total	709,176	713,722	745,544	768,274	813,734	854,648	904,654	941,022	991,028	1,050,126	1,100,132	1,172,868	1,227,420

Daily Max. MGD	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Zone1	44.0	44.0	45.0	45.0	46.0	47.0	48.0	49.0	50.0	51.0	52.0	54.0	55.0
Low	32.0	32.0	32.0	32.0	33.0	33.0	34.0	34.0	35.0	35.0	36.0	37.0	37.0
High	12.0	12.0	13.0	13.0	13.0	14.0	14.0	15.0	15.0	16.0	16.0	17.0	18.0
Zone2	27.0	27.0	28.0	28.0	29.0	30.0	31.0	32.0	33.0	34.0	35.0	36.0	37.0
Zone3	28.0	28.0	28.0	28.0	29.0	30.0	32.0	33.0	34.0	35.0	36.0	37.0	38.0
Zone4	34.0	34.0	35.0	36.0	37.0	38.0	39.0	40.0	41.0	42.0	43.0	45.0	46.0
Zone5	6.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	15.0	16.0	18.0	20.0
Zone6	4.0	4.0	4.0	4.0	5.0	5.0	6.0	6.0	7.0	8.0	9.0	10.0	11.0
Zone7	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	15.0	16.0	18.0	20.0
Zone8	6.0	6.0	7.0	8.0	9.0	10.0	11.0	11.0	12.0	13.0	14.0	15.0	16.0
Zone9	1.0	1.0	2.0	3.0	4.0	5.0	6.0	8.0	11.0	13.0	16.0	19.0	20.0
Zone10	1.0	1.0	1.0	1.0	2.0	3.0	4.0	4.0	4.0	5.0	5.0	6.0	7.0
Total	156.0	157.0	164.0	169.0	179.0	188.0	199.0	207.0	218.0	231.0	242.0	258.0	270.0

By Zone

Population	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Zone1	869,249	870,998	872,747	874,496	876,533	878,571	880,609	882,647	884,685	886,886	889,088	891,290	893,492	895,695
Low	559,203	560,400	561,598	562,796	564,157	565,518	566,880	568,241	569,603	571,150	572,698	574,246	575,794	577,342
High	310,046	310,598	311,149	311,700	312,376	313,053	313,729	314,406	315,082	315,736	316,390	317,044	317,698	318,353
Zone2	655,496	655,657	655,817	655,978	656,176	656,374	656,571	656,769	656,968	657,156	657,346	657,535	657,724	657,914
Zone3	675,671	677,173	678,675	680,177	681,743	683,311	684,878	686,445	688,013	689,812	691,612	693,411	695,211	697,011
Zone4	762,369	770,722	779,075	787,429	796,457	805,485	814,513	823,541	832,570	841,108	849,647	858,186	866,724	875,264
Zone5	708,180	732,999	757,818	782,638	806,402	830,168	853,933	877,698	901,464	927,883	954,302	980,722	1,007,142	1,033,562
Zone6	251,808	262,086	272,364	282,642	292,919	303,197	313,475	323,753	334,032	340,055	346,079	352,102	358,126	364,150
Zone7	876,959	916,143	955,327	994,511	1,039,060	1,083,609	1,128,159	1,172,708	1,217,258	1,267,908	1,318,558	1,369,208	1,419,858	1,470,508
Zone8	702,707	718,998	735,289	751,581	770,103	788,625	807,147	825,669	844,191	865,249	886,307	907,365	928,423	949,482
Zone9	779,078	784,046	789,013	793,981	805,933	817,885	829,837	841,790	853,743	875,474	897,205	918,937	940,669	962,401
Zone10	422,023	434,653	447,282	459,913	474,271	488,630	502,990	517,349	531,708	548,033	564,359	580,684	597,010	613,336
Total	6,703,540	6,823,475	6,943,407	7,063,345	7,199,597	7,335,855	7,472,112	7,608,369	7,744,630	7,899,564	8,054,503	8,209,440	8,364,379	8,519,323

Served Population	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Zone1	684,094	692,624	701,154	709,685	717,879	726,073	734,268	742,463	750,658	759,223	767,790	776,356	784,922	793,489
Low	461,076	465,596	470,117	474,637	478,637	482,637	486,636	490,636	494,636	498,956	503,276	507,595	511,915	516,236
High	223,018	227,028	231,037	235,047	239,242	243,436	247,632	251,827	256,021	260,267	264,514	268,761	273,007	277,253
Zone2	465,677	475,944	486,212	496,480	506,785	517,090	527,396	537,701	548,007	558,303	568,599	578,896	589,193	599,490
Zone3	488,716	501,822	514,929	528,036	538,254	548,472	558,691	568,910	579,129	589,865	600,603	611,340	622,077	632,814
Zone4	590,122	604,017	617,913	631,808	647,332	662,856	678,379	693,903	709,428	725,713	741,998	758,284	774,569	790,855
Zone5	309,371	335,147	360,924	386,701	416,914	447,128	477,341	507,555	537,769	573,219	608,669	644,120	679,570	715,022
Zone6	142,245	153,243	164,240	175,238	188,290	201,343	214,396	227,449	240,502	252,122	263,742	275,362	286,983	298,603
Zone7	418,330	453,532	488,734	523,936	570,144	616,352	662,560	708,768	754,977	814,309	873,641	932,973	992,305	1,051,638
Zone8	332,932	354,531	376,130	397,730	423,933	450,136	476,339	502,542	528,745	560,435	592,126	623,816	655,507	687,198
Zone9	382,344	400,459	418,574	436,689	460,337	483,986	507,634	531,283	554,932	588,305	621,679	655,052	688,426	721,800
Zone10	145,352	158,441	171,530	184,620	201,113	217,607	234,100	250,594	267,088	287,648	308,209	328,769	349,330	369,891
Total	3,959,183	4,129,760	4,300,340	4,470,923	4,670,981	4,871,043	5,071,104	5,271,168	5,471,234	5,709,142	5,947,056	6,184,968	6,422,882	6,660,800

Coverage (%)	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Zone1	78.7%	79.5%	80.3%	81.2%	81.9%	82.6%	83.4%	84.1%	84.9%	85.6%	86.4%	87.1%	87.8%	88.6%
Low	82.5%	83.1%	83.7%	84.3%	84.8%	85.3%	85.8%	86.3%	86.8%	87.4%	87.9%	88.4%	88.9%	89.4%
High	71.9%	73.1%	74.3%	75.4%	76.6%	77.8%	78.9%	80.1%	81.3%	82.4%	83.6%	84.8%	85.9%	87.1%
Zone2	71.0%	72.6%	74.1%	75.7%	77.2%	78.8%	80.3%	81.9%	83.4%	85.0%	86.5%	88.0%	89.6%	91.1%
Zone3	72.3%	74.1%	75.9%	77.6%	79.0%	80.3%	81.6%	82.9%	84.2%	85.5%	86.8%	88.2%	89.5%	90.8%
Zone4	77.4%	78.4%	79.3%	80.2%	81.3%	82.3%	83.3%	84.3%	85.2%	86.3%	87.3%	88.4%	89.4%	90.4%
Zone5	43.7%	45.7%	47.6%	49.4%	51.7%	53.9%	55.9%	57.8%	59.7%	61.8%	63.8%	65.7%	67.5%	69.2%
Zone6	56.5%	58.5%	60.3%	62.0%	64.3%	66.4%	68.4%	70.3%	72.0%	74.1%	76.2%	78.2%	80.1%	82.0%
Zone7	47.7%	49.5%	51.2%	52.7%	54.9%	56.9%	58.7%	60.4%	62.0%	64.2%	66.3%	68.1%	69.9%	71.5%
Zone8	47.4%	49.3%	51.2%	52.9%	55.0%	57.1%	59.0%	60.9%	62.6%	64.8%	66.8%	68.8%	70.6%	72.4%
Zone9	49.1%	51.1%	53.1%	55.0%	57.1%	59.2%	61.2%	63.1%	65.0%	67.2%	69.3%	71.3%	73.2%	75.0%
Zone10	34.4%	36.5%	38.3%	40.1%	42.4%	44.5%	46.5%	48.4%	50.2%	52.5%	54.6%	56.6%	58.5%	60.3%
Total	59.1%	60.5%	61.9%	63.3%	64.9%	66.4%	67.9%	69.3%	70.6%	72.3%	73.8%	75.3%	76.8%	78.2%

PerCapita (Lpcd)	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Zone1	157	160	164	167	170	174	177	180	183	187	190	193	197	200
Low	157	160	164	167	170	174	177	180	183	187	190	193	197	200
High	157	161	164	167	170	174	177	180	183	187	190	194	197	200
Zone2	157	161	164	167	170	174	177	180	183	187	190	194	197	200
Zone3	157	161	164	167	170	174	177	180	183	187	190	194	197	200
Zone4	157	161	164	167	171	174	177	180	183	187	190	194	197	200
Zone5	136	139	142	144	148	151	154	157	159	163	167	170	172	175
Zone6	158	162	165	167	171	175	178	181	183	187	191	194	197	200
Zone7	109	112	115	117	121	125	128	131	133	137	141	144	147	150
Zone8	108	111	114	117	121	125	128	130	133	137	141	144	147	150
Zone9	108	111	114	117	121	124	127	130	133	137	141	144	147	150
Zone10	113	116	119	121	125	129	132	135	137	141	145	148	151	154
Total	140	143	145	148	151	154	157	159	162	165	168	171	174	176

Daily Max. MGD	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Zone1	254,576	259,122	263,668	272,760	277,306	281,852	286,398	290,944	295,490	300,036	304,582	309,128	313,674	322,766
Low	172,748	172,748	177,294	181,840	181,840	186,386	186,386	190,932	195,478	195,478	200,024	200,024	204,570	209,116
High	81,828	86,374	86,374	90,920	95,466	95,466	100,012	100,012	100,012	104,558	104,558	109,104	109,104	113,650
Zone2	172,748	177,294	181,840	190,932	195,478	200,024	204,570	209,116	218,208	222,754	227,300	231,846	236,392	245,484
Zone3	181,840	186,386	195,478	204,570	209,116	213,662	218,208	222,754	227,300	231,846	236,392	240,938	245,484	254,576
Zone4	218,208	222,754	231,846	240,938	245,484	254,576	263,668	272,760	281,852	286,398	295,490	304,582	313,674	322,766
Zone5	100,012	109,104	118,196	127,288	136,380	150,018	159,110	172,748	186,386	200,024	213,662	227,300	240,938	254,576
Zone6	54,552	59,098	63,644	68,190	72,736	77,282	81,828	86,374	95,466	100,012	104,558	109,104	113,650	118,196
Zone7	104,558	113,650	127,288	140,926	154,564	168,202	186,386	200,024	218,208	236,392	259,122	277,306	300,036	322,766
Zone8	81,828	86,374	95,466	104,558	113,650	122,742	131,834	140,926	154,564	163,656	172,748	186,386	195,478	209,116
Zone9	95,466	104,558	109,104	118,196	122,742	131,834	140,926	150,018	159,110	168,202	181,840	195,478	209,116	222,754
Zone10	36,368	40,914	45,460	50,006	54,552	59,098	68,190	72,736	81,828	86,374	90,920	100,012	104,558	113,650
Total	1,300,156	1,359,254	1,431,990	1,518,364	1,582,008	1,659,290	1,741,118	1,818,400	1,918,412	1,995,694	2,086,614	2,182,080	2,273,000	2,386,650

Daily Max. MGD	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Zone1	56.0	57.0	58.0	60.0	61.0	62.0	63.0	64.0	65.0	66.0	67.0	68.0	69.0	71.0
Low	38.0	38.0	39.0	40.0	40.0	41.0	41.0	42.0	43.0	43.0	44.0	44.0	45.0	46.0
High	18.0	19.0	19.0	20.0	21.0	21.0	22.0	22.0	22.0	23.0	23.0	24.0	24.0	25.0
Zone2	38.0	39.0	40.0	42.0	43.0	44.0	45.0	46.0	48.0	49.0	50.0	51.0	52.0	54.0
Zone3	40.0	41.0	43.0	45.0	46.0	47.0	48.0	49.0	50.0	51.0	52.0	53.0	54.0	56.0
Zone4	48.0	49.0	51.0	53.0	54.0	56.0	58.0	60.0	62.0	63.0	65.0	67.0	69.0	71.0
Zone5	22.0	24.0	26.0	28.0	30.0	33.0	35.0	38.0	41.0	44.0	47.0	50.0	53.0	56.0
Zone6	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	21.0	22.0	23.0	24.0	25.0	26.0
Zone7	23.0	25.0	28.0	31.0	34.0	37.0	41.0	44.0	48.0	52.0	57.0	61.0	66.0	71.0
Zone8	18.0	19.0	21.0	23.0	25.0	27.0	29.0	31.0	34.0	36.0	38.0	41.0	43.0	46.0
Zone9	21.0	23.0	24.0	26.0	27.0	29.0	31.0	33.0	35.0	37.0	40.0	43.0	46.0	49.0
Zone10	8.0	9.0	10.0	11.0	12.0	13.0	15.0	16.0	18.0	19.0	20.0	22.0	23.0	25.0
Total	286.0	299.0	315.0	334.0	348.0	365.0	383.0	400.0	422.0	439.0	459.0	480.0	500.0	525.0

B. WATER SOURCE SURVEY

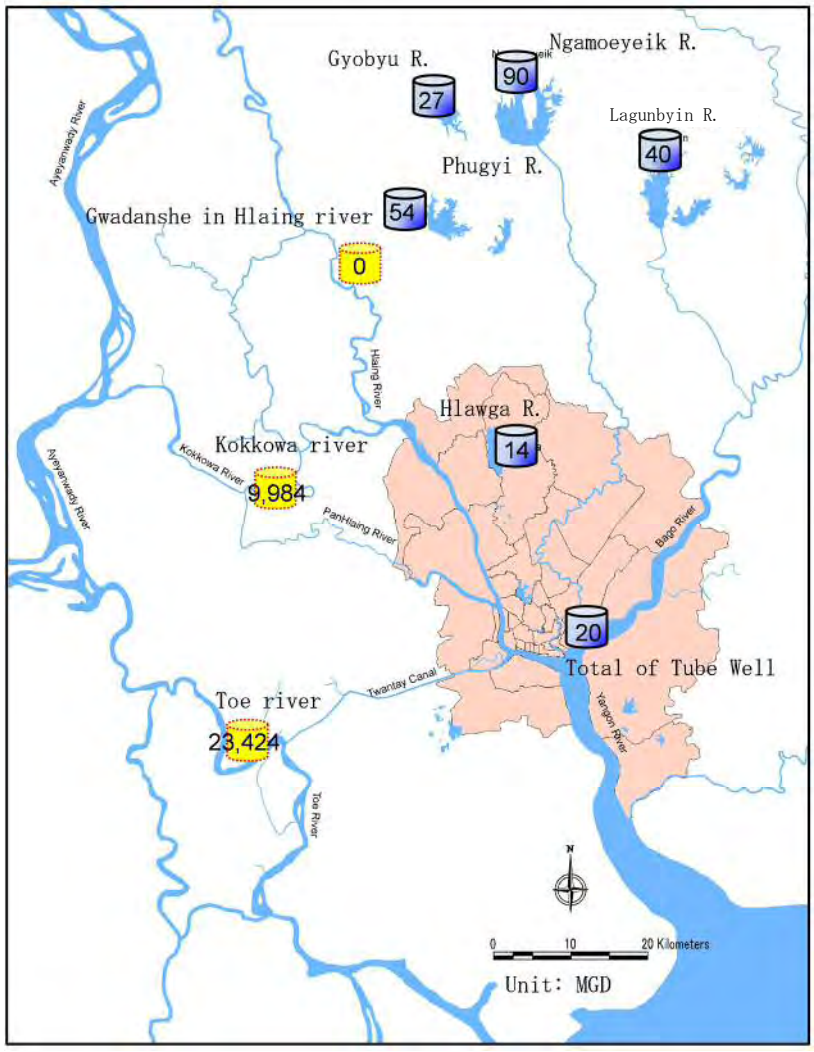
1. Development of Potential Surface Water (Reservoir and River)

Table B.1 shows the list of water supply sources while Figure B.1 shows the map of water sources around Yangon City. The current water supply source of 215 MGD (977,400 m³/day) are utilized continually. To meet future increased water demand, the potential of Kokkowa river and Toe river as new sources of water are studied. The existing ground water source (20 MGD) shall be gradually abolished after the development of river water source and distribution facilities.

Table B.1 List of Water Supply Sources

Name	Water Supply Volume	
	m^3/day	MGD
1) Existing Water Resource		
Gyobyu Reservoir (Surface water)	121,500	27
Hpugyi Reservoir (Surface water)	243,000	54
Hlawgar Reservoir (Surface water)	63,000	14
Ngamoeyeik (Surface water: First + Second Phase)	405,000	90
Sub-Total	832,500	185
2) Planned Water Resource		
Lagunbyin Reservoir (Surface water)	135,000	30
Total-Existing fixed sources	977,400	215
3)Required river source		
Kokkowa River	1,909,300	420
Toe River		
Total 1) + 2) + 3)	2,886,700	635

Source: JICA Study Team



Source: JICA Study Team

Figure B.1 Map of Water Resource for Water Supply around Yangon City

2. Evaluation of Existing Reservoirs

In 2002 JICA-M/P study, the water balance study was carried out for Gyobyu, Phugyi, Hlawga, and Ngamoeyeik reservoirs (drinking water sources) and Lagunbyin reservoir (an exclusive irrigation reservoir). The simulation period was adopted as the last six years (May 1995–December 2000) with a 10-year return period, which covers the severe drought year of 1998. Table B.2 shows the results of analysis of the water balance study in the 2002 JICA study. The capacity of the current reservoir for water supply was recognized as 868,600 m^3/day (186.5 MGD) approximately, on condition of maintaining the low water level in each reservoir during the drought year. In addition, it was analyzed that Lagunbyin reservoir will enable to divert 10 MGD for drinking water source.

Table B.2 Results of Reservoir Water Balance Study

Name	Low Water level Unit: ft	Water Supply Unit: m^3/day (MGD)
Gyobyu Reservoir	138.0	118,300 (27.0)
Hpugyi Reservoir	90.0	245,700 (54.0)
Hlawgar Reservoir	47.0	75,075 (16.5)
Ngamoeyeik (First + Second stage)	81.0	409,500 (90.0)
Lagunbyin Reservoir	46.0	45,000 (10.0)

Source: JICA Study Team

To evaluate the results of water balance study in the 2002 JICA survey, an examination was made for the applicability of the 2002 JICA survey to the existing conditions based on comparing the rainfall data of the previous study with the recent rainfall data. The methods of evaluation are summarized below.

a. Long term fluctuation

The rainfall data used in the 2002 JICA survey rainfall data was compared with the rainfall data of years from 2001 to 2010. As a result of comparison, it is observed that the average rainfall in 2001 to 2010 was higher than the average rainfall in 1965 to 2000. It was also found out that little rainfall during 2001-2010 has not been renewed from any observatories.

b. Non-exceedance probability

In the 2002 JICA study, the probability by annual rainfall has been studied using the rainfall from January to December in Bago, Tharrawaddy, and Kaba Aye. Table B.3 shows the non-exceedance probability of annual rainfall at these stations as estimated by Gumbel's Minimum Values method.

Table B.3 List of Non-Exceedance Probability Annual Rainfall

Station Name	2 years	5 years	10 years	20 years	50 years	100 years	Number of Records
Bago	3,284.9	2,922.3	2,740.0	2,598.7	2,454.5	2,369.3	36
Tharrawady	2,206.1	1,963.4	1,829.9	1,719.1	1,597.1	1,519.2	36
Kaba Aye	2,680.7	2,413.8	2,296.5	2,214.5	2,139.7	2,100.4	33

Source: 2002 JICA Study

Table B.4 shows the list of non-exceedance probability estimation by the latest annual rainfall from 2001 to 2010. There are no large differences in the past ten years for non-exceedance probability rainfall in each station, and no changes in water trend were also determined.

Table B.4 List of Non-Exceedance Probability Annual Rainfall from 2001 to 2010

Station Name	2 years	5 years	10 years
Bago	3,386.0	2,854.0	2,513.0
Tharrawady	2,165.0	1,847.0	1,831.0
Kaba Aye	2,757.0	2,478.0	2,315.0

Source: JICA Study Team

The results of water balance study in the 2002 JICA Survey (Table B.2) enabled the utilization of the current surface water supply sources (Table B.1).

3. Evaluation of Potential Water Sources

3.1 Water Flow Measurement Survey

Hlaing (Gwedanshe), Kokkowa, and Toe rivers were initially considered as potential water sources. Bago River was not considered because it has relatively low water availability according to the 2002 JICA survey. Available amounts of water intake from these water sources depend highly on the river flow from January to April which is lowest during dry season. From the river flow data in Hlaing and Bago rivers, the minimum flow is dropping to approximately one-hundredth of the maximum value.

Currently, no water flow but water level is monitored for both rivers. To covert the water level to water flow, the JICA Study team requested MOAI to measure flow rate and cross section of the rivers. The MOAI carried out the measurement in November 2012 in Kokkowa river and in December 2012 in Toe river. Also, to measure the minimum flow rate, measurement was made in March 2013 in both rivers. In addition, planned irrigation plans were confirmed with MOAI. The following are measurement results.

River	Flow rate (Date)	
	2012	2013
Kokkowa	1,941m^3/s(24 Nov.)	1,233 m^3/s (20 Mar.)
Toe	2,572m^3/s(11 Dec,)	1,930m^3/s (18 Mar.)

Source: MOAI

3.2 River Maintenance Flow

While planning water intake from the river, maintenance of minimum flow is considered taking into account the protection of nearby flora and fauna, fishing, and landscape. The definition of normal flow is combined with the maintenance flow, viable water source amount, flow discharge for maintaining normal flow functions of water, and target flow discharge on the management of low water level through the year.

Maintenance flow is the part of flow in river which cannot be utilized as water available for intake from the source. Following its characteristic, it is necessary to assess the distinction of each river and season in terms of fishing, landscape, and saltwater intrusion. However, the available information is insufficient to determine the ideal maintenance flow in this study. In response to this situation, maintenance flow is assumed to be half of the 10-year minimum drought discharge as referred to the Japanese manual. In the case of Japan, there was a tendency where the maintenance flow was between the 10-year average drought discharge and the 10-year minimum drought discharge. Though the characteristics of rivers in Yangon is very different from the rivers in Japan, it is assumed that: 1) Water levels in target rivers use a minimum value in daily fluctuations, and 2) the characteristic of river flow is applicable to its maintenance flow which is lower than the 10-year minimum drought discharge.

The 10-year average drought discharge in the Kokkowa River was estimated using the following processes presented below, as well as the background of available amounts of direct river intake.

Table B.5 Estimation of 10-year Minimum Drought Discharge in the Kokkowa River

Process	Subject	Remarks
A	Set of Basic Condition (River Cross Section of Target River)	Refer: Actual river cross section
B	Set of Basic Condition (Characteristics of Minimum Rainfall over the Past 10 years)	Target year: 2001-2010
C	Set of Cross Section Area (A) and Velocity (V) in 10-year minimum drought discharge	Refer: Measurement of river flow discharge on site
D	Calculation of 10-year minimum drought discharge (Q)	Q = A x V

Source: JICA Study Team

3.3 Water Source Evaluation

3.3.1 Hlaing River (Gwedanshe)

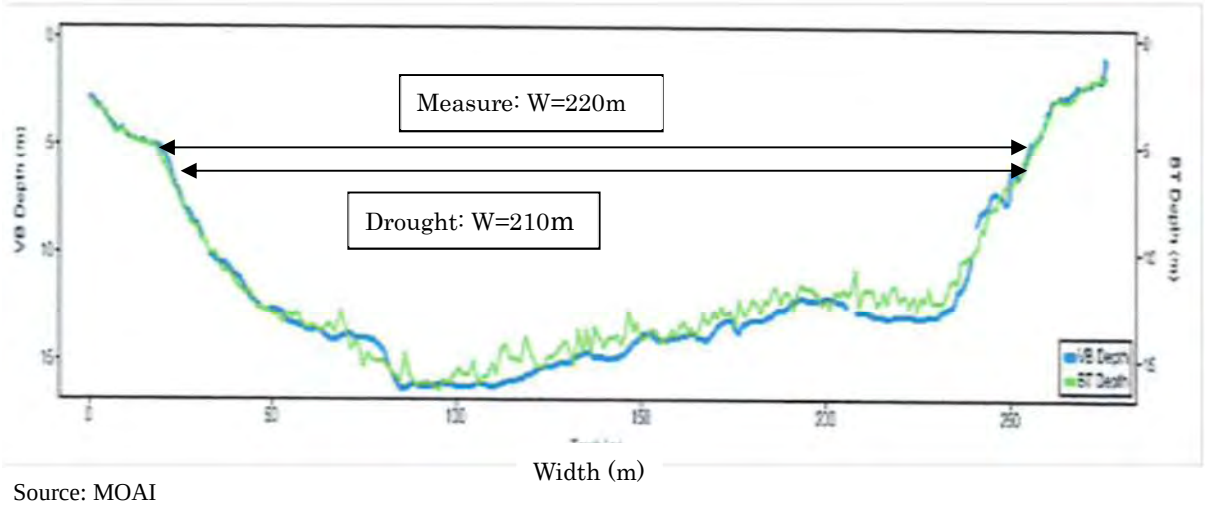
Hlaing River's flow (10-year average drought discharge) in the dry season was applied as 11.4 m^3/s, the data for Gwedanshe. This is same as the considerations made in the 2002 JICA survey for rainfall from 2001 to 2010. However, the possibility of the Hlaing River's direct water intake in the dry season does not exist. The current water intake facilities for irrigation (2.287 m^3/s,) were confirmed near the intake point and alternative irrigation projects (4.67 m^3/s, 89.64 MGD) as reported by the MOAI. The maintenance flow in this river, assumed to be 4.0 m^3/s, was considered.

3.3.2 Kokkowa River

a. Set of Basic Condition (River Cross Section of Target River)

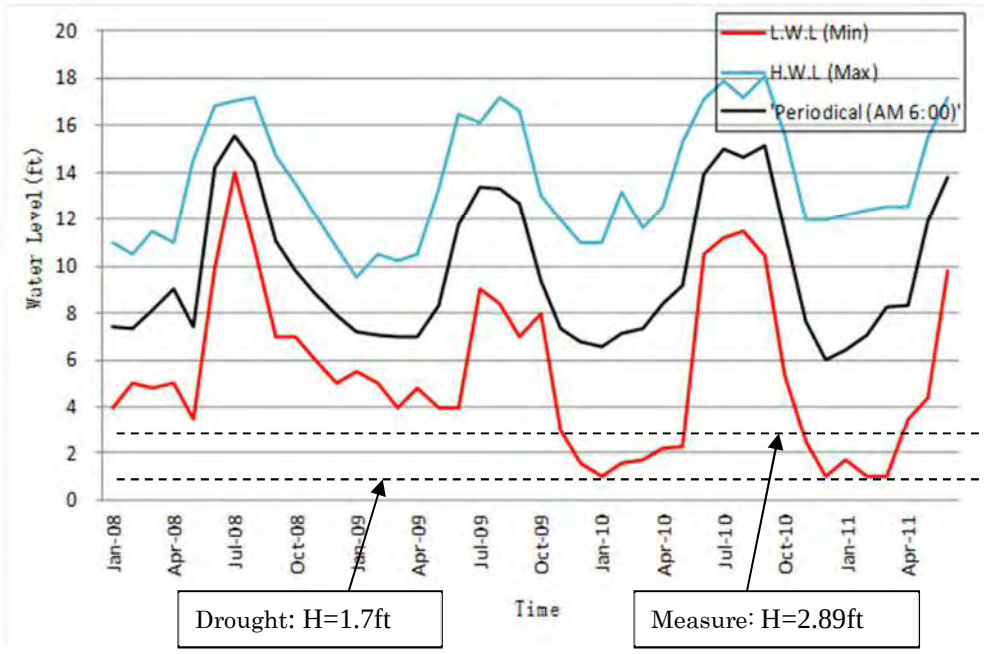
Figure B.2 shows the river cross section of Kokkowa River, which was obtained from the MOAI. The

cross section area was approximately 2,170 m^2 at a water level of 2.89 ft in the river which was close to the minimum water level in the past



Source: MOAI

Figure B.2 Cross Section at Pan Taing in Kokkowa River



Source: JICA Study Team based on MOAI Data

Figure B.3 Water Level at Pan Taing, Kokkowa River (2008 – 2011)

b. Set of Basic Condition (Characteristics of Minimum Rainfall over the Past 10 years)

The annual minimum rainfall occurred in 2010 during the period of 2001-2010. Table B.6 shows the water level changes from January 2008 to August 2011 (including 2010) in Kokkowa River. Maximum water level (rainy season) was 18.0 ft, the 355th day water level was 1.7 ft and the minimum water level (dry season) was 1.0 ft. The low water level in 2010 was the lowest. So, the 10-year minimum drought flow is assumed to occur in 2010, when the minimum rainfall occurred over the past ten years.

Table B.6 Water Level in Kokkowa River (FY 2008-2011)

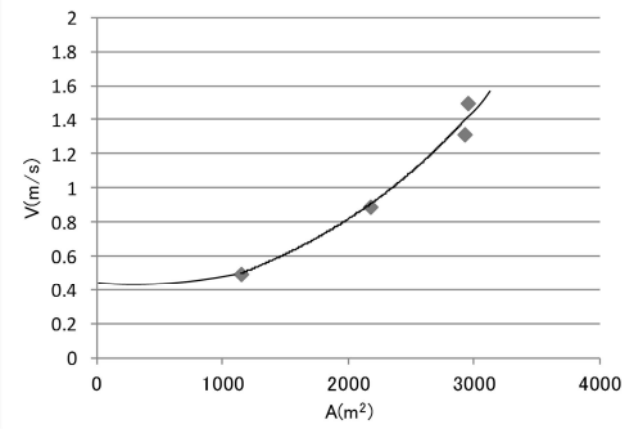
Unit: ft

	Max	95th day	185th day	275th day	355th day	Min	Mean
FY 2008	17.2	10.0	8.0	6.2	4.5	3.5	8.8
FY 2009	17.2	10.3	7.0	5.8	4.0	3.0	8.0
FY 2010	18.1	12.2	6.0	3.6	1.7	1.0	7.6
FY 2011*	17.2	12.2	7.2	4.5	1.2	1.0	8.1

*FY2011: August 2010 – July 2011
Source: JICA Study Team

c. Set of Cross Section Area (A) and Velocity (V) for 10-year minimum drought discharge

- Water level in case of the 10-year minimum drought discharge was assumed as 1.7 ft. from the above.
- River width in case of the 10-year minimum drought discharge was assumed as 210 m.
- The cross-sectional area in case of the 10-year minimum drought discharge was assumed as 780 m^2, (A=≒ A'2,170 – H(2.89-1.7)ft x W(210 + 220) m / 2)
- Flow rate of the 10-year minimum drought discharge is shown as the relationship between the cross-sectional area (A) and the velocity (V) (see Figure B.4) taken from the results of the cross-sectional survey in Figure B.2. Thus, the flow rate in the dry season was assumed as 0.5 m/s which is about one-third of the HWL during rainy season.



Source: JICA Survey Team

Figure B.4 Relation Between the Cross Section (A) and Velocity (V) of Kokkowa River

d. Calculation of the 10-Year Minimum Drought Discharge

Q minK = A x V ≒ 1,045 m^3/s
A = 2,090 m^2: Cross-sectional area for the 10-year average drought discharge
V = 0.5 m/s: Velocity for the 10-year average drought discharge

e. Flow Measurement on 20 March 2013, the Drought Period

Flow was measured as 1,233m^3/s at the water level of 0.23ft which is nearly the same as the estimated

value. Flow measured on 24 November 2012 was 1,941 m^3/s at a water level of 2.89 ft.

f. Water Intake Amount for YCDC

Water amount available for YCDC is at least 520 m^3/s, half of the 10-year minimum drought discharge, considering the river maintenance flow and water required for other irrigation projects of MOAI. Total of 153 MGD (12.0m^3/s) water is planned for irrigation schemes according to MOAI, 10.12MGD for Pantaing Sluice (1), 52.85MGD for Pantaing Sluice (2), 47.98MGD for Khunnaingtan Sluice, and 42.47MGD for Chaungnyiako Sluice.

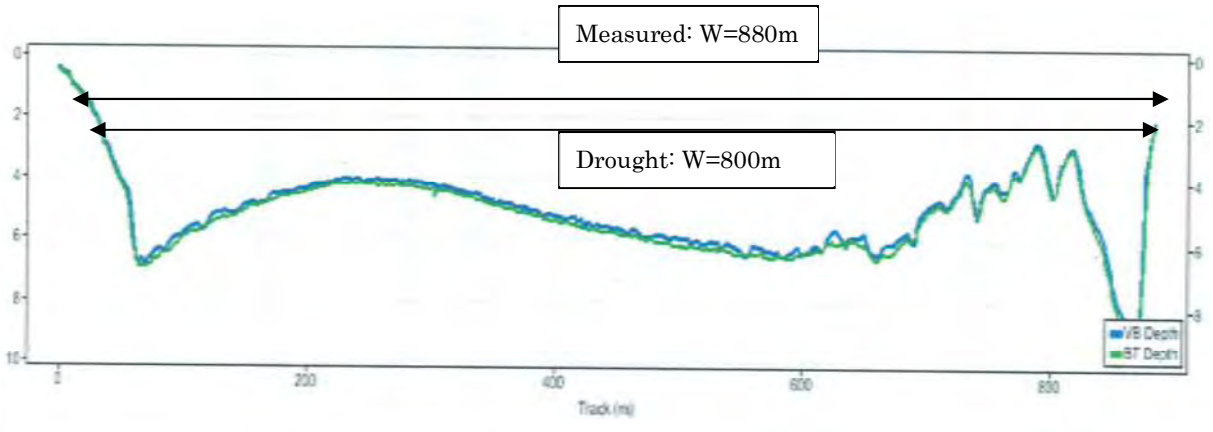
3.3.3 Toe River

The 10-year minimum drought discharge was estimated using the same process as used in case of the Kokkowa River.

Figure B.5 shows the river cross section of Kokkowa River, which was obtained from the MOAI. The underwater cross section area was approximately 2,170 m^2 at the water level of 2.89 ft which was close to the minimum water level in the past

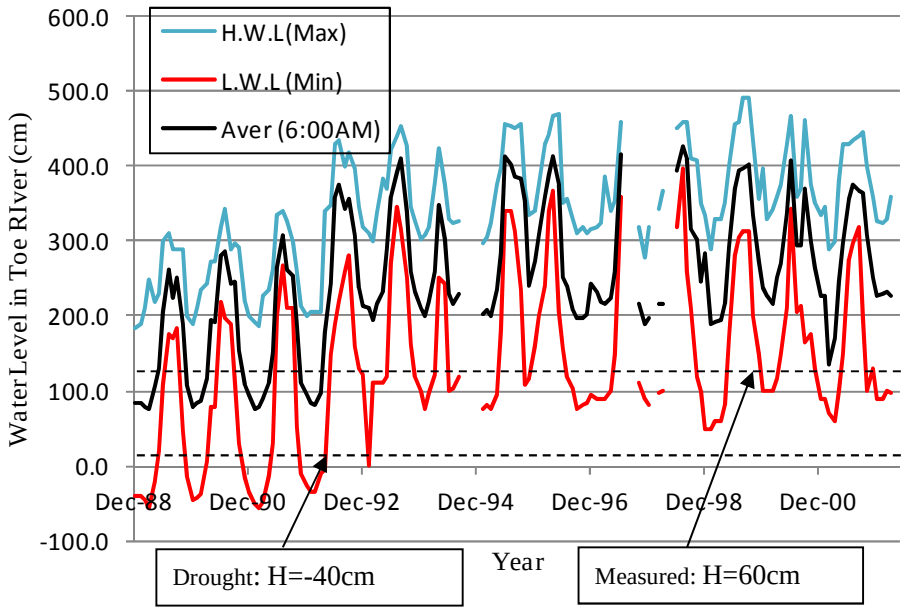
a. Set of Basic Condition (River Cross Section of Target River)

Figure B.5 shows the cross section at the proposed intake point in the Toe River measured on 11 December 2012. This cross section area was determined as 4,340 m^2 at the water level of 60 cm, which was almost the lowest water level.



Source: JICA Study Team

Figure B.5 Cross Section in Toe River



Source: JICA Study Team based on MOAI Data

Figure B.6 Water Level at Pann Hlaing, Toe River (1989-2002)

b. Set of Basic Condition (Minimum Drought Flow Discharge)

Ten-year drought flow is estimated assuming it occurred in 2010 same as in case of the Kokkowa River. However, water level data in 2010 was not available so that water level data continuously available (between January 1989 and April 2002, March 2011 and August 2012) was alternatively used.

- Water level data between January 1989 and April 2002 is shown in Table below. Water level data of 355th day and minimum was not estimated due to lack of data during dry period.
- The highest water levels in the years ranged from 354 to 486 cm while the lowest ranged from 80 to 300 cm according to the latest data (between March 2011 and August 2012). These levels are similar to the past records (January 1989 to April 2002). So all data were judged effective.
- The lowest and the 355th day water levels were -46 cm and -40cm, respectively, both in 1989 during period from January 1989 to April 2012. Thus, -46 cm water level was judged as a 10-year drought water level.

Figure B.7 Water Level in the Toe River (1989-2001 and 2011-2012)

unit : cm

	Max	95th day	185th day	275th day	355th day	Min	Mean
FY 1989	273	190	46	-20	-40	-46	77.1
FY 1990	312	216	84	-14	-38	-45	104.2
FY 1991	312	220	56	-18	-46	-56	101.1
FY 1992	386	296	160	0	-29	-34	158.6
FY 1993	426	292	178	127	113	100	221.1
FY 1994	314	127	105	--	--	--	153.9
FY 1995	430	344	186	92	--	--	234.1

	Max	95th day	185th day	275th day	355th day	Min	Mean
FY 1996	432	320	190	116	85	76	218.3
FY 1997	426	168	120	96	--	--	178.9
FY 1998	430	296	130	--	--	--	234.6
FY 1999	690	321	180	90	60	50	211.4
FY 2000	398	270	188	140	110	100	214.1
FY 2001	376	300	180	100	60	60	201.9

Source: JICA Study Team based on MOAI Data

c. Set of Cross Section Area (A) and Velocity (V) for 10-year minimum drought discharge

- Water level for the 10-year minimum drought discharge was lower by 1 m than the water level measured on 11 December 2012. Width is assumed as 800 m.
- The cross-sectional area for the 10-year minimum drought discharge was assumed as 4,080 m^2, (A ≒ A'4,340 – H(0.6+0.4)ft x W(880 + 850)m / 2).
- The flow velocity of 0.6 m/s was measured on 11 December 2012 which is regarded as low flow discharge. So, this flow velocity is also the same as for 10-year drought flow.

d. Calculation of the 10-Year Minimum Drought Discharge

Q minT = A x V ≒ 2,448 m^3/s
A = 4,080 m^2: Cross-sectional area in case of the 10-year drought discharge
V = 0.6 m/s: Velocity for the 10-year drought discharge

e. Flow Measurement on 18 March 2013, the Drought Period

Flow was measured as 1,930 m^3/s at a water level of 52 cm which is nearly the same as the above estimated value. Flow measured on 11 December 2012 was 2,573 m^3/s at a water level of 60 cm.

f. Water Intake Amount for YCDC

Water amount available for YCDC is at least 1,220 m^3/s, half of the 10-year minimum drought discharge, considering the river maintenance flow. There are no irrigation projects around here.

The followings are attached to Annex.
Flow measurement in Kokkowa river (10th August 2012, 30th November, 20th March 2013, MOAI)
Flow measurement in Toe river (30th November, 18th March 2013, MOAI)

Water Quality Test for Kokkowa River

1.1 Introduction

Water quality test of Kokkowa River water was implemented. Overview of water sampling and water quality test are given below.

Table 1 Water Test Items and Survey Overview

Water quality survey of water source	
Sampling date	17-Jul, 19-Aug 2015 and 25-Feb 2016 (3 times)
Sampling point	Near intake point
Test Items	pH, Turbidity, Electric Conductivity (EC), Total dissolved solid (TDS), Chloride, Alkalinity, Nitrate, Nitrite, Ammonia, Iron, Manganese, Coliform (E coli), Fecal Coliform
Salt water intrusion survey	
Sampling date	17-Jul 2015 and 25-Feb 2016 (2 times)
Sampling point	Near intake point and downstream from Intake point
Sampling Method	At the time of high-tide water, take sample at the intake point and downstream of intake point. Surface water and subsurface water (at about 5 m depth from surface) were sampled.
Test Items	Water Temperature, pH, EC, TDS, Chloride
Sedimentation test	
Sampling date	From 27-May 2015 to 25-Feb 2016 (several times per month)
Test Items	Turbidity, Color (supernatant water)
Test Method	Predetermined time standing of sampling water and measure the turbidity and color of supernatant water
Coagulation-sedimentation property (Jar test)	
Sampling date	From 17-Jul to 21 Dec 2015 (5 times)
Test Items	pH, Turbidity, Color, Fe, Mn
Test Method	Decide suitable coagulation treatment condition using Jar tester. In addition, treatment property of Fe and Mn by coagulation- sedimentation process was measured.
Chlorine consumption test	
Sampling date	17-Jul and 19-Aug 2015 (2 times)
Sampling point	Near intake point ×2 times (after coagulation-sedimentation process using Jar-tester)
Test Items	Free residual chlorine
Test method	After injection the predetermined amount of sodium hypochlorite solution into the sampling water, measure the free residual chlorine concentration of limited time.

Source: JICA Study Team

Water samples in Kokkowa River were taken near the new water intake facility construction site. Water sampling points of Salt water intrusion survey are shown below.

Source: JICA Study Team

Figure 1 Sampling Points of 1st time of Salt Water Intrusion Survey on 17-Jul 2015

		
Kokkowa River, 17 July 2015	Underwater Sampling at Kokkowa River, 17 July 2015	Measurement At Site (Kokkkowa River), 17 July 2015
		
Jar Test (YCDC Lab), 17 July 2015	Chlorine Demand Test (YCDC Lab), 17 July 2015	Chlorine Demand Test (YCDC Lab), 17 July 2015

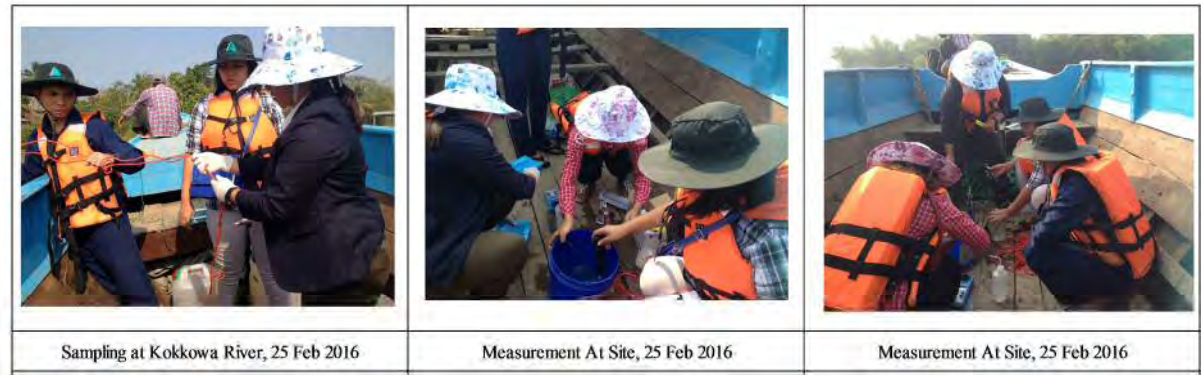
Photo 1 Sampling and Water Quality Test at YCDC Laboratory (1st; 17-Jul)

Sampling at Kokkowa River, 19 Aug 2015	Measurement At Site, 19 Aug 2015	Measurement At Site, 19 Aug 2015
Jar Test (YCDC Lab), 20 Aug 2015	Jar Test (YCDC Lab), 20 Aug 2015	Chlorine Demand Test (YCDC Lab), 20 Aug 2015

Photo 2 Sampling and Water Quality Test at YCDC Laboratory (2nd; 19 Aug.)

Source: JICA Study Team

Figure 2 Sampling Points of 2nd Time of Salt Water Intrusion Survey on 25-Feb 2016



Sampling at Kokkowa River, 25 Feb 2016	Measurement At Site, 25 Feb 2016	Measurement At Site, 25 Feb 2016

Photo 3 Sampling and Water Quality Test at YCDC Laboratory (3rd; 25 Feb. 16)

1.2 Water quality near water intake site

Water quality near water intake site is shown in Table 3. This table shows the data of YCDC tests (28-May 2015 to 25-Feb 2016), Study team tests (collaborative work with YCDC in 17-Jul, 19-Aug 2015 and 25-Feb 2016) and data from other reports.

Based on these data, turbidity ranged from 57 NTU (28-May 2015) to over 1,000 NTU (10 to 19-Aug 2015). In August 2015, serious flood occurred in the north-west area of Myanmar. This high level of turbidity (over 1,000 NTU) is assumed to be the result of the flood. Except these data (10 to 19-Aug 2015), average turbidity was 231 NTU (28-May to 25-Feb 2016) based on the results of YCDC laboratory only. National Drinking Water Quality Standard of Myanmar decides 5 NTU as the standard value. Therefore, reduction of turbidity is necessary to obtain clean tap water.

Color ranged from 25 to 1950 TCU. The highest value was observed in samples of 11-Aug and 19-Aug. Similar to turbidity, this high degree of color resulted from the occurrence of flood. However, National Drinking Water Quality Standard of Myanmar decides color level of 15 TCU. Therefore, reduction of color is also necessary to obtain clean tap water.

Iron (Fe) and Manganese (Mn) in samples of 10-Aug 2015 showed exponential increase. The reason of this increase is same as that of turbidity increase due to occurrence of the flood. Summary of Fe and Mn data except 10-Aug 2015 data is as follows;

Fe: Average 1.6 mg/L, Max: 4.8 mg/L, Min: 0.2 mg/L

Mn: Average 0.7 mg/L, Max: 2.8 mg/L, Min: 0.0 mg/L

In the National Drinking Water Quality Standards of Myanmar, the standard value of Fe is 1.0 mg/L, and Mn is 0.4 mg/L. On the other hand, WHO drinking water quality guideline 4th (Hereinafter, WHO-GL4th), the guideline values of Fe and Mn is not decided. However, presence of > 0.3mg/L of Fe and > 0.1 mg/L of Mn causes coloring trouble and offensive taste.

Considering National Drinking Water Quality Standard of Myanmar, both Fe and Mn exceed water

quality standard level. Moreover, considering the description of WHO-GL, removal of Fe and Mn is required in water treatment process.

Table 2 Water Quality Test Data Near The Water Intake Point

Test by	No	Date	pH	TDS (mg/l)	SS (mg/L)	EC (μS/cm)	Total Hardness (mg/L)	Fe (mg/L)	Mn (mg/L)	Turbidity (NTU)	Color (TCU)	Total Alkalinity (mg/L)	Ca (mg/L)	Mg (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Salinity (mg/L)	Nitrite(NO2) (mg/L)	Nitrate(NO3)	Ammonia(NH4) (mg/L)	E-coli	Fecal Coli
China FS		14.6.2012	7.6				80.0	1.0		280.0	120.0					20.0						
JICA MP		9.12.2012	7.8	56.0		24.0	54.0	4.6	1.0	365.0	180.0					4.0		0.019	N.D.			
China FS		8.12.2012	8.2	99.0	113.0		90.0	2.9		116.0	60.0					6.0						
Korea FS		28.12.2012	7.5	146.0			50.0	1.0	< 0.01	100.0	25.0	71.0	13.2	4.1		13.0			<0.01		Detected	N.D.
JICA MP		8.3.2013	8.2	19.0		220.0	94.0	4.6	N.D.	75.0	20.0					4.0		0.006	N.D.		Detected	Detected
China FS		2.4.2013	8.0	69.0	382.0		98.0	1.8		236.0	80.0					17.0						
		5.4.2013	8.4	67.0	488.0		102.0	2.9		306.0	110.0					12.0						
YCDC	1	28.5.2015	7.5	74.9		149.9	68.0	1.2	0.2	57.0		8.0	11.2	9.6	8.0	31.0	70				Detected	Detected
	2	2.6.2015	7.2	89.7		179.4	108.0	1.2	0.4	120.0		12.0	33.7	5.7	12.0	19.0	90					
	3	8.6.2015	6.6	66.6		133.0	84.0	2.0	0.3	129.0		36.0	14.4	11.5	36.0	15.0	70					
	4	15.6.2015	7.1	65.9		114.9	64.0	1.9	0.5	204.0		42.0	12.8	7.7	42.0	24.0	70					
	5	22.6.2015	7.3	58.9		117.5	76.0	2.2	0.9	376.0		36.0	8.0	13.4	36.0	21.0	60					
	6	29.6.2015	7.4	42.1		84.8	84.0	1.6	1.0	685.0		40.0	6.4	9.6	40.0	31.0	40					
	7	6.7.2015	7.2	42.3		84.7	52.0	1.6	0.8	242.0		36.0	6.4	8.6	36.0	14.0	50					
	8	17.7.2015	7.0	20.4		26.1	76.0	1.8	1.3	523.0		56.0	9.6	12.5	56.0	20.0	20					
JICA Team		17.7.2015																0.0	0.3	0.3	Detected	Detected
YCDC	9	3.8.2015	6.9	53.9		10.8	68.0	1.1	0.7	214.0		40.0	4.7	10.6	40.0	17.0	60					
	10	10.8.2015	7.1	69.3		140.6	44.0	35.8	7.5	2520.0	1950.0	24.0	4.8	7.7	24.0	18.0	70					
	11	17.8.2015	6.7	71.0		142.8	72.0	0.9	2.8	1000.0		122.0	16.0	7.7	122.0	10.0	70					
	12	19.8.2015	7.4	93.3		193.3	84.0	1.1	1.9	1000.0		24.0	16.0	10.5	24.0	20.0	90					
JICA Team		19.8.2015								1190.0	513.0							0.0	1.1	0.1	Detected	Detected
YCDC	13	24.8.2015	7.3	62.8		125.7	68.0	1.1	1.3	496.0	210.0	24.0	12.8	8.6	24.0	14.0	60					
	14	31.8.15	7.2	50.4		100.9	72.0	0.7	1.4	524.0		56.0	16.0	7.7	56.0	9.0	50					
	15	7.9.15	7.1	46.1		93.0	48.0	0.8	2.4	570.0		52.0	11.2	4.8	52.0	13.0	50					
	16	21.9.15	6.9	44.0		88.1	48.0	4.5	1.0	245.0		86.0	11.2	4.8	86.0	12.0	50					
	17	28.9.15	7.0	58.1		116.5	56.0	0.3	0.5	186.0		88.0	8.0	8.6	88.0	25.0	60					
	18	6.10.15	7.2	52.9		104.5	48.0	2.1	0.6	205.0		80.0	9.6	5.8	80.0	6.0	50					
	19	12.10.15	6.9	61.6		123.0	44.0	1.8	0.6	188.0		80.0	10.4	4.3	80.0	14.0	60					
	20	20.10.15	8.3	75.0		150.6	76.0	1.5	0.2	410.0		112.0	16.0	8.6	112.0	14.0	80					
	21	2.11.15	7.3	79.3		163.6	76.0	1.4	0.4	227.0		94.0	17.6	7.7	94.0	15.0	80					
	22	9.11.15	7.0	103.2		206.0	76.0	2.6	0.4	141.0		106.0	14.4	9.6	106.0	19.0	100					
	23	16.11.15	6.7	95.6		191.7	92.0	1.5	0.5	59.0		114.0	24.1	7.7	114.0	20.0	90					
	24	23.11.15	6.6	83.3		166.6	80.0	4.8	0.6	124.0		116.0	19.2	7.7	116.0	11.0	80					
	25	30.11.15	7.7	88.8		177.7	80.0	0.4	0.0	102.0		114.0	17.6	8.6	114.0	13.0	90					
	26	7.12.15	6.6	80.0		144.6	70.0	4.0	0.6	118.0		110.0	19.0	7.0	110.0	10.0	80					
	27	14.12.15	7.0	95.6		190.8	104.0	1.8	0.3	59.0		110.0	25.7	9.6	110.0	12.0	90					
	28	21.12.15	7.5	103.6	283.5	211.0	80.0	1.8	0.5	124.0	120.0	94.0	20.8	6.7	94.0	21.0	100					
	29	28.12.15	6.7	37.6		74.8	92.0	0.4	0.0	134.0		94.0	19.2	10.5	94.0	14.0	40					
	30	11.1.16	7.4	105.4		208.0	80.0	0.2	0.1	217.0		84.0	25.7	3.8	84.0	16.0	100					
	31	18.1.16	6.9	105.8		211.0	124.0	1.4	0.4	64.0		120.0	30.5	11.5	120.0	28.0	100					
	32	25.1.16	7.4	104.8		210.0	92.0	2.1	0.4	71.0		100.0	22.4	8.6	100.0	20.0	100					
	33	22.2.16	7.1	104.9		214.0	120.0	0.5	0.1	298.0		96.0	24.1	14.4	96.0	16.0	100					
	34	25.2.16	7.6	110.8		226.0	100.0	0.7	0.2	52.0		96.0	22.4	10.6	96.0	20.0	110					
JICA Team		25.2.16									47.0							0.0	0.0	0.3		
Target values of YCDC Laboratory			6.5 to 8.5	<500 mg/L		<1000 μ S/cm	< 500 mg/L	< 1 mg/L	<0.4 mg/L	< 5 NTU	< 15 TCU		<250 mg/L	<150 mg/L	<250 mg/L	<250 mg/L	<250 mg/L				0 in 250 ml	

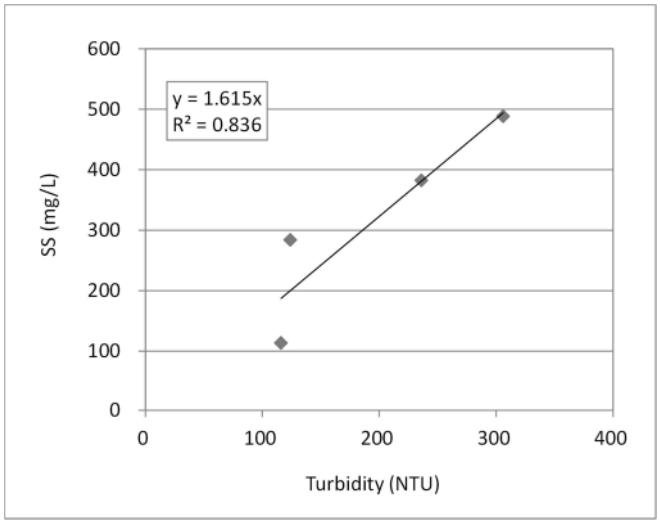
Source: Results compiled by EDWS Laboratory

Suspended solid (SS) was measured according to Standard Methods, 2540D (Total suspended solids). Purpose of this analysis is to obtain SS/Turbidity coefficient to design sedimentation basin.

SS analysis was done on 21-Dec 2015. Result of SS and turbidity analysis is shown below. In this table, China FS data (2012 – 2013) is shown as reference data. Correlation between Turbidity and SS is shown in Figure 3. Obtained SS/Turbidity coefficient was 1.62 as average.

Table 3 Calculation of SS/Turbidity Coefficient

Test by	Date	SS (mg/L)	Turbidity (NTU)	SS/Turbidity
China FS	8.12.2012	113.0	116.0	0.97
China FS	2.4.2013	382.0	236.0	1.62
	5.4.2013	488.0	306.0	1.59
YCDC	21.12.2015	283.5	124.0	2.29
Average				1.62



Source: YCDC and Edited by JICA Study Team

Figure 3 Correlation between Turbidity and SS

1.3 Salt water intrusion survey

Result of salt water intrusion survey is shown below. Both survey were implemented during high water (after new moon). Summary of survey data is shown below.

Table 4 Summary of Salt Water Intrusion Survey (17 July 2015)

Sampling location	Time	pH	EC (µS/cm)	TDS (mg/L)	Turbidity (NTU)	Chloride (mg/L)
Intake point (Surface)	8:33	7.8	89	43	496	13.2
Intake point (about 5 m depth)	8:36	7.7	84	42	475	5.2
4 km downstream (Surface)	9:46	7.6	85	42	344	8.9
4 km downstream (about 5 m depth)	9:50	7.7	80	40	392	17.0

Source: YCDC

Table 5 Summary of Salt Water Intrusion Survey (25 Feb 2016)

Sampling location	Time	pH	EC (µS/cm)	TDS (mg/L)	Turbidity (NTU)	Chloride (mg/L)
3 km upstream (about 5 m depth)	8:40	7.97	212	106	90	20
Intake point (about 5 m depth)	9:03	7.83	206	103	121	20
3 km downstream (about 5 m depth)	9:20	7.80	208	102	90	18
6 km downstream (about 5 m depth)	9:43	7.65	205	102	150	16
10 km downstream (about 5 m depth)	10:08	7.42	216	107	425	20
15 km downstream (about 5 m depth)	10:27	7.58	234	116	1520	22
20 km downstream (about 5 m depth)	10:42	7.41	263	131	1980	32

Source: YCDC

Chloride ranges 5.2 to 32.0 mg/L. In Myanmar Drinking Water quality Standard, required value of Chloride is 250 mg/L. Considering this value, adverce effect of salt water intrusion is inconsiderable.

Note: WHO Guideline 4th describes that threshold level of taste (Chloride) is 200 - 300mg/L. Hence, Chloride ranges of intake point is under standard value.

According to the site measurement result, Turbidity increases after Kokkowa River is combined with Bawlal River.

1.4 Sedimentation test

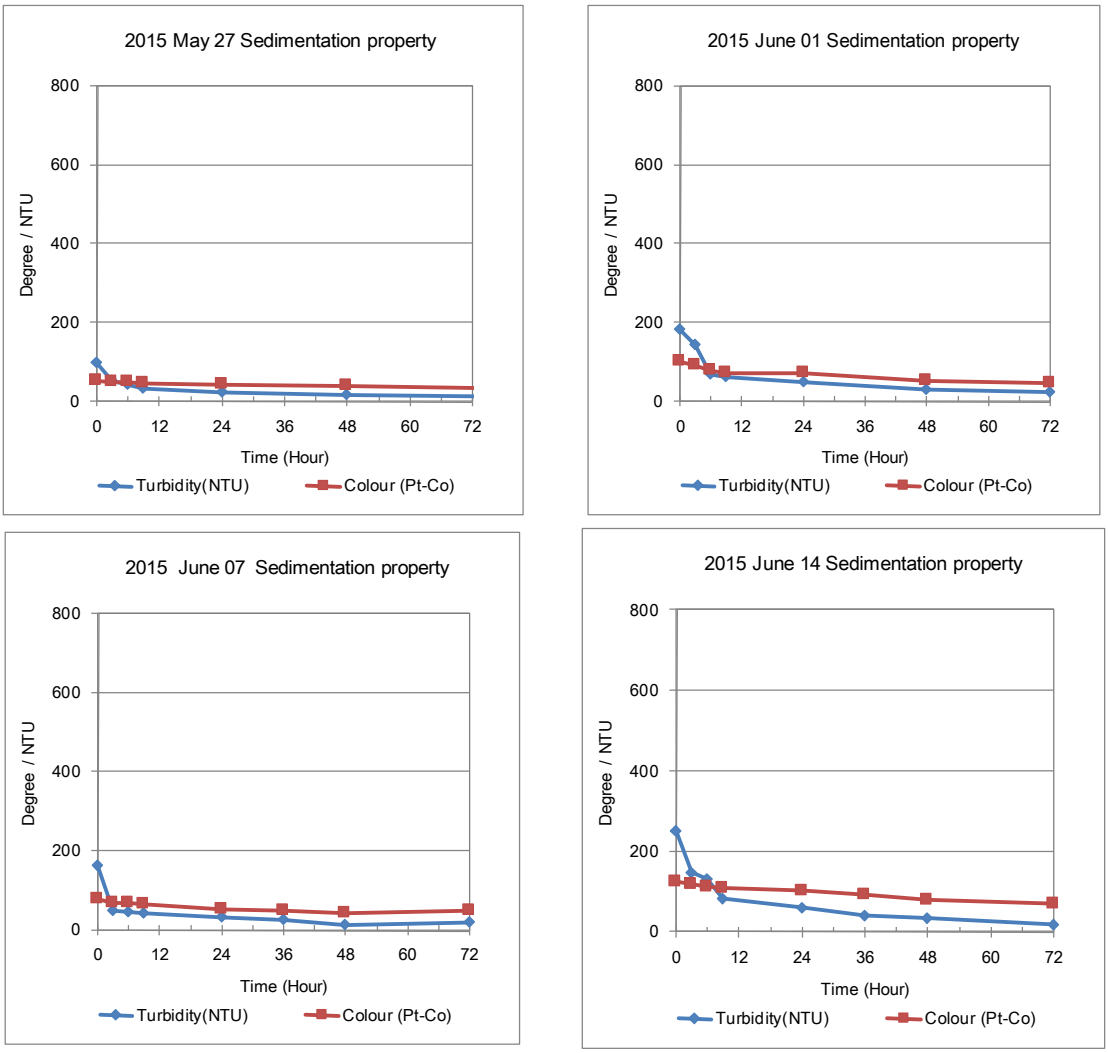
Sedimentation property of Kokkowa River water was tested. Purpose of this test is to obtain a base data to design pre-sedimentation pond to reduce turbidity before water purification process. Sedimentation property was assessed by the temporal change (reduction) of turbidity and color in the supernatant of sample at intervals of 0 hour, 3 hour, 6 hour, 9 hour, 24 hour, 36 hour, 48 hour and 72 hour.

Source: JICA Study Team

Photo 4 Progress of Sedimentation Test

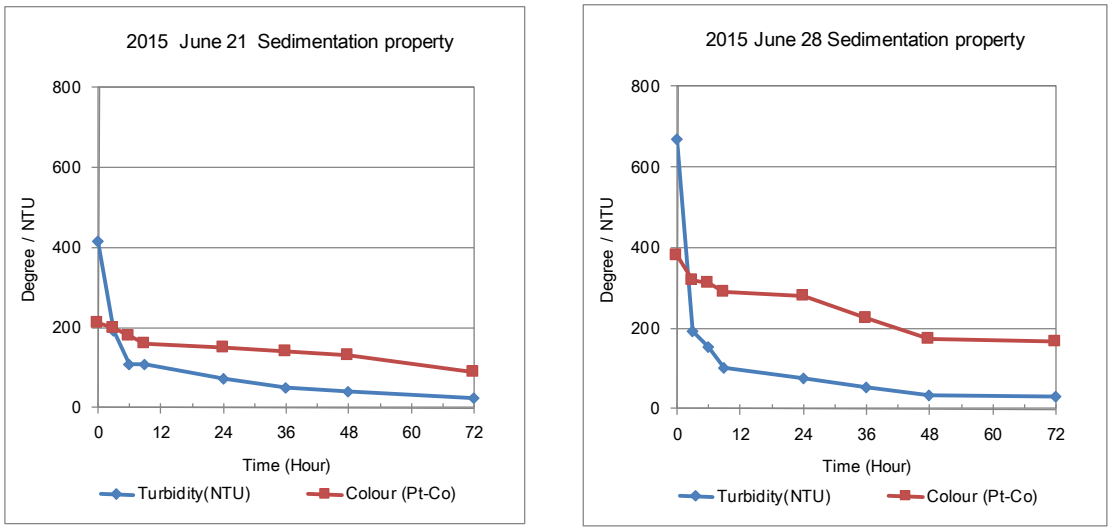
In this survey, Turbidity was measured using WA-PT-4DG Turbidity meter (Kyoritsu Chemical-check Lab.). This Turbidity meter measures Kaolin turbidity unit. However, Myanmar uses Nephelometric turbidity unit (NTU). Therefore, measured data by this turbidity meter have to be converted to NTU. Conversion factor of turbidity is calculated by the comparison of NTU and Kaolin turbidity of Kokkowa River water. Calculated conversion factor was 0.5 (Kaolin / NTU).

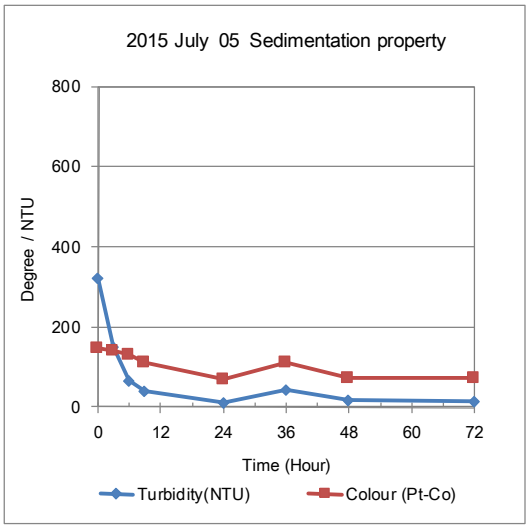
Result of sedimentation test is shown below. Turbidity and color in supernatant decreases gradually. It seems that sedimentation period of 24 to 48 hours is necessary to stabilize the residual turbidity and color in supernatant. Considering this result, adequate retention time of pre-sedimentation pond is 24 to 48 hours.

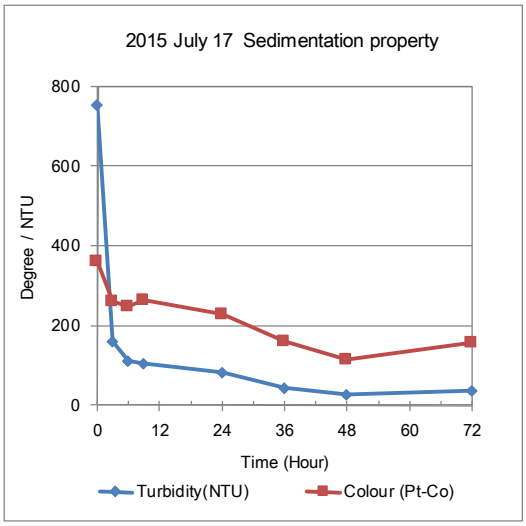


Source: JICA Study Team

Figure 4 Result of Sedimentation Test (May and June)

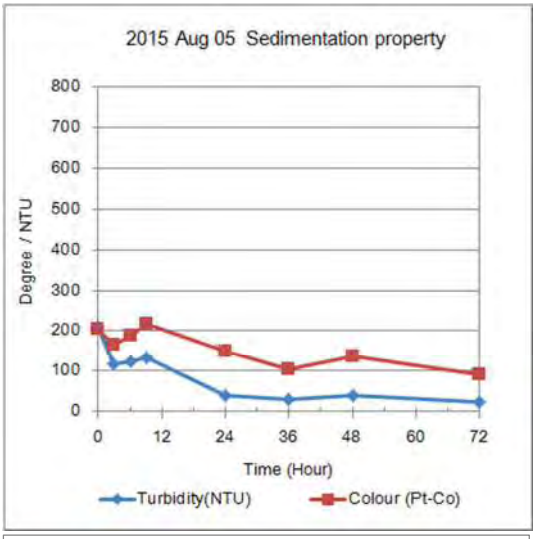


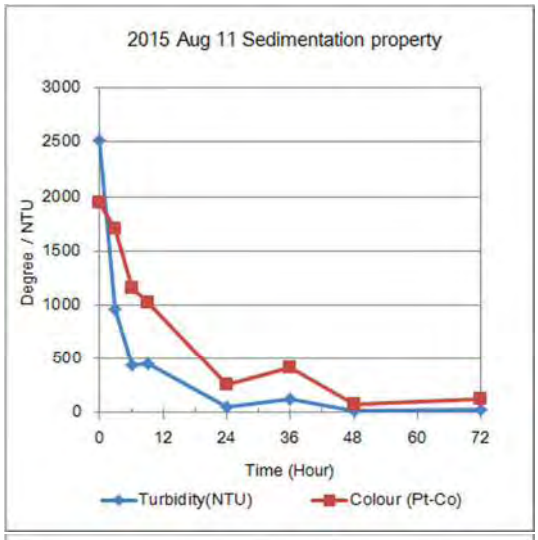


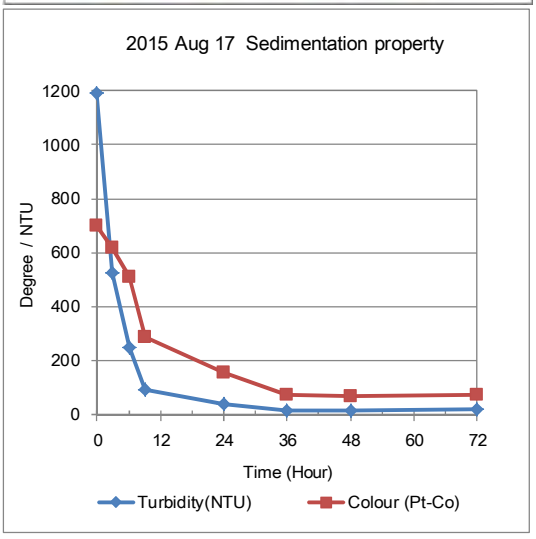


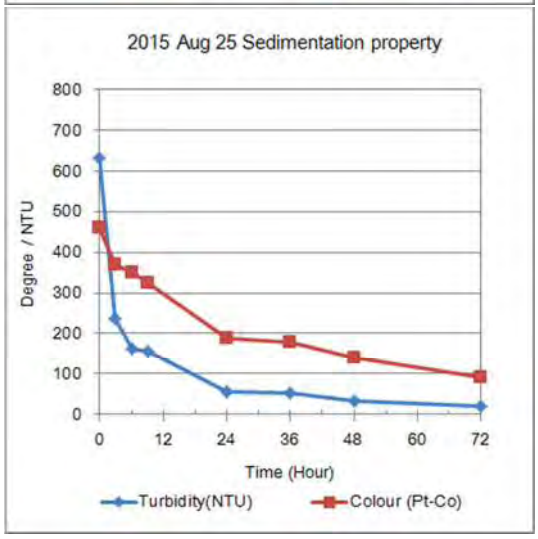
Source: JICA Study Team

Figure 5 Result of Sedimentation Test (June and July)



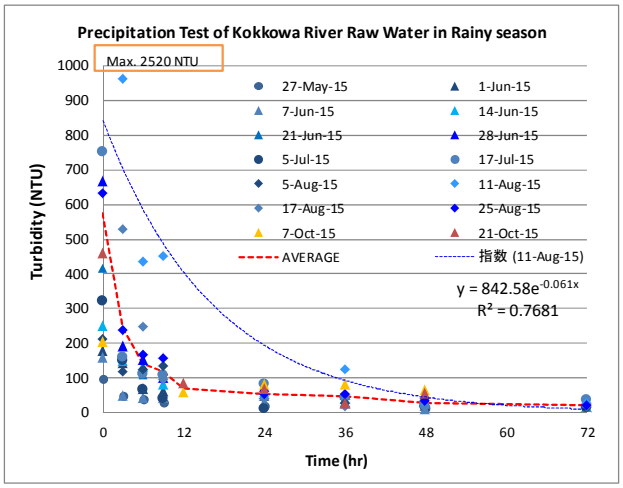


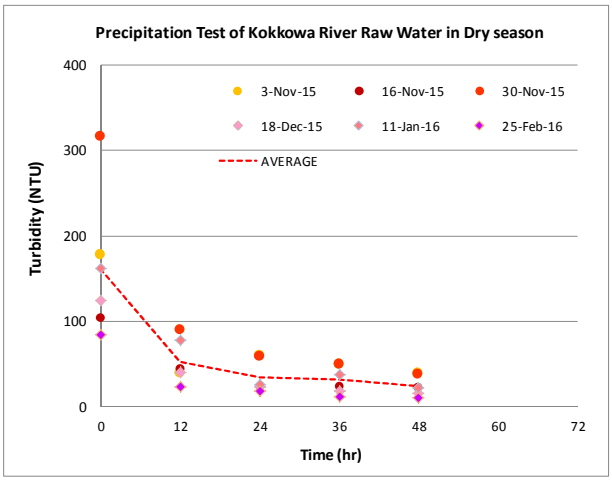




Source: JICA Study Team

Figure 6 Result of Sedimentation Test (August)





in Rainy Season (From May to Nov 2015) **in Dry Season (From Nov 2015 to Feb 2016)**

Source: JICA Study Team

Figure 7 Results of Sedimentation Test in Rainy and Dry Season

1.5 Coagulation-sedimentation treatment

Coagulation-sedimentation treatment was simulated by Jar-test. Considering a primary clarifier process, Jar test was conducted to the supernatant of 24 hours settled raw water.

Condition of Jar-test is as follows;

Rapid mixing: 120 rpm/5min→Slow mixing: 40rpm/15min→Sedimentation: 20min

Result of Jar test is shown below. Considering the standard value of turbidity and color in the Myanmar Drinking Water Quality Standard, desired value after coagulation - sedimentation process is;

Turbidity: < 5 NTU, Color : < 15 TCU.

Turbidity of raw water ranged from 52 to 379 NTU and color ranged from 75 to 410 degree. July and August was rainy season, and December was dry season. Highest level of turbidity was observed in the sample of 19 August. On the other hand, highest color was observed in the sample of 20 October.

Optimum ACH dose ranged from 5 to 20 ppm. However, optimum ACH dose for raw water in October was very high (60ppm for turbidity, 50ppm for color).

Table 6 Summary of Jar Test, Optimum ACH Injection Ratio and Removal of Turbidity

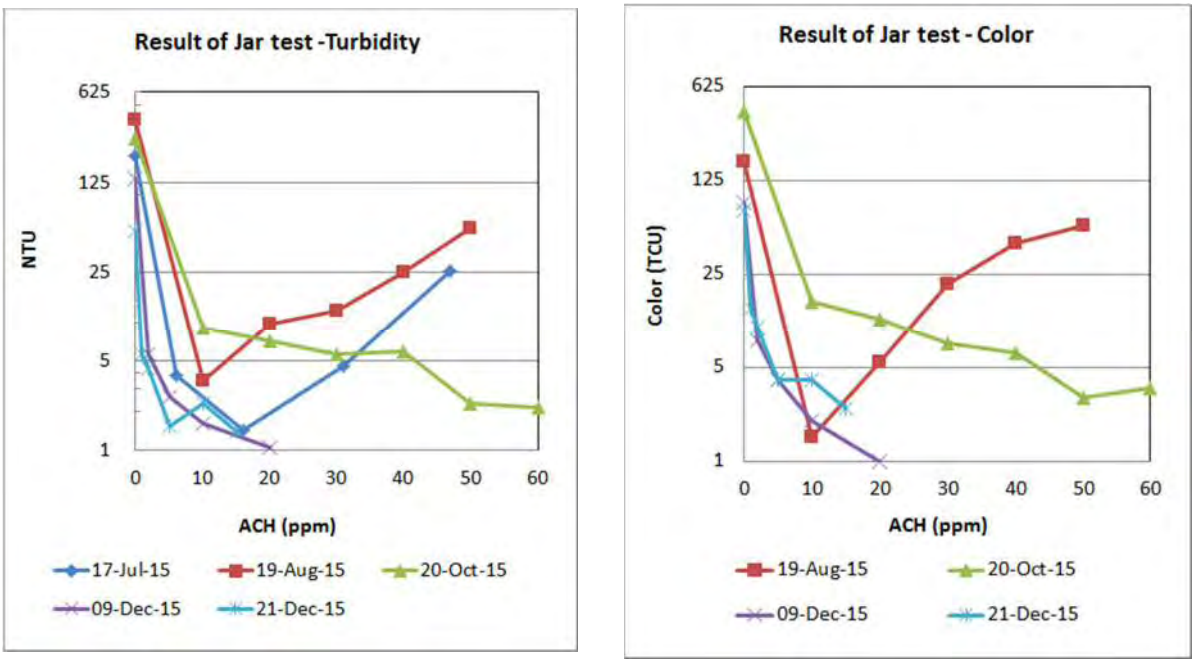
Sampling date	Optimum ACH dose (ppm)	Turbidity (NTU)	
		Raw water	After coagulation
17 Jul. 2015	16	201	1.4
19 Aug. 2015	10	379	3.5
20 Oct. 2015	60	273	2.2
9 Dec. 2015	20	133	1.0
21 Dec. 2015	5	52	1.5

Source: YCDC

Table 7 Summary of Jar Test, Optimum ACH Injection Ratio and Removal of Color

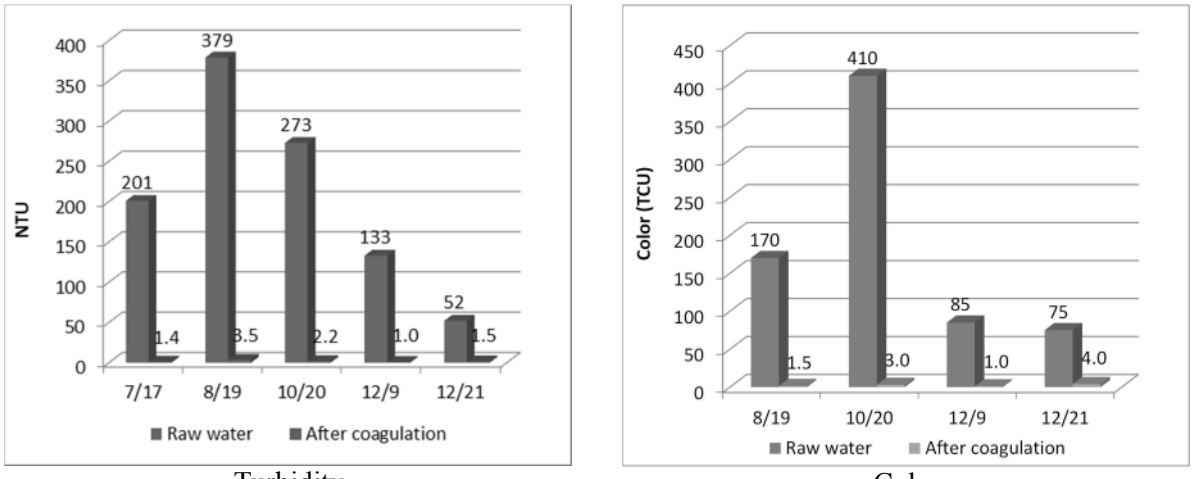
Sampling date	Optimum ACH dose (ppm)	Color (TCU)	
		Raw water	After coagulation
19 Aug. 2015	10	170	1.5
20 Oct. 2015	50	410	3.0
9 Dec. 2015	20	85	1.0
21 Dec. 2015	5	75	4.0

Source: YCDC



Source: YCDC and Edited by JICA Study Team

Figure 8 Result of Jar test, Turbidity and Color



Turbidity Color

Source: YCDC and Edited by JICA Study Team

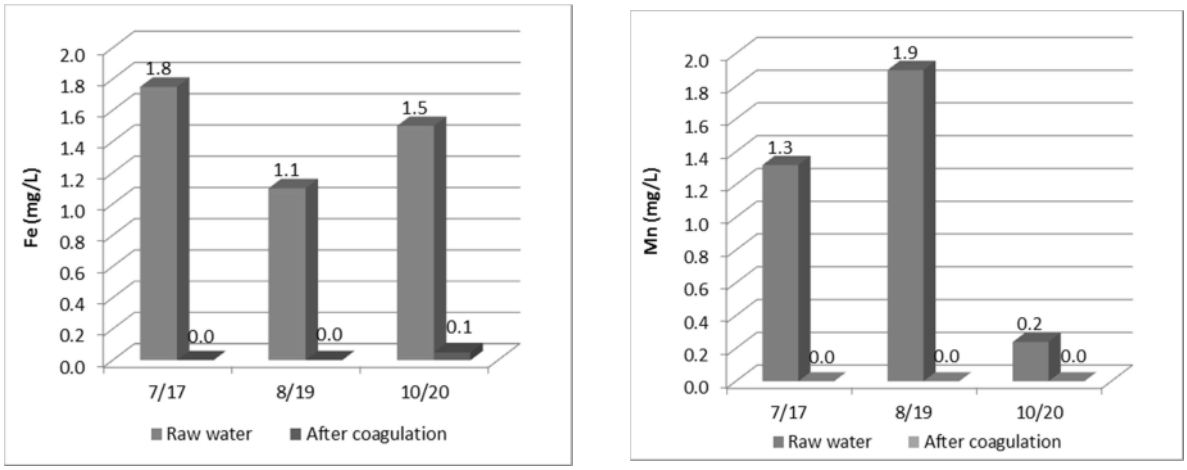
Figure 9 Removal Property of Turbidity and Color by Coagulation - Sedimentation Process

In this coagulation – sedimentation test, removal of Fe and Mn was investigated. In this survey, Fe and Mn concentration before/ after coagulation – sedimentation treatment was compared. Condition of coagulation- sedimentation process is same as that of 19 Aug. (Coagulant injection ratio: 31 ppm). pH before coagulation is: 7.0, and after coagulation is: 7.2.

Test result is shown below. WHO-GL[4th] describes that presence of Fe > 0.3 mg/L and Mn > 0.1 mg/L will deteriorate the quality of water (e.g. color, odor). On the other hand, Myanmar Drinking Water Quality Standard decides following standard values of Fe and Mn;

Fe: 1.0 mg/L, Mn: 0.4 mg/L

In this test, Fe and Mn were removed by coagulation and sedimentation process.

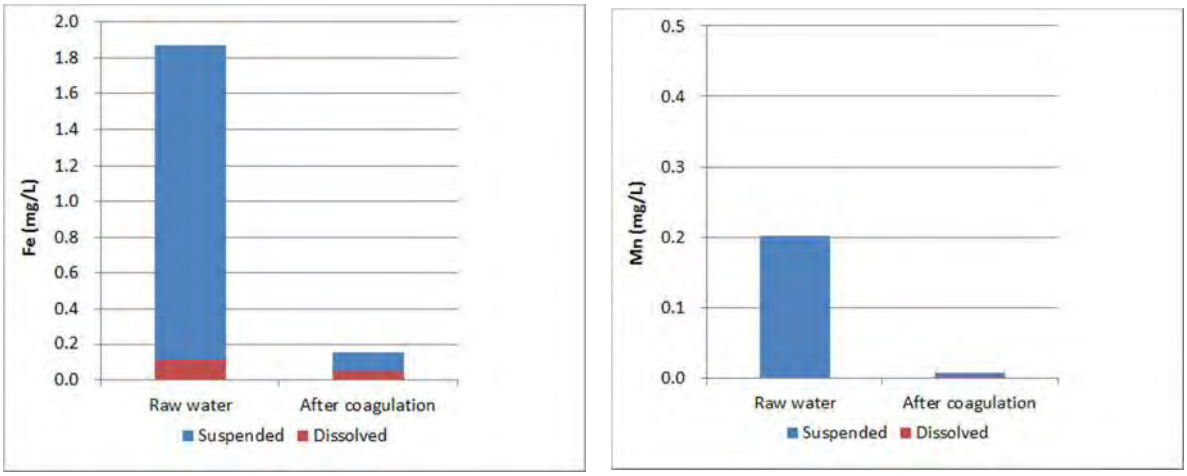


Source: YCDC and Edited by JICA Study Team

Figure 10 Removal Properties of Fe and Mn by Coagulation - Sedimentation Process

To confirm the treatment property of Fe and Mn, additional confirmatory experiment was conducted. In this experiment, separation analysis of dissolved form and suspended form of Fe and Mn was adopted. Separation of dissolved form was done using 0.45 μm membrane filter.
Confirmatory experiment was done using Kokkowa raw water (Sampling: 19 Aug.). ACH injection rate was 5 ppm.

As shown in Figure below, major part of Fe and Mn were in suspended form. Thus, it is expected that major part of Fe and Mn exist as particle (dissolved on particle or colloidal form) and were transported as suspended matter.
This experiment showed that Fe and Mn of suspended form were well removed by coagulation - sedimentation process. Therefore, it is judged that the implementation of adequate coagulation – sedimentation treatment can reduce Fe and Mn in raw water.



Source: YCDC and Edited by JICA Study Team

Figure 11 Removal Properties of Fe and Mn (Morphological Analysis)

1.6 Chlorine consumption test

In this study, chlorine consumption before and after coagulation – sedimentation treatment was measured. Chlorine consumption before coagulation – sedimentation treatment is a simulation of pre chlorination treatment process, and chlorine consumption after coagulation – sedimentation treatment is a simulation of mid-chlorination treatment process.

Test was carried out 2 times. Condition of coagulation – sedimentation of each test is shown below;

Table 8 Summary of Jar Test for Chlorine Consumption Test

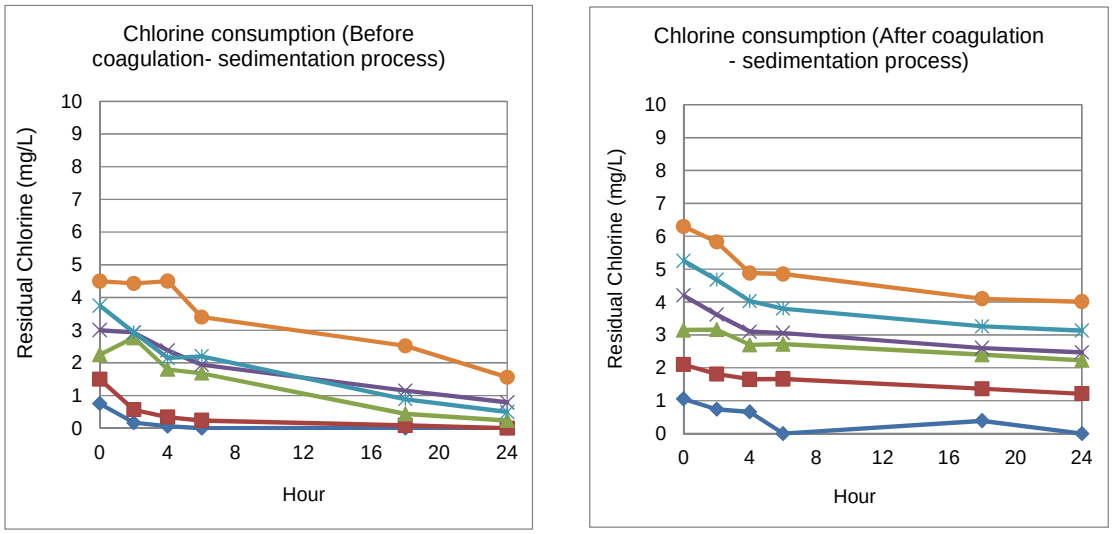
Date	Coagulant injection ratio (ppm)	Turbidity (NTU)	
		Before*	After*
17 June 2015	16 ppm	172.0	1.4
19 Aug.2015	31 ppm	298.0	3.0

Note: Before: Raw water before coagulation and sedimentation process
After: Filtered water After coagulation and sedimentation process
Source: YCDC and Edited by JICA Study Team

Time course of residual: Time course of residual chlorine is shown below. Both test (17-June 2015 and 19-Aug. 2015) showed that decrease of residual chlorine is reduced after coagulation – sedimentation process. This result is because Fe, Mn or other oxidizable matter by chlorine are reduced by coagulation – sedimentation process.

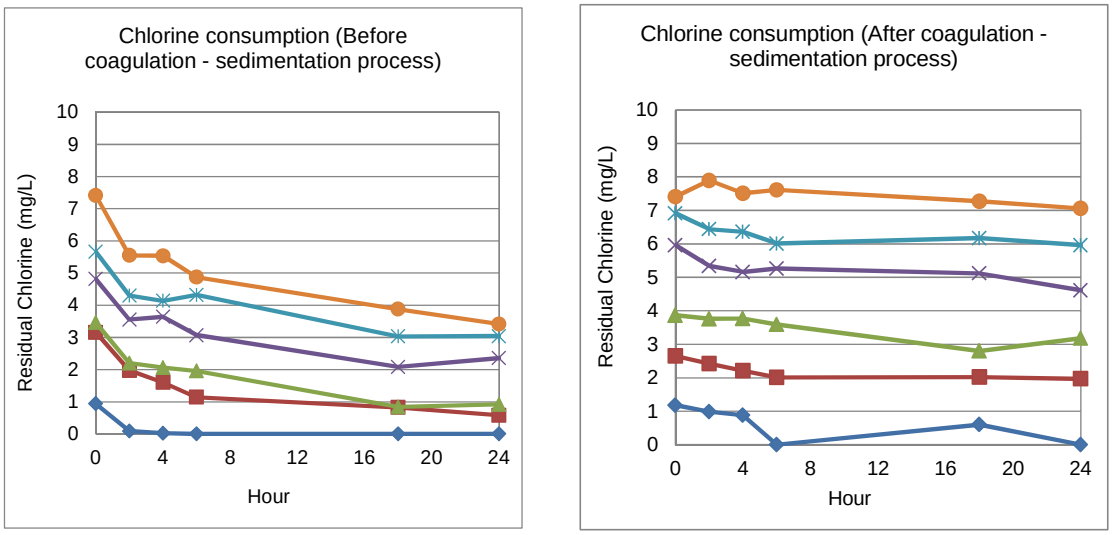
This test simulates mid chlorination process. Therefore, this test result means that implementation of adequate coagulation – sedimentation process ensures more long-term retention of disinfection effect. Based on this result, when 1 mg/L of residual chlorine is necessary in water distribution system, injection ratio of chlorine is estimated about 2 mg/L.

Note: In figure 12 and 13, Residual chlorine at 0 hour means injection ratio of chlorine.



Source: YCDC and Edited by JICA Study Team

Figure 12 Chlorine Consumption Test (Date: 17-Jul 2015)



Source: YCDC and Edited by JICA Study Team

Figure 13 Chlorine Consumption Test (Date: 19-Aug. 2015)

Figure 15 (17-Jul 2015) and Figure 16 (19- Aug. 2015) show relationship between chlorine injection and residual chlorine at time intervals of (2, 4, 8, 18 and 24 hours after commencing test). These figure also show the test result of before (upper tier) and after (lower tier) sedimentation – coagulation treatment process.

In the result of 17-July 2015, residual chlorine curve in upper tier (before sedimentation - coagulation) shows slight evidence of break – point (See test result of 18hours and 24 hours). Moreover, residual chlorine curve of upper tier shows the evidence of chlorine consumption by oxidation. This evidence means that this water sample contains substance to be oxidized by chlorine (e.g. Fe, Mn. etc.). Concentration of Fe, Mn and NH_4-N in the water sample is shown in Table 9. From this water quality data, chlorine consumption by Fe and Mn is estimated. However, in case of the after coagulation – sedimentation phase (lower tier in Figure 15), trace of chlorine consumption is almost reduced. This

difference means that coagulation – sedimentation process can reduce chlorine consumption matter in the water sample.

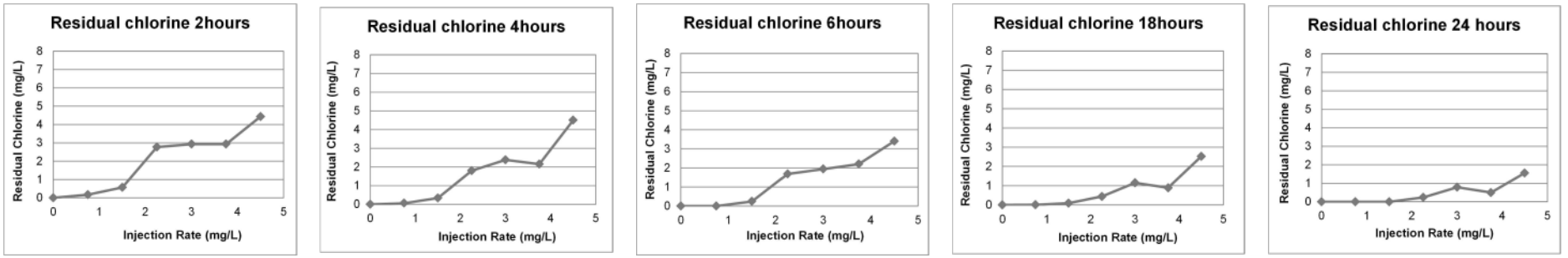
On the other hand, residual chlorine curve of 19-Aug. 2015 did not show the trace of break point. In case of before coagulation – sedimentation phase (upper tier in Figure 16), slight evidence of chlorine consumption was observed, however, these evidences were reduced by coagulation – sedimentation process (lower tier in Figure 16). The reason behind this result is similarly explained as the case of 17-Jul 2015 experiment. That is, chlorine consumption matter was removed by coagulation – sedimentation process.

1.7 Conclusion

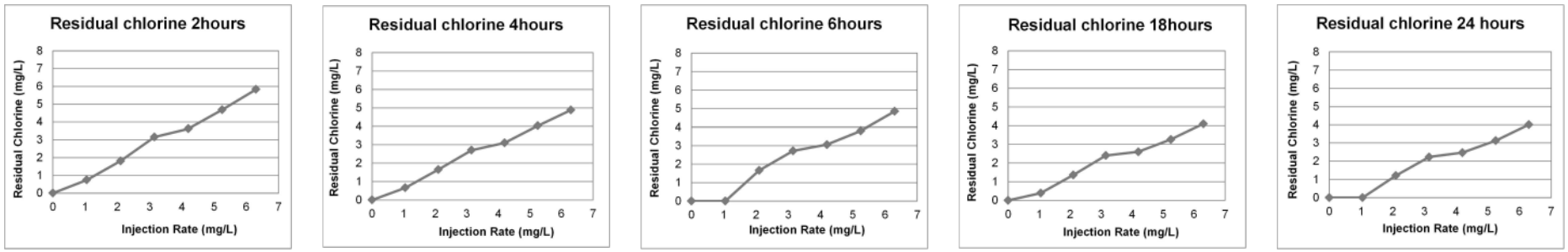
In this water quality test, water treatment property (coagulation – sedimentation and chlorination) of Kokkowa River water was investigated. In coagulation – sedimentation treatment process, Turbidity, Fe and Mn were removed. In addition, coagulation – sedimentation process removed chlorine consuming materials.

Considering these result, in the water purification of Kokkowa River water, adequate implementation of coagulation – sedimentation process is important factor to produce clear and safe water.

Before coagulation - sedimentation



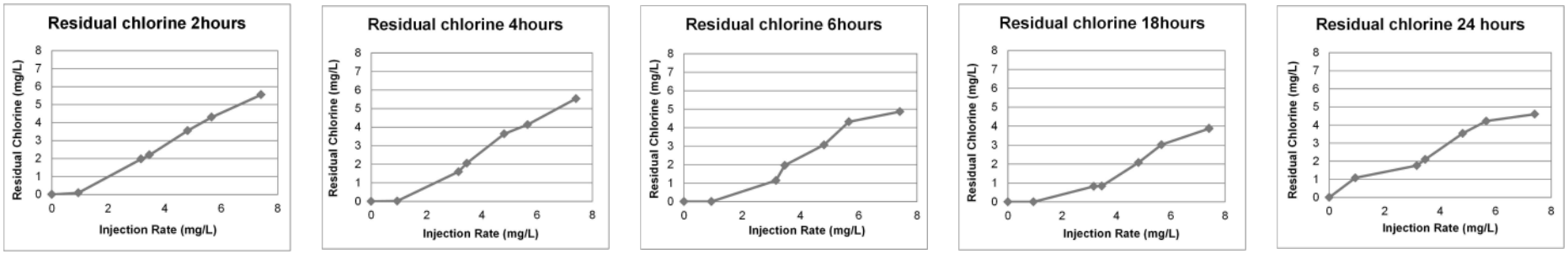
After coagulation - sedimentation



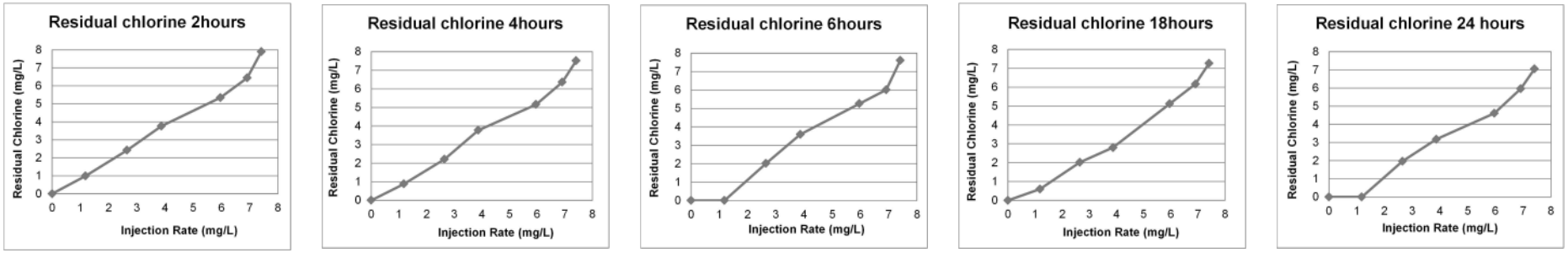
Source: YCDC and Edited by JICA Study Team

Figure 15 Chlorine Consumption Curve (Test Date: 17 July 2015)

Before coagulation - sedimentation



After coagulation - sedimentation



Source: YCDC and Edited by JICA Study Team

Figure 16 Chlorine Consumption Curve (Test Date: 19 Aug. 2015)