REPUBLIC OF ZAMBIA
MINISTRY OF WATER DEVELOPMENT SANITATION AND ENVIRONMENTAL PROTECTION
LUSAKA WATER AND SEWERAGE COMPANY

PREPARATORY SURVEY ON LUSAKA CITY WATER SUPPLY IMPROVEMENT PROJECT

FINAL REPORT

OCTOBER 2018

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

NIPPON KOEI CO., LTD.
SANYU CONSULTANTS INC.

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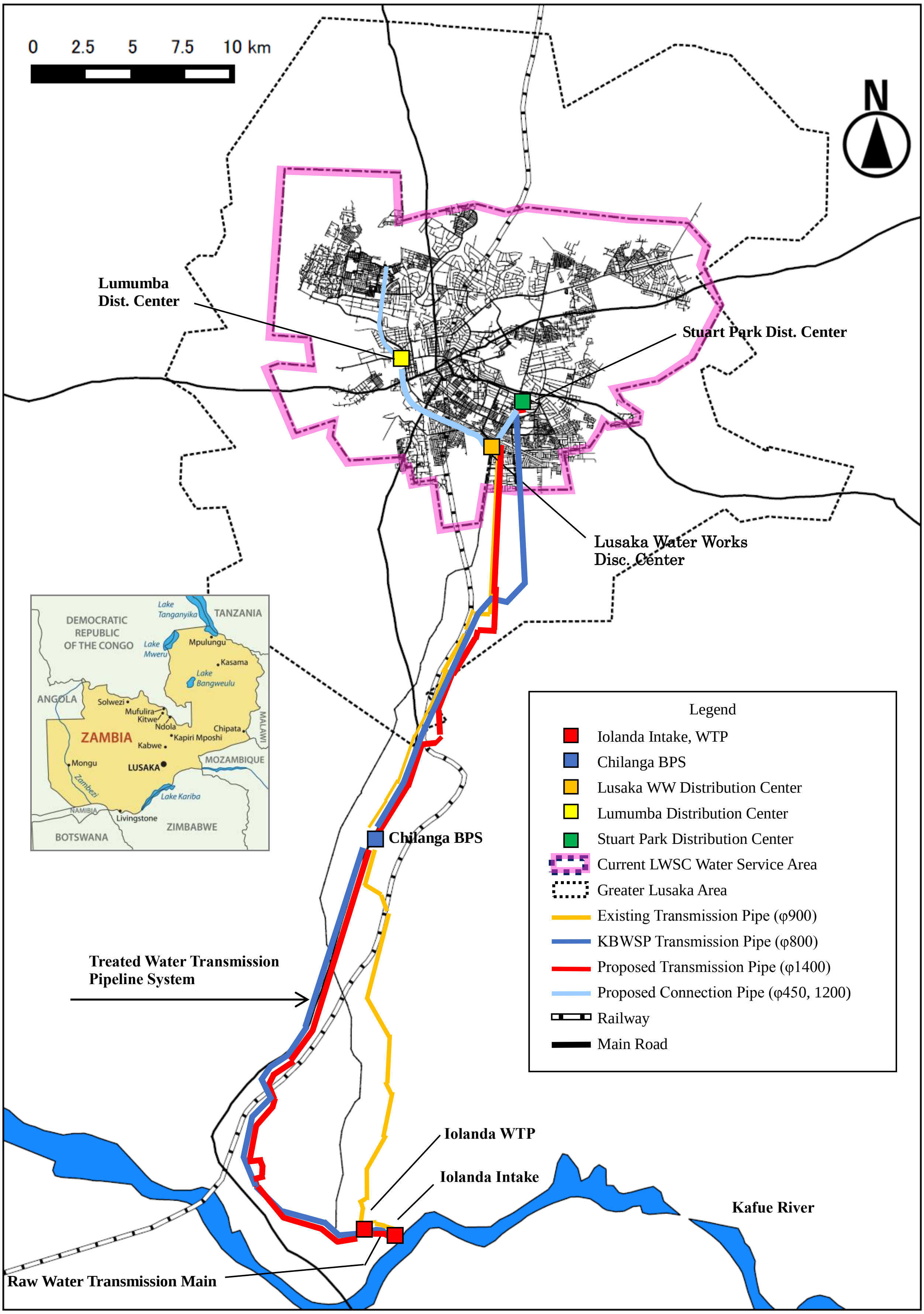
Exchange Rate

USD 1 = JPY 104 = ZMK 9.53 = EUR 0.897

(As of End of August 2016)



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LIST OF ABBREVIATIONS

ACP	Asbestos Cement Pipe
ADF	African Development Fund
AfDB	African Development Bank
AMIPS	Asset Management & Infrastructure Systems
B&CI	Billing and Customer Information System
BOT	Build Operate Transfer
BPS	Booster Pump Station
CDS	Community Development Specialist
CEC	Copperbelt Energy Corporation
CIF	Cost, Insurance and Freight
CITE	Convention on the International Trade in Endangered Species of Wild Flora and Fauna
CP	Contract Package
CS	Construction and Supervision
CSO	Central Statistics Office
CU	Commercial Utility
D/D	Detailed Design
DB	Design-Build
DBB	Design-Bid-Build
DCI(P)	Ductile Cast Iron (Pipe)
DFR	Draft Final Report
DHID	Department of Housing and Infrastructure Development
DMA	District Metered Area
DTF	Devolution Trust Fund
DWA	Department of Water Affairs
ECZ	Environmental Council of Zambia
EDAMS	The Satellite Image of Google Earth
EHS	Environment Health and Safety
EIA	Environmental Impact Assessment
EIB	European Investment Bank
EIRR	Economic Internal Rate of Return
EIS	Environmental Impact Statement
EN	Exchange of Notes
EPPCR	Environmental Protection and Pollution Control (Environmental Impact Assessment) Regulations
ESAMI	Eastern and Southern African Management Institute
ESIA	Environmental and Social Impact Assessment
ESSU	Environment and Social afeguards Unit
F/S	Feasibility Study
FIRR	Financial Internal Rate of Return
FR	Final Report

GDP	Gross Domestic Product
GI	Galvanized Iron
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GNI	Gross National Income
GP	Galvanized Pipe
GPRC	General Packet Radio Service
GRM	Grievance Redress Mechanism
GRZ	Government of Zambia
GS	Galvanized Steel
HDPE	High Density Polyethylene
ICB	International Competitive Bidding
IFC	International Finance Corporation
IRMS	Integrated Remote Monitoring System
ISO	International Standard Organization
JETRO	Japan External Trade Organization
JICA	Japan International Cooperation Agency
JICA TCP	JICA Technical Assistance Project
JPY	Japanese Yen
JST	JICA Study Team
KBWSP	Kafue Balk Water Supply Project
KfW	Kreditanstalt fur Wiederaufbau
LAN	Local Area Network
LCC	Lusaka City Council
LMIC	Lower Middle Income Countries
LPA	Lunzua Power Authority
Lpcd	Litter per capita per day
LUM	Lumumba Reservoir
LWSC	Lusaka Water and Sewerage Company
LWSSDP	Lusaka Water Supply, Sanitation and Drainage Project
LWW	Lusaka Water Works
M/P	Master Plan
MCC	Millennium Challenge Corporation
MCC M/P	Lusaka Water Supply Investment Master Plan prepared by MCC
MLD	Million Litter per Day
MLGH	Ministry of Local Government and Housing
MM	Man-Month
MMEWD	Ministry of Mines, Energy and Water Development
MMS	Maintenance Management System
MOF	Ministry of Finance
MW	Megawatt

MWDSEP	Ministry of Water Development, Sanitation and Environmental Protection
MWS	Ministry of Works and Supply
NGO	NonGovernmental Organization
NPV	Net Present Value
NRW	Non-Revenue Water
NTU	Nephelometric Turbidity Unit
NWASCO	National Water Supply and Sanitation Council
O&M	Operation and Maintenance
ODA	Official Development Assistance
OJT	On the Jobsite Training
OP	Operational Policy
PAC	Polyaluminium Chloride
PAHs	Project Affected Households
PAP	Project Affected Person
PI(s)	Performance Indicator(s)
PMU	Project Management Unit
PPI	Private Participation in Infrastructure
PPP	Public Private Partnership
PQ	Pro-qualification
PS	Performance Standard
PVC	Polyvinyl Chloride
RAP	Resettlement Action Plan
RDA	Road Development Agency
RMS	Remote Monitoring System
RTU	Remote Terminal Unit
SADC	Southern African Development Community
SAPP	Southern Africa Power Pool
SCADA	Supervisory Control And Data Acquisition
SCF	Standard Conversion Factor
SP	Steel Pipe
SPR	Steward Part Reservoir
TCU	True Color Unit
TDS	Total Dissolved Solid
TOR	Terms of Reference
TSW	Total Sold Water
UPS	Uninterruptible Power System
uPVC	Unplasticized Polyvinyl Chloride
USD	United States Dollars
VAT	Value Added Tax
VCB	Vacuum Circuit Breaker
WACC	Weighted Average Cost of Capital

WARMA	Water Resources Management Authority
WB	World Bank
WHO	World Health Organization
WSC	Water and Sewerage Company
WSPIP	Water Sector Performance Improvement Project
WTP	Water Treatment Plant
W.W.	Water Works
ZAWA	Zambia Wildlife Authority
ZEMA	Zambia Environmental Management Agency
ZESCO	Zambia Electricity Supply Corporation Limited
ZMW	Zambian Kwacha
ZS	Zambian Standard

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

Lusaka City, the capital of the Republic of Zambia, is located in Lusaka Province. The city and surrounding urban areas in Chilanga District, Chongwe District, Kafue District, and Chibombo District, which are also located in Lusaka Province, form Greater Lusaka.

Water supply and sewerage services in the urban areas of Lusaka Province are provided by the Lusaka Water Supply and Sewerage Company (LWSC). According to an infrastructure development plan by LWSC called as the “Concept Note on Lusaka City Water Supply Improvement Project”, the maximum daily water demand of Greater Lusaka in 2014 was about 480,000 m^3/day but water supply capacity of LWSC was only 225,000 m^3/day, which was less than 50% of the water demand. About 40% of the water service is from a surface water and the remaining 60% comes from a groundwater. As a result, at the center of Lusaka City, the water supply service duration is 16 hours on average. Furthermore, with the increase in water demand and degradation of groundwater extraction due to frequent power outage and water quality deterioration, the water supply service duration has a declining trend.

Future water demand for Greater Lusaka is expected to increase continuously due to further urbanization progress and population growth. According to the abovementioned concept note, the maximum daily water demand in 2025 is projected to be 873,000 m^3/day and the growing water shortage is anticipated to generate a negative impact on the lives of citizens, as well as economic and industrial development. For sustainable development of Greater Lusaka and Zambia, the development of water supply system, which is one of the critical basic infrastructures, is an urgent task.

Under the above circumstances, the Japan International Cooperation Agency (JICA) implemented in 2012 the “Information Collection Survey on the Urban Water Supply Sector in the Republic of Zambia” to collect basic data regarding the urban water supply conditions in Greater Lusaka. Subsequently, JICA and the Government of Zambia, represented by the Ministry of Local Government and Housing agreed to conduct the “Preparatory Survey on Lusaka Water Supply Improvement Project” (hereinafter referred to as the Study) to examine the viability of implementing the Lusaka Water Supply Improvement Project (hereinafter referred to as the Project) through Japanese official development assistance (ODA) loan to contribute in enhancing the water supply capacity of Greater Lusaka.

1.2 Objectives of the Study, Main Contents and Target Area

1.2.1 Objectives of the Study

The main objective of the Study is to conduct surveys required for examining the viability of implementing the Project under Japanese ODA loan. The Study includes identification of project scope, preliminary design of facilities in the Project, cost estimation, preparation of implementation schedule, preparation of procurement and construction plans, planning of project implementation structure, planning of operation and maintenance structure, environmental and social considerations, etc. in the Project.

In addition to JICA, the African Development Bank (AfDB) is also considering financing. If both loans are realized, it will be co-financing project between JICA and AfDB.

1.2.2 Main Contents of the Study

The main contents of the Study are as follows.

1) Collection and analysis of related information
2) Present status study of the target area and water supply sector
3) Field survey (topographic survey, geotechnical investigation, water quality analysis)
4) Consideration of project size and contents
5) Facility planning, and its preliminary design
6) Review of organization reform related to water supply service
7) Environmental and social considerations
8) Formulation of Project Implementation Plan
9) Calculation of approximate project cost
10) Economic and financial cost
11) Establishment of project evaluation and operation effect indicator

Also, LWSC is implementing the following projects supported by other donors in parallel with the Study. Consistency and synergy of the Project with these projects of other donors need to be taken into account to maximize the Project's effect.

・Lusaka Water Supply, Sanitation and Drainage Project (MCC Project)

The project, which is financed by Millennium Challenge Corporation (MCC), will implement the prioritized components among all the other ones proposed in the master plan also prepared by MCC. The tender process and contract signing were concluded and the project will contribute to an increase the water supply capacity of LWSC by 14,000 m^3/day through rehabilitation of the existing water treatment plant and rehabilitation and expansion of water distribution networks in Greater Lusaka.

・Kafue Bulk Water Supply Project: KBWSP

The project is being implemented under loan assistance by the Chinese government. The project includes water intake, water treatment plant with a capacity of 50,000 m^3/day, and a treated water transmission system to Greater Lusaka. The construction started in the end of 2015.

1.2.3 Target Area of the Study

The Study covers Greater Lusaka, which is the planned target area of the Project in the concept note by LWSC. Greater Lusaka consists of Lusaka City and the surrounding urban areas in Chilanga District, Chongwe District, Kafue District, and Chibombo District.

CHAPTER 2 SOCIAL AND NATURAL CONDITIONS, INFRASTRUCTURE DEVELOPMENTS AND CURRENTS SITUATION OF THE WATER AND SEWERAGE SERVICES IN THE STUDY AREA

2.1 Social and Natural Conditions, and Infrastructure Developments

2.1.1 Administrative Areas and Population

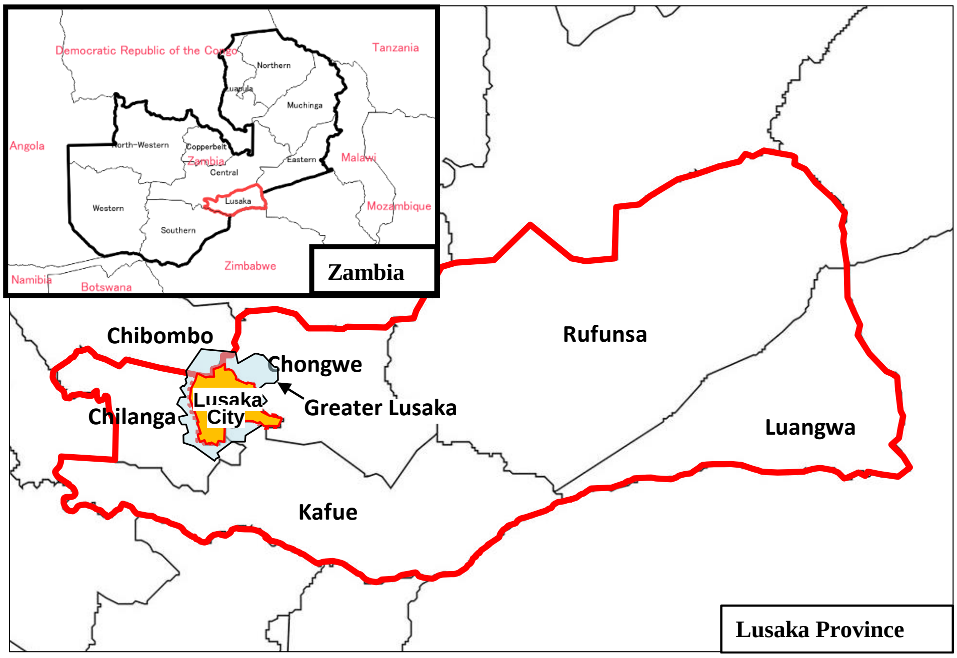
The Republic of Zambia is a landlocked country located in Southern Africa and bordered by eight countries, i.e.: Democratic Republic of the Congo, United Republic of Tanzania, Republic of Malawi, Republic of Mozambique, Republic of Zimbabwe, Republic of Namibia, Republic of Angola, and Republic of Botswana. The total area of the country is approximately 750,000 km^2. It is located at latitude 8° to 18° south and 22° to 23.5° east longitude. The study area covers Greater Lusaka, which includes the whole area of Lusaka City and its surrounding urban areas and forms an urban agglomeration including the capital of Lusaka.

Figure 2.1.1 shows the administrative divisions of Lusaka Province and location of Lusaka City. Figure 2.1.2 shows the administrative divisions in Lusaka City and Greater Lusaka. Table 2.1.1 indicates the total area, population density, and population in Zambia, Lusaka Province, Greater Lusaka, and Lusaka City. The population of Greater Lusaka accounted for approximately 14% of the total population in Zambia based on the population statistics in 2010. About 95% of the population of Greater Lusaka is concentrated in Lusaka City.

Table 2.1.1 Census Record and Current Population Estimate

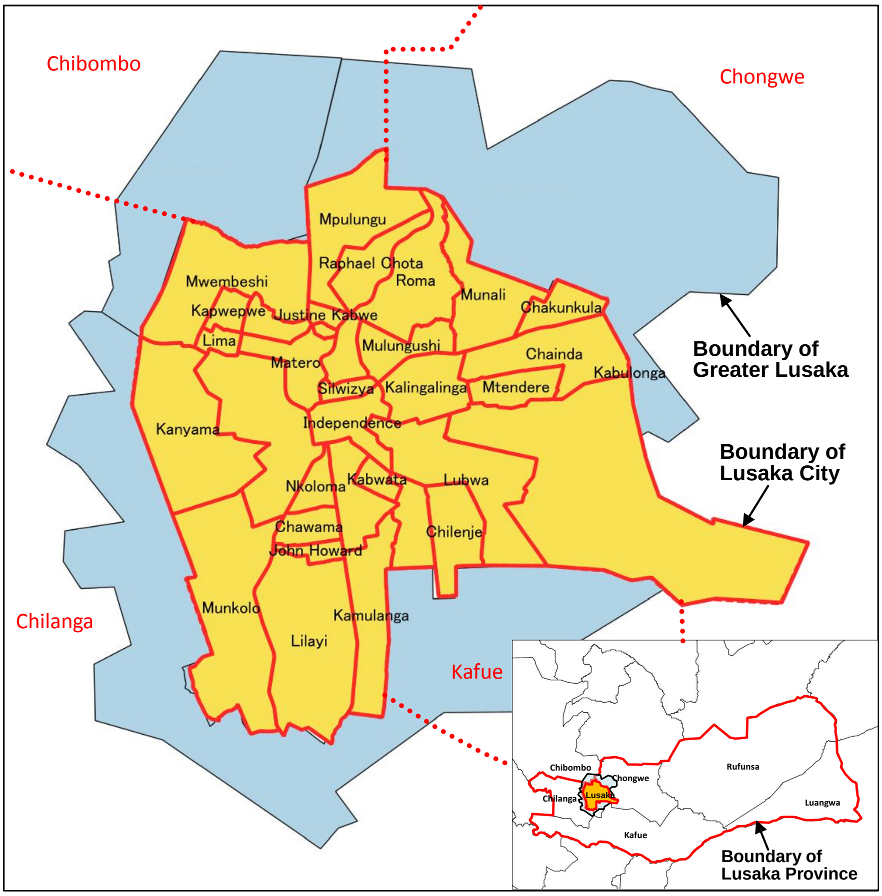
Region	Year 1990 (Person)	Year 2000 (Person)	Year 2010 (Person)	Year 2015 (Forecast) (Person)	Total Area (km^2)	2010 Population Density (Person /km^2)
Zambia	7,759,117	9,885,591	13,092,666	15,933,883	752,612	17
(Population growth rate)/year		2.5%	2.8%	4.0%		
Lusaka Province	991,226	1,391,329	2,191,225	2,888,575	21,896	100
(Population growth rate)/year		3.4%	4.6%	5.7%		
Greater Lusaka*			1,829,578	2,343,962*	822	2,226
(Population growth rate)/year				5.1%		
Lusaka City	761,064	1,084,703	1,747,152	2,236,000	422	4,140
(Population growth rate)/year		3.6%	4.9%	5.1%		

Note:*Population of Greater Lusaka is an estimated value under the Millennium Challenge Corporation (MCC) Master Plan (M/P).
Source: Population Statistics and Location in Maps and Charts, Zambia, Central Statistical Office, 2013



Source: JICA Study Team

Figure 2.1.1 Administrative Divisions of Lusaka Province and Location of Lusaka City



Source: JICA Study Team

Figure 2.1.2 Administrative Divisions of Lusaka City and Greater Lusaka

2.1.2 Politics

The Republic of Zambia is a constitutional state with a presidential government and adopts the unicameral National Assembly. The president is directly elected serving a term of five years basically and the presidential term is limited to second term. The president is the head of administration and has an authority to direct the government including right to appoint/dismiss the vice president and cabinet ministers and the supreme command to the army. The first president was Kenneth Kaunda from the United National Independence Party (UNIP) and he served from 1964 to 1991. After that, three presidents from the Movement for Multi-Party Democracy (MMD) served successively. The current president, Mr. Edgar C. Lungu, is from Patriotic Front (PF), which occupies 86 of the 158 seats in the parliament (as of August 2015). His previous presidency was until August 2016 and he was re-elected at the election held on 11th August 2016.

2.1.3 Economics

The nominal gross national income (GNI) per capita of Zambia increased steadily and came up to USD 1,490 in 2015. As shown in Table 2.1.2, nominal GNI per capita increased steadily and the World Bank categorized the country as Lower Middle Income Country (LMIC) in 2011. Real growth rate of GNI per capita shows high economic growth rate, which is at 7.2%.

Gini coefficient[1], which is an indicator of income distribution equality, decreased until 2002, but increased again from 2004 as shown in Table 2.1.3 at around 0.55 until 2010. According to the World Development Indicators, it is 0.40 in Senegal and 0.47 in Cameroon in Sub-Sahara Africa. Compared with the figures of these two countries (Senegal is USD 1,040 in 2012 and Cameroon is USD 1,199 in 2015), whose GNI is close to that of Zambia, equality of income distribution along with economic growth was not satisfactory in Zambia.

Table 2.1.2 Per Capita GNI and Transition of GNI in Zambia

Indicator	Year				
	1995	2000	2005	2010	2015
GNI (Nominal: Million USD)	3,440	3,487	6,662	18,278	26,174
GNI Per capita (Nominal: USD)	370	330	550	1,310	1,490
Growth rate (%/year) of GNI Per capita (Nominal: USD)	-	-2.8	13.6	24.2	3.3
GNI (Constant: Million USD)	7,765	9,489	12,404	18,903	-
GNI Per capita (Constant: USD)	839	896	1,030	1,358	-
Growth rate (%/year) of GNI Per capita (Constant: USD)	-	1.7	3.5	7.2	-
Consumer Price Index (100 in year 2010)	6.7	23.8	59.9	100	144

Source: World Development Indicators (The World Bank) [Accessed on 22nd December 2016]

Even referring to the poverty ratio of Table 2.1.4, poverty is nevertheless not resolved although income grows. On the contrary, the ratio tends to rise. Expansion of income disparity is recognized.

[1] Index to measure the gap of income distribution. The range of coefficients ranges from zero to one, and the disparity increases in proportion to the magnitude of the coefficient.

Table 2.1.3 Transition of Gini Coefficient in Zambia

Item	Year							
	1991	1993	1996	1998	2002	2004	2006	2010
Gini Coefficient (%)	0.61	0.53	0.48	0.49	0.42	0.54	0.55	0.56

Source: World Development Indicators (The World Bank) [Accessed on 22nd December 2016]

Table 2.1.4 Poverty Ratio in Zambia

	2002	2004	2006	2010
Poverty Ratio below USD 1.90/day (Proportion to Population: %)	49.44	56.69	60.46	64.42
Poverty Ratio below USD 3.10/day (Proportion to Population: %)	75.08	74.02	76.86	78.87

Source：World Development Indicators (The World Bank) [Accessed on 22nd December 2016]

The monthly household incomes of Lusaka Province and Copperbelt Province are much higher than those of other provinces as shown in Table 2.1.5. Many people from these provinces come to Lusaka to find job opportunity but the all could not get one. The population growth rate from 2000 to 2010 in Lusaka Province was 4.9% per year that was far higher than 2.8% all over the country. However, the unemployment rate in Lusaka Province is higher than in other provinces (see Table 2.1.8) and there are many jobless people in Lusaka accordingly. There is a considerable gap between the rich and the poor in Lusaka, e.g., white collar workers in contrast with employees in informal sectors and unemployed people.

Table 2.1.5 shows the per capita monthly income for each province based on the household income survey. The per capita income of Lusaka Province was ZMW (Zambian Kwacha) 463/month in 2010, showing steady growth compared with that of ZMW 302/month in 2006.

The per capita income of Lusaka City in 2006 and 2010 is the same level as “urban average”. There is no income data of Lusaka in 2015, but it is inferred that it is growing like “urban average”.

According to the preliminary figures of the draft in 2015, it is inferred that the per capita income of Lusaka Province has increased from 2010 to 2015 compared with the city average that recorded values similar to those of Lusaka in 2006 and 2010.

Table 2.1.5 Monthly Per Capita Income of Each Province

Unit: ZMW/month

Province	Year		
	2006	2010	2015
Central	118	219	
Copperbelt	246	449	
Eastern	87	144	
Luapula	92	139	
Lusaka	**302**	**463**	
Northern	95	163	
North-Western	97	234	
Southern	139	277	
Western	73	171	
Rural Average	82	158	185.9
Urban Average	280	470	796.4
Entire country	152	269	444.2

Source: Living Conditions Monitoring Survey Report 2006, 2010 and 2015 (Draft Version)

2.1.4 Industry

The service sector is the leading sector followed by the industry as shown in Table 2.1.6. For the period from 2001 to 2011, percentage of gross domestic product (GDP) of the industry sector boomed with the increase in export of copper, while the percentage of the service sector decreased and the agriculture sector slightly decreased as well. Since the economy of Zambia is highly dependent on copper industry[2], as experienced in recent years, the variation of international price of copper has significantly affected the economy of Zambia, which is one of the biggest issues in this country. GRZ expresses that it is an agenda to promote foreign investment and industrial structural reform in agriculture and tourism sectors for a stable economic growth.

According to the articles of the Japan External Trade Organization (JETRO), copper and copper products accounted for 74.4% of the total export amount from Zambia in 2014. The major importations were machinery (15.5%) and petroleum (14.9%). Major exports were to China (14.1%), Democratic Republic of the Congo (13.4%), and South Africa (6.1%) and major imports were to South Africa (31.8%), Democratic Republic of the Congo (18.7%), and China (9.3%).

Lusaka City was developed historically as a center of transportation of corn and tobacco production and then became the center of commercial and service industries. The employment rate in the agricultural sector is low while the female employment rate to the total one is high in the sales and service sectors. As shown in Table 2.1.7, Lusaka Province has the largest number of employees among all the provinces, with concentrated labor population.

The major products in Lusaka City are food, cement, woven cloth, and shoes, while in the suburban areas, major products are beef, leather, and daily use products. As shown in Table 2.1.8, the service industry which occupies a majority in the industry of Lusaka City, includes wholesale, retail and tourism, as well as financial and real estate industries that are common in urban areas.

Table 2.1.6 Ratio of Industrial Composition (% to GDP)

Unit: %

Sector	Year			
	2001	2009	2010	2011
Agriculture	22.0	21.6	20.4	19.5
Industry	25.4	34.2	36.0	37.3
Service	52.5	44.2	43.6	43.2
Total	100.0	100.0	100.0	100.0

Source: Zambia Poverty Statistics (2014) JICA, NTC international

2 The estimated reserve of copper in Zambia is approximately 10% of the total reserve in the world.

Table 2.1.7 Number of Employees Over 15 Years Old by Gender and State in 2014

State Region/City	Total Number of Employee		Male		Female	
	Number	%	Number	%	Number	%
Total	**5,859,225**	**100.0**	**2,789,012**	**100.0**	**3,070,213**	**100.0**
Region	3,394,221	57.9	1,593,232	57.1	1,800,989	58.7
City	2,465,004	42.1	1,195,780	42.9	1,269,224	41.3
State						
Central	581,719	9.9	275,662	9.9	306,057	10.0
Copperbelt	933,451	15.9	451,985	16.2	481,466	15.7
Eastern	728,058	12.4	349,107	12.5	378,951	12.3
Luapula	411,845	7.0	194,885	7.0	216,960	7.1
Lusaka	**1,047,560**	**17.9**	**522,327**	**18.7**	**525,233**	**17.1**
Muchinga	315,175	5.4	151,839	5.4	163,336	5.3
Northern	460,882	7.9	219,561	7.9	241,321	7.9
North Western	284,617	4.9	126,614	4.5	158,003	5.1
Southern	698,760	11.9	326,087	11.7	372,673	12.1
Western	397,159	6.8	170,945	6.1	226,213	7.4

Source: Labour Force Survey Report (2015) Central Statistical Office Lusaka

Table 2.1.8 Working Population Ratio by Gender

Female	Ratio (%)							
	Specialist, Engineer, Manager	Office Worker, Ministry, Clergy	Sales, Service	Skilled Worker	Non-skilled Worker	Agriculture	Unemploy ment	Total
Central	4.2	1.5	43.1	1.9	0.0	46.6	2.6	100
Copperbelt	11.7	1.3	60.3	3.8	0.3	18.1	4.5	100
Eastern	2.4	0.9	24.1	1.7	0.0	66.6	4.3	100
Luapula	1.8	0.3	27.9	0.9	0.4	67.0	1.6	100
Lusaka	**11.1**	**4.5**	**71.3**	**4.0**	**0.5**	**4.6**	**4.1**	**100**
Muchinga	2.4	0.4	21.4	1.1	0.1	72.6	2.1	100
Northern	1.6	0.2	20.4	1.2	0.2	75.7	0.7	100
North Western	4.2	0.8	24.6	1.0	0.2	65.9	3.3	100
Southern	4.5	0.7	34.4	1.5	0.1	56.2	2.6	100
Western	4.0	0.2	28.4	1.3	0.2	62.5	3.4	100
Male	Ratio (%)							
	Specialist, Engineer, Manager	Office Worker, Ministry, Clergy	Sales, Service	Skilled Worker	Non-skilled Worker	Agriculture	Unemploy ment	Total
Central	4.7	0.7	12.3	10.8	3.0	63.2	5.3	100
Copperbelt	7.9	1.2	25.2	22.5	9.8	22.1	11.3	100
Eastern	2.8	0.5	12.4	10.5	3.4	66.7	3.7	100
Luapula	2.4	0.2	7.5	5.0	2.2	80.9	1.7	100
Lusaka	**8.9**	**2.2**	**33.8**	**23.0**	**11.6**	**12.5**	**8.1**	**100**
Muchinga	4.5	0.7	10.4	10.7	2.7	67.3	3.6	100
Northern	4.0	0.7	10.5	8.9	1.4	72.5	1.9	100
North Western	4.0	0.6	12.1	15.3	5.1	58.9	4.0	100
Southern	4.9	0.6	13.1	11.5	3.4	59.9	6.6	100
Western	4.0	0.7	15.8	10.3	2.2	63.8	3.2	100

Source: DHS Zambia 2013-2014

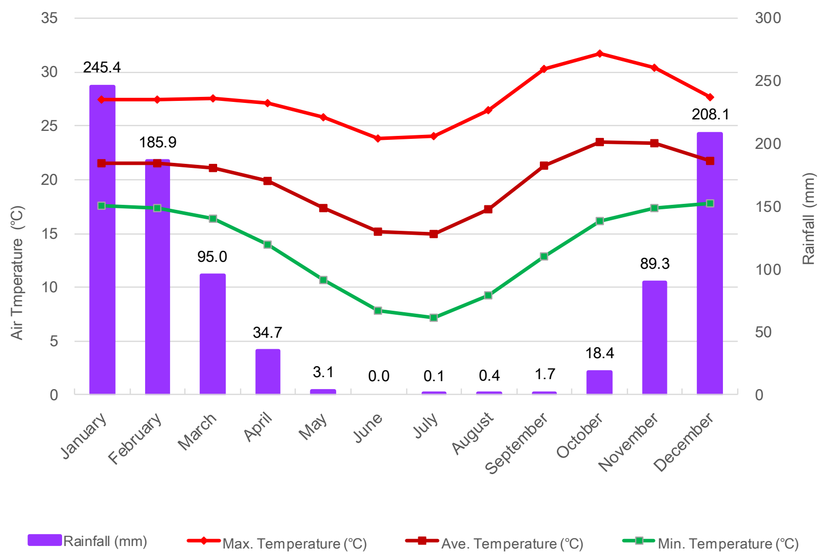
2.1.5 Climate

According to the Koppen Climate Classification, the climate of Zambia is categorized as temperate highland climate. There are three seasons, namely: cool dry season from May to August, hot dry season from September to October, and rainy season from November to April.

The climate in Lusaka City is characterized by hot summer and warm winter as shown in Figure 2.1.3. The highest temperature occurs in October. The average maximum monthly temperature is 32 ℃.

The minimum temperature occurs in July; and the mean monthly temperature is 14.9 ℃. The temperature goes below 10 ℃ at night only in June and August.

Annual average rainfall is 882 mm and 97% of rainfall is concentrated during the rainy season for six months from November to April.



Source: National Oceanic and Atmospheric Administration

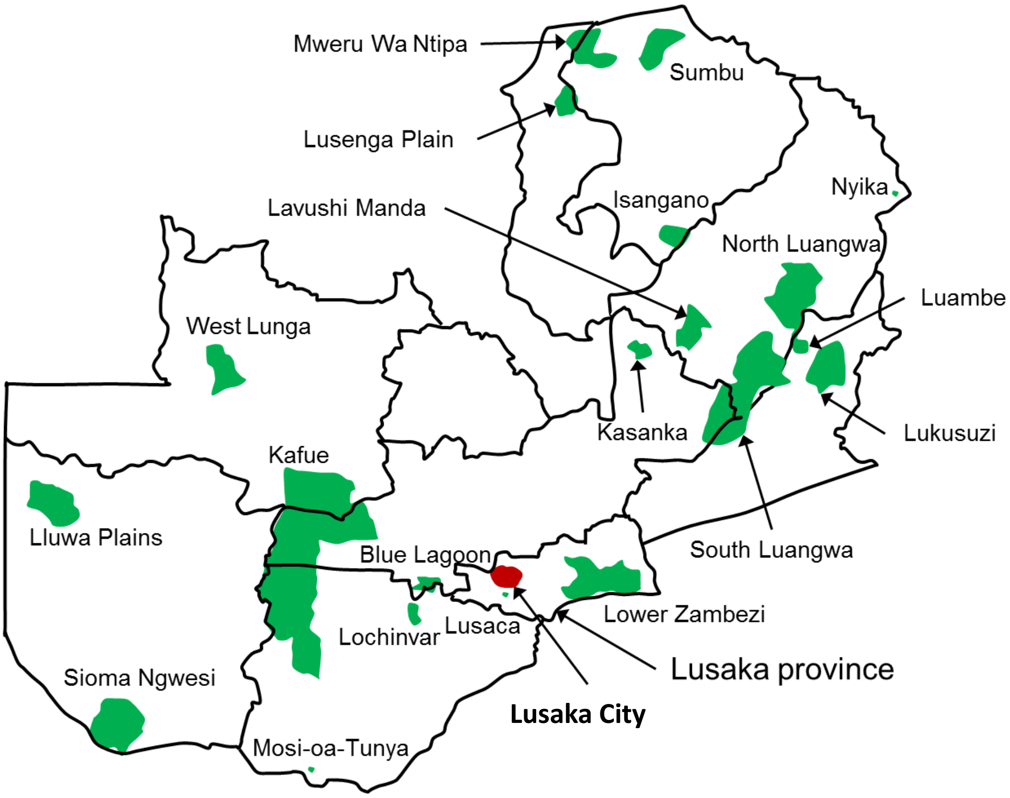
Figure 2.1.3 Temperatures and Rainfall in Lusaka

2.1.6 Animals, Plants and Natural Parks

Zambia is rich in flora and fauna and focuses on the preservation of wildlife. There are 20 national parks and 35 wildlife preservation zones as shown in Figure 2.1.4. The total area of the national parks and wildlife preservation zones accounts for 30% of the territory. The Zambia Wildlife Authority (ZAWA) manages the national parks and wildlife preservation zones. In addition, there are 180 national forests and 307 local forests managed by the Forestry Administration in accordance with the Forest Act.

The Lower Zambezi National Park in Lusaka Province is located in the north of the Zambezi River which flows along the southern border and is registered under the Ramsar Convention. Before the area was designated as a national park in 1983, it was privately owned by the president. Therefore, the area has been protected from ravages of tourists and the nature and the unique wildlife of Zambia have remained. In the south of the Zambezi River, there is the Mana Pools National Park in Zimbabwe.

Within Lusaka Province, the Lusaka National Park was established with a limited extent for the wildlife reserve in 2011 and has been opened to the public since 2015. Any of these national parks in Lusaka Province is located outside of Greater Lusaka.



Source: JICA Study Team

Figure 2.1.4 National Parks in Zambia

2.1.7 Current Status of Transportation Infrastructure

Zambia is a landlocked country; railways and roads are the major transportation infrastructure as shown in Figure 2.1.5. Most of the main arterial roads are passing through the capital Lusaka. The main railroad line leads from Livingstone in the southern province to Copperbelt Province via Lusaka City. Furthermore, the railroad is currently connected to Congo, Tanzania, Zimbabwe, and a connection line to Malawi is under construction.

The Lusaka International Airport located in Lusaka City has a hub function of air route in Zambia, and it is also used for military use.

Another old airport located near the city center is not for passenger transport.

Source: Map No. 3731 Rev. 4 United Nations, January 2004, Department of Peacekeeping Operations Cartographic Section

Figure 2.1.5 Transportation Network of Zambia

2.1.8 Current Status of Electricity Infrastructure

(1) Existing Electric Power Supply

The existing electric power supply in Zambia mainly consists of hydroelectric power as shown in Table 2.1.9. In 2016, the existing power connected to the Zambia Electricity Supply Corporation (ZESCO) electric system consists of 2,368 MW of hydroelectric power, 23.75 MW of small hydroelectric power, and 300 MW of diesel electric power, totalling to 2,692.55 MW. In addition, off-grid diesel generators, mini-hydropower station of independent power producers (IPP), and private electric generators are operated. These are extremely small scale.

Large power generating facilities are owned by ZESCO. The electric power supply from four hydropower stations, i.e., Kariba North, Kafue Gorge, Kariba North Extension, and Victoria Falls, cover 90% of the total energy generated in Zambia[3]. These power plants are located around Lusaka Province.

Table 2.1.9 Existing Power connected to the Zambia Electricity Supply Corporation (ZESCO) Electric System (2016)

Generating Station	Generated Power (MW)	Generation Method	Operation Agency
Kafue Gorge	990	Hydro	ZESCO
Kariba North Bank	720	Hydro	ZESCO
Victoria Falls	108	Hydro	ZESCO
Lusiwasi	12	Mini-hydro	ZESCO
Chishimba Falls	6	Mini-hydro	ZESCO
Musonda Falls	5	Mini-hydro	ZESCO
Lunzua	0.75	Mini-hydro	ZESCO
Lunsemfa	31	Hydro	Lunsemfwa Hydro Power Ltd
Mulungshi	25	Hydro	Lunsemfwa Hydro Power Ltd
Kariba North Extension	360	Hydro	Kariba North Bank Power Extension Corporation (KNBEPC) Limited (100%-owned subsidiary by ZESCO)
Lunzua Ext.	14.8	Hydro	ZESCO
Itezhi Tezhi	120	Hydro	ZESCO、Tata
Maamba 1U, 2U	300	Coal	Maamba Collieries Limited (MCL)
Total	2,692.55		

Source: JICA Power Transmission Line Study Team

(2) Outline of Current Status of Power Supply

Along with the economic growth in recent years, Zambia electricity demand has increased by 3-4% a year since 2005, so power is tight. For the performance in 2014, installed capacity of the power generation facilities was only about 1,870 MW[4], against about 2,000 MW of the peak electricity demand for the whole country and power shortage has already become apparent.

According to the draft final report (DFR) of JICA (JICA Power Line Survey), in 2006, maximum demand was 1,428.4 MW in June. In 2014, maximum demand was 1,949 MW in December. Consumption peaks appeared during the dry season from June to December, indicating a trend toward peak demand in the dry season. The 8-year average demand growth rate is about 4% per year.

[3] In terms of installed capacity, it occupies 80% of the country at four hydropower stations.
[4] 1,870 MW is the capacity of the power generation facility in 2014, which is different from the capacity as of 2016 shown in Table 2.1.9.

According to the "Report on ZESCO Load Shedding Engineering Institution on Zambia", the water level of Kariba Dam has been lowered by excess generation of the Kariba North Bank Extension (operation commenced in May 2014). The electric power shortage has been continued because sufficient generating power cannot be secured due to the lower water level of Kariba. Currently, it is not possible to secure the same power generation capacity as the capacity of power generation facilities.

Also, in Zambia where 90% of total power generation depends on water power generation, the amount of power generation is greatly affected by seasonal fluctuations.

In the rainy season, it is possible to generate enough electricity to cover domestic demand, but in the dry season, coupled with the decrease in electricity generation due to lowering of the water level and peak demand, significant power shortage occurs.

To compensate the electric power shortage in Zambia, electric power had been imported from Zimbabwe via power line between Kariba North Bank and Kariba South Bank in Zimbabwe in 2014.

(3) Electric Power Development Plan

Many electric power development projects are planned in Zambia to meet the increasing power demand. Table 2.1.10 shows a new power plant expected to start operation by 2025 as identified by "Preparatory Survey on Southern Area Transmission System Improvement Project in Republic of Zambia" (the JICA Transmission Power Line Survey). However, the progress is behind schedule.

Table 2.1.10 List of New Electric Power Plant Planned to Run from 2017 to 2025

Year	Generating Station	Generated Power (MW)	Generation Method	Operation Agency
2018	Kabompo Gorge	40	Hydro	CEC (Copper Belt Energy Corporation)
2018	Musonda Falls Upgrade	5	Hydro	ZESCO/Sinohydro
2018	Kabompo Gorge	40	Hydro	CEC
2018	Mujila	1.4	Hydro	ZESCO
2019	Chavuma and Chanda Falls	15	Hydro	Sinohydro
2019	EMCO 1U, 2U	300	Coal	EMCO Energy Zambia Limited (EMCO)
2019	Maamba 3U, 4U	300	Coal	Maamba Collieries Limited (MCL)
2019	Chishimba Falls Upgrade	9	Hydro	ZESCO/KfW
2020	Kalungwishi	247	Hydro	Lunzua Power Authority (LPA)
2021	Kafue Gorge Lower	750	Hydro	Gov. of Zambia and Sinohydro
2023	Batoka Gorge	1200	Hydro	Not yet determined
		2,907.4		

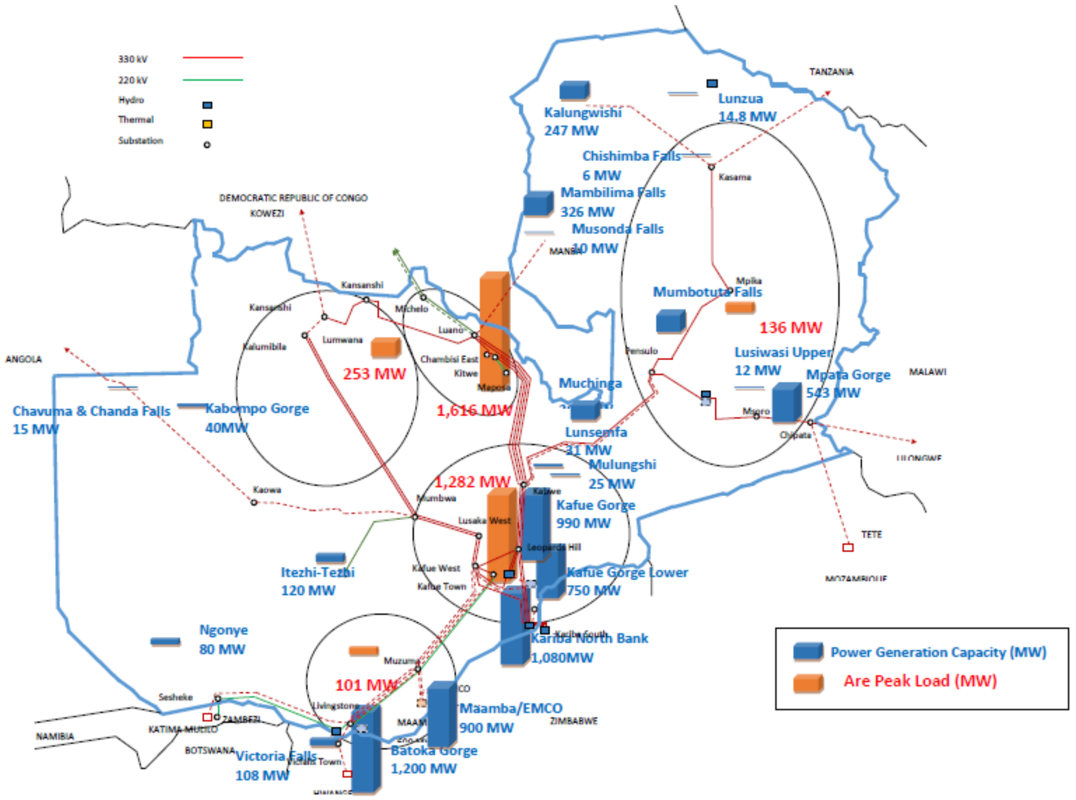
Source: JICA Power Transmission Line Study Team

(4) Electric Power Demand and Supply Forecast

1) Electric Power Demand and Supply Forecast in Zambia

The peak electric power demand in Zambia in 2030 is supposed to reach 3,386 MW. Figure 2.1.6 shows the distribution prediction of peak electric power demand and capacity of electric power facilities based on the JICA Electric Power Line Survey.

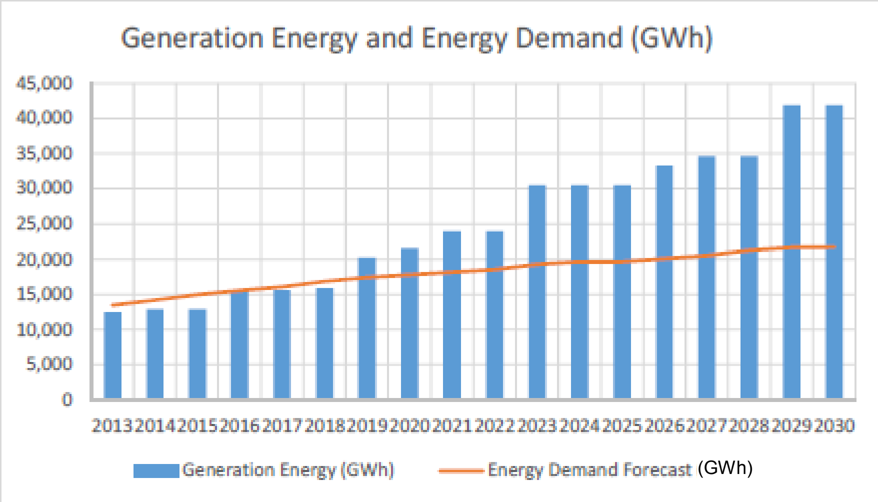
Demands for Lusaka Province (1,282 MW) and Copperbelt Province (1,616 MW), where many power demands are expected, are 38% and 48% of the national demand, respectively.



Source: JICA Power Line Study Team

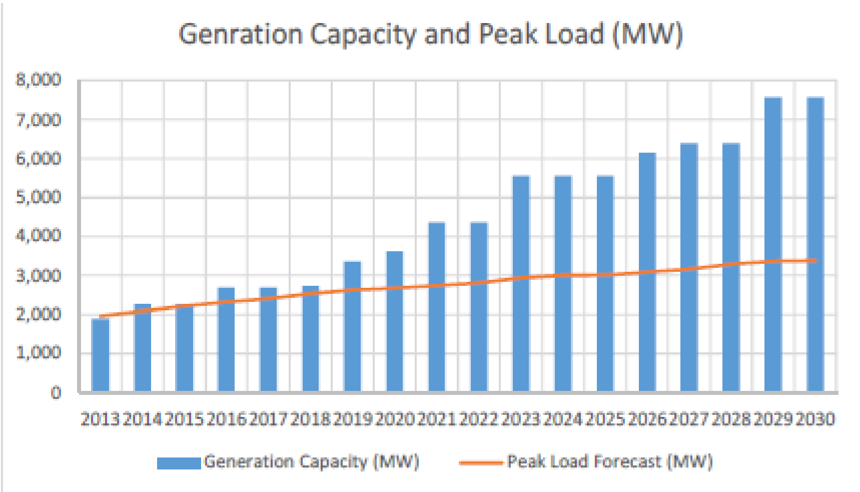
Figure 2.1.6 Regional Distribution of Peak Electric Power Demand and Capacity of Power Generation Plants in 2030

Figure 2.1.7 shows the comparison of annual energy generation and energy demand forecast described in the DFR of JICA Power Transmission Line Survey. Figure 2.1.8 shows the energy generation capacity and peak load forecast. Annual generation energy will be lower than annual energy demand until 2018. However, from 2019, annual generation power will be larger than the annual power demand and surplus will occur. The surplus power can be exported to neighbouring countries from Zambia.



Source: JICA Power Transmission Line Study Team

Figure 2.1.7 Generation Energy and Energy Demand Forecast



Source: JICA Power Transmission Line Study Team

Figure 2.1.8 Generation Capacity and Peak Load Forecast

2) Electric Power Demand and Supply Forecast around Lusaka Province

Currently, 90% of power generation plant is concentrated around Lusaka Province; however, the power demand of Lusaka is less than 40% of the total power demand in Zambia. Therefore, for the electric power demand and supply balance in Lusaka Province, the generation capacity is larger than the peak power demand. Since electric power generated around Lusaka is provided across the country, there is no surplus power around Lusaka Province. Like other areas in Zambia, power shortage will continue also in Lusaka Province until 2018. However, Iolanda Water Treatment Plant and Chilanga Booster Pumping Station are preferentially supplied with dedicated power and are not affected by the power shortage. As described later in Section 2.3.3 (3), the average power outage time between 2010 and 2015 in the Iolanda Water Purification Plant and the Chilanga Booster Pumping Station is 148 hours on average (about 6 days out of 365 days/year).

2.2 Current Status of Water and Sewerage Services

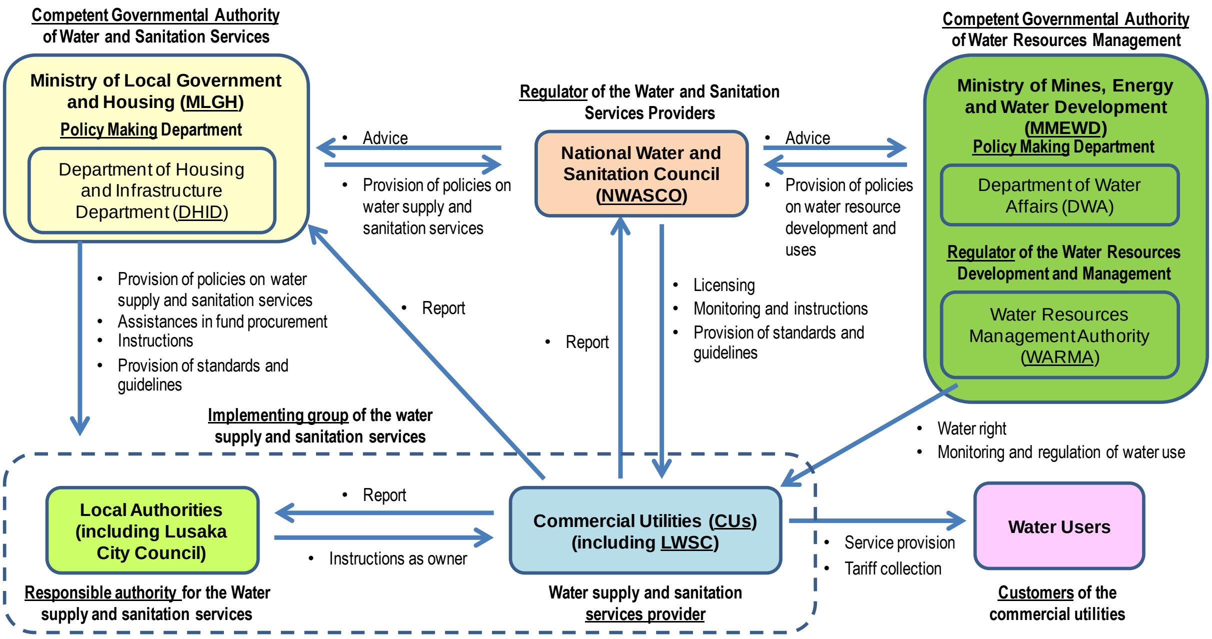
2.2.1 Institutional System for Urban Water Supply

(1) Administrative Framework

The administrative framework for urban water supply, sewerage and sanitation in Zambia was established in accordance with the National Water Policy (See 2.2.1(4)) promulgated in 1994. In compliance with the policies and guidelines prepared by the Ministry of Local Government and Housing (MLGH), the water supply and sewerage entities perform the services under the supervision of the National Water Supply and Sanitation Council (NWASCO).

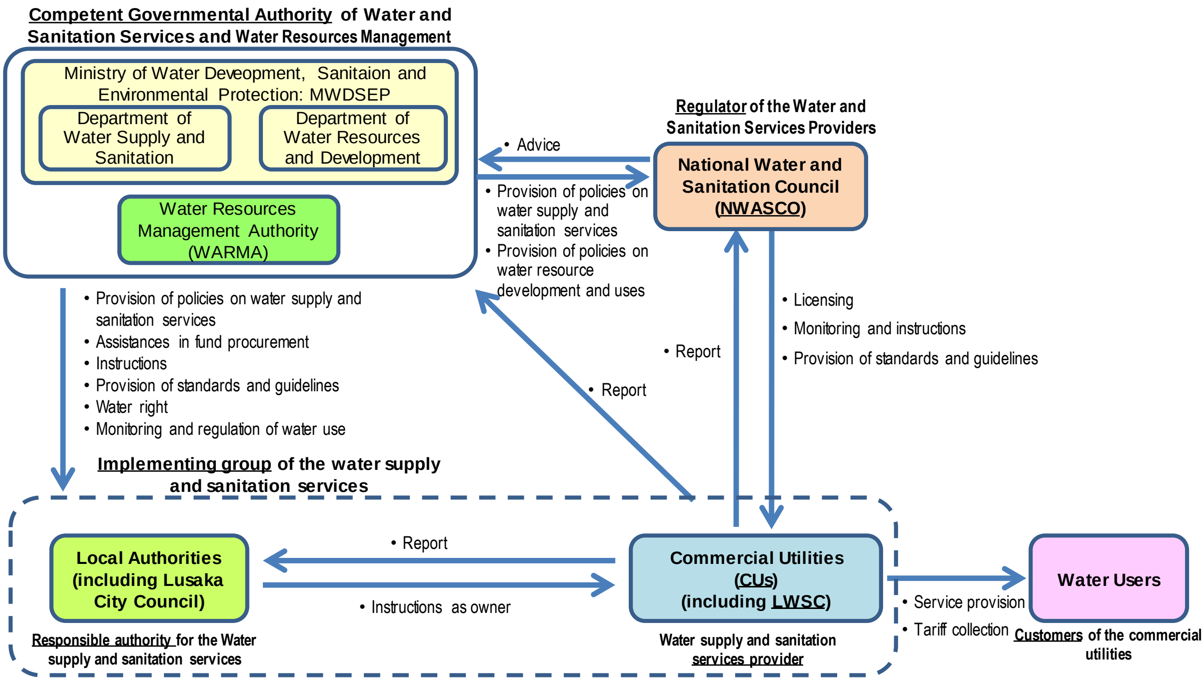
In most of the localities including the study area, the water and sewerage companies called as "Commercial Utilities" (CUs) provide the services. In addition, private water service providers are serving in some parts of localities. Each province has a CU in principle and the local authorities in the province have an equity in CU.

Figure 2.2.1 shows the former administrative framework, before the organizational reform in 2017, for water and sewer services being done by CU. Where a water service provider conducts the services, the "Implementation Group" composed of local authorities and CUs is replaced with the water service provider



Source: JICA Study Team

Figure 2.2.1 Former Administrative Framework for Urban Water Supply in Zambia



Source: JICA Study Team

Figure 2.2.2 New Administrative Framework for Urban Water Supply in Zambia (2017)

In 2017, the newly established Ministry of Water Development, Sanitation and Environmental Protection(MWDSEP) is taking over the works of water supply and sanitation sector of MLGH and water resources management sector of the Ministry of Mines, Energy and Water Development (MMEWD). For this reason, the administrative framework of the urban water supply sanitation sector has been changed as shown in Figure 2.2.2.

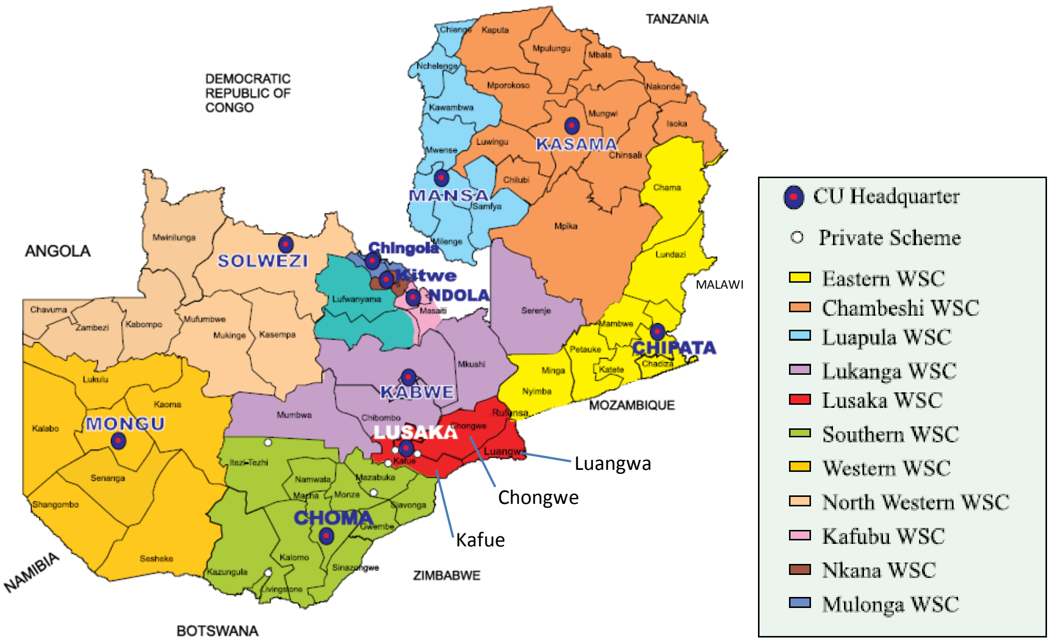
(2) Jurisdiction of Water and Sewerage Company

Figure 2.2.3 shows the jurisdictional area of each water and sewerage company (WSC or CU). The WSC is basically organized in each province but there is an exception; Copperbelt Province has three WSCs. In Muchinga Province, which was newly created in 2010, in the areas separated from the Eastern Province and Northern Province, Eastern WSC and Chambeshi WSC continue to provide the services in their original jurisdictions, respectively.

The jurisdiction of Lusaka Water Supply and Sewerage Company (LWSC) covers Greater Lusaka. The LWSC is supplying water to three cities (Lusaka City, Kafen Town, and Chongwe Town[5]) that compose the Lusaka Region and a part of the Choma Region of the Kabwe Province adjacent to the north of the province (See Figure 2.2.3). In addition, the LWSC is also supplying a small amount of water to Luangwa Town located in the east of Lusaka Province, Chirundu Town in Southern Province adjacent to the south of Lusaka Province.

[5] Part of Kafue Region, Chongwe Region, Chiranga Region

There are other water service providers serving three localities in Lusaka Province. They are located outside Greater Lusaka.



WSC: Water and Sewerage Company
Source: WASCO Annual Report 2015(Urban and Peri-Urban Water Supply and Sanitation Sector Report 2015)

Figure 2.2.3 Jurisdiction of Water and Sewerage Companies and Private Companies

(3) Water Trust

LWSC entrusts individual water service providers with the services in some localities. Such water service providers are called “Water Trust” and their localities are collectively known as “Water Trust Areas”. Water Trust carry out a series of services including construction and operation of water sources (wells), water distribution, and tariff collection. They are independent from LWSC in terms of organization and financial management. As LWSC licensed by NWASCO has an obligation to provide a certain level of services in any of the Water Trust Areas, LWSC supervises Water Trusts in their accounting and water quality testing. When Water Trust plans to repair and/or expand its facilities, the budget should be appraised and accepted by LWSC. When Water Trust faces technical difficulties, LWSC sends engineers to support Water Trust and receives the costs from Water Trust. Water Trust has its own wells as water source. LWSC sells bulk water to three Water Trusts when they face water shortage.

Institutional position of Water Trust is unclear. Water Trust originated from a self-supported community organization assisted by nongovernmental organization (NGO) for providing water supply services to the community that was not served by LWSC, before expanding service areas from the central Lusaka to suburbs. In Zambia, water supply provider serving 50 or more customers should be licensed by NWASCO. But Water Trust did not meet the qualifications for the license, and so they could perform the services in the form of subletting by LWSC. LWSC did not have sufficient water source and distribution network to provide water supply to those areas, so that the actions of Water Trust were practical for LWSC to expand its service areas even indirectly.

To maintain the water supply services, LWSC needs to provide many supports for Water Trusts due to the lack of their management and technical capability. As LWSC's direct service areas are already gradually expanding to Water Trust Areas, LWSC envisages involving Water Trust Areas in its direct service areas.

(4) Relevant Policies and Law

1) National Water Policy

The National Water Policy, which was promulgated in November 1994, defines the functions of the authorities responsible for water supply and sanitation. It also announced the establishment of NWASCO as the regulator of the water service providers. The policy aims at establishing a well-defined institutional structure that will achieve the equitable provision of adequate quantity and quality of water for all citizens. The principles announced in the policy including sectoral reform are as follows:

- Separation of water resources management from water supply and sanitation[6];
- Separation of implementation agency and regulatory agency of water supply and sanitation sector;
- Devolution of authority for water supply and sanitation to local governments and private companies;
- Realization of long-term full cost recovery of water supply and sanitation services;
- Human resource development leading to more effective services;
- Adoption of technologies suitable for local circumstances; and
- Enhancement of the national government funding for urban water supply and sanitation sector.

2) National Water Supply and Sanitation Act No. 28

The National Water Supply and Sanitation Act No. 28, which was enacted in 2007, gives the local governments' options in performing the water supply and sanitation services and prescribes the establishment of NWASCO. The options given to the local governments are as follows:

1. The local government provides the services by itself.
2. The local government organizes a CU to be licensed and regulated by NWASCO.
3. The local government holds the assets and entrusts a private firm with the services.
4. The local government finances jointly with a private firm the establishment of an entity to perform the services. The shareholding ratio of the private firm should be less than 49%.

[6] However, it was decided in 2016 that ministries concerning water supply and sanitation services and ministries concerning water resources will be integrated again, and a new ministry has been established in 2017 (See Section 2.2.1 (1)).

After the National Water Policy in 1994, all local governments chose to establish CUs. For the purpose of full cost recovery, the local governments took an approach to hold the assets by themselves and establish the individual account for water supply and sanitation services apart from the general account.

3) Water Sector after the Issuance of National Water Supply and Sanitation Act No. 28

In accordance with the National Water Policy, NWASCO started the nationwide supervision for the water supply and sanitation service providers since 2000. In Lusaka Province, the local government transferred their water assets to LWSC, which had been established in 1998. In other regions, CUs were gradually established by the province. All of the provinces established CUs by 2009.

As mentioned above, CU establishment is just one of the possible options. However, all local governments decided to establish CU, because it is thought to be the best option to separate water supply and sanitation business from general account for the achievement of full cost recovery, under the condition that the local governments hold their assets.

(5) Water Quality Standard and Design Standard

1) Water Quality Standard

The Drinking Water Quality Standard is stipulated in “ZS190:2010” comprising six categories: (i) General Physical Characteristics of Drinking Water, (ii) Non-toxic Chemical Substances, (iii) Toxic Chemical Substances, (iv) Pesticide, (v) Microbiological, and (vi) Radioactive. Table 2.2.1 shows the values of Zambian standard and the World Health Organization (WHO) standard.

Table 2.2.1 Zambia Water Quality Standard (ZS 190: 2010) and WHO Standard (2014)

General Physical Characteristics of Drinking Water	ZS 190: 2010	WHO
Parameters	Maximum Acceptable Values	
Odor	Within acceptable range for users	Within acceptable range for users
Color	15 TCU	Within acceptable range for users
Taste	Within acceptable range for users	Within acceptable range for users
pH	6.5-8.0	Not established*5
Hardness (total) as Calcium Carbonate ($CaCO_3$)	500 mg/liter	Not established*5
Dissolved solids (total)	1000 mg/liter	Not established*5
Turbidity	5 NTU	Less than 1-5 NTU
Conductivity	1500 µs/cm	-
Non-Toxic Chemical Substances		
Substance	Maximum Acceptable Values	
Calcium (Ca)	200 mg/liter	Not established
Chloride (Cl^-)	250 mg/liter	250 mg/liter
Residual chlorine	0.2-0.5 mg/liter	0.2-0.5 mg/liter
Copper (Cu)	1.0 mg/liter	2.0 mg/liter
Iron (Fe)	0.3 mg/liter	0.3 mg/liter
Magnesium (Mg)	150 mg/liter	Not established
Sulphate ($SO^{2-}{}_4$)	400 mg/liter	Not established
Zinc (Zn)	3.0 mg/liter	Not established
Phenolic compounds (as phenol)	0.002 mg/liter	0.2 mg/liter
Detergents (alkyl benzene sulphonate)	1.0 mg/liter	Not established
Sodium (Na)	200 mg/liter	200 mg/liter
Toxic Chemical Substances		
Substance	Maximum Acceptable Values	
Aluminum (Al)	0.2 mg/liter	0.1-0.2 mg/liter
Arsenic (As)	0.01 mg/liter	0.01 mg/liter
Cadmium (Cd)	0.003 mg/liter	0.003 mg/liter
Barium (Ba)	0.7 mg/liter	0.7 mg/liter
Chromium (Cr)	0.05 mg/liter	0.5 mg/liter
Cobalt (Co)	0.5 mg/liter	-
Cyanide (CN^-)	0.01 mg/liter	Not established
Fluoride (F^-)	1.5 mg/liter	1.5 mg/liter
Lead (Pb)	0.01 mg/liter	0.01 mg/liter
Mercury (Hg)	0.001 mg/liter	0.006 mg/liter
Manganese (Mn)	0.1 mg/liter	Not established
Nitrates (NO_3^--N)	10 mg/liter	Not established
Nitrates (NO_3^-)	Not established	50 mg/liter
Nitrite (NO_2^--N)	1.0 mg/liter	Not established
Nitrite (NO_2^--)	Not established	3.0 mg/liter
Selenium (Se)	0.01 mg/liter	0.04 mg/liter
Silver (Ag)	0.05 mg/liter	Not established
Pesticide (Agrichemical/Pesticide)		
Pesticide	Maximum Acceptable Values	
Aldrin/ Dieldrin	0.01 µg/liter	0.03 µg/liter
Chlordane	0.3 µg/liter	0.2 µg/liter
2,4-D	30 µg/liter	30 µg/liter
DDT	1.0 µg/liter	1.0µg/liter
Endosulfan	2.0 µg/liter	Not established
Endrin	0.2 µg/liter	0.6 µg/liter

General Physical Characteristics of Drinking Water	ZS 190: 2010		WHO
Heptachlor and heptachlor epoxide	0.1 μg/liter		Not established
Hexachlorobenzene	0.01 μg/liter		Not established
Lindane (Gamma BHC)	3.0 μg/liter		-
Methoxychlor	30 μg/liter		20 μg/liter
Toxaphene	5.0 μg/liter		Not established
Microbiological			
Types of Drinking Water	Maximum Acceptable Values per 100 ml		Coliform and Fecal Coliform Group
	Fecal Coliform group	Coliform group	
Treated water entering the distribution system	0*1	0*1	0
Untreated water entering the distribution system	0*1	3*1	-
	0*2	0*2	-
	0*3	0*3	-
	0*4	20*4	-
Water in the distribution system	0*2	10*2	0
	0*4	20*4	0
Radio Active			
Substance	Maximum Acceptable Values		
Gross alpha activity	0.1 Bq/liter		0.5 Bq/liter
Gross beta activity	1.0 Bq/liter		1.0 Bq/liter

*1: In any one sample
*2: In any two consecutive samples
*3: 0 in 95 percent of yearly samples
*4: In an occasional sample but not in consecutive samples
*5: In drinking water, it does not occur at a concentration harming health.
Source: ZS 190: 2010(Zambia Bureau of Standards), WHO Standard (2014)

2) Design Standard

National design standard for water supply system does not exist in Zambia. There is a draft of design standard prepared by LWSC in October 2010 but it has not been finalized yet.

2.2.2 Organizations Concerned with the Urban Water Supply Sector

(1) Lusaka Water Supply and Sewerage Company (LWSC)

LWSC is one of the CUs providing water supply and sanitation services in Zambia. The Lusaka City Council established LWSC in 1988. LWSC initiated its full-fledged operation since 1990. LWSC is registered in accordance with the Companies Act and holds the assets taken over from the city council in accordance with the Statutory Instrument.

The organizational structure of LWSC is discussed in Section 5.1.1 in Chapter 5.

(2) Ministry of Water Development and Sanitation and Environmental Protection (MWDSEP)

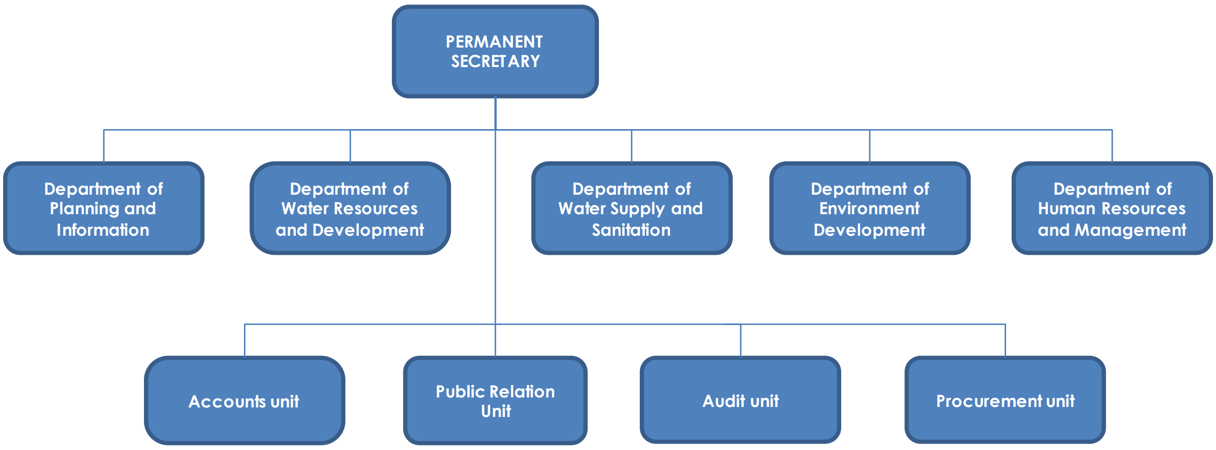
The Ministry of Water Development and Sanitation and Environmental Protection (MWDSEP) was created by reorganizing central government ministries and agency of Zambia in 2017, The ministry was to bring all water related issues under one ministry in order to promote efficiency and effectiveness.
MWDSEP is central government office having jurisdiction over a water sector including water resource

development, water supply and sanitation services, environmental development that is composed of five departments and four units as shown on Figure 2.2.4.

In the Ministry, Department of Water Supply and Sanitation handles the water supply and sanitation services.

The department is responsible for the formulating management policies, reviewing programs and implementing water supply and sanitation services to improve the health and socio-economic benefit of the residents.

The organizational structure of MWDSEP is discussed in Section 5.1.2 in Chapter 5.



Source: JICA Study Team based on the data provided by MWDSEP

Figure 2.2.4 Organization Structure of MWDSEP

(3) National Water Supply and Sanitation Council (NWASCO)

In accordance with the National Water Supply and Sanitation Act No. 28, NWASCO commenced the nationwide supervision of the water supply and sanitation services in 2000 in view of efficiency and sustainability. According to the Strategic Plan 2013-2015 of NWASCO, its core functions are as follows:

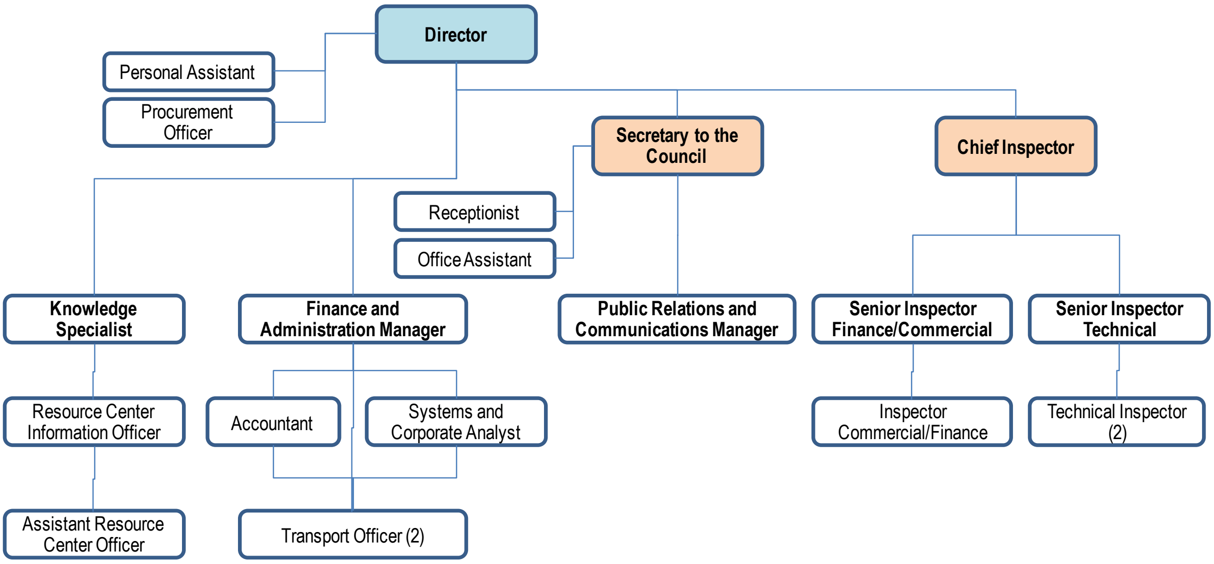
- To license water and sanitation service providers;
- To advise the government on water supply and sanitation issues;
- To establish and enforce standards and guidelines for water supply and sanitation sector;
- To advise water service providers on process for handling complaints from consumers; and
- To promote information to consumers on water supply and sanitation issues.

A function to supervise water supply and sanitation services is not spelled out clearly in the plan but is obviously a fundamental function of NWASCO. In addition, NWASCO has another important function to approve water tariff proposed by water service provider.

NWASCO conducts a review of business reports submitted by water service provider and carries out the planned detailed inspection on the water service provider as well as spot checks to investigate sites randomly selected without any advance notice. When problems are detected, NWASCO issues the order for improvement. If the order for improvement is not fulfilled, NWASCO has a right to suspend the license of the water service provider. In fact, NWASCO suspended the license of Chambechi WSC in

December 2012. MLGH appointed North Western WSC as Statutory Manager to oversee the operation of the WSC.

Figure 2.2.5 shows the organizational structure of NWASCO, as of 2013. There are three management officials, namely; the Director, Secretary to the Council, and Chief Inspector. The total number of staff member is 21. The inspectors under Chief Inspector are responsible for the supervision and instruction on the water supply and sanitation services.



Note: The number in "( )" show numbers of staffs for each position only in cases of 2 or more.
Source: JICA Study Team based on Annual Report 2013(NWASCO)

Figure 2.2.5 Organization Structure of NWASCO

(4) Ministry of Mines, Energy and Water Development (MMEWD)

In 2012, the Ministry of Energy and Water Development and Ministry of Mines were merged into the Ministry of Mines, Energy and Water Development (MMEWD). In order to achieve sustainable development and management of mineral resources, energy, and water resources in the country, MMEWD prepares the national policies, regulations, and guidelines; and oversee the development activities.

The Department of Water Affairs (DWA) and Water Resource Management Authority (WARMA) take care of the water resources development under MMEWD. DWA prepares the policies, regulations and guidelines, while WARMA monitors and regulates the use of water resources including surface water and groundwater. WARMA authorized the water right of LWSC to use 855,750 m^3/day from the Kafue River on 12th December 2013.

2.2.3 Water and Sewer Service by LWSC

(1) Service Area

LWSC is responsible for water and sewerage services mainly in urban areas of Lusaka Province. In addition to Lusaka City, LWSC also provides water supply services to four urban areas as shown in

Table 2.2.2, such as Kafue Town (Kafue District), Chongwe Town (Chongwe District), Luwanga Town (Luwanga District), and Chirundu Town (adjacent to the south side of Lusaka Province).

In Lusaka Province, consisting of Lusaka City and five districts, two districts, i.e., Rufunsa and Chilanga, are not covered by LWSC. The service areas of LWSC expand across the provincial border, e.g., a part of Chibombo District to the north of Lusaka City and Chirundu Town to the south of Kafue District. The total number of service connections is 91.0% while the total water consumption (revenue water) is 95.2% in Lusaka and its suburbs. LWSC's services are highly concentrated in Lusaka accordingly.

Table 2.2.2 Service Connection and Revenue Water of Five Urban Areas

Area	Service Connection 2015		Revenue Water: 2014	
	Number	Percentage	Million m^3/year	Percentage
Lusaka*	85,700	91.0%	49.97	95.2%
Kafue	6,055	6.4%	1.82	3.5%
Chongwe	1,148	1.2%	0.25	0.5%
Chirundu	928	1.0%	0.28	0.5%
Luangwa	353	0.4%	0.15	0.3%
Total	94,184	100.0%	52.47	100.0%

*In this data, water supply to Lusaka City includes water supply to Chibombo District.
Source: LWSC Annual Report, 2015 and data provided by Non-revenue Water Team of LWSC

(2) Performance Indicators

Table 2.2.3 shows the performance indicators of LWSC for the past ten years. The indicators cover the whole service areas of LWSC and are considered to be almost the same as those for Lusaka and its surrounding areas with 91% of the service connections and 95% of the water consumption.

LWSC's service coverage rate increased up to 85.3% in 2012 and became almost stable. The service coverage rate dropped to 82.9% in 2015. Except for 2015, the service connections and the service population increased. The reason for the decrease of the service coverage rate in 2015 is unclear[7]. The household connection rate was not improved, and was only 48.5% out of 82.9% of the service coverage rate in 2015.

Of the performance indicators, the attention should be paid to two indicators, i.e.: non-revenue water rate and volume of water production. Annual water production increased until 2010 but decreased after 2013. As a result, the water production and water consumption per capita in 2015 decreased to two-thirds of 2010 in conjunction with the increase of population served. The decrease of water production affected water supply hours, which was 17 hours in 2015 and 20 hours in 2013. The non-revenue water rate was not improved, as it was 51% in 2006 and remained 47% in 2015. Meanwhile, the water meter installation rate increased from 45% in 2006 to 71.5% in 2015. It is considered that the accuracy of evaluating the non-revenue water rate has been improved along with the water meter installation.

[7] The fact that the number of households connected is decreasing is a direct cause, but in the Lusaka area where the population increase is remarkable and the service area is also expanding, it is an unnatural figure movement. The cause is unknown.

The number of O&M staff per 1,000 connections is an indicator generally applied to assess the operational efficiency of water utility. It was reduced from 13 persons in 2006 to nine persons in 2015. This indicator is less than one person in many water utilities in Japan and is less than five persons in developing countries. Compared with the referenced figures, the operational efficiency of LWSC seems to be low.

Table 2.2.3 Service Indicators of LWSC

Indicator	Unit	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1. Coverage of Water Supply Services											
Population in service areas	1,000	1,627.6	1,643.9	1,712.4	1,831.4	1,937.6	1,966.7	2,026.2	2,113.2	2,184.6	2,246.8
Population served	1,000	1,041.7	1,101.4	1,167.9	1,285.3	1,459.9	1,608.6	1,727.8	1,827.5	1,882.3	1,862.8
Service coverage rate	%	64.0	67.0	68.2	70.2	75.3	81.8	85.3	86.5	86.0	82.9
Household connection rate	%							42.7	38.9	41.9	48.5
Rate of population served by public stand posts and koisks	%							57.3	61.1	58.1	51.5
Number of connections	case	48,676	52,488	71,417	73,240	76,749	78,394	79,475	85,832	92,440	94,184
Number of connections for domestic use	case		45,384	66,175	66,375	71,039	73,100	75,215	79,954	86,090	85,280
Number of connections for non-domestic use	case		7,104	5,242	6,865	5,710	5,294	4,260	5,878	6,350	8,904
2. Service Level											
Annual water production	Million m^3 /year	78.9	80.0	94.5	95.2	98.6	98.5	96.8	98.0	88.5	80.6
Water production per capita	L/person/day	208	198	222	203	185	168	153	141	129	118
Water consumption per capita	L/person/day					64	73	53	57	54	40
Water quality standard conformity rate	%	80	79	84	85	89	90	91	95	98	95
Average hours of water supply	hour	15	16	16	17	18	20	20	20	18	17
Number of customer complaints	case	30,023	16,257	14,825	17,641	21,589	10,002	13,522	19,870	24,713	27,572
Complaints response rate	%		80	73	69	82	98	98	95	96	92
3. Meter, Non-revenue Water											
Water meter installation rate	%	45.0	49.0	50.0	52.0	62.0	67.0	68.0	70.0	72.0	71.5
Total of billing water	Million m^3 /year									51	43
Metered billing water rate	%									65.8	45.8
Unmetered billing water rate	%									34.2	54.2
Non-revenue water	%	51.0	50.0	51.0	48.0	43.0	44.0	45.0	42.0	42.0	47.0
Lost water per distribution pipe	L/km/day								63,820	63,321	61,895
Lost water per connection	L/case/day								1,289	1,100	1,096
4. Sewerage and Sanitation Service *											
Number of connections	case									31,210	31,388
Service coverage rate of sewerage and sanitation	%	9.0	9.0	17.0	19.0	65.0	67.0	69.0	71.0	75.0	73.7
Population served with sewerage and sanitation	1,000	146.5	147.9	291.1	340.7	1,257.6	1,322.2	1,400.9	1,505.7	1,631.4	1,655.0
Sewerage service rate	%							23.6	15.2	26.9	17.2
Sanitation service rate	%							76.4	84.8	73.1	82.8
5. **Organization, Finance**											
Tariff collection rate	%								98	96	99
O& M coverage rate by tariff collection	%	102	111	91	106	102	108	124	123	100	88
Recovery rate for total project cost covered by revenue	%	105	98	105	112	115	110	106	105	87	87

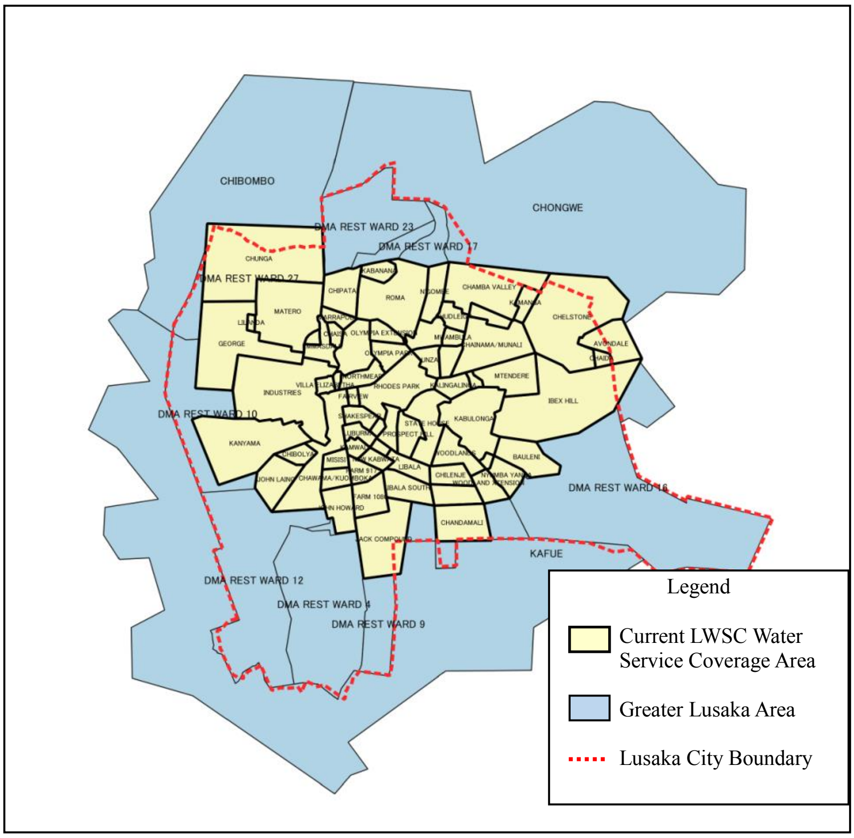
Indicator	Unit	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Number of O&M staff per 1000 connections of water supply	Person	13	12	11	11	11	11	10	10	9	9
Number of O&M staff per 1000 connections of water supply & sewerage	Person								7	7	7

Note: Service population include that in Water Trust Area, In the other hand, water production volume, revenue water volume, NRW rate and so on exclude that in Water Trust Area.
*Sanitation service is sludge removal service form septic tank.
Source: NWASCO Annual Report (from 2006 to 2015)

2.2.4 Water Supply and Sewerage Services in the Study Area

(1) Administrative Boundaries and Water Supply Areas by LWSC

The Preparatory Survey covers the whole area of Greater Lusaka (the Study Area), which include the LWSC Service Area. In 1990, LWSC took over the services from Lusaka City Council and expanded its service coverage area gradually across the administrative boundary of Lusaka City as shown in Figure 2.2.6. The jurisdictions area of LWSC also covers areas other than Greater Lusaka (Lusaka City, a part of Chibombo, Kafue Town, and Chongwe Town). But, the "Current LWSC Water Service Coverage Area" used in the Study defines the current LWSC service coverage area in Greater Lusaka.

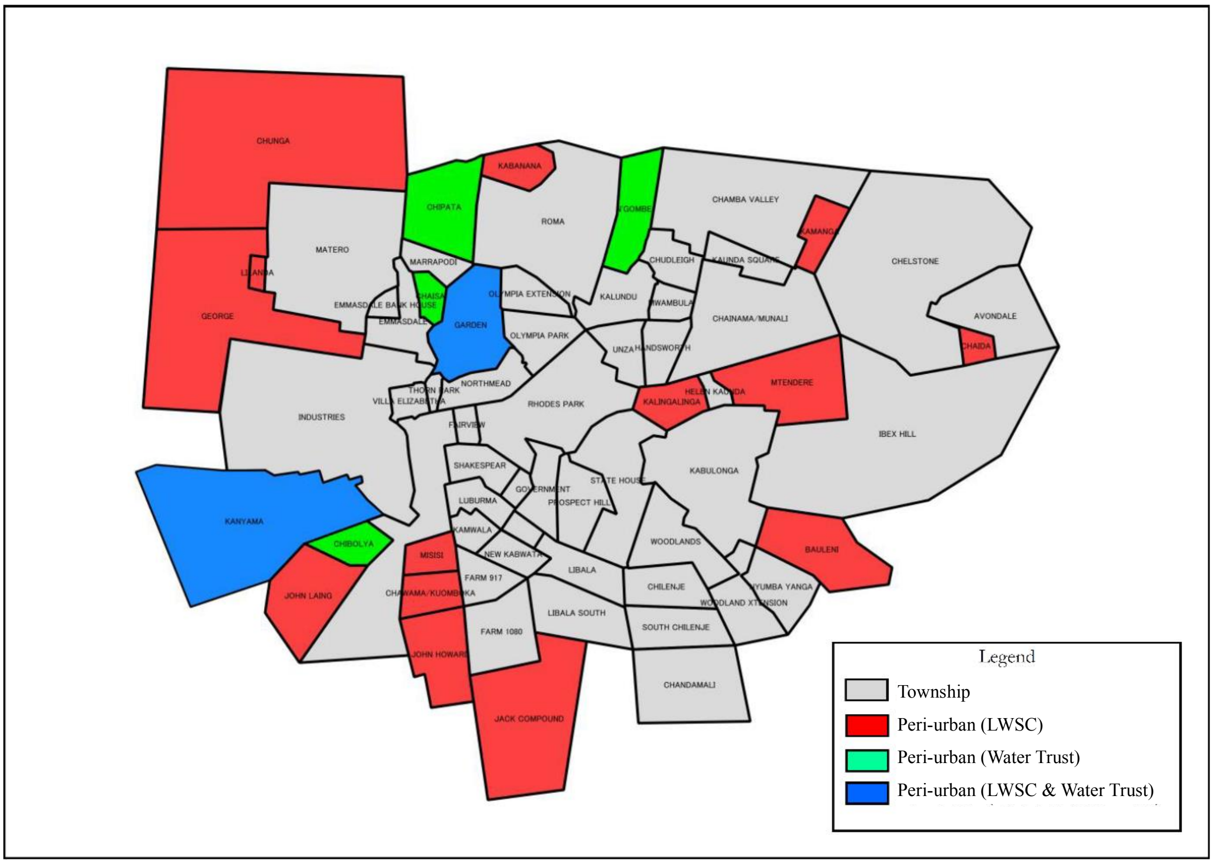


Source: JICA Study Team

Figure 2.2.6 Current LWSC Service Area and Administrative Boundary of Lusaka City

The LWSC Service Area includes 46 townships (developed areas based on urban planning) and 20 peri-urban areas (developed area not based on urban planning) as shown in Figure 2.2.7. Also, in part of peri-urban, there is Water Trust Area which manages water supply project by some local unions called Water Trust.

In addition, the LWSC service area and Water Trust Area co-exist in other part of peri-urban areas.

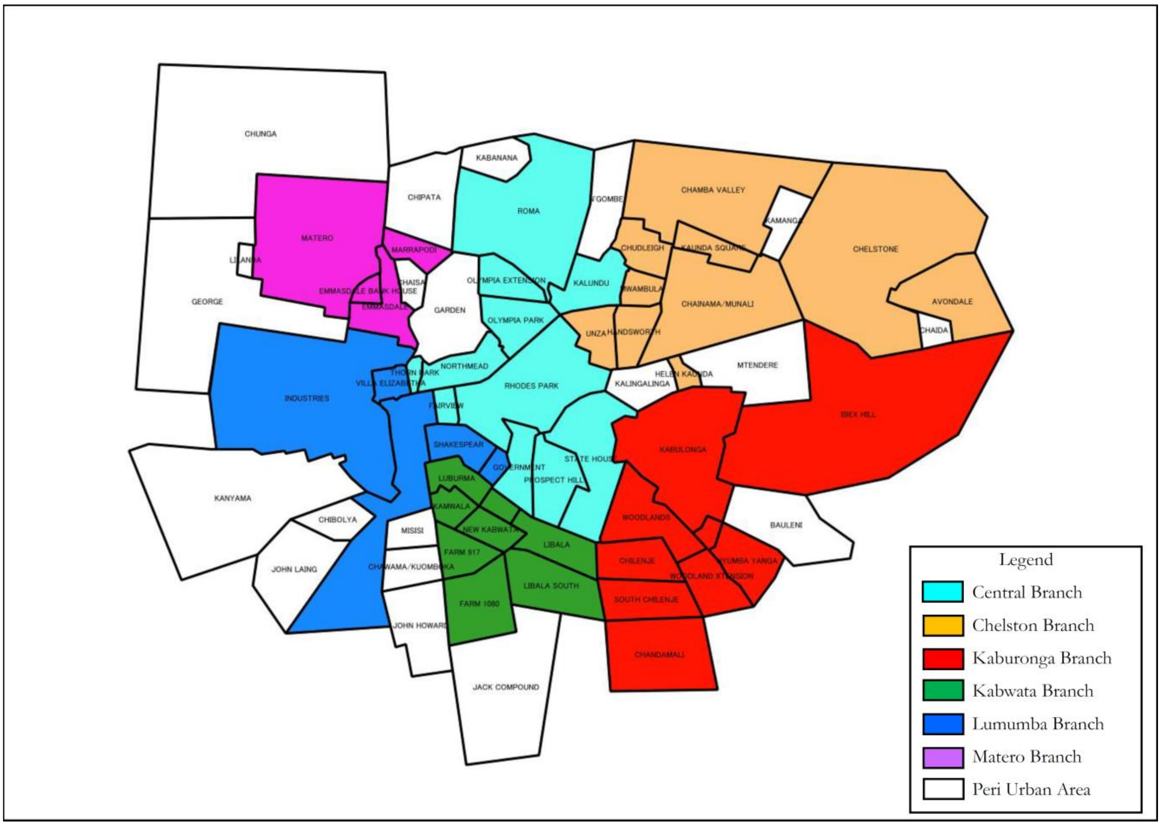


Source: JICA Study Team based on the data provided by LWSC

Figure 2.2.7 Township, Peri-urban Area, and Water Trust Area

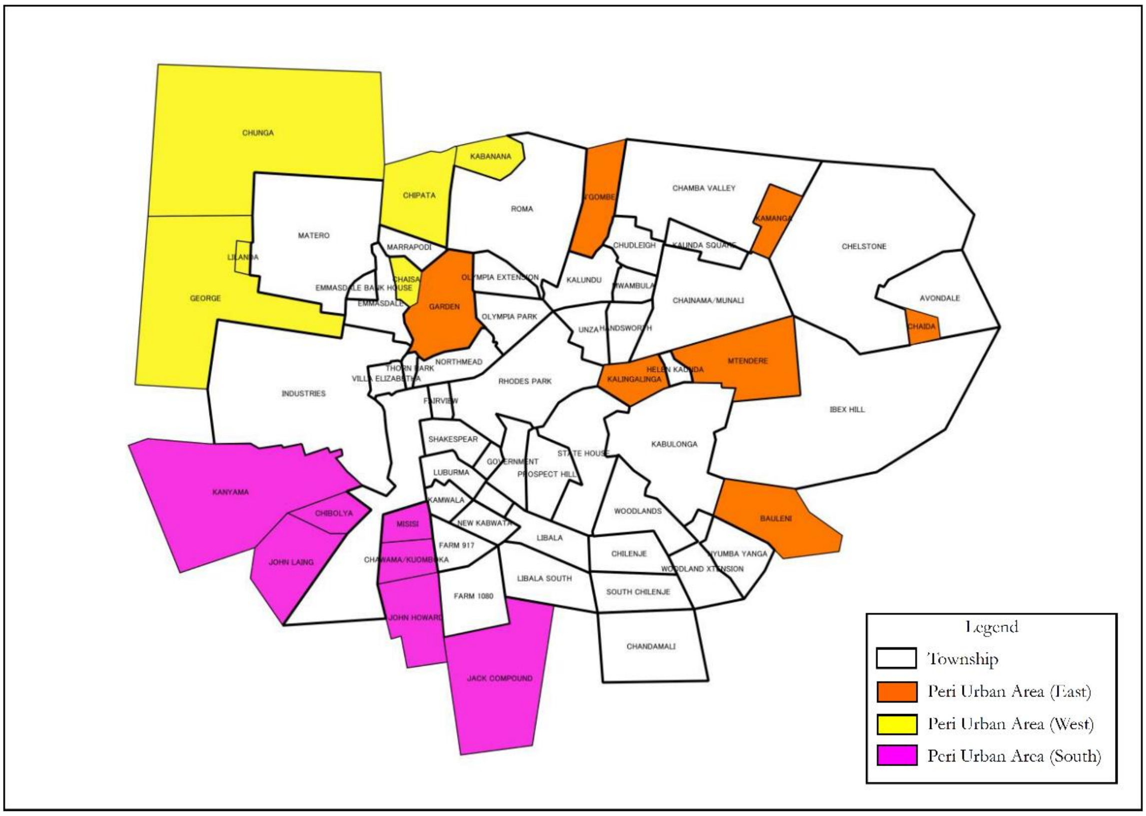
LWSC groups 46 townships into six administrative zones (Central, Chelstone, Kabulonga, Kabwata, Lumumba, and Matero) as shown in Figure 2.2.8. There is an LWSC branch office in each administrative zone. Matero Branch zone had been a part of Lumumba Branch zone and then became an individual zone to keep the service quality efficiency against the rapid population growth in recent years.

In addition, 20 peri-urban areas are grouped into three, namely: East, South and West as shown in Figure 2.2.9. In addition, LWSC plans to manage the distributed amount by region, with a total of 66 areas including 46 townships and 20 peri-urban areas as District Metered Area (DMA).



Source: JICA Study Team based on the data provided by LWSC

Figure 2.2.8 46 Townships and Six Branches in LWSC Service Area



Source: JICA Study Team based on the data provided by LWSC

Figure 2.2.9 Peri-urban Area in LWSC Service Area

(2) Water Supply Connection and Population Served by the Service Area

Table 2.2.4(1/2) shows the population, number of service connections, population served, and service coverage rate in each township, peri-urban area, and Water Trust Area. The data of the population and service connections were provided by the Corporate Planning Department of LWSC. The population served was estimated from the number of service connections through discussion with LWSC.

The population served is estimated assuming 10 persons per house connection, 400 persons per public tap, and 600 persons per water kiosk. The reasons of the estimation are as follows:

1) LWSC estimates that the population in townships is 620,804 and the number of house connections is 56,460; Also there is no public water tap and water kiosk in the townships. Assuming service population per one house connection is 10 persons, service population is 564,600 and the water service rate is 90.9% in townships. It is almost same with the LWSC estimate that the water service coverage in townships is more than 90%.

2) As shown in Table 2.2.3, LWSC water service coverage in entire Lusaka Province is 82.9% in 2015. Assuming service population per one house connection is 10 persons, service population per one public water tap is 400 persons, and service population per one kiosk is 600 persons, the water service coverage in LWSC service area is 82.6%. It is almost same as the service coverage as shown in the indicator of Table 2.2.3.

3) The unit service population as shown above are discussed with LWSC, and it was agreed that the figures are suitable to show the current situation of LWSC service level. However, the unit service populations are expected to decrease in the future, due to improvement of LWSC service level.

Table 2.2.4 (1/2 and 2/2) shows the service population by types of connection in the existing LWSC service coverage area, calculated using the unit service populations above.

Table 2.2.4(1/2) Population Served by Connection Type in LWSC Service Area (Summary)

Area		Population	Estimate of Service Population			Service Rate	House Connection Rate
			House Connection	Communal Taps/ Kisks	Total		
LWSC Water Service Coverage Area		1,923,218	839,660	755,800	1,595,460	83%	44%
Sevice Area by LWSC		1,342,669	768,260	432,000	1,200,260	89%	57%
1	Township	620,804	564,600	-	564,600	91%	91%
2	Peri-Urban	721,865	203,660	432,000	635,660	88%	28%
Sevice Area by Water Trust		580,549	71,400	323,800	395,200	68%	12%
1	Township	-	-	-	-	-	-
2	Peri-Urban	580,549	71,400	323,800	395,200	68%	12%

Source: JICA Study Team based on the data provided by LWSC, Corporate Planning Department, 2015

Table 2.2.4(2/2) Population Served by Connection Type in LWSC Service Area

		Population in Service Area	Number of Connection			Population	Estimate of Service Population			Service rate
			Household Connections	Communal Taps	Kiosks		Household Connection	Communal Taps/ Kisks	Total	
LWSC Service Coverage Area		**1,923,218**	**83,966**	**901**	**659**	**1,923,218**	**839,660**	**755,800**	**1,595,460**	**83%**
1	Township	620,804	56,460	-	-	620,804	564,600	-	564,600	91%
2	Peri-Urban	721,865	20,366	867	142	721,865	203,660	432,000	635,660	88%
3	Water Trust Area (Peri-Urban)	580,549	7,140	34	517	580,549	71,400	323,800	395,200	68%
TOWNSHIP										
CEN	Olympia Park	8,548	912	0	0					
	Olympia Park Extension	5,369	528	0	0					
	Kalundu	8,067	712	0	0					
	Roma	8,068	613	0	0					
	Rhodespark	13,541	1489	0	0					
	Fairview	6,194	481	0	0					
	Northmead	9,759	1175	0	0					
	Thornpark	9,494	268	0	0					
	Prospect Hill	9,406	444	0	0					
	Statehouse	4,061	384	0	0					
	Government	4,369	526	0	0					
	Sikanze	1,876	9	0	0	88,752	-	-	-	-
CHE	UNZA	38,859	3	0	0					
	Handsworth	2,646	272	0	0					
	Chudleigh			0	0					
	Mwambula	12,576	595	0	0					
	Chainama	12,092	1487	0	0					
	Helen Kaunda	6,864	611	0	0					
	Chelston-LC	25,994	3227	0	0					
	Avondale Southend	18,998	2099	0	0					
	Chamba Valley	4,040	335	0	0					
	Kaunda Square	28,493	3114	0	0	150,562	-	-	-	-
KBL	Woodlands	8,199	837	0	0					
	Woodlands Extension	12,926	1300	0	0					
	Kabulonga & Sunningdale	8,948	1788	0	0					
	New Ibex Hill	3,766	753	0	0					
	Nyumba Yanga	12,366	1541	0	0					
	Chilenje South	26,147	2871	0	0					
	Chilenje	22,260	2419	0	0					
	Chandamali	7,960	1309	0	0	102,572	-	-	-	-
KBT	Luburma	4,112	279	0	0					
	Libala	16,411	1817	0	0					
	Kabwata	14,260	1532	0	0					
	New Kamwala	11,359	1194	0	0					
	New Kabwata	14,603	1815	0	0					
	Farm 1080	13,225	1846	0	0					
	Farm 917	7,298	1027	0	0					
	Libala South	16,645	2044	0	0	97,913	-	-	-	-
LUM	Shakespear	9,946	865	0	0					
	Town/Kabelenga	18,018	975	0	0					
	Industrial Area	25,392	800	0	0					
	Villa Elizabetha	2,949	391	0	0	56,305	-	-	-	-
MAT	Emmasdale	7,958	1135	0	0					
	Matero			0	0					
	Marrapodi	112,144	7896	0	0					
	Emmasdale Bank Houses	4,598	742	0	0	124,700	-	-	-	-
Total		**620,804**	**56,460**	**0**	**0**	**620,804**	**564,600**	**0**	**564,600**	**91%**
Peri-Urban (managed by LWSC)										
PERI-URBAN EAST	Kalingalinga	40,931	1,857	60	15					
	Mtendere	81,381	3,339	14	0					
	Garden	16,084	1,528	12	0					
	Bauleni	32,342	1,196	42	7					
	Kamanga	15,966	575	14	7					
	Chaida	22,929	491	17	15	209,633	89,860	90,000	179,860	86%
PERI-URBAN SOUTH	Chawama	89,117	2,596	65	19					
	John Howard	18,760	484	39	6					
	Kanyama	48,920	1,110	37	27					
	Misisi	22,541	291	39	12					
	John Laing	42,167	301	40	24					
	Jack Compound	22,500	255	23		244,005	50,370	150,000	200,370	82%
PERI-URBAN WEST	George	148,072	3,527	374	8					
	Lilanda	65,867	1,040	89	1					
	Chunga	25,431	708	2	0					
	Kabanana	28,857	1,068	0	1	268,227	63,430	192,000	255,430	95%
Total		721,865	**20,366**	**867**	**142**	**721,865**	**203,660**	**432,000**	**635,660**	**88%**
Peri-Urban (Water Trust Area)										
EASTERN ZONE	NG'OMBE	101,000	480	34	67					
	KALIKILIKI (Mtendere)	25,165	347	0	26					
	GARDEN (Garden)	50,234	165	0	52					
	MTENDERE EAST (Mtendere)	56,000	1024	0	18					
SOUTHERN ZONE	CHIBOLYA	47,000	627	0	32					
	KANYAMA (Kanyama)	160,000	1493	0	157					
WESTERN ZONE	CHAZANGA (Matero)	66,000	1870	0	58					
	CHIPATA	51,000	824	0	65					
	CHAISA	24,150	310	0	42					
Total		580,549	**7140**	**34**	**517**	**580,549**	**71,400**	**323,800**	**395,200**	**68%**

Source: JICA Study Team based on the data provided by LWSC, Corporate Planning Department, 2015

(3) Revenue Water Amount by Service Area

Table 2.2.5 shows the revenue earning water supplied by LWSC to township and peri-urban area in 2013, 2014, and 2015. The amount of water in the table is the sum of domestic water and non-domestic water. Table 2.2.6 shows the water production volume and revenue earnings in Water Trust Areas.

Table 2.2.5 Revenue Water of LWSC in Township and Peri-Urban Area (including Domestic Water and Non-domestic Water Use)

	Population (2015)	Population Served (2015)	Revenue Water of LWSC (m^3/day)			Revenue Water Volume per Person, 2015 (m^3/day)
			2013	2014	2015	
1) Township						
Central Branch	88,752	80,717	26,097	32,660	26,743	331
Chelstone Branch	150,562	136,931	18,764	20,057	16,248	119
Kabulonga Branch	102,572	93,286	18,313	18,878	17,649	189
Kabwata Branch	97,913	89,049	19,912	22,867	27,359	307
Lumumba Branch	56,305	51,207	19,438	16,524	11,149	218
Matero Zone	124,700	113,410	6,123	5,946	7,068	63
Total	**620,804**	**564,600**	**108,646**	**116,932**	**106,216**	**188**
2) Peri-urban						
Peri-urban East Zone	209,633	179,860	7,706	8,173	7,214	40
Peri-urban South Zone	244,005	200,370	7,823	4,035	4,636	23
Peri-urban West Zone	268,227	255,430	7,931	7,702	5,982	23
Total	**721,865**	**635,660**	**23,460**	**19,910**	**17,832**	**28**

Source: The population data is provided by LWSC Corporate Planning Department. Daily average revenue water volume data is provided by LWSC. Service population and revenue water volume are estimated by the JICA Study Team.

Table 2.2.6 Revenue Water in Water Trust Area (2015)

DMA	Area	Population	Estimated Service Population	Water Production (m^3/day)	Revenue Water Amount (m^3/day)			Unit Revenue Water Amount (Lpcd)
					Household Connection	Standposts & Kiosks	Total	
N'gombe	all area	101,000	58,600	2,442	411	193	605	10.3
Mtendere	Kalikiliki	25,165	19,070	364	136	163	299	15.7
Garden	some part	50,234	32,850	856	522	197	719	21.9
Mtendere	Mtendere East	56,000	21,040	1,440	455	408	863	41.0
Chibolya	all area	47,000	25,470	750	331	343	673	26.4
Kanyama	some part	160,000	109,130	2,442	469	1,713	2,182	20.0
Matero	Chazanga	66,000	53,500	1,353	403	502	904	16.9
Chipata	all area	51,000	47,240	1,617	588	956	1,544	32.7
Chaisa	all area	24,150	28,300	638	206	432	638	22.6
Total		580,549	395,200	11,903	3,521	4,907	8,428	21.3

Note: 1. As there are no data of water production volume and water supply volume in Chazanga (Matero), these are estimated using the average volume per person in other area of Water Trust Area.
2. Service populations were estimated based on the numbers of connections in Table 2.2.4.

Source: The population data for the target area is provided by LWSC Corporate Planning Department. The data of water production volume and revenue water volume are provided by LWSC, Peri-urban Department.

(4) Water Supply Volume for Each Customer Class by Each Billing Method

LWSC adopts three water charge categories, i.e.: "Metered Postpaid", "Unmetered Postpaid", and "Prepaid". Even though the billed volume is quantified for each category, it is hard to quantify the supplied volume accurately as "Unmetered Postpaid" accounts for 35% in terms of the billed volume. Prepaid system was introduced in 2013 and was expected to increase.

Table 2.2.7 shows the daily average revenue earnings in 2015. Table 2.2.8 shows mean daily revenue water volume of LWSC in each year between 2013 and 2015. The total volume of domestic water and non-domestic water ranges from 124,048 m^3/day to 136,842 m^3/day; there was no considerable difference by year. However, non-domestic water in 2015 was 21,172 m^3/day, which is extremely small and irrational. In particular, the detailed data indicated that the revenue earnings from the government organizations decreased significantly. The reason for the above is uncertain.

Table 2.2.7 Water Supply Volume by Billing System for Domestic Water and Non-domestic Water by LWSC (2015)

Usage	Target Area		Water Supply Volume by Billing System (m^3/day)				Water Supply Volume per Person (Lpcd)
			Metered Postpaid	Unmetered Postpaid	Prepaid	Total	
Domestic Water	Township	CEN	6,883	6,693	6,101	19,677	246.3
		CHE	8,723	4,002	658	13,383	98.8
		KBL	9,703	6,412	661	16,776	181.7
		KBT	5,265	6,829	14,898	26,993	306.3
		LUM	1,366	537	1,196	3,099	61.2
		MAT	4,345	1,991	107	6,443	57.4
		Subtotal	**36,285**	**26,465**	**23,620**	**86,371**	**154.6**
	Peri-urban	PUE	1,737	5,218	9	6,964	38.7
		PUS	460	3,224	0	3,684	18.4
		PUW	1,973	3,885	0	5,857	22.9
		Subtotal	**4,170**	**12,326**	**9**	**16,505**	**26.0**
	Total		**40,455**	**38,792**	**23,630**	**102,876**	**86**
Non-domestic Water	Township	CEN	4,083	1,202	1,782	7,066	88.5
		CHE	2,635	225	5	2,865	21.1
		KBL	503	323	47	873	9.5
		KBT	147	189	30	366	4.2
		LUM	5,208	2,841	0	8,050	158.8
		MAT	197	428	0	625	5.6
		Subtotal	**12,773**	**5,207**	**1,865**	**19,845**	**35.5**
	Peri-urban	PUE	78	172	0	249	1.4
		PUS	763	189	0	952	4.8
		PUW	0	125	0	125	0.5
		Subtotal	**840**	**487**	**0**	**1,327**	**2.1**
	Total		**13,613**	**5,694**	**1,865**	**21,172**	**17.7**
Grand Total			**54,068**	**44,486**	**25,494**	**124,048**	**103.9**
Ratio of water volume by billing system			44%	36%	20%	100%	---

Source: Data provided by LWSC Billing Department, Prepaid Department and NRW Department.

Table 2.2.8 Daily Average Water Supply Volume of Domestic Water Use and Non-domestic Water Use by LWSC (2013-2015)

Year	Domestic Water Use (m^3/day)	Non-domestic Water Use (m^3/day)	Total (m^3/day)
2013	94,361	37,745	132,106
2014	97,744	39,098	136,842
2015	102,876	21,172	124,048
Average	98,327	32,672	130,999

Source: Data provided by LWSC Billing Department and Prepaid Department

(5) Estimate of Unit Water Demand

Table 2.2.9 shows the population, population served, water supply volume of domestic water and non-domestic water, and domestic water use volume per person in the LWSC service area. Out of the 1.19 million persons, 0.56 million persons serviced by LWSC live in township and supplied with 155 Lpcd. On the other hand, 0.64 million persons live in peri-urban and supplied with 26 Lpcd. The daily average water supply volume for domestic use by LWSC in 2015 was 102,876 m^3/day. The volume of 86,371 m^3/day accounting for 84% of the daily average water supply volume is supplied for township. The residents in the township account for 47% of the total population in the LWSC service area, and consume 84% of the total domestic water. Moreover, most of the non-domestic water is consumed in township.

Table 2.2.9 Water Supply Status in LWSC Service Area (2015)

	LWSC Service Area			Water Trust Area	Total
	Township	Peri-urban	Total		
Population	620,804	721,865	1,342,669	580,549	1,923,218
Population served			0		
Household connection	564,600	203,660	768,260	71,400	839,660
Public tap, Water kiosk	0	432,000	432,000	323,800	755,800
Total	564,600	635,660	1,200,260	395,200	1,595,460
Household connection rate	91%	28%	57%	12%	44%
			0		
Water supply volume by LWSC			0		
Domestic water (m^3/day)	86,371	16,505	102,876	-	102,876
Except for domestic water (m^3/day)	19,845	1,327	21,172	-	21,172
Total (m^3/day)	106,216	17,832	124,048	-	124,048
Domestic water per person	155 Lpcd	26 Lpcd	86 Lpcd	-	86 Lpcd
Revenue water per person	188 Lpcd	28 Lpcd	104 Lpcd	-	104 Lpcd

Source: JICA Study Team based on the data provided by LWSC

(6) Current Status of Sewerage and Sanitation Service

Table 2.2.10 shows the existing service coverage of sewerage and sanitation by LWSC in 2015. The past trend is shown in Table 2.2.3 indicating the service coverage rate of sewerage and sanitation in Lusaka Province.

The development of sewerage and sanitation facilities in Lusaka City is improved in the past ten years. But the service coverage rate of sewerage and sanitation fell behind that of water supply. In 2006, the service coverage rate of sewerage and sanitation for the entire province was 9% and it increased up to 73.7% in 2015 as shown in Table 2.2.3. In the LWSC service area, however, most of the population are served with septic tanks, which have less effective treatment process compared with sewerage treatment facility. Users connected to the sewerage system are 17.2% of 73.7% of the people served with sewerage and sanitation.

Many of the people living in peri-urban areas are not either served with sewerage or sanitation, and only using pit latrines. Under these situations, there is a concern that groundwater contamination by sewage will progress due to future population growth.

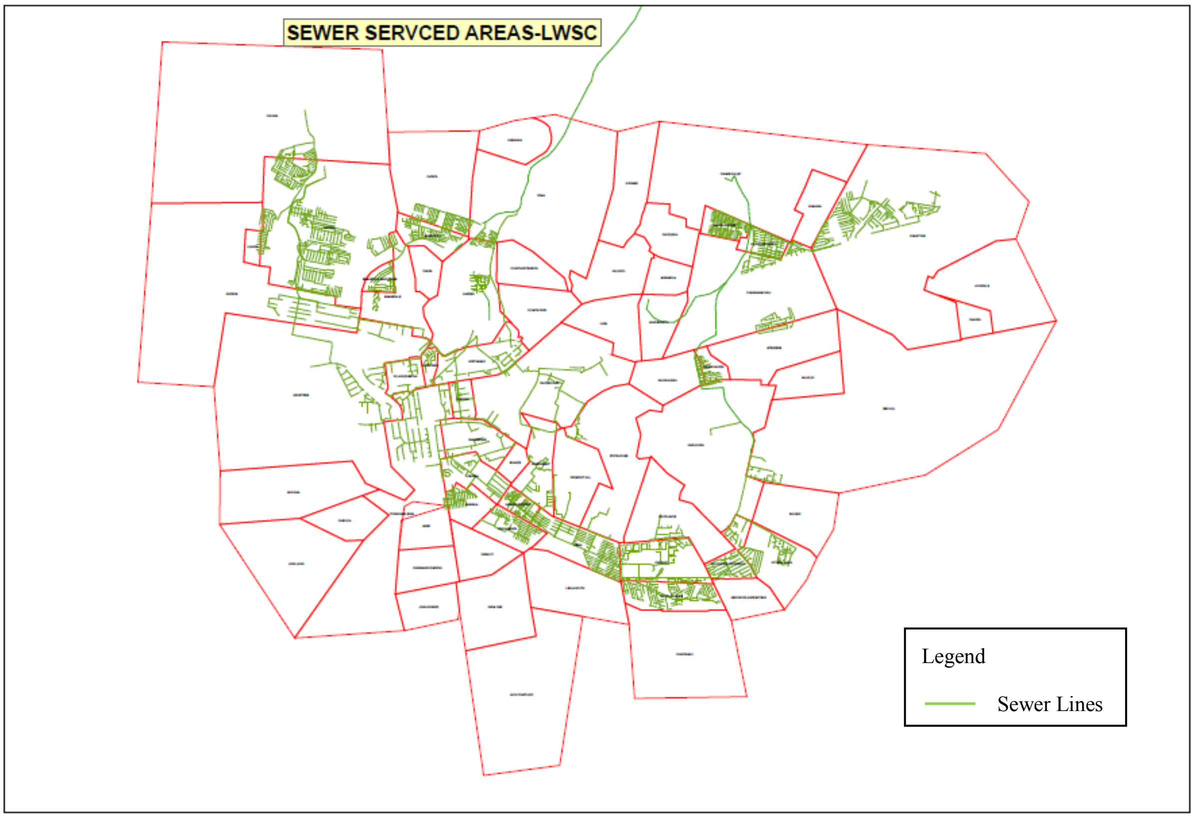
Table 2.2.10 Coverage Rate of Sewerage and Sanitation Service in Lusaka LWSC Service Area

	Population (2015)	Connection Rate
Population of LWSC service area in Lusaka Province	2,246,800	-
Sanitation facility service population	1,655,000	73.7%
Sewerage service population	209,794	73.7% x 17.2%= 12.7%
Sanitation service population *	1,009,941	73.7% x 82.8%= 61.0%

*: Population using septic tank

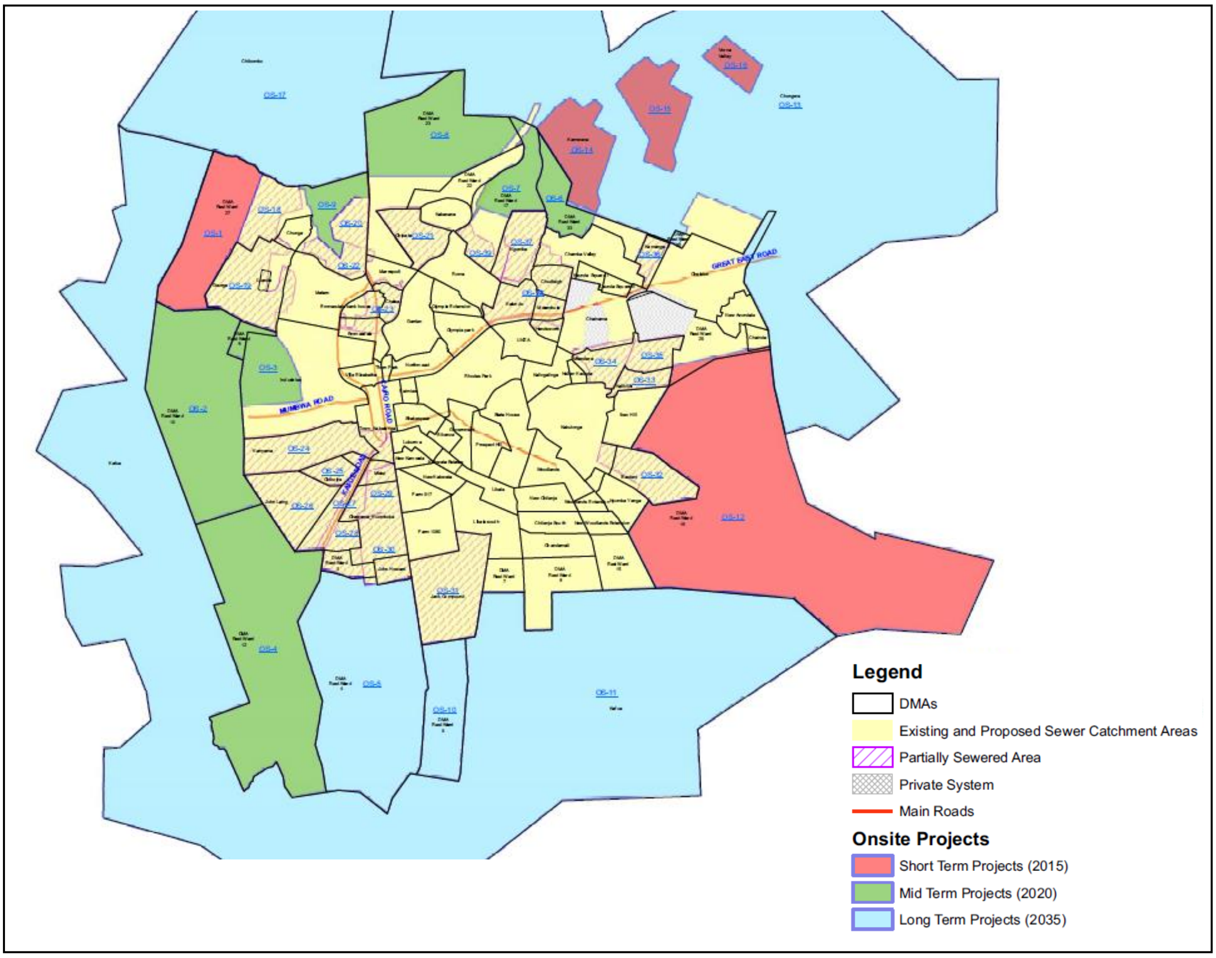
Source: JICA Study Team based on the data provided by LWSC

Figure 2.2.10 shows the installation status of the sewerage network in the existing LWSC service area. Currently, projects financed by the World Bank and African Development Bank (AfDB) are making efforts to improve the sanitation facilities (septic tank). Figure 2.2.11 shows the planned areas for sewerage network development and sanitation facility development in the future.



Source：LWSC

Figure 2.2.10 Existing Sewerage Network in LWSC Service Area



Source: MCC Sanitation Master Plan, Lusaka, 2011

Figure 2.2.11 Sewerage Network and Sanitation Facility Installation Plan in Lusaka City

2.3 Current Situation of Water Supply System

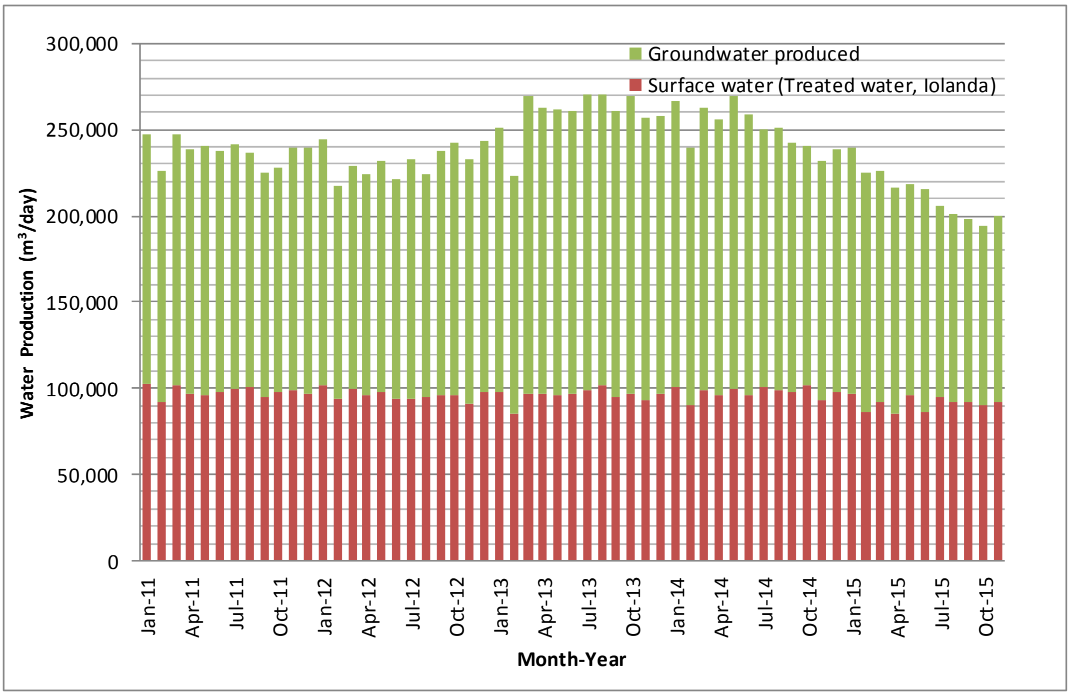
2.3.1 Water Source for Water Supply System

(1) Outline

Water sources of LWSC are groundwater in Lusaka City and surface water of the Kafue River located 50 km away from Lusaka City. The existing water intake, water treatment plant (WTP), and water transmission facility sourced from the Kafue River are called as “Kafue Bulk Water Supply System”. The water transmission main of Kafue Bulk Water Supply System runs through Kafue Town where LWSC provides water supply services but is dedicated to the LWSC service area in Lusaka City. Other small-sized water treatment plant sourced from the Kafue River supplies water to Kafue Town.

Figure 2.3.1 shows water production by water sources for the LWSC service area. The design capacity of Kafue Bulk Water Supply System is around 110,000 m^3/day, while the current water supply volume stays at around 100,000 m^3/day. The capacity of groundwater sources is 145,000 m^3/day and the actual production yield fluctuates between 100,000 m^3/day and 167,000 m^3/day. The groundwater yield tends to decrease after May 2014.

The reason of decreasing groundwater yield is the limited operation hours of pumps due to the shortage of electricity. Other reason is the closing of some wells due to groundwater level lowering and contamination of water quality. In addition, the Water Supply Investment Master Plan (2011) by Millennium Challenge Corporation (MCC) points out the deterioration of the existing facilities as one of the reasons.



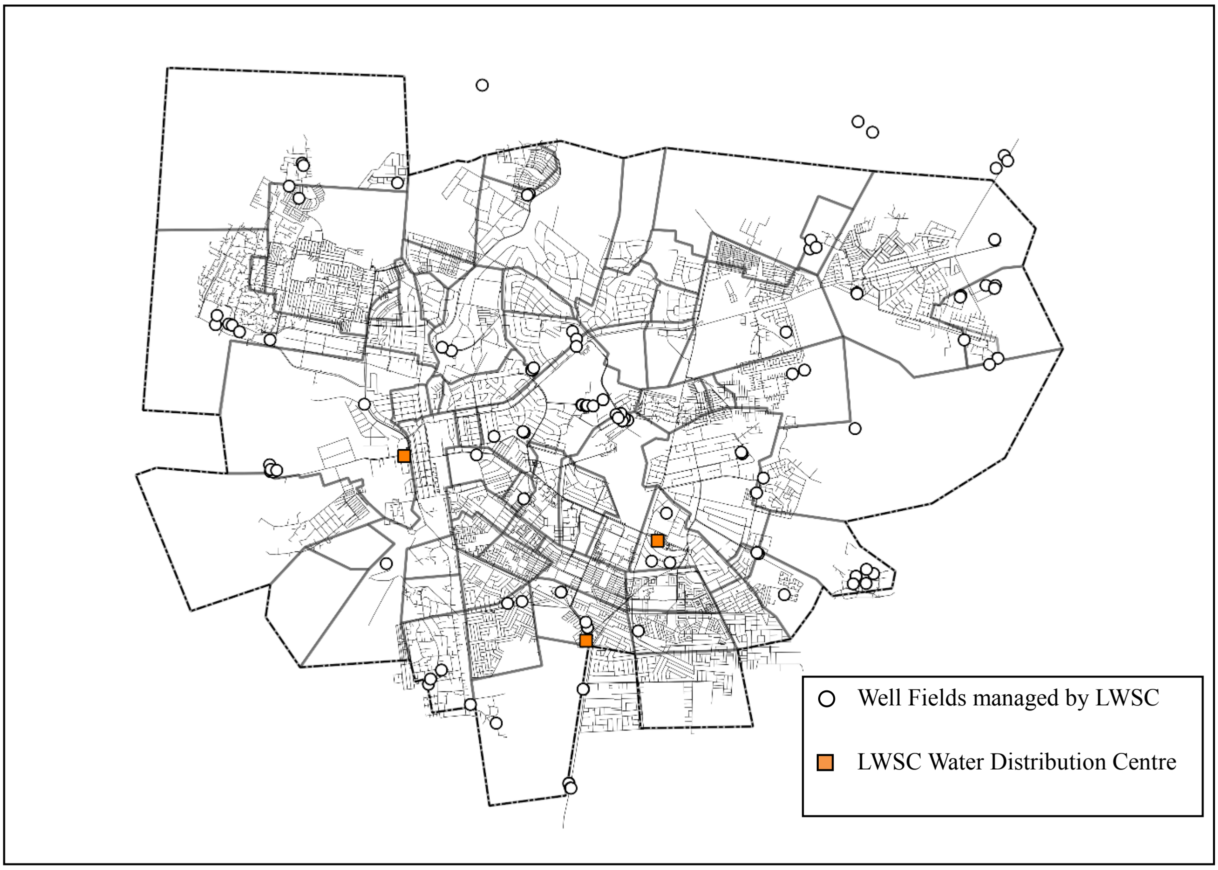
Source: JICA Study Team based on the data provided by LWSC
Note: Estimation values are listed in May and August in 2013 due to lack of data

Figure 2.3.1 LWSC Water Production by Water Source in Greater Lusaka

(2) Groundwater

1) Distribution of Wells

Figure 2.3.2 shows the location of well fields, comprising 116 wells in total, operated by LWSC. Other than wells owned by LWSC, there are also many wells owned by private household, commercial entity, and Water Trust but no data is available for the wells.



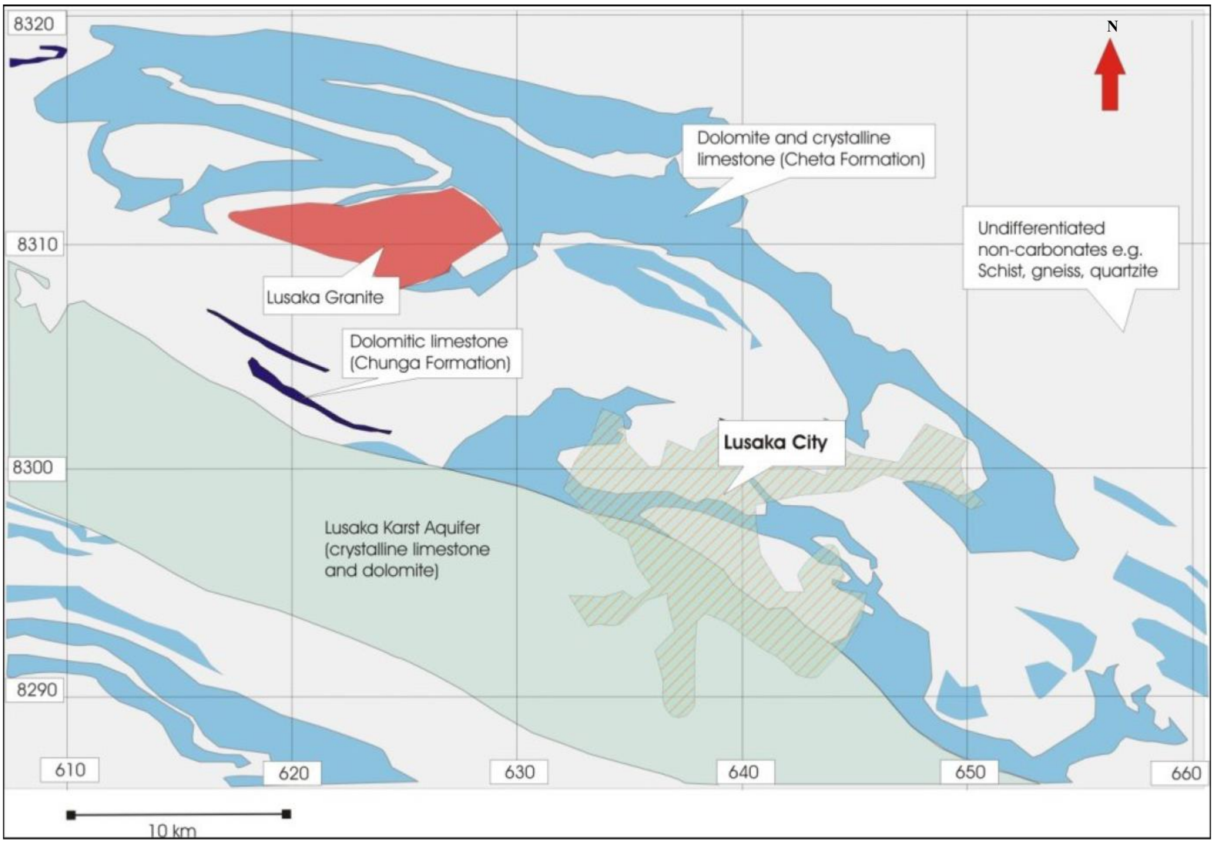
Note: The water distribution centres are described in Section 2.3.4.
Source: JICA Study Team based on the data provided by LWSC

Figure 2.3.2 Locations of Well Field Managed by LWSC in the LWSC Service Area

2) Characteristics and Location of Aquifer

The groundwater is mainly pumped from an aquifer called as Lusaka Karst Aquifer, which expands over the southern part of Lusaka as shown in Figure 2.3.3. According to the MCC Master Plan, the characteristics of the aquifer are as follows:

- The area is located on plateau where the elevation is between 1,200 m and 1,300 m.
- The maximum size of aquifer is 70 km in length, 10 km in width, a thickness of 30 m.
- Water level is high and average depth of wells is less than 50 m from the ground surface.
- Estimated safe yield is 180,000 m^3/day.



Source: MCC M/P

Figure 2.3.3 Area of Lusaka Karst Aquifer

3) Water Quality

Some wells managed by LWSC have an increasing nitrate nitrogen concentration. As shown in Table 2.2.1, in accordance with the Zambian Drinking Water Quality Standards, nitrate nitrogen concentration should be less than 10 mg-N/liter, which is 44.5 mg/liter, when calculated by molar weight ratio of NO_2 and N.[8] However, nitrate nitrogen exceeding the standards was detected in 36 wells as shown in Table 2.3.1. The total production capacity of these wells is estimated at about 25,200 m^3/day[9]. This amount of 25,200 m^3/day is equivalent to 17.4% of the total production capacity of 145,000 m^3/day of wells managed by LWSC.

Groundwater contamination due to sewage infiltration into the ground was thought to be a cause of the increasing nitrate nitrogen concentration. Figure 2.3.4 shows the distribution of wells by grade of concentration. The wells contaminated by nitrate nitrogen concentration exceeding the standard are widely distributed in the LWSC service area. Of these, the wells contaminated by nitrate nitrogen concentration exceeding twice the standard are concentrated in peri-urban areas where pit latrines are mainly used. Infiltration of sewage is strongly related to the increase in nitrate nitrogen concentration.

[8] In the WHO standards, the acceptable value of nitrate nitrogen is 50 mg/liter
[9] The total production capacity of these wells is 1,400 m^3/day by pumping for 18 hours per day.

There are 12 wells exceeding twice the standard. The total production capacity of such wells is 630 m^3/hour, equivalent to 11,340 m^3/day.

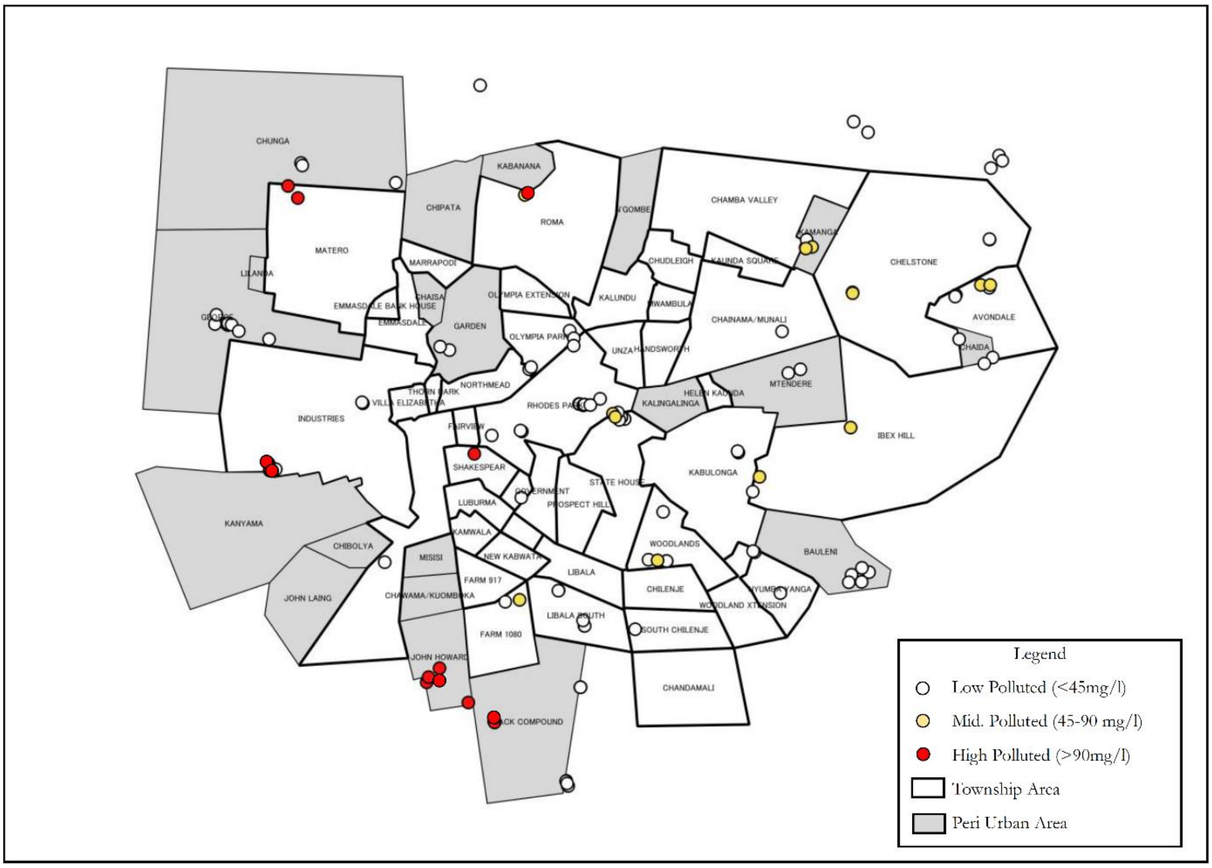
According to the MCC Master Plan, water quality was analysis at 15 wells and exceeded the tolerance of WHO guidelines for hardness, nitrate nitrogen, and microorganism in some wells. However, the MCC Master Plan did not report the location and owners of the wells tested. High hardness was caused by limestones in Lusaka. The MCC Master Plan describes that nitrate nitrogen and microorganism were caused by contamination due to infiltration of sewage and the contamination was remarkable in private owned wells.

As of October 2012, LWSC operated 101 wells but abandoned six wells due to contamination in November 2012. Afterwards, no well has been abandoned up to date. Meanwhile, it is anticipated that the groundwater would be further contaminated due to increase in population in the areas where sewerage system and septic tanks are not adopted.

Table 2.3.1 Wells with Nitrate Nitrogen Exceeding the Drinking Water Quality Standards

No.	Location	Pump Capacity (m3/hr)	NO3- (mg/L)		
			Nov. & Dec. 2012	Feb. & Mar. 2013	Jan., Sep. and Oct, 2013
1	Buckley 1	8	47		
2	Buckley 2	17		55	
3	Roadside 1	100		76	
4	Roadside 2	130			57
5	Roadside 4	95	54	183	57
6	Roadside 5	75	48	187	52
7	Roadside 6	150			48
8	Chunga BH1	50	48	132	55
9	Chunga BH2	8	51	180	87
10	Changa 6F	64		67	
11	New Abondale BH 2	15	50		
12	Kamanga BH2	0	56		
13	Kamanga BH5	2.8	65		
14	Kamanga BH7	0	59		
15	Kamanga BH8	0	65		
16	Salama BH1	0	71		
17	Ibex Hill BH	17	47		
18	Mass Media BH5	80	56		
19	Mass Media BH6	45	71		
20	Kabanana BH	44		107	
21	George BH2	0		72	
22	George BH4	0			55
23	Farm 1080 BH A	36		52	
24	John Haward BH	23		153	50
25	Jack BH A	0		238	
26	Jack BH B	0		214	
27	Jack BH 1	0			47
28	Jack BH 2	14			46
29	Chawana BH	0			265
30	Chawana BH1	95		198	217
31	Chawana BH2	65		208	239
32	Chawana BH3	100		111	
33	Chawana reservoir	0			55
34	Woodlands BH2	54		64	
35	Chilenje south BH	40			50
36	Nipa BH	75			155
	Total	1,403			

Note: Highlighted columns show that locations recorded more than twice of the drinking water quality standards.
Source: JICA Study Team based on the data provided by LWSC



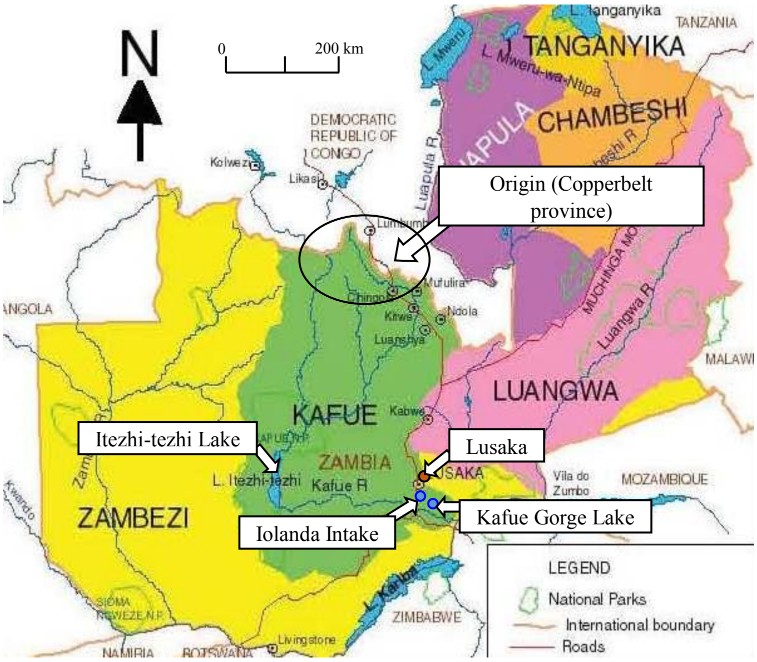
Source: JICA Study Team based on the data provided by LWSC

Figure 2.3.4 Nitrate Nitrogen Concentration/Distribution of Wells in Current LWSC Service Coverage Area

(3) Surface Water (Kafue River)

1) Kafue River Watershed

Kafue River is the surface water source for the LWSC service area. Kafue River originates from the watershed between Zambezi and Zaire in Copperbelt Province. The river flows to the south and enters into the Itezhi-tezhi Lake. After the Itezhi-tezhi Lake, the river runs to the east through the Kafue Flats and reaches Kafue Gorge Lake. The basin area of the Kafue River is 157,000 km^2 and the length is 1,300 km. Figure 2.3.5 shows the basin and route of Kafue River.



Source: River Basins of Zambia, National Water Resources Report

Figure 2.3.5 Basin and Route of Kafue River

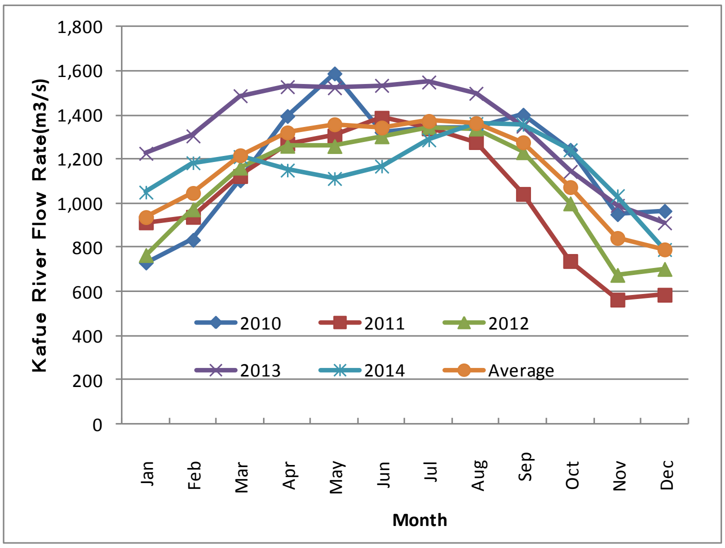
The Iolanda Intake abstracting raw water from Kafue River is located about 240 km downstream of the Itezhi-tezhi Dam and about 15 km upstream of the Kafue Gorge Dam. The Kafue Flats spread along the river section between the two dams. The flow velocity of Kafue River in the Kafue Flats is slow and water flows throughout the year. Figure 2.3.6 shows the location of the Iolanda Intake and two dams in the Kafue Flats.

Source: Reporting the Kafue Flats, *A Partnership to Environmental Flows in Zambia*, P Shelle and J Pittock

Figure 2.3.6 Location of Iolanda Intake and Two Dams in Kafue Flats

2) Water Flow Rate and Water Level

The Water Resources Management Authority (WARMA) Kasaka Hydrometric Station is located about 6 km upstream from the Iolanda Intake to measure water level and flow rate in Kafue River. The flow records at Kasaka Hydrometric Station for 2010-2014 are shown in Figure 2.3.7.

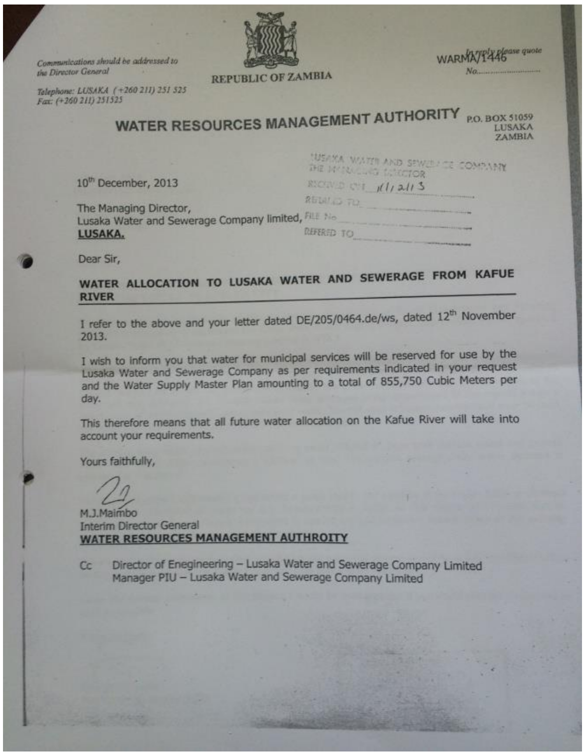


Source: JICA Study Team based on WARMA data (Observation point: Kasaka Station, Kafue)

Figure 2.3.7 Flow Rate of Kafue River (from 2010 to 2014)

The maximum discharge from 2010 to 2014 was 1,589 m^3/s (137,000,000 m^3/day) in May 2011. The minimum discharge was 564 m^3/s (49,000,000 m^3/day) in November 2011. The water level and flow rate at the Iolanda Intake were dependent on the flow regulation by the Itezhi-tezhi Dam and flow retardation in the Kafue River section in the Kafue Flats. LWSC obtained the water right to take 9.9 m^3/s (855,750 m^3/day) from Kafue River in December 2013. There was no serious impact on the natural and social environment by abstracting water. The amount of water rights is less than 2% of the minimum flow rate of the Kafue river, and it is considered that there is no serious impact on the natural environment and the social environment due to water intake.

The water right authorized by WARMA covers all water abstracting from the Kafue River of LWSC. Therefore, the LWSC has been developing not only this project, but also the existing Iolanda water treatment plant (water treatment capacity after completion of restoration project: 110,000 m^3/day) and water supply project for the Kahue River under construction (50,000 m^3/day in the first phase, and future expansion 150,000 m^3/day). So, it is permitted to withdraw total amount of 855,750 m^3/day.



Communications should be addressed to the Director General

Telephone: LUSAKA (+260 211) 251 525
Fax: (+260 211) 251525

REPUBLIC OF ZAMBIA

In reply please quote No. WARMA/1446

WATER RESOURCES MANAGEMENT AUTHORITY

P.O. BOX 51059
LUSAKA
ZAMBIA

10th December, 2013

The Managing Director,
Lusaka Water and Sewerage Company limited,
LUSAKA.

Dear Sir,

WATER ALLOCATION TO LUSAKA WATER AND SEWERAGE FROM KAFUE RIVER

I refer to the above and your letter dated DE/205/0464.de/ws, dated 12th November 2013.

I wish to inform you that water for municipal services will be reserved for use by the Lusaka Water and Sewerage Company as per requirements indicated in your request and the Water Supply Master Plan amounting to a total of 855,750 Cubic Meters per day.

This therefore means that all future water allocation on the Kafue River will take into account your requirements.

Yours faithfully,

M.J.Maimbo
Interim Director General
WATER RESOURCES MANAGEMENT AUTHROITY

Cc Director of Enegineering – Lusaka Water and Sewerage Company Limited
Manager PIU – Lusaka Water and Sewerage Company Limited

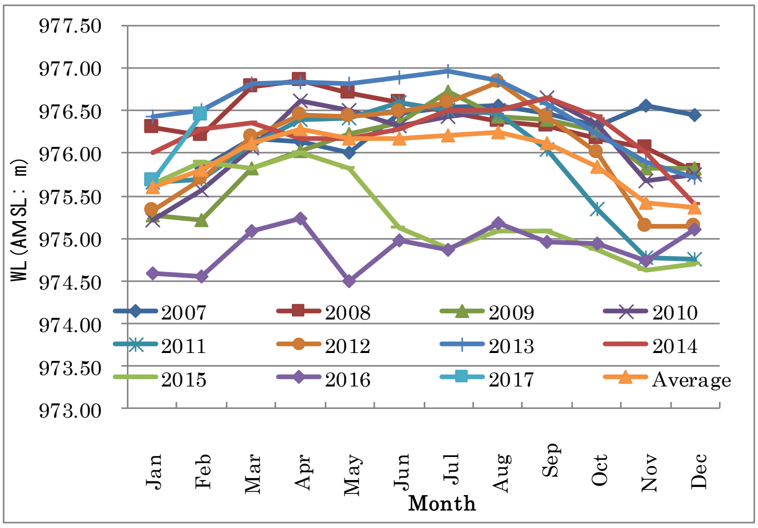
Source: JICA Study Team

Photo 2.3.1 Approval of Water Right on Kafue River for LWSC

LWSC is measuring the water level of Kafue River at the Iolanda Intake. The water level fluctuates seasonally as shown in Figure 2.3.8. After February 2007, the highest water level was 976.96 m above mean sea level in July 2013 while the lowest water level was 974.56 m above mean sea level in May 2016.

According to the seasonal fluctuation of the water level data, the lowest water level is around January when the rainfall peaks and water level rises up thereafter to the highest water level in July. The highwater level is not occurred in the rainy season and it is presumed to be related to the water storage function of Kafue Plain located upstream of Kafue River and the operation of Itezhi-tezhi Dam. In Kafue Plain, the water level is lowered and the reservoir area decreases in the dry season, whereas in March and April at the end of the rainy season, the reservoir area increases and the water storage function works. Due to the water storage function of Itezhi-tezhi Dam and Kafue Plain, the Kafue River at the vicinity of the existing Iolanda Intake located downstream of the dam shows the lowest water level in January despite the peak of rainfall. After that, Itezhi-tezhi Dam releases water from February, the amount exceeding the storage capacity of Kafue Plain increases the flow and level of Kafue River.

The highwater level in July in the vicinity of the existing Iolanda water intake is affected Kafue Gorge dam operation located downstream of the intake. Furthermore, Zambia was hit by drought in 2015 and 2016, and the water level of Kafue River also declined greatly, but since January 2017, it exceeds the average water level and the water level recovery can be confirmed.



Source: JICA Study Team based on the water analysis result in Iolanda Treatment Plant

Figure 2.3.8 Water Level of Kafue River (Iolanda Intake Facility)

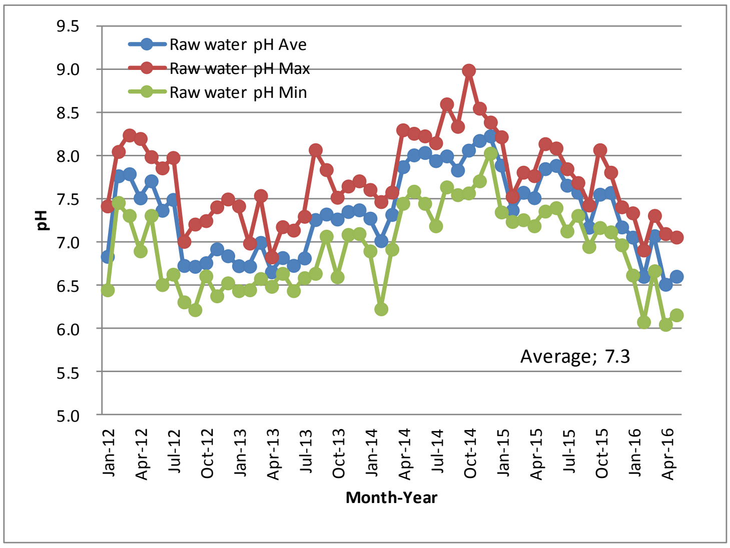
3) Water Quality

In the Iolanda Water Treatment Plant (WTP), raw water quality of Kafue River was analyzed. Based on LWSC's data after January 2012, pH, turbidity, and color of Kafue River are described below.

i) pH

Figure 2.3.9 indicates the pH values of raw water from the Kafue River. The highest value was pH 9.0; the lowest value was pH 6.0; and the average value was pH 7.3. There was no seasonal factor for pH variation. From April to December in 2014, the values exceeding the average pH 8.0 often have been recorded. Except for the abovementioned period, the values stayed between pH 6.7 and pH 7.8, within the usual range of a natural river.

The abnormally high pH in 2014 was hard to consider as a natural phenomenon, and it is estimated that there is a problem in the accuracy of the equipment, since almost constant numerical increase is recognized.



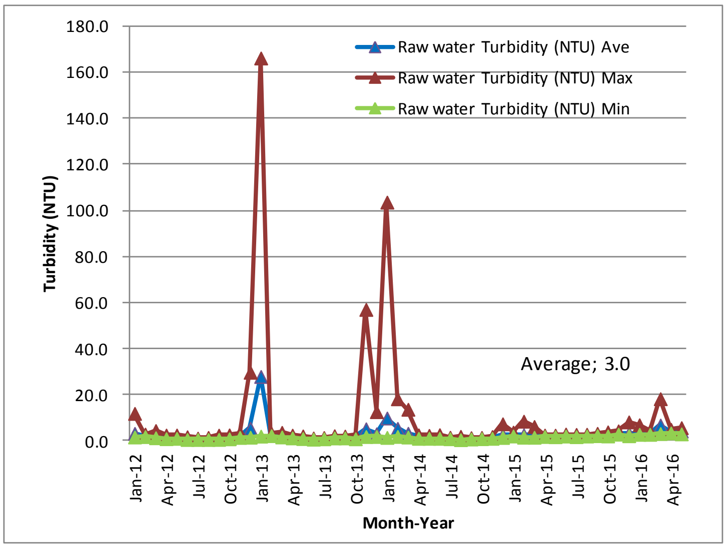
Source: JICA Study Team based on the water analysis result in Iolanda Treatment Plant

Figure 2.3.9 Monthly pH Values of the Kafue River (Average, Maximum, and Minimum Values)

ii) Turbidity

Figure 2.3.10 shows the raw water turbidity taken from Kafue River. The minimum turbidity value is 0.4 NTU and the average value is 3.0 NTU. Both values stayed at a low level. Meanwhile, 166.2 NTU was recorded on 10 January 2013 (13.7 NTU on 9 January and 60.8 NTU on 11 January). In addition, 260 NTU was recorded in the past. Although the degree differs depending the year, there is a phenomenon in which the turbidity rapidly increased in January of the rainy season peak.

It is supposed that LWSC's water analysis results for turbidity would be lower than half of the actual turbidity values as discussed in Section 2.3.6 later. Even though the actual turbidity may be higher than the above, the raw water turbidity at the Iolanda Intake still shows low value even if it is considered twice the measured value.

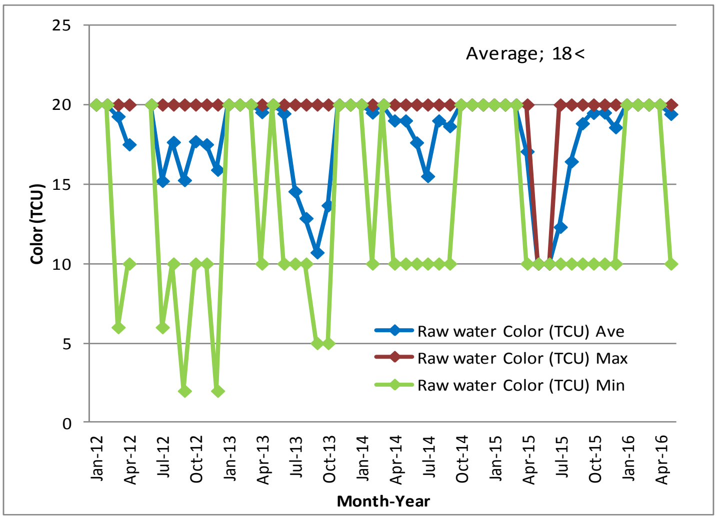


Source: JICA Study Team based on the water analysis result in Iolanda Treatment Plant

Figure 2.3.10 Monthly Turbidity of Kafue River (Average, Maximum, and Minimum Values)

iii) Color

Figure 2.3.11 shows the color of raw water taken from the Kafue River. The chronoscope used by the water laboratory in the Iolanda Water Treatment Plant can measure only up to 20 TCU. Therefore, the maximum recorded value shows 20 TCU. It is obvious that the actual value of color often exceeds 20 TCU as seen in the graph of the maximum value. As seen in the graph of the minimum value, the value of color tends to become high in January together with turbidity.



Source: JICA Study Team based on the water analysis result in Iolanda Water Treatment Plant

Figure 2.3.11 Monthly Color of Kafue River (Average, Maximum, and Minimum Values)

iv) Impact of Wastewater from Kafue

The town of Kafue is located 13 km upstream from the Iolanda Intake and has sewage treatment plant and industrial factories. Effluent of domestic sewage and industrial wastewater is controlled by the licensing system prescribed in the Water Pollution Control (Effluent and Waste Water) Regulations (1993), in accordance with the Environmental Protection and Pollution Control Act (1990).

In other words, raw water contamination by wastewater, treated water, and industrial wastewater is to be managed by a license system. Table 2.3.2 compares the results of river water quality survey by the JICA Study in the vicinity of the existing Iolanda Water Treatment Plant to the wastewater / sewage discharge regulation, and the Zambian Water Quality Standards. Based on the water quality analysis results, the Kafue River water meets the Zambian Drinking Water Quality Standard (AZ 190, 2010) except for turbidity, color, and residual chlorine. Also, al the water quality of each item is within the regulation of wastewater and sewage discharge, and water quality standard Zaire..

Table 2.3.2 Comparison Between Water Quality Standard for Kafue River and Effluent Standard in Zambia

No.	Parameter	Environmental management Act from Zambia	Zambia Water Standard	6/6/2016	8/6/2016	10/6/2016	20/6/2016	22/6/2016	24/6/2016
				Intake	Intake	Intake	Intake	Intake	Intake
1	pH	6.0-9.0	6.5-8.0	7.88	8.07	7.92	7.85	7.84	8.05
2	Total Cond	4,300 US/em	150 ms/m	23.3	23	22.8	23.4	23.3	23.6
3	Total Hard [mg/l CaCO3]	-	500	118	123	126	120	124	125
4	TDS [mg/l]	3,000	1,000	160	168	172	172	150	170
5	TDS by Sum [mg/l]	-	-	107	109	111	108	110	111
6	SS [mg/l]	100	-	<20	<20	<20	<20	<20	<20
7	Colour [mg/l [Pt-Co]]	20	15	4	18	24	20	19	10
8	Turbidity [NTU]	15	5	9.52	10.9	7.85	8.61	9.84	8.88
9	P Alk. [mg/l CaCO3]	-	-	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
10	M Alk. [mg/l CaCO3]	-	-	83.9	83	84.3	83.3	84.2	86.6
11	Al [mg/l]	2.5	0.2	<0.05	<0.05	0.19	0.16	0.16	<0.05
12	Ca [mg/l]	-	200	27.9	28.9	29.4	28.5	29.1	29.8
13	Fe [mg/l]	2	0.3	<0.05	<0.05	0.09	0.07	0.08	<0.05
14	K [mg/l]	-	-	1.72	2	1.69	1.86	1.87	1.7
15	Mg [mg/l]	500	150	11.8	12.3	12.7	11.9	12.4	12.2
16	Mn [mg/l]	1	0.1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
17	Na [mg/l]	-	200	8.22	8.08	7.95	8.28	8.1	7.25
18	Si [mg/l]	-	-	7.34	7.78	8.33	7.94	8.22	7.6
19	F [mg/l]	2	1.5	0.337	0.183	0.209	0.202	0.22	0.212
20	Cl [mg/l]	800	250	3.45	2.65	2.4	2.36	2.41	2.45
21	NO3 as N [mg/l]	50	10	0.183	<0.13	<0.13	<0.13	<0.13	0.134
22	NO2 as N [mg/l]	2	1	0.005	0.006	0.027	0.005	0.005	0.005
23	SO4 [mg/l]	1,500	400	33.4	36.2	35.1	32.9	34.5	35
24	CN [mg/l]	0.2	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
25	Coliforms [Colonies/100ml]	25,000	-	130	170	93	89	1800	10
26	Faecal Col [Colonies/100ml]	5,000	-	40	0	26	2	1	0
27	BOD [mg/l O2]	50	-	<10	<10	<10	<10	<10	<10
28	DO [mg/l O2]	5	-	8	8	8	8	8	8
29	Ag [mg/l]	0.1	0.05	0.001	0.001	<0.001	0.001	0.001	0.001
30	As [mg/l]	0.5	0.01	0.001	0.001	0.001	0.001	0.001	0.001
31	Ba [mg/l]	0.5	0.7	0.238	0.261	0.233	0.203	0.227	0.231
32	Cd [mg/l]	0.5	0.003	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
33	Co [mg/l]	1	0.5	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
34	Cr [mg/l]	0.1	0.05	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
35	Cu [mg/l]	1.5	1	<0.001	0.085	<0.001	<0.001	<0.001	0.002
36	Hg [mg/l]	0.002	0.001	0.001	0.001	0.001	0.002	0.001	0.001
37	Pb [mg/l]	0.5	0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
38	Se [mg/l]	0.02	0.01	0.002	<0.001	0.003	0.001	0.002	0.001
39	Zn [mg/l]	10	3	0.032	0.026	0.034	0.032	0.036	0.023
40	Ammonia as N [mg/l]	5	-	0.06	0.056	0.067	0.046	0.049	0.095
41	Ammonia as NH3 [mg/l]	10	-	0.073	0.068	0.081	0.055	0.06	0.115
42	Total P as P [mg/l]	1	-	<0.05	<0.05	<0.05	0.06	<0.05	<0.05
44	Phenols [mg/l]	0.2	0.002	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
45	Free residual chlorine [mg/l]	-	0.2-0.5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Source: JICA Study Team

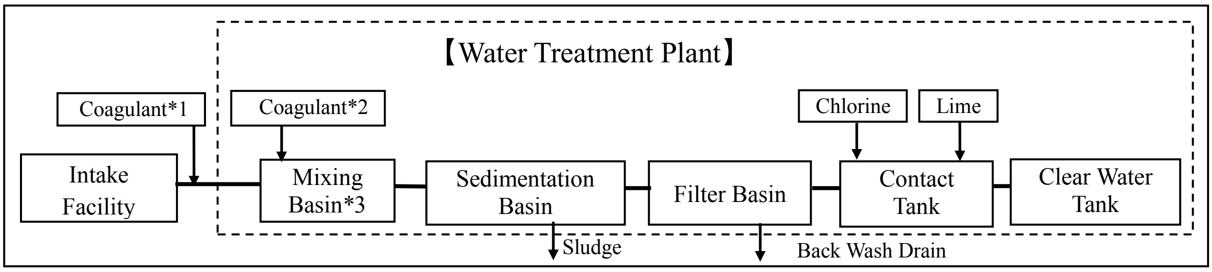
2.3.2 Water Intake and Transmission Facility and Water Treatment Plant

(1) Treatment Process

Water treatment process of the existing Iolanda Water Treatment Plant (WTP) is shown in Figure 2.3.12. Moreover, panoramic images of the intake facility and WTP are shown in Photos 2.3.2 and 2.3.3, respectively. The design daily maximum water production of the WTP is 110,000 m^3/day.

The Iolanda WTP adopts rapid filtration method but does not have any of sludge treatment facility and backwash water treatment facility. Sludge deposits from coagulation, sedimentation basin and backwash water drained from the filters are discharged to the Mucho River outside the plant directly. The

Preparation of Feasibility Studies and Preliminary Design for Water Supply and Sanitation Projects, 2012 (Feasibility Study of MCC project) pointed out that sewage treatment plant should be installed when renovating the existing Iolanda WTP, but the Zambian government judged that the sewage treatment is not necessary for the time being. Table 2.3.3 shows the specifications of major equipment of the Iolanda WTP and problems identified.



Note: *1: Temporary facility, *2: Permanent facility (Not in use due to out of order), *3, Not in use due to out of order
Source: JICA Study Team

Figure 2.3.12 Process Flow of Iolanda WTP

Source: JICA Study Team

Photo 2.3.2 Iolanda Water Intake Facility

Source: JICA Study Team

Photo 2.3.3 Iolanda WTP

Table 2.3.3 Principal Features and Problems of the Existing Iolanda WTP

Facility	Principal Features	Problems
Intake Facility (Intake Tower)	- Intake gate: sluice gate, 4 units (2 units at high position and 2 units at low position) - Screen: travelling screen, 2 units - Intake pump ・Vertical multi-stage turbine ・4 units (including one stand-by) ・Head: 40 m, Discharge:1,700 m^3/hour, Output: 250 kW	- Breakdown of travelling screen (2 units) - Sedimentation in suction pit - Water leakage from pump - Water leakage from valve

Facility	Principal Features	Problems
Raw Water Rising Main	- Steel pipe; Diameter 675 mm×2 lines - Electromagnetic flow meter: one unit per line - Temporary coagulant injector: 2 units of diaphragm pump, polymer flocculent (Sudfloc)	- Temporary coagulant injector is installed due to deterioration and breakdown of the existing one.
Coagulant Dosing Facility	- Saturation tanks: 9.8 m (L) × 3.0 m (W) × 3.0 m (H, effective depth: 2.7 m) × 2 units, capacity: 79 m^3 per unit - Circulation pumps: 150 liter/min × 2 units (including one stand-by) - Solution tanks: 3.0 m (L) × 1.8 m (W) × 1.8 m (H, effective depth: 1.5 m) × 3 units, capacity: 8 m^3 per unit - Dosing pumps: 23 liter/min × 3 units - Mixers: 1.5 kW × 3 units	- Deterioration and saturation of solution tanks - Deterioration and damage of circulation pumps - Deterioration and damage of dosing pumps - Breakage and deterioration of pipes - Deterioration of mixers
Mixing Basin	- Number of basins: 2 units - Dimension: 2.7 m (L) ×2.7 m (W) × 4.7 m (H, effective depth: 4.4 m) - Capacity: 27 m^3 per unit - Number of mixer: 2 units - Retention time: 0.7 min (full operation)	- Damage of one mixer and malfunction of another mixer - Sedimentation of chemicals at the bottom of the basin
Chemical and Sedimentation Basin	- Type: suspended solid contact clarifier (sludge blanket type with sludge corn and without mixer) - Number of clarifier: 30 units - Dimension of clarifier: 9 m (L) × 9 m (L) × 9.5 m (H, effective depth: 8.7 m) - Capacity: 216 m^3 per unit - Retention time: 85 min - Up-flow rate: 33 mm/min (1.98 m/hour)	- Clogging of sludge extraction pipe - Corrosion of sludge extraction pipe - Water leakage from sludge extraction system - Malfunction of sludge extraction valve - Water leakage from concrete joint - Deterioration of sludge corn - There is the case when the supernatant water in clarifier is more turbid than raw water. The reason is deemed that flock was mingled with supernatant water.
Rapid Sand Filter	- Type: gravity filter - Number of filter basins: 20 units, dimension of unit: 10.7 m (L) × 4.6 m (W) × 3.7 m (H) - Area of filtration: 48.9 m^2/unit - Filtration rate: 5 m/hour (120 m/day) - Thickness of sand filter: 600 mm - Thickness of gravel layer: 500 mm - Washing method: air scouring and back washing - Back wash pumps: 480 m^3/hour, 30 kW × 4 units (including one stand-by) - Blower for air scouring: 1,770 m^3/hour, 37 kW × 2 units (including one stand-by)	- Damage of blower (One unit) - Water leakage from piping - Corrosion of and water leakage from the valves - Malfunction of pressure meter and flow meter for back washing - No sump pump in pump hall - Damage of filter sand washing machine
Chlorine Dosing Plant	- Chlorine agent: liquid chlorine (900 kg cylinder) - Consumption: 120 to160 kg/day	- Nothing

Facility	Principal Features	Problems
Central pH Plant	- Chemicals: hydrated lime - Solution tanks: 2 units (including one stand-by), 2.5 m (L) × 2.0 m (W) × 1.5 m (H, effective depth: 0.75 m) - Capacity: 3.8 m^3/unit - Materials: mild steel and nylon coating - Mixers: two units in total, one unit for each solution tank - Slurry circulation pumps: 2 units (including one stand-by) × 100 liter/min - Feeder: 1 unit, 0.7 m (L) × 0.4 m (W) × 0.4 m (H), 1.5 liter/min	- Deterioration of the facilities
Contact Tank	- Number of tank: 1 unit (with 2 divisions) - Estimated dimension: 11 m (L) × 8 m (W) × 4.4 m (H) - Estimated capacity: 290 m^3	- Nothing
Treated Water Reservoir	- Number of reservoir: 1 unit (with 2 divisions) - Estimated dimension: 60 m (L) × 27 m (W) × 4.4 m (H) - Estimated capacity: 5,300 m^3	- Water leakage from concrete construction joint - Re-bar corrosion and abruption of concrete - Some valves are not operable.
High Lift Pump Station (Transmission Pump Station)	- Transmission pump; 4 units (including one stand-by) - The details are described in Section 2.3.3.	- Refer to Section 2.3.3.
Substation	- 11/3.3 kV, 7,500 kVA transformer × 2 units for intake and transmission pumps (including one stand-by) - 11/0.4 kV transformer × 1 unit for equipment of WTP and administration office	- Nothing

Source: MCC's F/S Report (January 2012) and information collected by the JICA Study Team

(2) Treated Water Quality

Based on the data measured at the water laboratory in the Iolanda WTP, pH, turbidity, and color are described below. It is being monitored on a daily basis. The drinking water standard of Zambia refers to Table 2.2.1 above-mentioned.

i) Water Quality of Treated Water

Table 2.3.4 shows the water quality data of treated water in the existing Iolanda WTP, which were conducted under the MCC FS in August 2012 and by the JICA Study Team in June 2016. Both results showed the same level of quality, which meets the Zambian Standard. Also, the water quality data of 2012 and 2016 are almost similar.

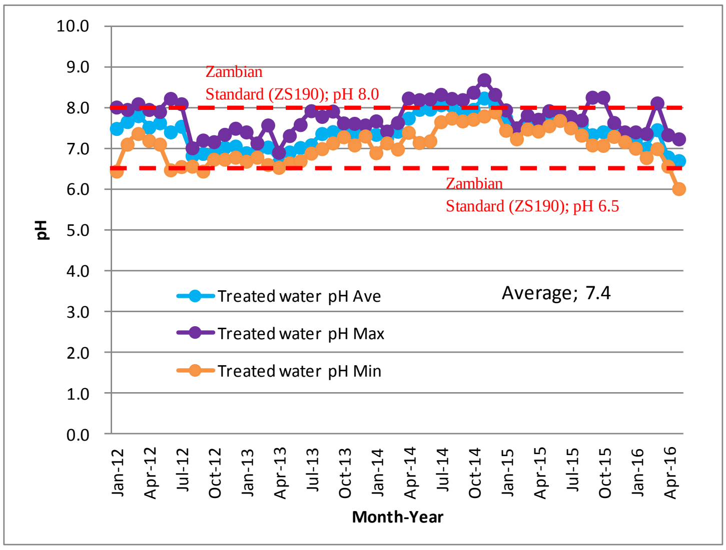
Table 2.3.4 Water Quality Data of Treated Water in the Existing Iolanda WTP

Parameter	Drinking Water Quality Standards in Zambia ZS190 : 2010	MCC F/S Date 2012/8/24	This Project Date 2016/6/23
pH	6.5 - 8.0	7.96	7.41
Color (TCU)	15	10	5
Turbidity (NTU)	5	0.81	1.59
Conductivity (mmhos/cm)	1500	186	255
Total Dissolved Solids (mg/l)	1000	93	128
Total hardness (mg CaCOs/l)	500	122	122
Iron (mg/1)	0.3	<0.01	<0.01
Aluminum (mg/1)	0.2	—	<0.03
Mercury (mg/1)	0.001	—	<0.0002
Chlorides (mg/1)	250	14.0	16
Arsenic (mg/1)	0.01	<0.0002	<0.0002
Nitrites (N02-Nmg/1)	1	<0.001	<0.01
Zinc (mg/1)	3	0.006	<0.005
Nitrates (NO3-Nmg/1)	50	<0.01	<0.01
Cadmium (mg/1)	0.003	—	<0.0003
Calcium (mg/l)	200	24.0	24
Fluorides (mg/l)	1.5	0.08	0.13
Sodium (mg/l)	200	—	11.54
Manganese (mg/1)	0.1	<0.01	<0.01
Total coliforms (#/100ml)	0	0	0
Feacal coliforms (#/100ml)	0	0	0

Source： MCC's F/S and field report collected by the JICA Study Team

ii) pH

Figure 2.3.13 shows the pH values of treated water at the Iolanda WTP. The maximum value is pH 8.7 while the minimum value is pH 6.0; and the average value is pH 7.4. Sometimes, the value is out of the range of the water quality standard between pH 6.5 and pH 8.0. This is due to erroneous injection of hydrated lime. The value exceeding pH 8.0 is recorded almost every year, which is consistent with the period when raw water pH is high. The pH value out of the standard does not bring direct impact on human health. But alkaline agent should be adjusted responding to the pH values of raw water.



Source: JICA Study Team based on the water analysis result in Iolanda Treatment Plant

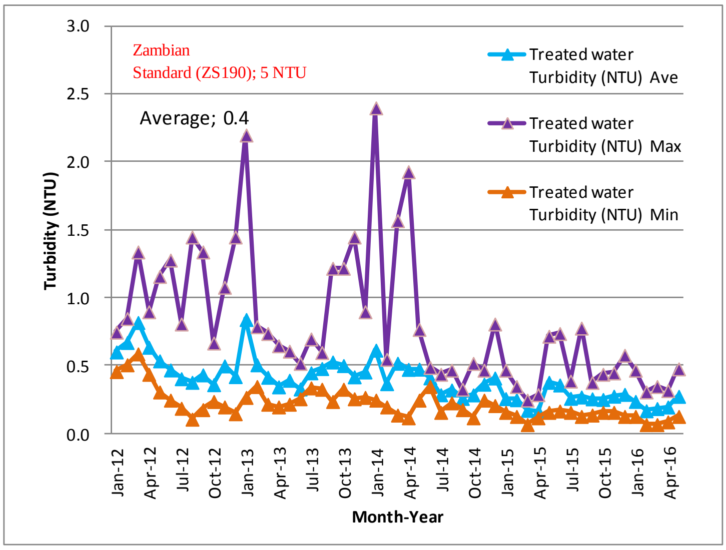
Figure 2.3.13 Monthly pH Values of Iolanda WTP (Average, Maximum, and Minimum Values)

iii) Turbidity

Figure 2.3.14 shows the turbidity at the Iolanda WTP. The minimum value is 0.1 NTU while the maximum value is 2.4 NTU; and the average value is 0.4 NTU. When turbidity of raw water increases in January, turbidity of treated water also tends to increase but the maximum value is far below the standard of 5 NTU and treated turbidity is good according to the analyzed data by LWSC. However, as described in Section 2.3.6, the turbidity standard conformity rate in the distribution pipe network is not 100%. Even considering the deterioration of water quality in the transmission and distribution pipe network, the LWSC water quality analysis results may show lower values than the actual ones. Also, the turbidity of raw water may be measured lower than the actual. Therefore, improvement of turbidity control in the process of coagulation sedimentation and sand filtration is also necessary.

During the observation by the JICA Study Team at the WTP, flocks formed in the sedimentation tanks flowed into the filtration tanks and the surface in filtration tanks was undulated*[10]. The sand surface height of the filtration pond was also uneven and it was not a situation where proper filtration could be done. These observations suggest that turbidity treatment could not be conducted properly.

[10] This phenomenon is commonly referred to as carry-over, which occurs when coagulation sedimentation is not carried out properly



Source: JICA Study Team based on the water analysis result in Iolanda Treatment Plant

Figure 2.3.14 Monthly Turbidity Values of Iolanda WTP (Average, Maximum, and Minimum Values)

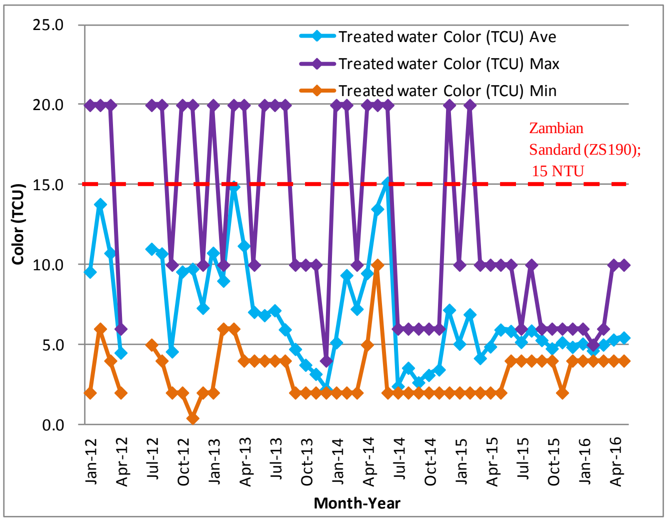
iii) Color

Figure 2.3.15 shows the color of treated water in the Iolanda WTP.

As chronoscope of the water laboratory in the Iolanda WTP can measure up to 20 TCU only, the maximum recorded value is 20 TCU. Although the standard of color value is 15 TCU, the monthly maximum value often exceeds 15 TCU. In June 2014, the average value exceeded 15 TCU. Considering the limitation of the measuring equipment, the average value by month would often exceed 15 TCU.

Due to failure of chemical feeding facility, the chemical (coagulant) is fed by temporary facility, which was installed at the starting point of the raw water transmission line. Chromaticity treatment can be affected.

The color that is out of standard does not bring direct impact on human health but it is desirable to improve the color component management. As a result of this study, no color component could be confirmed. According to the water quality analysis conducted by the MCC F/S and the JICA Study Team, the concentrations of iron and manganese are within the standard values, and color tends to increase at high turbidity. It seems to contain mud and organic matter.



Source: JICA Study Team based on the water analysis result in Iolanda Treatment Plant

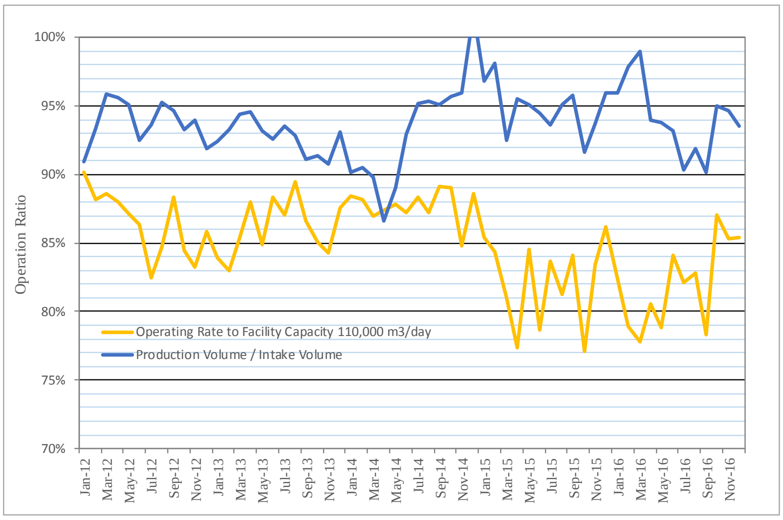
Figure 2.3.15 Monthly Color Values of Iolanda WTP (Average, Maximum, and Minimum Values)

(3) Operation of Existing Intake, Water Transmission and Water Treatment Facilities

The operation ratio had been 85-90% from 2012 to 2014; however, it declined to less than 85% after 2015 despite the situation where water demand is not satisfied. On the other hand, the operation rate of treatment process has been 90-95%, which is as efficient as normal WTP. Therefore, the main reason of the operation rate decrease is not the processing efficiency inside the WTP but supposed to be the decrease of water intake due to reduction of pump capacity and/or power shortage.

MCC project will renew the intake pumps and remove sand in intake pit in order to improve water intake capacity. Therefore, operation rate of Iolanda WTP is expected to increase by up to 90-95%. In addition, along with facility improvement and performance improvement of operation staff for MCC project to produce synergistic effects, operation rate of 95% can be achieved.

An average of annual hours of power cut between 2011 and 2015 is approximately 148 hours. It decreased the operation rate by 2%.



Note: Operation ratio of treatment process = outflow / inflow x 100
Source: JICA Study Team based on the monitoring data by LWSC

Figure 2.3.16 Operation Ratio and Treated Water Efficiency by Iolanda WTP

The operation and maintenance (O&M) for the water intake, raw water main, and WTP is performed by 40 staffs. Daily operation is managed by 3-shift system. "Daily Operation Report" is prepared events to share takeover matters. In the daily operation report, operating data are recorded such as inflow and outflow rates by flow meters, pump operation hours, chemical dosing rates, backwash time of filtration tank, pump motor current and temperature, lubrications, chemical stocks, and so on.

Some equipment are left deteriorated or malfunction in the WTP due to the expiration of period for manufacturer's support service and difficulty in procurement of spare parts from the domestic market. Planned inspection and maintenance coupled with capacity development of staffs crucial.

2.3.3 Water Transmission Facility

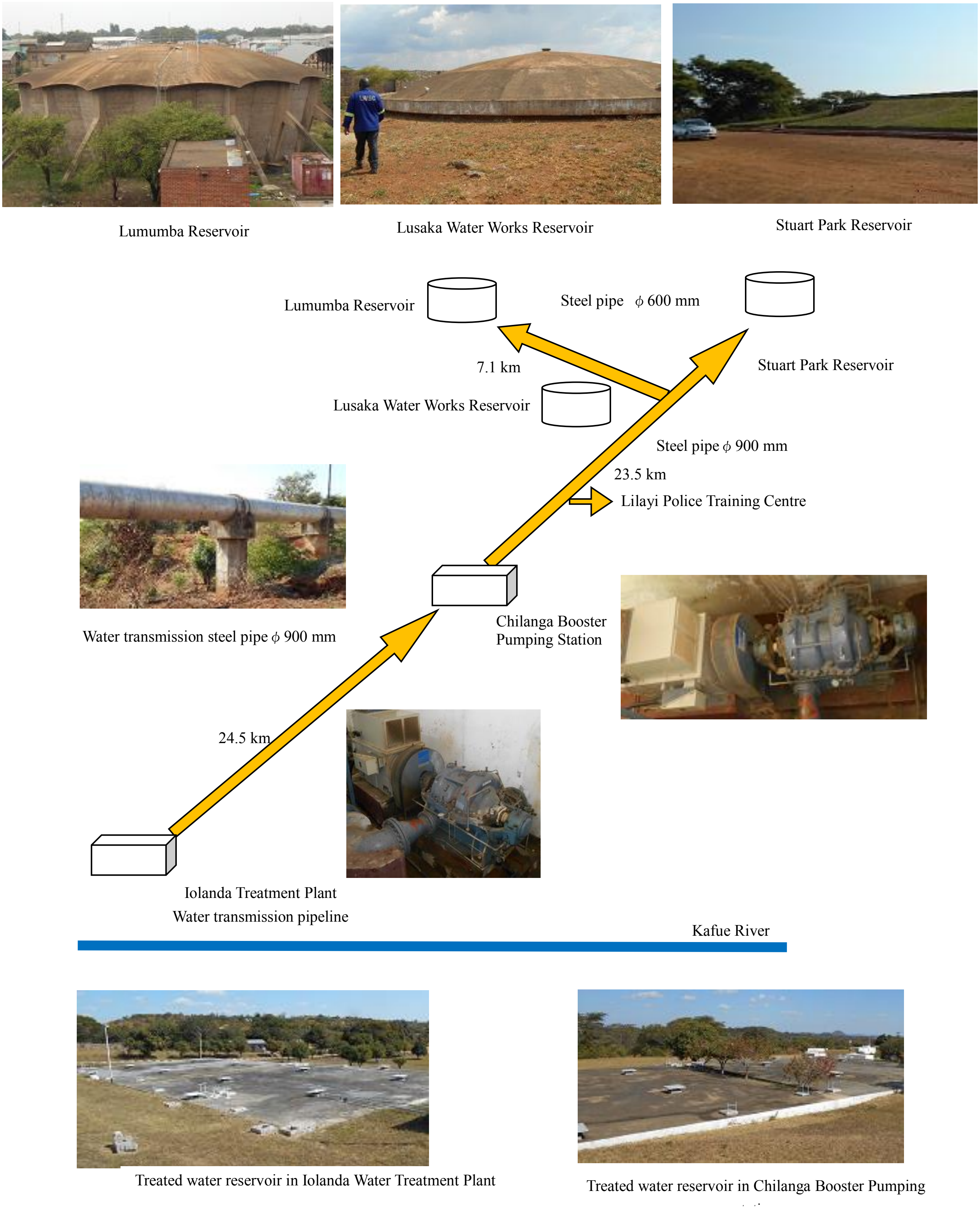
(1) Current Status of Water Transmission Facility

The water treated in Iolanda WTP is transferred to three distribution centers in Lusaka, through Iolanda Pumping Station in the Iolanda WTP site and Chilanga Booster Pumping Station. Three distribution centers are named as: Stuart Park, Lusaka Water Works, and Lumumba. These distribution centers deliver some of the water to service population directly, and transfer another water to other reservoirs. These three distribution centers have a relatively large capacity reservoir and this is the reason why they are called "Distribution Centre".

The existing water transmission system and water transmission facilities are shown in Figure 2.3.17 and Table 2.3.3. The existing water transmission main is a steel pipe installed in 1968 and the length from the Iolanda WTP to Stuart Park Reservoir is 48 km with a lift of 300 m. The high water level of Stuart Park Reservoir is 1,309 m, which is 20 m higher than other two reservoirs. The trunk transmission main to Stuart Park Reservoir is diameter 900 mm and then branches off to Lusaka Water Works Reservoir in the south part of Lusaka. The branch transmission main is diameter 600 mm and runs through the Lusaka Water Works to reach Lumumba Reservoir in the west part of Lusaka. On the way to Stuart Park

Reservoir, a distribution main branches off to/from Chilanga Booster Pumping Station to Lilayi Police Training Centre.

The Iolanda Pumping Station and Chilanga Booster Pumping Station, at halfway point of the trunk transmission main, each have four Japanese pumps with high pump head (three for regular use and one for back up; total number is 8) installed by Japanese grant aid project in 1988. In addition, electric motors of the pumps are also made in Japan.



Source: JICA Study Team based on the data provided by LWSC

Figure 2.3.17 Current Water Transmission Facility (Water Transmitted Upward in the Figure)

Table 2.3.5 Specification of Current Water Transmission Facility

Location	Facility	Altitude
Reservoirs in Lusaka (Categorized as water distribution facility)	1. Stuart Park Reservoir - Concrete 1A Capacity: 11,365 m^3 HWL:1,309 m - Concrete 1B Capacity :11,365 m^3 HWL:1,309 m - Concrete 2 Capacity: 22,730 m^3 HWL:1,309 m - Concrete 3 Capacity: 22,730 m^3 HWL:1,309 m - Concrete 4 Capacity: 22,730 m^3 HWL:1,309 m 2. Water Works Reservoir - Contact Tank Plant 1 Capacity: 870 m^3 HWL:1,290 m - Plant 2 No.1 Capacity: 2,273 m^3 HWL:1,288 m - Plant 2 No.2 Capacity: 2,273 m^3 HWL:1,288 m 3. Lumumba Reservoir - Concrete No.1 Capacity: 4,545 m^3 HWL:1,285 m - Concrete No.2 Capacity: 4,545 m^3 HWL:1,285 m	Average HWL Stuart Park Reservoir 1,307 m Water Works Reservoir 1,286 m Lumumba Reservoir 1,278 m
Water transmission main to Chilanga Booster Pumping Station	1. Water transmission main to Stuart Park Reservoir - Installed in 1968, Steel pipe ϕ900 mm, Length: 23.5 km, Altitude: 1,155 to 1,307m 2. Branch water transmission main to Lusaka Water Works Reservoir and Lumumba Reservoir - Steel pipe ϕ600 mm, Length: 7.1 km, Altitude: 1,286 to 1,278 m	Altitude difference within the section 152 m -8 m
Chilanga Booster Pumping Station	1. Treated water reservoir - Capacity: 4,550 m^3, HWL: 1,156 m 2. Pump equipment (same equipment composition as water transmission pump in Iolanda Water Treatment Plant) - Horizontal axis two stages pump, Regular use: 3 nos, Stand-by: 1 no - Diameter: Intake 450 mm and Discharge 250 mm, Flow rate: 25.5 m^3/min, Total pump head: 242 m - Motor: 3.3 kV, 1350 kw, Rote valve in outlet side, Diameter:400 mm	Chilanga WTP HWL 1,155 m
Water transmission main from Iolanda WTP to Chilanga Booster Pumping Station	Installed in 1968, Steel pipe ϕ900 mm, Length: 24.5 km, Altitude:1,007 to1,155 m Water control valve: 20 nos, Air valve: 76 nos, Sludge drainage valve: 37 nos (The number of valves is the total number of valves from Iolanda Water Treatment Plant to Stuart Park Reservoir)	Altitude difference within the section 148 m
Iolanda WTP Pump equipment	1. Treated water reservoir capacity 4,550 m^3 , HWL 1,008 m 2. Pump equipment (Same components of the Chilanga Booster Pumping Station) - Horizontal axis two stages pump, Regular use: 3 nos, Stand-by: 1 no - Diameter: Intake 450 mm and Discharge 250 mm, Flow rate: 25.5 m^3/min, Total pump head: 242 m - Motor: 3.3 kV, 1,350 kw, Rote valve in outlet side, Diameter: 400 mm	Iolanda WTP HWL 1,007 m

Source: JICA Study Team based on the data provided by LWSC

(2) Water Transmission Volume

Water transmission volume from the Iolanda WTP is shown in Table 2.3.6. The water transmission volume for each reservoir is controlled by a branching valve installed at branch point to Lusaka Water Works Reservoir as well as a branching valve to Lumumba Reservoir. An electromagnetic flow meter is installed at outlets of both Iolanda Pumping Station and Chilanga Booster Pumping Station to record water transmission volume. Distribution ratio by water destination is not fixed according to the monthly report of Iolanda Treatment Plant and the interview with LWSC.

Table 2.3.6 Water Transmission Volume by Each Water Destination (January to December 2015)

No.	Reservoir	Water level (m)	Water amount (m^3/day)	percentage
1	Stuart Park Reservoir	1,309	43,459	48.3%
2	Lusaka Water Works Reservoir	1,288	37,920	42.1%
3	Lumumba Reservoir	1,285		
4	Lilayi Police Training Center	(Altitude) 1,293	2,556	2.8%
5	Water transmitted to Lusaka (1+2+3+4)		83,935	93.2%
6	Leakage (from Chilanga BPS to Lusaka) (7-5)		1,280	1.4%
7	Water transmitted from Chilanga BPS	1,156	85,215	94.6%
8	Decrease (from Iolanda WTP to Chilanga BPS (9-7)		4,869	5.4%
9	Water transmitted rom Iolanda WTP	1,008	90,084	100%

Note: Reduction of water amount of No.8 came from a gap of measured value at the outlet of BPS.
Source: Prepared by JICA Study Team based on LWSC Iolanda Water Treatment Plant Monthly Report (December 2015).

(3) Electricity Usage and Countermeasure for Outage

Electricity consumption was 126,439 kWh/day in Iolanda WTP and Chilanga Booster Pumping Station in 2015 as shown in Table 2.3.7. (Average value from January to December 2015) Electricity consumption of the Iolanda WTP includes consumed electricity for water intake pump, water transmission pump, and backwashing equipment (backwashing pump and air washing blower) in rapid filtration tank.

Table 2.3.7 Electricity Consumption in Water Transmission Facilities from Iolanda WTP to Lusaka City

1	Electric Consumption in Iolanda WTP	75,352	kWh/day
2	Electric Consumption in Chilanga BPS	51,087	kWh/day
3	Electric Consumption of Iolanda-Chilanga system (1+2)	126,439	kWh/day
4	Water amount coming through Iolanda-Chilanga system	83,935	m^3/day
5	Electric Consumption per m^3 (3÷4)	1.506	kWh/m^3

Source: LWSC Iolanda Water Treatment Plant Annual Report (December 2015)

Outage experienced for 148 hours annually for 2010 – 2015 on average at the Iolanda WTP and Chilanga Booster Pumping Station. The frequency occurs 0 to five times per month. Once outage occurs, it lasts for 10 minutes to a few hours and sometimes more than eight hours. Planned outage is sometimes announced in advance but normally occur without any notice. Since transmission pumps have a flywheel, excess water hammer does not occur even if the pump suddenly stops due to outage.

The Iolanda WTP is 25 km away from the Chilanga Booster Pumping Station and these receives electricity from different systems. An outage way not always occur at the same time in the separate system. When the Iolanda WTP meets an outage, the Chilanga Booster Pumping Station can operate continuously for one hour until water level of pump pit decreases to water level for pump stop. When the Chilanga Booster Pumping Station has blackout, water stored at the reservoirs in Lusaka can be distributed. The total storage of the reservoirs is approximately 150,000 m^3 equivalent to 1.36 day's production capacity of the Iolanda WTP.

When an outage occurs at the Chilanga Booster Pumping Station, the situation is informed to the Iolanda WTP by radio or mobile phone. If the Iolanda Treatment Plant has a power under the situation, the water transmission pump operation shall be suspended. If the suspension is delayed, the pump pit in the Chilanga Booster Pumping Station will be full and will overflow. The radio system includes an uninterruptible power supply (UPS).

(4) Maintenance of Existing Transmission Pipeline

The existing transmission main was planned by British colonial government before Zambia's independence in 1964 and has been used nearly for five decades up to date. Pipe material is steel and the exposed pipe at two sections across the dry riverbed is coated by rubber. Some parts of the rubber on the exposed pipe are broken away but corrosion of pipe material is not observed. Around 133 units of valve are installed on the 48-kilometre pipeline. Water leakage is detected at some sluice valves and air valves. As seen, valve destructions to steal water is reported around Chilanga, vandalism on public property has been a crucial issue.

LWSC assigns two staffs at the Iolanda WTP for maintenance of the transmission main from Iolanda to Lusaka. They work as plumbers and welders and usually working in cooperation with other staff to maintain the transmission main. The existing transmission main is a single pipe system connected by welding. Therefore, repair does not take place frequently. The transmission main from Iolanda to Chilanga is laid along the unpaved road or in bare ground. Due to the bushes in this section, it is hard to find the position of pipe for inspection and repair.

Washout valves do not function due to sedimentation at some locations. To repair water leakage at valve, water transmission should be suspended and water remaining inside the pipe should be drained out by pump as the existing transmission pipeline main is the sole pipeline and it is hard to repair the leakage quickly. It is expected that other transmission mains will be installed through the MCC project, Chinese project, and Japanese ODA loan project and then the backup for the water transmission will be ensured in case of repairs and accidents.

The existing transmission pumps have been operated nearly for 30 years from 1988. LWSC replaced bearing, shaft, and impeller of pumps before. As of December 2015, No. 1 pump at Iolanda and No.2 pump at Chilanga were not operational due to trouble of vacuum circuit breaker (VCB) in the pump operation panel. The stand-by pumps were operated to keep the design capacity. One-unit motor at Chilanga was replaced in 2011 and another at Iolanda was replaced in 2014. As countermeasure against water hammer generated by pump shutdown, fly wheel is installed at the pump and surge tank and air valve are installed along the transmission main.

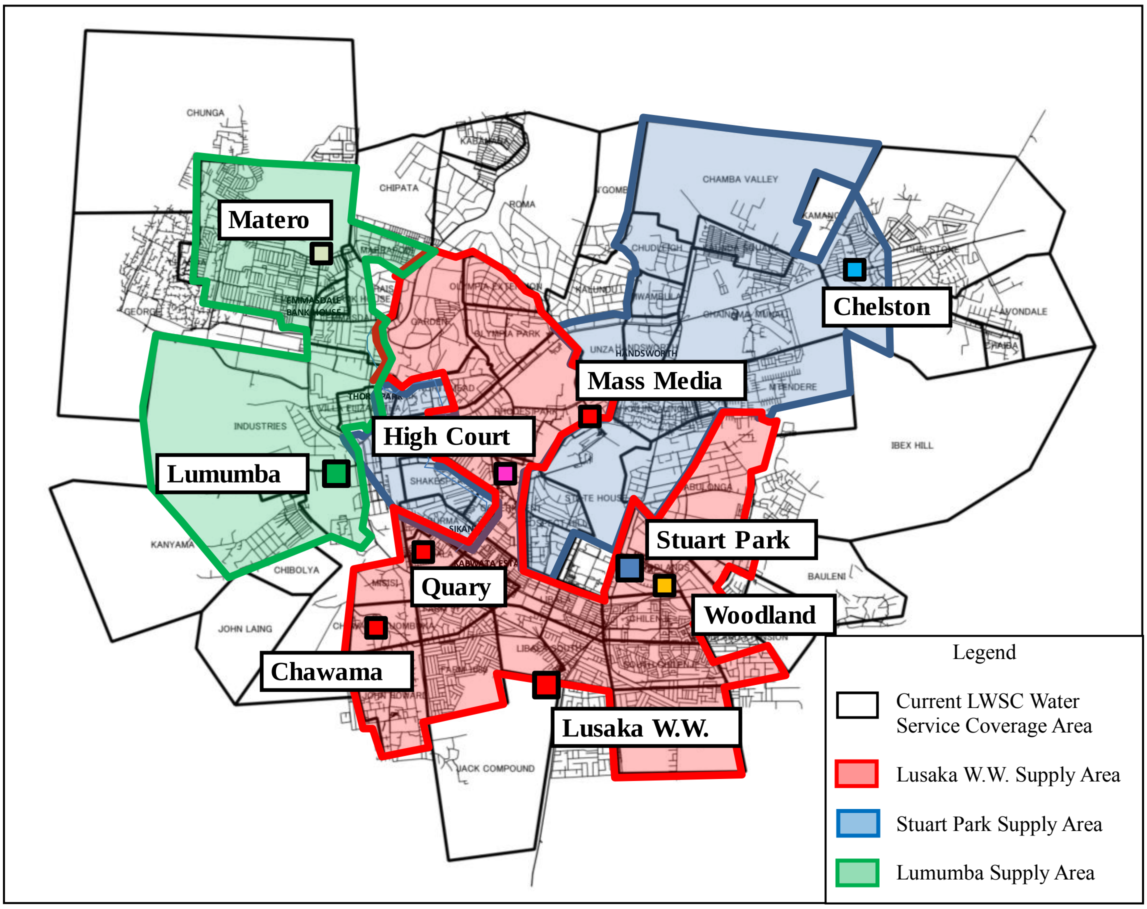
2.3.4 Distribution Facility

(1) General

The water transmission system from the Iolanda WTP sends water via the booster pumping station at Chilanga to Lusaka. Water is received at the three main distribution centers of Lusaka Water Works

(LWW) Reservoir, Stuart Park Reservoir (STP), and Lumumba Reservoir (LUM) as shown in Figure 2.3.18. These main distribution centers distribute water directly to consumers and also transfer water to other distribution centers by gravity or pumping.

The water distribution network in Lusaka is composed of reservoirs, pumping stations, and 1,684 km of distribution mains. The water distribution network does not cover entirely the LWSC service area. In localities that are not covered by the water distribution network, people receive water from groundwater source.



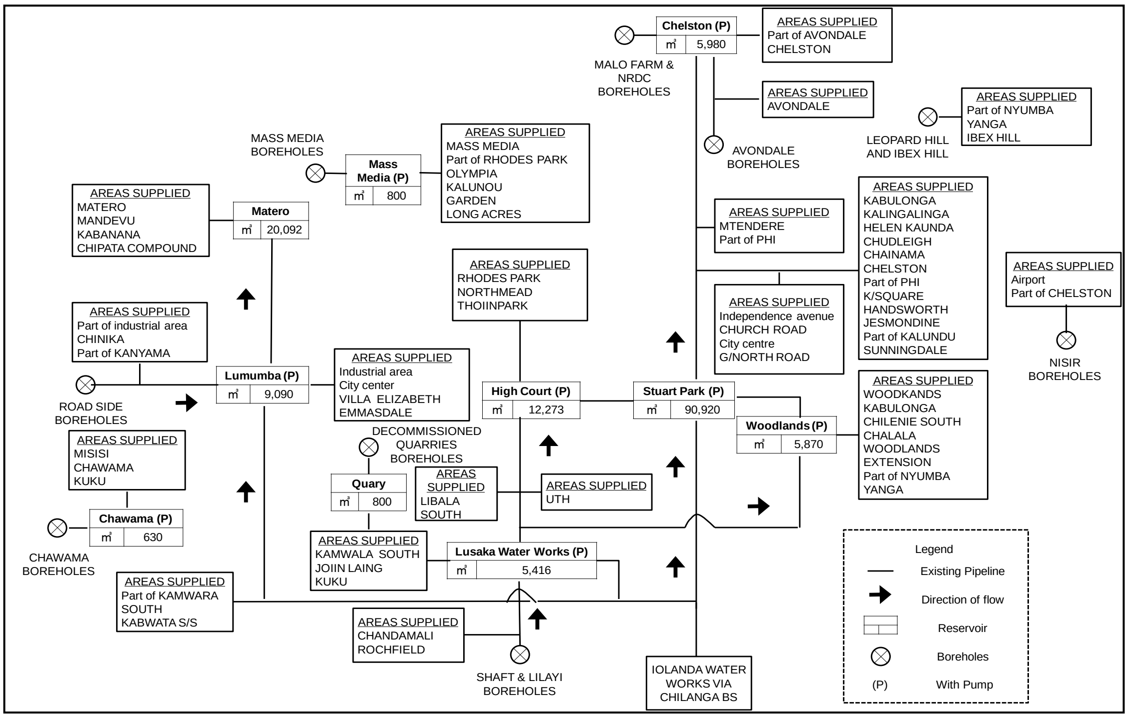
Source: JICA Study Team based on the data provided by LWSC

Figure 2.3.18 Layout of the Existing Distribution Pipes in Lusaka City

(2) Reservoir

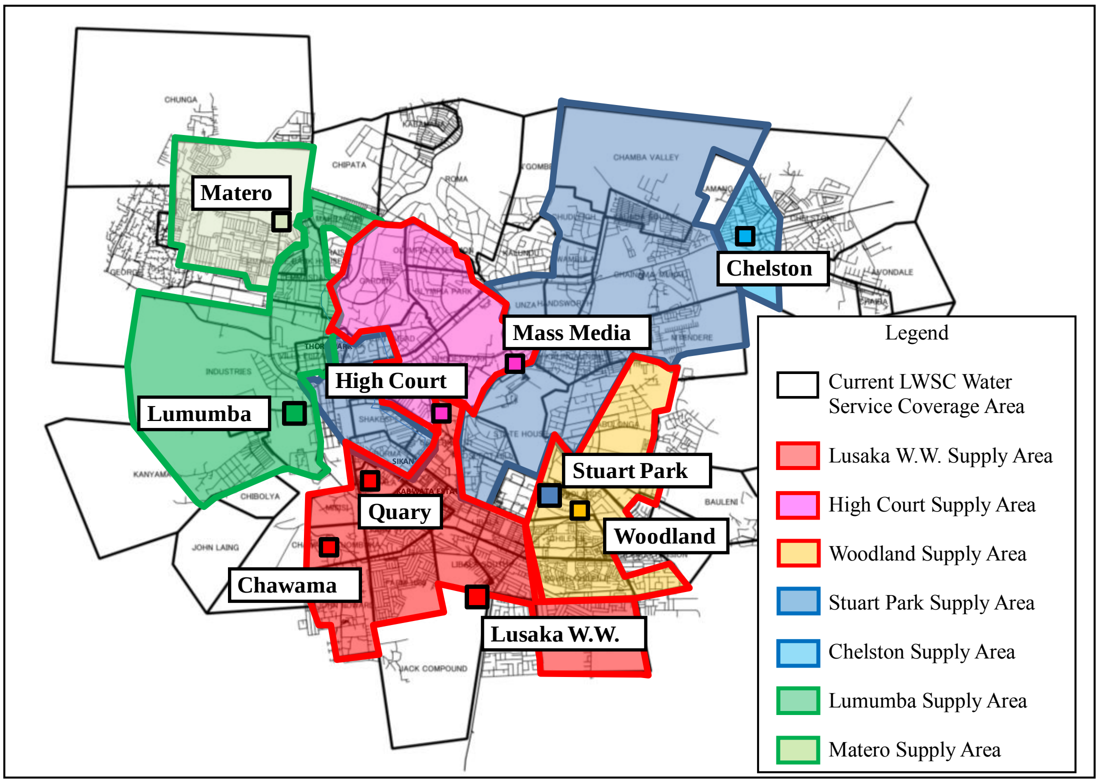
The distribution network with main distribution reservoirs in Lusaka is shown in Figure 2.3.19, Figure 2.3.20, and Table 2.3.8. There are 28 distribution tanks in total at 10 reservoirs with large capacity (Stuart Park, Woodlands, High Court, Lumumba, Lusaka Water Works, Chawama, Matero, Quary, Mass Media, and Chelston) in Lusaka as shown in Table 2.3.8.

Water is transferred from the Iolanda WTP to the distribution centers and subsequent reservoirs: from Lusaka Water Works Distribution Center to Woodlands and High Court reservoirs, from Lumumba Distribution Center to Matero Reservoir, and from Stuart Park Distribution Center to Chelston Reservoir, respectively. Mass Media, Chawama, and Quary reservoirs are not connected to the distribution centers and stored only the pumping water from the wells. It is distributed to an independent distribution network.



Source: JICA Study Team

Figure 2.3.19 Distribution Network with Main Distribution Reservoirs in Lusaka City



Source: JICA Study Team

Note: Quary Reservoir is currently used. Mass Media Reservoir and Chawama Reservoir are small-sized facilities supplying only part of the neighboring areas.

Figure 2.3.20 Target Supply Area of Major Ten Reservoirs

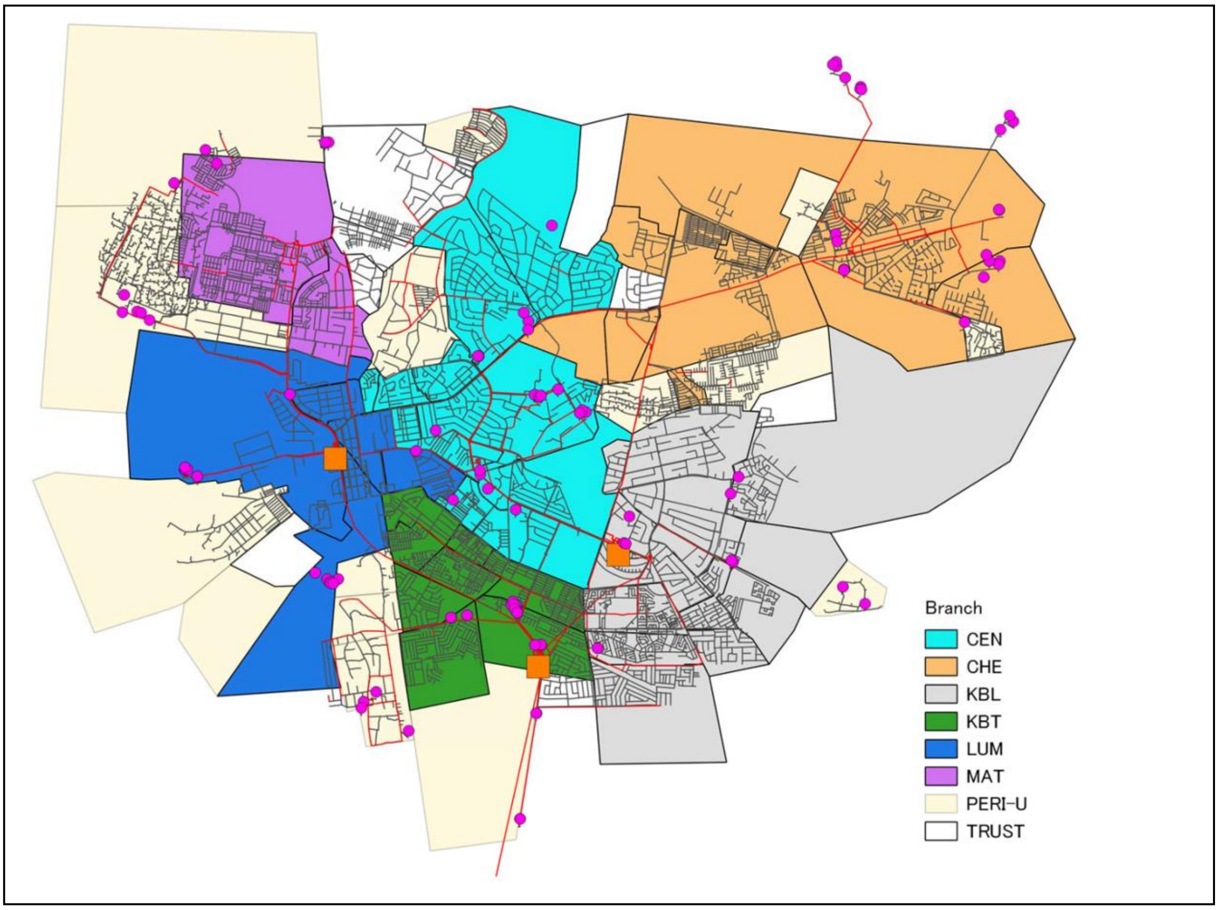
Table 2.3.8 Capacity of Major Reservoirs

Storage Reservoir Location	Description	Type	TWL	m^3	Note
1) Stuart Park	Concrete 1A	Underground	1,309	11,365	
	Concrete 1B	Underground	1,309	11,365	
	Concrete 2	Underground	1,309	22,730	
	Concrete 3	Underground	1,309	22,730	
	Concrete 4	Underground	1,309	22,730	
2) Woodlands	Concrete	Ground	1,324	4,550	
	Concrete	Elevated	1,346	1,320	
3) High Court	Concrete No.1	Ground	1,300	2,273	
	Concrete No.2	Ground	1,300	2,273	
	Concrete No.3	Ground	1,300	2,273	
	Concrete No.4	Ground	1,300	4,545	
	Concrete	Elevated	1,315	909	Not in Use
4) Lumumba	Concrete No.1	Ground	1,285	4,545	
	Concrete No.2	Ground	1,285	4,545	
5) Lusaka Water Works	Contact Tank Plant 1	Ground	1,290	870	
	Plant 2 No.1	Ground	1,288	2,273	
	Plant 2 No.2	Ground	1,288	2,273	
6) Chawama	Tower	Elevated	1,307	180	
		Ground	1,283	450	
7) Matero	Concrete	Ground	1,295	11,000	
	Steel tank 1	Ground	1,301	2,273	Not in Use
	Steel tank 2	Ground	1,301	2,273	
	Steel tank 3	Ground	1,301	2,273	
	Steel tank 4	Ground	1,301	2,273	
8) Quary	Concrete	Ground	1,281	800	Not in Use
9) Mass Media	Concrete	Ground	1,271	800	
10) Chelston	Concrete	Elevated	1,270	980	
	Concrete	Ground	1,247	5,000	
Total				151,871	Including All

Source: JICA Study Team

(3) Distribution Pipe

The LWSC service area is divided into six branches including Central, Chelston, Kabuwata, Kubulunga, Lumumba, and peri-urban as well as Matero zone, which was separated from Lumumba Branch. Figure 2.3.21 shows the area division of branches and zone and the existing distribution network.



Source: JICA Study Team based on the data provided by LWSC

Figure 2.3.21 LWSC Area Division of Lusaka City and Neighboring Areas

Table 2.3.9, Figure 2.3.22, and Figure 2.3.23 show the material and size of the existing distribution mains in the LWSC service area. Total length of existing distribution pipe is 1,684 m. There are several types of pipe: asbestos cement pipe (ACP), galvanized pipe (GP), steel pipe (SP), polyvinyl chloride (PVC), unplasticized polyvinyl chloride(uPVC) and high-density polyethylene (HDPE). ACP and GP are generally less durable and account for 54% (917 km) of the total length of the distribution mains. In addition, there is 1% (18 km) of the distribution mains whose material is unknown. These would be made of old materials such as ACP and SP. Based on the materials, it is presumed that more than half of the distribution mains are less durable.

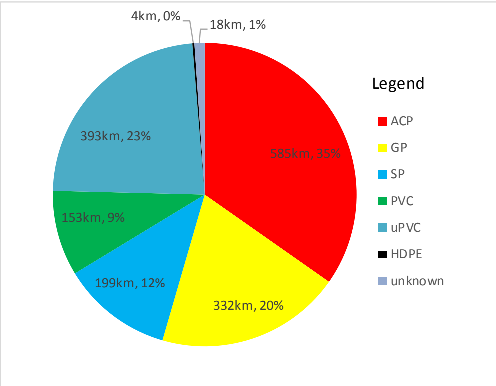
Table 2.3.9 Distribution Pipe Length by Pipe Diameter and Material

Unit: m

Material / Diameter (mm)	ACP	GP	SP	PVC	uPVC	HDPE	Unknown	Total
13	0	89	0	0	0	0	0	89
19	0	3,126	102	0	0	0	0	3,228
25	1,292	9,190	1,844	593	0	0	25	12,943
32	28	1,703	0	0	0	0	0	1,731
36	0	0	63	0	0	0	0	63
38	1,528	1,890	276	0	0	0	0	3,694
40	130	2,038	0	7,463	0	0	0	9,630
50	19,243	50,029	3,340	16,587	99,087	0	4,448	192,734
57	0	0	0	0	189	0	0	189
60	0	0	0	982	147	0	0	1,129
63	0	0	0	11,879	9,894	200	0	21,974
73	0	0	0	0	230	0	0	230
75	141,579	137,261	6,321	27,894	74,632	0	2,661	390,347
83	0	0	0	0	364	0	0	364
90	0	0	0	7,479	1,881	590	0	9,951
93	0	0	0	0	244	0	0	244
100	176,463	78,898	2,778	16,566	85,344	139	4,988	365,175
110	0	0	0	15,653	29,408	0	0	45,061
125	436	2,444	477	6,474	0	0	112	9,944
140	0	0	0	374	0	0	0	374
150	147,257	38,748	12,697	16,639	51,731	0	290	267,362
160	0	0	0	5,179	6,500	0	0	11,679
200	56,479	4,423	33,200	18,400	21,491	0	1,095	135,088
220	0	0	0	64	0	0	0	64
225	555	1,715	381	0	0	0	33	2,684
250	7,402	0	3,007	177	8,174	0	0	18,759
300	13,713	0	12,861	0	2,888	2,643	1,071	33,175
325	0	0	0	554	0	0	0	554
350	0	0	555	0	0	0	0	555
375	16,872	924	5,461	0	0	0	472	23,730
400	0	0	1,517	0	0	0	0	1,517
450	2,206	0	48,651	0	0	0	3,065	53,921
600	0	0	15,812	0	0	0	18	15,831
650	0	0	4,582	0	0	0	0	4,582
660	0	0	2,333	0	0	0	0	2,333
900	0	0	42,819	0	333	0	0	43,152
Total	585,182	332,479	199,076	152,957	392,536	3,571	18,278	1,684,079
Percentage of Total	34.7%	19.7%	11.8%	9.1%	23.3%	0.2%	1.1%	100.0%

Remarks: uPVC pipe with dia 900 mm is supposed to be steel pipes with dia. 900 mm

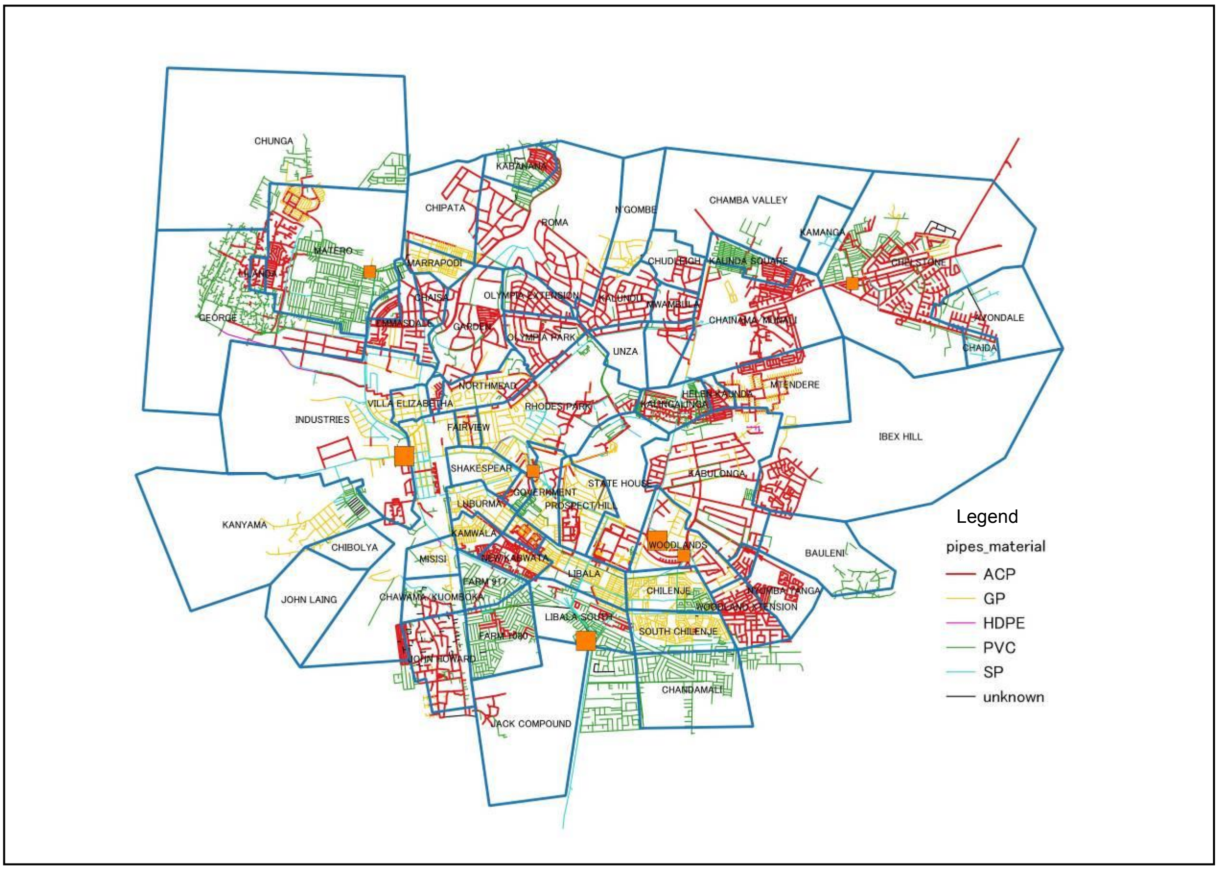
Source : JICA Study Team based on GIS data by LWSC



Material	Length (km)
ACP (Asbestos Cement)	585
GP （Galvanized Steel）	332
SP （Steel）	199
PVC （Polyvinyl Chloride）	153
uPVC （Unplasticized Polyvinyl Chloride）	393
HDPE (High-density Polyethylene)	4
Unknown	18
Total	1,684

Source: JICA Study Team

Figure 2.3.22 Distribution Pipe Length and Ratio by Pipe Material



Source: JICA Study Team

Figure 2.3.23 Distribution Pipe Network by Pipe Material

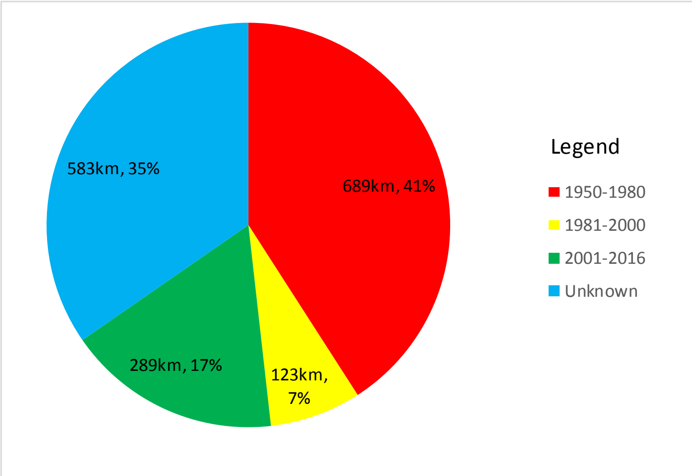
Usable life of pipe is said to be around 40 years in general. But it should be noted that ACP and GP tend to deteriorate after 20 years. Of the distribution mains in the LWSC service area, 41% (689 km) had been installed from 1950 to 1980 and has already passed 40 years as shown in Table 2.3.10, Figure 2.3.24, and Figure 2.3.25. Moreover, ages are unknown for 35% (583 km). All of these are not always deteriorated pipes as some of these are HDPE installed recently. It is presumed that more than half of the distribution mains would be aged over 40 years by the year 2020.

Table 2.3.10 Distribution Pipe Length by Pipe Diameter and Age

Unit: m

Diameter (mm) \ Age	1950-1980	1981-2000	2001-2016	Unknown	Total
13	0	0	89	0	89
19	351	0	531	2,346	3,228
25	5,091	275	358	7,218	12,943
32	439	0	121	1,171	1,731
36	0	0	0	63	63
38	1,632	0	117	1,944	3,694
40	33	5,920	331	3,489	9,772
50	55,243	5,974	16,841	114,534	192,592
57	0	0	189	0	189
60	0	75	0	1,054	1,129
63	0	10,387	10,186	1,401	21,974
73	0	0	230	0	230
75	201,127	16,893	64,976	107,351	390,347
83	0	0	0	364	364
90	0	6,555	2,471	925	9,951
93	0	0	0	244	244
100	150,857	35,284	71,859	107,175	365,175
110	0	2,524	41,685	853	45,061
125	2,922	6,299	0	723	9,944
140	0	361	0	13	374
150	124,283	17,935	41,704	83,440	267,362
160	0	3,358	8,118	203	11,679
200	58,588	8,514	22,399	45,586	135,088
220	0	0	64	0	64
225	1,715	0	0	969	2,684
250	5,054	0	345	13,360	18,759
300	14,689	1,405	5,638	11,443	33,175
325	0	0	0	554	554
350	0	0	0	555	555
375	14,702	0	0	9,028	23,730
400	0	0	588	929	1,517
450	37,215	1,579	0	15,127	53,921
600	7,791	0	0	8,039	15,831
650	4,582	0	0	0	4,582
660	2,333	0	0	0	2,333
900	0	0	0	43,152	43,152
Total	688,647	123,338	288,841	583,253	1,684,079
Percentage of Total	40.9%	7.3%	17.2%	34.6%	100.0%

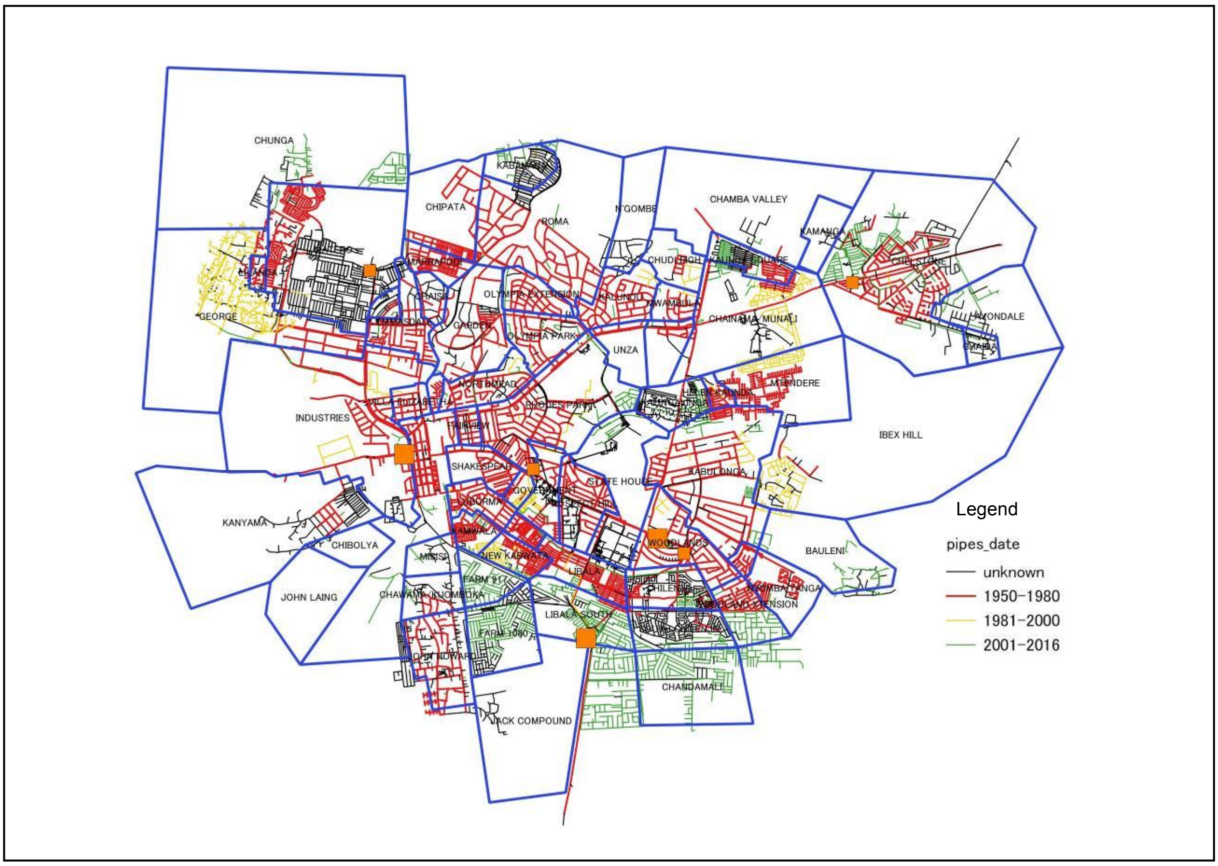
Source: JICA Study Team



Installation Year	Length (km)
1950-1980	689
1981-2000	123
2001-2016	289
unknown	583
Total	1,684

Source: JICA Study Team

Figure 2.3.24 Distribution Pipe Length and Ratio by Installation Year



Source: JICA Study Team

Figure 2.3.25 Distribution Pipe Network by Installation Year

As there are less durable pipes and old pipes as mentioned above, the existing distribution mains in the LWSC service area are deteriorated as a whole. In particular, it is presumed that many water leakages would be occurring on ACP and GP. PVC pipes may also have many water leakages as the pipe material is not flexible and joints are simply connected with adhesive. It is also presumed that there would be many water leakages at branch of service pipes including illegal connections. Table 2.3.11 shows the total length of water distribution pipes by age and material. Asbestos cement pipe, polyvinyl chloride pipe, galvanized steel pipe, and steel pipe are used as standard materials to be adopted for water distribution pipes according to the LWSC's water supply facility design guidelines, but application of each pipe material is not stipulated. The water pipes that LWSC initially used were asbestos pipes, galvanized steel pipes, and steel pipes, but they are gradually decreasing. Currently, polyvinyl chloride pipe and rigid polyvinyl chloride pipe are the main piping materials.

Table 2.3.11 Distribution Pipe Length by Age and Material

Material \ Age	1950-1980	1981-2000	2001-2016	Unknown	Total
ACP	344,654	68,418	35,118	136,992	585,182
GP	234,518	1,220	7,189	89,552	332,479
SP	96,962	4,571	7,434	90,109	199,076
PVC	12,047	49,129	55,103	36,678	152,957
uPVC	426	0	178,656	213,454	392,536
HDPE	0	0	3,571	0	3,571
Unknown	40	0	1,771	16,467	18,278
Total	688,647	123,338	288,841	583,253	1,684,079

Unit：m
Source: JICA Study Team

Table 2.3.12 shows the distribution pipe length by materials in each DMA. In part of township (Kabulonga, Matero, Roma, Chelstone, and Chainama/Munali) and peri-urban (George and John Howard), there are more than 20 km length of asbestos pipe.

Table 2.3.13(1/2) shows the distribution pipe length by age in each DMA. In part of township (Kabulonga, Matero, Roma, Chelstone, Rhodespark, and Woodlands) and peri-urban (George, Industries, Garden and Chipata), there are more than 20 km of over 40 years aged pipe in 2020.

Kabulonga, Roma, Chelstone, and George have long-length asbestos cement pipe and over 40 years aged pipe. It is thought to be efficient to proceed with the distribution pipe improvement in these areas.

Table 2.3.13(2/2) shows the distribution pipe diameter in each DMA. The proportion by diameter of distribution pipe is occupied 66% by medium pipe diameter of 75mm to 160mm, then small diameter pipe of 73mm or less is 14%.

Table 2.3.12 Distribution Pipe Length by Material in Each DMA

Unit: m

	Material / DMA	ACP	GP	SP	PVC	uPVC	HDPE	Unknown	Total
1	CHUNGA	500	4,804	0	8,358	14,130	0	0	27,793
2	AVONDALE	9,160	19	5,306	1,111	3,391	0	668	19,655
3	GARDEN	18,684	8,100	324	2,674	3,264	0	0	33,046
4	N'GOMBE	2,432	7,139	0	0	0	0	139	9,710
5	KABULONGA	37,601	11,604	22	10,951	2,436	590	0	63,204
6	LILANDA	785	0	0	1,281	0	0	21	2,087
7	GEORGE	23,931	699	4,169	40,374	0	0	0	69,173
8	INDUSTRIES	13,623	13,636	14,580	1,538	866	2,643	0	46,887
9	CHIBOLYA	0	0	0	0	0	0	0	0
10	VILLA ELIZABETHA	0	9,980	8,936	0	0	0	0	18,917
11	EMMASDALE BANK HOUSE	9,242	994	1,736	188	0	0	0	12,160
12	EMMASDALE	7,585	442	578	0	1,615	0	306	10,526
13	MATERO	21,014	5,846	7,290	3,435	127,286	0	9	164,880
14	CHIPATA	9,086	13,344	692	0	0	0	0	23,122
15	CHAISA	4,123	0	3,069	1,017	0	0	0	8,209
16	MARRAPODI	8,045	8,154	0	1,288	1,023	0	1,032	19,542
17	THORN PARK	2,203	543	37	0	202	0	0	2,984
18	MISISI	416	1,945	905	543	1,198	0	0	5,007
19	CHAWAMA/KUOMBOKA	3,171	617	1,471	2,359	1,438	0	1,943	11,001
20	LUBURMA	1,237	8,478	0	219	327	0	0	10,262
21	KAMWALA	3,956	8,049	0	229	868	0	0	13,101
22	KABWATA ESTATES	11,653	5,996	0	0	0	0	0	17,649
23	GOVERNMENT	3,372	14,974	11,984	0	937	139	0	31,406
24	SIKANZE	498	2,287	0	6,811	1,397	0	0	10,993
25	SHAKESPEAR	3,193	11,155	3,128	16	0	0	0	17,493
26	FAIRVIEW	847	8,373	2,004	0	0	0	0	11,223
27	NORTHMEAD	4,746	7,098	210	0	538	0	0	12,592
28	RHODES PARK	15,440	20,551	14,120	3,345	8,013	0	0	61,469
29	OLYMPIA PARK	13,219	2,821	521	609	809	0	0	17,978
30	ROMA	31,628	2,105	3,092	842	3,573	0	530	41,770
31	OLYMPIA EXTENSION	10,192	0	0	0	179	0	0	10,371
32	CHAMBA VALLEY	5,076	1,715	0	1,166	5,751	0	0	13,707
33	UNZA	0	0	0	504	464	0	0	968
34	CHUDLEIGH	5,402	0	0	0	549	0	0	5,951
35	KALUNDU	16,575	88	0	191	804	0	0	17,658
36	MWAMBULA	6,449	0	44	0	322	0	0	6,814
37	HANDSWORTH	3,236	0	208	0	325	0	0	3,769
38	CHAINAMA/MUNALI	39,652	2,847	11,557	249	3,481	0	0	57,786
39	CHELSTONE	51,733	3,800	3,137	3,663	22,568	0	2,081	86,981
40	IBEX HILL	19,112	176	0	259	0	0	0	19,548
41	KALINGALINGA	9,728	38	1,567	400	7,476	0	973	20,183
42	MTENDERE	10,039	11,350	0	0	0	0	0	21,389
43	HELEN KAUNDA	10,583	84	0	671	1,016	0	0	12,353
44	STATE HOUSE	13,838	18,698	1,176	2,613	2,051	0	0	38,375
45	PROSPECT HILL	6,715	13,610	4,258	0	1,028	0	0	25,610
46	SOUTH CHILENJE	579	21,603	4,326	8,709	14,233	0	184	49,633
47	CHILENJE	488	27,078	13,757	0	9,950	0	46	51,320
48	WOODLANDS	11,425	10,868	8,039	37	2,230	0	23	32,623
49	BAULENI	1,564	0	0	473	10,260	0	0	12,296
50	WOODLAND XTENSION	15,288	174	513	486	5,580	0	0	22,041
51	NYUMBA YANGA	15,248	0	0	0	490	0	0	15,738
52	KAUNDA SQUARE	11,006	0	0	416	15,144	0	0	26,567
53	CHANDAMALI	0	0	0	5,224	18,108	0	0	23,332
54	FARM 1080	4,607	87	0	13,472	16,851	0	2,935	37,952
55	JOHN HOWARD	24,734	967	0	3,753	2,969	0	2,624	35,047
56	JACK COMPOUND	3,180	0	4,245	1,158	201	0	0	8,784
57	KANYAMA	0	12,140	1,555	237	7,135	0	1,727	22,794
58	JOHN LAING	0	0	0	0	0	0	0	0
59	TOWN/KABELENGA	6,034	8,839	8,882	3,608	453	200	228	28,244
60	FARM 917	1,704	0	779	7,333	9,187	0	0	19,003
61	NEW KABWATA	7,916	2,360	3,219	2,019	57	0	0	15,572
62	LIBALA SOUTH	3,173	309	6,543	7,180	18,105	0	1,159	36,470
63	LIBALA	1,363	14,983	729	2,975	1,062	0	0	21,113
64	KABANANA	3,669	0	0	0	15,034	0	722	19,425
65	KAMANGA	2,007	0	2,174	0	3,430	0	0	7,611
66	CHAIDA	0	0	0	0	0	0	0	0
	Unknown	1,475	912	38,195	0	22,733	0	928	63,214
	Total	585,182	332,479	199,076	152,957	392,536	3,571	18,278	1,684,079

Source: JICA Study Team

Table 2.3.13(1) Distribution Pipe Length by DMA and Age

Unit：m

	DMA \ Age	1950-1980	1981-2000	2001-2016	Unknown	Total
1	CHUNGA	3,665	3,171	16,205	4,751	27,793
2	AVONDALE	543	0	5,079	14,033	19,655
3	GARDEN	20,851	369	2,714	9,113	33,046
4	N'GOMBE	1,530	902	0	7,278	9,710
5	KABULONGA	45,076	4,146	6,001	7,980	63,204
6	LILANDA	785	435	0	867	2,087
7	GEORGE	22,485	37,696	22	8,970	69,173
8	INDUSTRIES	31,231	6,039	3,620	5,996	46,887
9	CHIBOLYA	0	0	0	0	0
10	VILLA ELIZABETHA	17,674	0	0	1,243	18,917
11	EMMASDALE BANK HOUSE	7,983	0	630	3,548	12,160
12	EMMASDALE	6,927	0	116	3,483	10,526
13	MATERO	26,964	984	791	136,141	164,880
14	CHIPATA	23,122	0	0	0	23,122
15	CHAISA	5,422	0	0	2,787	8,209
16	MARRAPODI	10,311	0	636	8,594	19,542
17	THORN PARK	2,690	0	202	92	2,984
18	MISISI	94	0	1,465	3,448	5,007
19	CHAWAMA/KUOMBOKA	2,741	0	1,787	6,473	11,001
20	LUBURMA	9,143	0	1,054	64	10,262
21	KAMWALA	7,414	3,762	1,507	418	13,101
22	KABWATA ESTATES	17,054	571	0	24	17,649
23	GOVERNMENT	18,512	0	1,076	11,819	31,406
24	SIKANZE	2,333	7,185	1,397	78	10,993
25	SHAKESPEAR	17,404	16	0	72	17,493
26	FAIRVIEW	9,494	0	0	1,729	11,223
27	NORTHMEAD	10,173	0	616	1,803	12,592
28	RHODES PARK	31,994	3,262	9,801	16,412	61,469
29	OLYMPIA PARK	13,656	701	2,652	969	17,978
30	ROMA	31,099	101	1,007	9,563	41,770
31	OLYMPIA EXTENSION	9,441	0	0	930	10,371
32	CHAMBA VALLEY	4,590	934	1,858	6,325	13,707
33	UNZA	0	0	504	464	968
34	CHUDLEIGH	2,018	2,643	549	741	5,951
35	KALUNDU	16,330	288	1,040	0	17,658
36	MWAMBULA	6,386	0	44	385	6,814
37	HANDSWORTH	2,664	0	0	1,106	3,769
38	CHAINAMA/MUNALI	17,580	23,649	2,051	14,506	57,786
39	CHELSTONE	37,299	369	26,926	22,387	86,981
40	IBEX HILL	1,878	14,221	0	3,448	19,548
41	KALINGALINGA	99	37	5,394	14,654	20,183
42	MTENDERE	18,709	618	0	2,062	21,389
43	HELEN KAUNDA	9,597	1,070	1,574	112	12,353
44	STATE HOUSE	14,735	136	2,680	20,823	38,375
45	PROSPECT HILL	13,641	2,674	821	8,475	25,610
46	SOUTH CHILENJE	1,229	0	22,177	26,227	49,633
47	CHILENJE	17,564	0	5,084	28,672	51,320
48	WOODLANDS	21,591	858	3,888	6,286	32,623
49	BAULENI	1,357	0	6,251	4,688	12,296
50	WOODLAND XTENSION	6,322	0	14,797	922	22,041
51	NYUMBA YANGA	12,289	0	2,373	1,076	15,738
52	KAUNDA SQUARE	8,990	1,366	8,036	8,174	26,567
53	CHANDAMALI	0	0	19,556	3,776	23,332
54	FARM 1080	0	0	20,913	17,039	37,952
55	JOHN HOWARD	18,048	0	2,393	14,606	35,047
56	JACK COMPOUND	4,056	0	0	4,727	8,784
57	KANYAMA	4,050	0	418	18,326	22,794
58	JOHN LAING	0	0	0	0	0
59	TOWN/KABELENGA	17,580	162	4,313	6,189	28,244
60	FARM 917	0	0	13,492	5,511	19,003
61	NEW KABWATA	4,973	4,282	2,617	3,700	15,572
62	LIBALA SOUTH	870	0	25,182	10,418	36,470
63	LIBALA	14,762	32	5,374	945	21,113
64	KABANANA	0	264	2,079	17,081	19,425
65	KAMANGA	713	204	4,520	2,174	7,611
66	CHAIDA	0	0	0	0	0
	Unknown	912	191	23,562	38,549	63,213
	Total	688,647	123,338	288,841	583,253	1,684,078

Source: JICA Study Team

Table 2.3.13(2) Distribution Pipe Diameter in Each DMA

Unit：m

No.	Diameter (mm) / DMA	13-73	75-93	100-140	150-160	200-250	300-375	400-450	600-660	900	Total
1	CHUNGA	8,984	10,649	3,803	4,356	0	0	0	0	0	27,793
2	AVONDALE	2,475	3,952	5,971	1,060	6,196	0	0	0	0	19,655
3	GARDEN	932	14,785	5,019	6,860	4,829	298	324	0	0	33,046
4	N'GOMBE	1,324	2,872	2,634	2,880	0	0	0	0	0	9,710
5	KABULONGA	1,708	17,683	21,764	8,125	13,924	0	0	0	0	63,204
6	LILANDA	754	435	458	0	0	441	0	0	0	2,087
7	GEORGE	17,257	11,571	10,050	17,166	7,272	2,527	1,065	2,266	0	69,173
8	INDUSTRIES	2,107	6,229	6,500	13,703	8,726	3,938	5,186	497	0	46,887
9	CHIBOLYA	0	0	0	0	0	0	0	0	0	0
10	VILLA ELIZABETHA	767	4,570	4,320	324	3,722	0	5,214	0	0	18,917
11	EMMASDALE BANK HOUSE	678	4,970	2,155	2,067	555	0	0	1,736	0	12,160
12	EMMASDALE	470	6,199	2,889	390	578	0	0	0	0	10,526
13	MATERO	92,666	2,363	18,952	28,641	10,863	5,124	2,281	3,991	0	164,880
14	CHIPATA	8,628	2,375	4,010	4,893	2,525	692	0	0	0	23,122
15	CHAISA	0	1,825	779	3,016	1,356	0	1,232	0	0	8,209
16	MARRAPODI	4,545	2,628	1,994	2,759	3,885	3,399	0	0	333	19,542
17	THORN PARK	304	815	1,511	317	37	0	0	0	0	2,984
18	MISISI	1,851	1,292	960	94	0	0	811	0	0	5,007
19	CHAWAMA/KUOMBOKA	3,262	2,540	518	3,209	0	0	1,471	0	0	11,001
20	LUBURMA	1,057	7,149	643	553	0	859	0	0	0	10,262
21	KAMWALA	595	6,725	2,389	3,199	193	0	0	0	0	13,101
22	KABWATA ESTATES	924	6,390	6,082	1,656	0	2,597	0	0	0	17,649
23	GOVERNMENT	3,117	7,168	4,954	2,603	4,288	110	9,166	0	0	31,406
24	SIKANZE	3,462	3,544	2,589	0	1,397	0	0	0	0	10,993
25	SHAKESPEAR	463	10,117	2,877	1,890	2,145	0	0	0	0	17,493
26	FAIRVIEW	0	3,849	4,473	0	0	897	2,004	0	0	11,223
27	NORTHMEAD	796	6,032	3,760	1,542	463	0	0	0	0	12,592
28	RHODES PARK	3,045	21,627	13,346	6,409	7,539	4,392	5,110	0	0	61,469
29	OLYMPIA PARK	887	6,523	4,071	1,874	2,158	2,466	0	0	0	17,978
30	ROMA	1,205	13,063	12,276	6,738	3,678	4,809	0	0	0	41,770
31	OLYMPIA EXTENSION	0	674	6,110	1,017	1,828	742	0	0	0	10,371
32	CHAMBA VALLEY	314	7,761	2,952	966	1,715	0	0	0	0	13,707
33	UNZA	316	651	0	0	0	0	0	0	0	968
34	CHUDLEIGH	0	1,947	3,396	608	0	0	0	0	0	5,951
35	KALUNDU	155	844	9,496	6,937	227	0	0	0	0	17,658
36	MWAMBULA	25	3,285	2,584	902	0	19	0	0	0	6,814
37	HANDSWORTH	563	3,007	0	199	0	0	0	0	0	3,769
38	CHAINAMA/MUNALI	4,317	6,151	16,629	8,812	5,016	11,045	0	5,818	0	57,786
39	CHELSTONE	22,349	15,023	22,939	17,870	3,447	5,353	0	0	0	86,981
40	IBEX HILL	259	667	13,030	5,591	0	0	0	0	0	19,548
41	KALINGALINGA	5,350	4,094	7,155	2,870	715	0	0	0	0	20,183
42	MTENDERE	9,481	5,491	1,520	3,332	1,564	0	0	0	0	21,389
43	HELEN KAUNDA	642	5,072	2,230	864	3,545	0	0	0	0	12,353
44	STATE HOUSE	5,779	9,487	12,964	5,340	4,805	0	0	0	0	38,375
45	PROSPECT HILL	55	7,217	6,355	7,272	4,681	0	30	0	0	25,610
46	SOUTH CHILENJE	322	11,758	19,726	10,228	3,274	4,326	0	0	0	49,633
47	CHILENJE	7,341	16,210	9,912	3,351	2,160	1,001	7,717	0	3,627	51,320
48	WOODLANDS	1,630	13,702	4,744	4,430	1,132	1,556	3,991	1,088	350	32,623
49	BAULENI	2,099	3,707	1,136	3,998	1,357	0	0	0	0	12,296
50	WOODLAND XTENSION	0	5,560	10,151	4,693	1,637	0	0	0	0	22,041
51	NYUMBA YANGA	0	3,409	6,300	5,929	100	0	0	0	0	15,738
52	KAUNDA SQUARE	416	17,859	3,852	3,864	576	0	0	0	0	26,567
53	CHANDAMALI	230	4,261	10,527	2,737	5,576	0	0	0	0	23,332
54	FARM 1080	0	2,935	21,634	7,761	2,836	0	2,786	0	0	37,952
55	JOHN HOWARD	5,231	6,255	6,932	8,766	7,595	268	0	0	0	35,047
56	JACK COMPOUND	0	1,254	2,938	347	0	0	4,183	0	62	8,784
57	KANYAMA	3,446	6,489	10,949	178	1,732	0	0	0	0	22,794
58	JOHN LAING	0	0	0	0	0	0	0	0	0	0
59	TOWN/KABELENGA	3,535	4,186	6,354	7,321	5,023	0	570	1,255	0	28,244
60	FARM 917	0	2,658	9,793	3,648	2,126	0	779	0	0	19,003
61	NEW KABWATA	140	6,927	3,637	1,059	589	0	0	3,219	0	15,572
62	LIBALA SOUTH	418	3,636	13,495	10,700	3,017	577	1,517	2,877	235	36,470
63	LIBALA	1,990	10,573	4,715	2,662	823	0	0	0	350	21,113
64	KABANANA	838	10,581	3,573	1,507	2,344	581	0	0	0	19,425
65	KAMANGA	2,774	2,619	1,724	493	0	0	0	0	0	7,611
66	CHAIDA	0	0	0	0	0	0	0	0	0	0
	Unknown	3,493	5,787	10,450	7,004	829	0	0	0	35,652	63,214
	Total	247,776	401,674	421,650	279,578	156,596	58,013	55,438	22,745	40,609	1,684,079

Source: JICA Study Team

(4) Operation and Maintenance of Distribution Facilities

1) Current Situation

Because of the insufficient water production volume for water demand, LWSC closes the outlet valves of the reservoirs or stops the pump operation at the water distribution centers at nighttime in order to recover water storage in the reservoirs. LWSC resumes the water distribution by opening the outlet valves or starting the pumps in the early morning when the water demand starts to rise. Operation of the valves and pumps is conducted at a standardized time in a day, e.g., closing the valves at 9:00 p.m. and opening the valves at 5:00 a.m., depending on the water level in the reservoir. The operators determine the timing according to the actual water level in the reservoir or operator’s experiences. In principle, the operation is performed to store water at nighttime as much as possible to cope with the daytime water demand. The valve is closed at an early time when the water level becomes low. At present, the reservoirs cannot be filled fully because of the insufficient water production volume.

The operators are permanently stationed at the water distribution centers with two shifts in a day. The operators read the water level gauge and check outflow meters of the reservoir or pumping stations every hour. Inflow to the reservoir is not measured as no reservoir is equipped with inflow meter. Monitored water levels and flows are transferred to the central monitoring room at the Stuart Park Water Works by radio and are recorded in a designated format by hand writing.

Valve operations are carried out not only at the distribution centers but also at the control points in the distribution network. All these valves are operated manually. The operators visit each site by vehicle to operate the valves from the water distribution center.

2) Water Leakage Inspection, Check and Repair

Table 2.3.14(1/2) shows annual water leakage repairs for the past five years. Table 2.3.14(2/2) shows the data classified by branch. As LWSC’s database system for maintenance was put into operation in 2015, the historical records of repair are not recorded sufficiently. Therefore, the database for customer management complaints is only an information source for the historical leakages.

For the past five years, the total number of repairs has decreased. The total number of repairs in 2015 was two-thirds of that in 2011. The number of repairs for the distribution main stays at a similar level for the past five years. The number of repairs for service pipe also stays at almost the same level except in 2011. It is observed that the number of repairs for valve tends to decrease. It is not clear whether the number of repairs for meter would tend to decrease or not.

According to the records classified by branch, peri-urban area (total of three areas) has the largest number and followed by Central Branch, Kabulonga Branch, and Chelston Branch in order. The records correspond to the length of pipes aged over 40 years. In contrast, Lumumba Branch with the largest length of aged pipes has the smallest number of repairs. Lumumba Branch has less length of asbestos pipes than that in other areas. Moreover, it is obvious that Lumumba Branch has less number of repairs for service connection pipe. Table 2.3.15 (1/2) and Table 2.3.15 (2/2) show the ratios of water transmission and distribution pipes by material and age for each branch office.

From the above, it is presumed that leakages would occur mainly on aged pipes and dependent on the type of pipes. Leakages tend to decrease slightly in number since 2011. But it should be noted that the said recent trend would also be brought by lowered water pressure due to water shortage. The lowered water pressure is not proven as water pressure measurement is not performed in the distribution network. At present, it should not be concluded that the deteriorated distribution network would tend to be improved.

Table 2.3.14(1/2) Annual Water Leakage Repair Results for the Past Five Years (2011 to 2015)

Content of Repair	Number of Repairs					
	2011	2012	2013	2014	2015	Total
Leakage repair of pipes (Distribution pipe)	254	205	182	249	184	1,074
Leakage repair of pipes (Water supply pipe)	2,594	1,817	1,943	2,056	1,753	10,163
Repair of damaged valves	419	321	136	115	106	1,097
Leakage repair of meters	1,383	1,070	1,228	1,063	958	5,702
Total	4,650	3,413	3,489	3,483	3,001	18,036

Source: JICA Study Team using the number of responding complaints regarding water leakage from LWSC information management system; EDAMS

Table 2.3.14(2/2) Water Leakage Repair Result by Area for the Past Five Years (Accumlation) (2011 to 2015)

Content of Repair	Number of Repairs									
	Branch Office					District	Peri-urban			Total
	CEN	CHE	KBL	KBT	LUM	MAT	PUE	PUS	PUW	
Leakage repair of pipes (Distribution pipe)	196	144	151	127	84	65	117	51	139	1,074
Leakage repair of pipes (Water supply pipe)	1,206	1,093	1,388	1,672	539	1,918	841	587	919	10,163
Repair of damaged valves	70	29	31	95	27	747	2	9	87	1,097
Leakage repair of meters	576	817	993	946	250	1,741	118	23	238	5,702
Final total	2,048	2,083	2,563	2,840	900	4,471	1,078	670	1,383	18,036
					10,434	4,471			3,131	18,036

CEN: Central Branch, CHE: Chelston Branch, KBL: Kablonga Branch, LUM: Lumumba Branch, MAT: Matero Branch, PUE: Peri-urban East Branch, PUS: Peri-urban South area, PUW: Peri-urban West area

Source: JICA Study Team using the number of responding complaints regarding water leakage from LWSC information management system; EDAMS

Table 2.3.15(1/2) Distribution Pipe Rate of Each Material in the LWSC Service Area

Material	Central Branch Office	Chelston Branch Office	Kabulonga Branch Office	Kabwata Branch Office	Lumumba Branch Office	Peri-urban	**Total**
ACP	38.4%	56.8%	35.3%	17.1%	15.9%	32.9%	**31.4%**
GP (Iron)	29.2%	3.8%	24.4%	24.9%	13.0%	11.7%	**17.3%**
GP (Steel)	0.2%	0.0%	0.0%	0.5%	0.0%	0.5%	**0.2%**
HEPD	0.0%	0.0%	0.2%	0.1%	0.0%	0.0%	**0.1%**
PVC	5.2%	3.4%	8.5%	13.2%	2.4%	14.5%	**7.9%**
uPVC	5.0%	23.7%	16.3%	18.9%	45.9%	13.3%	**21.6%**
SP	16.0%	7.2%	10.5%	14.3%	14.0%	9.3%	**11.9%**
Unknown	6.1%	5.1%	5.0%	11.0%	8.8%	17.8%	**9.6%**
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	**100.0%**

Remarks: Pipes in Matero area are included in Lumumba Branch
Source: JICA Study Team based on the data from LWSC

Table 2.3.15(2/2) Distribution Pipe Rate by Pipe Age Around Lusaka City

Progress Year after Building	Central Branch Office	Chelston Branch Office	Kabulonga Branch Office	Kabwata Branch Office	Lumumba Branch Office	Peri-urban	Total
0≤Year<10	4.0%	9.4%	18.3%	22.4%	1.1%	7.3%	9.3%
10≤Year<20	6.0%	18.7%	6.6%	16.9%	0.5%	13.3%	9.5%
20≤Year<30	0.0%	1.5%	4.6%	0.0%	0.6%	0.0%	1.0%
30≤Year<40	3.0%	6.6%	10.7%	5.0%	5.4%	5.9%	6.1%
40≤Year<50	31.3%	28.1%	16.2%	16.9%	19.2%	25.3%	22.8%
50≤Year<60	9.7%	7.4%	11.5%	12.0%	7.9%	6.3%	8.8%
60≤Year<70	20.9%	0.0%	4.3%	2.5%	5.5%	1.6%	5.8%
Unknown	24.9%	28.2%	27.8%	24.2%	59.8%	40.3%	36.7%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Remarks: Pipes in Matero area are included in Lumumba Branch
Source: JICA Study Team based on the data from LWSC

3) Issues

In the event that LWSC service area is faced with water shortage, it is unavoidable to suspend water distribution at night in order to cope with daytime water demand. The nighttime water outage encourages the citizens to save water and decrease leakage water at night. Considering the future increase of water supply volume, the O&M issues are as follows:

- Water levels and inflow rates are unknown in the reservoirs. In the meantime, the present measurements of water level and outflow are performed visually by hour. Thus, the data are not enough in deciding the time to suspend and resume water distribution. Therefore, it is hard to optimize distribution of limited water supply volume.
- The measurement and management of water pressure are not enough. There are many locations suffering from low or excess pressure of water supply. There is no fixed point to observe water pressure continuously. LWSC staffs go around for carrying out water pressure measurements using ten water pressure measuring instruments. As a result, excessive water pressure over 30 m is

frequently observed around Mass Media Reservoir in Central Branch. On the other hand, many areas are faced with low water pressure due to insufficient water volume distributed.

- At the reservoir without water level gauge, water overflows from a reservoir at night when the volume of water transmission increases.
- Inflow rate and water level in the reservoir are not measured. It is not possible to identify leakage volume from the reservoir.
- Operation of valves and pumps is required frequently. The work load of the manual operation for transmission and distribution network is a burden on staffs.
- Many of the distribution mains aged over 40 years cause water leakage. LWSC conducts repairs; however, there is no considerable improvement.

2.3.5 Supervisory Control

(1) Operation of SCADA System

LWSC installed the Supervisory Control and Data Acquisition (SCADA) system in 2010 through the Water Sector Improvement Project (WSPIP) assisted by the World Bank. SCADA system consists of the main servers and the Remote Terminal Units (RTUs). Operational data collected by RTUs are transmitted to the main server through the radio network for telemetry monitoring. There are 43 RTUs installed at key locations at the water treatment, transmission, and distribution facilities.

Existing Remote Technical Unit

Existing Antenna Tower

Although the basic system was developed, SCADA system has not been operational since 2012 due to the fault of the main server. Moreover, the existing SCADA system cannot be utilized properly due to lack of instrumentation equipment and limitation in the radio network connecting with RTUs.

In order to improve the current situation and make effective use of the system, improvement work on the existing SCADA system is planned in CP1 (Rehabilitation of Iolanda Treatment Works, Transmission and Distribution Centers) of the MCC project which includes procurement and installation of instrumentation and transmitter equipment. This work will start in January 2016 and scheduled to be completed in January 2018. SCADA components prioritized by the MCC project are shown in Table 2.3.16.

Table 2.3.16 SCADA Component Planned by MCC Project

Major component	Procurement contents	
Servers	Main and sub servers (use the existing)	
Network	GRPS network (use the existing)	
RTUs	43 locations (use the existing)	
Instruments (new procurement)	Place of installation	Iolanda WTP (Intake, treatment process, and transmission), Chilanga PS, Stuart Park Station, Chelston Station, 7C Station, Mass Media PS, High Court PS, Woodland PS, Chwama PS, Lusaka Water Works Station
	Instruments	Flow meter (inflow/outflow), turbidity meter, pH meter, water level meter, water pressure meter, electrical multi tester transmitters and monitor for above instruments Instruments to connect with RTU
Monitors (new procurement)	Place of installation	Control room in Stuart park
	Equipment	PC and UPS

Source: Attachment VIII-1 Bill of Quantities of LP-1, 90% Design Review Report, Lusaka Water Supply, Sanitation and Drainage Project (LWSSD)

2.3.6 Water Quality Management

Water quality tests are carried out for raw water and treated water at Iolanda WTP, water is transferred to Chilanga Booster Pumping Station, wells, reservoirs, and water supply network in Lusaka. Samples are analyzed in the LWSC water laboratory for the basic items: pH, water temperature, electrical conductivity, TDS, Chlorides, turbidity, color, *escherichia coli*, fecal coliform, and residual chlorine. Tests for heavy metal and agricultural chemical are outsourced to the Bureau of Standard in Lusaka. The main facilities including Chilanga Booster Pumping Station and Stuart Park Distribution Center installed additional chlorination equipment. Residual chlorine is an indicator for water quality control on the water transmission and distribution facilities.

According to the data from LWSC regarding treated water quality in the WTP, there are records of analysis results for one sample from Monday to Friday. Turbidity always meets the standards and color sometimes exceeds the standard as stated in Section 2.3.2 (2). Since 2015, coliform and fecal coliform have not been detected and residual chlorine satisfies the standard of 0.2 mg/L. There are only two times in the records which are out of standards such as residual chlorine that is less than 0.2 mg/L at Chilanga Booster Pumping Station.

As shown in Table 2.3.17, the water conformity rate of the distribution pipe network is almost satisfied in terms of electric conductivity, hardness, chloride, and fecal coliform, but there are other indices that do not meet the water quality standards in some years. It should be noted that the turbidity, color, and residual chlorine declined in water quality comprehension rate from 2015 to 2017. As the treated water data of the Iolanda WTP obtained from LWSC almost satisfy the water quality. The following issues seem to be a problem.

a. water quality deterioration occurs in the distribution network.

There is a possibility that a negative pressure is generated inside of the pipe because it is impossible to supply water for 24 hours. In addition, rupture of the aged pipe and leakage also seem to affect the deterioration of water quality.

b. Impact of construction by MCC project (in particular 2017)

Water quality has been extremely deteriorating since 2017 when construction began, so rehabilitation work may have an effect on the water quality.

c. Turbidity values resulting from water quality analysis at the Iolanda WTP are lower than actual values.

The JICA Study Team conducted an analysis of raw water and treated water on 23 June 2016. The analysis was entrusted to the Department of Civil Engineering, University of Zambia. The results are found to be different from those of LWSC using the sample taken on the same day as shown in Table 2.3.18. In particular, turbidity of treated water by the JICA Study Team's analysis is four times that of LWSC's analysis. It is presumed that there would be an issue on the accuracy of water quality analysis at the Iolanda WTP. Meantime, water quality contamination in the distribution network may be due to low water pressure during the suspended water supply at nighttime.

Table 2.3.17 Rate of Supplied Water Satisfying Water Quality Standard

Year	The Rate of LWSC Supplied Water Satisfied Water Quality Standard (%)								
	pH	Conductivity	Total Hardness	Chlorides	Turbidity	Colour	Residual Chlorine	Total Coliform	Feacal Coliform
2013	99	100	100	100	99	N/A	71	99	100
2014	98	100	98	100	98	97	91	100	100
2015	100	99	100	100	99	100	73	100	100
2016	91	100	100	99	94	99	53	98	99
2017	N/A	100	100	100	90	74	35	95	96

Note: Average of water quality test values of 9 DMA Data for 2017 are up to March.
Source: JICA Study Team based on the data provided by LWSC

Table 2.3.18 Comparison of Water Quality Analysis Results of Raw Water and Treated Water between the JICA Study Team and LWSC

Items	Unit	Value			
		Raw Water		Treated Water	
		LWSC	Study Team	LWSC	Study Team
pH	-	5.99	7.46	6.3	7.41
Color	TCU	> 20	12	6	5
Turbidity	NTU	4.12	8.34	0.37	1.59
Electricity conductivity	mmhos/cm	237.5	254	237.6	255
Solubility evaporation residues	mg/l	116.4	127	116.4	128

*Sampling day: 23 June 2016
Source: Water quality analysis results obtained from LWSC and the JICA Study Team

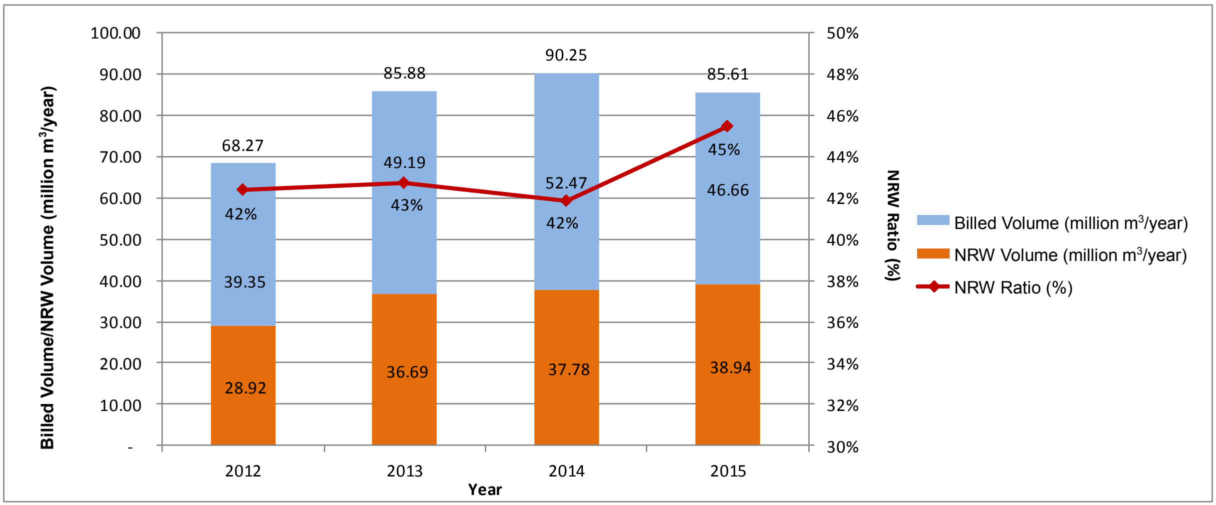
2.3.7 Non-revenue Water Management

(1) Review of the Monitoring Data of LWSC

Figure 2.3.26 presents the recent trend of non-revenue water (NRW) ratio in the Entire LWSC Jurisdiction. Table 2.3.19 shows the breakdown of NRW volume and ratio by branch. These are prepared by the JICA Study Team based on the monthly monitoring data compiled by the NRW Team of LWSC.

NRW ratio of LWSC has stayed in the range of 40% to 45% in these years as shown in Figure 2.3.26. NRW ratio varies by branch as shown in Table 2.3.14 and indicates fluctuation by year. Monthly fluctuation in the NRW ratio is outstanding as shown in Figure 2.3.27. For example, NRW ratio was approximately 30% in December 2014 but suddenly rose to 55% in May 2015; afterwards, it declined sharply.

The unusual behaviour of NRW ratio is obviously attributed to the absence of flow meter and water meter. As accurate data of water distribution and consumption volume are not available, many assumptions have to be done for estimating volumes of water distribution, accounted for water, and NRW. As shown in Figure 2.3.28, for example, in the case of monthly fluctuation data of the Central Branch Office, the monthly unmetered consumption indicates unreasonable fluctuation, which leads to the unusual behaviour of the NRW ratio. The unreasonable fluctuation in the unmetered consumption is assumed to be caused by change or error in the calculation method of the water consumption for unmetered customers. Moreover, water distribution volume in peri-urban area is assumed to be constant as shown in Figure 2.3.29, which confirms that the calculation of NRW volume and ratio still remains at a preliminary level. The similar unreasonable water volume fluctuations in the above examples are observed in all areas in the jurisdiction of LWSC.



Note: The amount of water in 2015 (total amount of water, billed volume and NRW volume) is converted to the annual water volume by converting the total water volume until October.

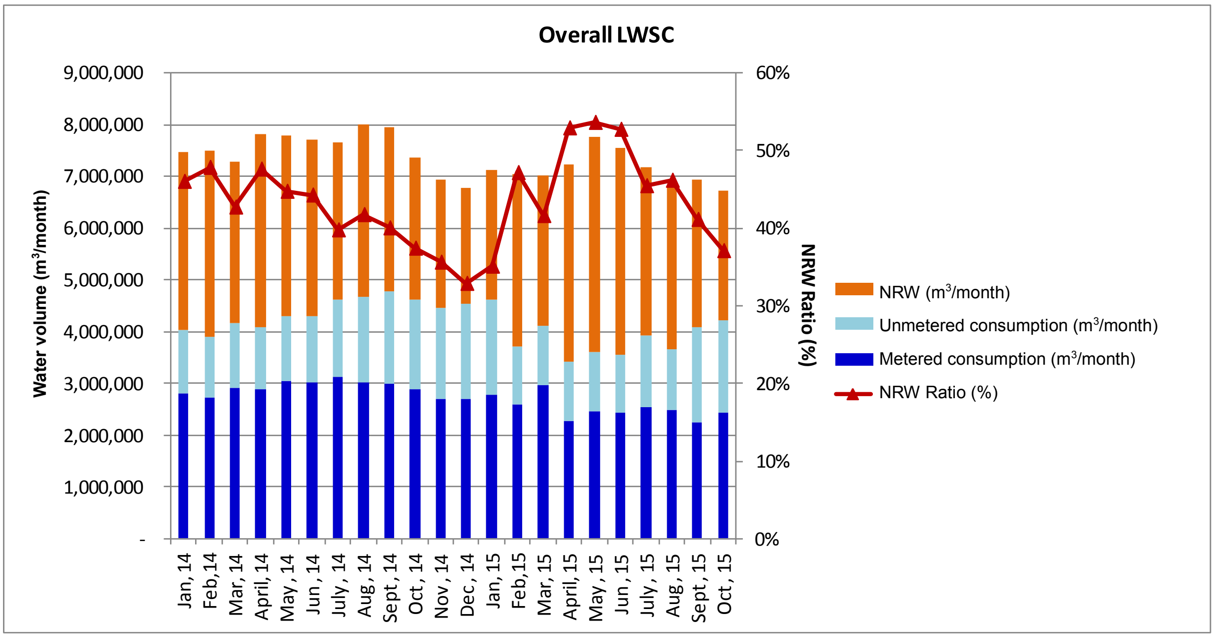
Source: JICA Study Team based on the monitoring data compiled by the NRW Team, LWSC

Figure 2.3.26 Recent Trend in NRW Volume and Ratio in the Entire LWSC Jurisdiction

Table 2.3.19 Transition of NRW in Each Area Managed by LWSC

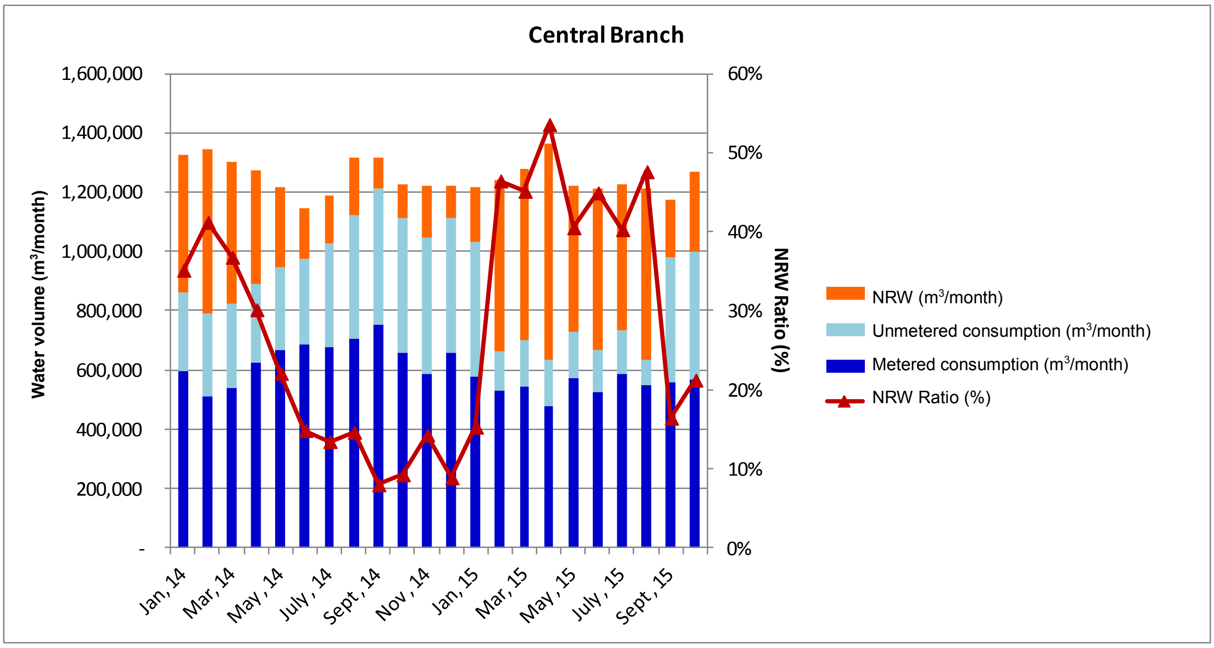
Area		2013	2014	2015	Rate of Aged Pipe*1	Rate of Accounted Water Without Meter *2
Central Branch	System input (million m^3/year)	15.91	15.1	14.2	86.80%	29.40%
	Accounted volume (million m^3/year)	9.53	11.92	10.28		
	NRW volume (million m^3/year)	6.39	3.17	3.92		
	NRW ratio (%)	40%	21%	28%		
Chelston Branch	System input (million m^3/year)	12.19	11.02	9.2	53.70%	32.70%
	Accounted volume (million m^3/year)	6.85	7.32	5.87		
	NRW volume (million m^3/year)	5.34	3.7	3.33		
	NRW ratio (%)	44%	34%	36%		
Kabulonga Branch	System input (million m^3/year)	9.26	9.15	9.75	59.80%	40.10%
	Accounted volume (million m^3/year)	6.68	6.89	6.56		
	NRW volume (million m^3/year)	2.57	2.26	3.2		
	NRW ratio (%)	28%	25%	33%		
Kabwata Branch	System input (million m^3/year)	9.63	9.71	12.12	55.60%	35.10%
	Accounted volume (million m^3/year)	7.27	8.35	10.05		
	NRW volume (million m^3/year)	2.36	1.36	2.07		
	NRW ratio (%)	25%	14%	17%		
Lumumba Branch	System input (million m^3/year)	12.79	9.45	10.05	92.40%	20.80%
	Accounted volume (million m^3/year)	7.09	6.05	5.24		
	NRW volume (million m^3/year)	5.69	3.39	4.81		
	NRW ratio (%)	44%	36%	48%		
Matero Branch	System input (million m^3/year)	3.72	4.06	3.72		
	Accounted volume (million m^3/year)	2.23	2.17	2.51		
	NRW volume (million m^3/year)	1.48	1.89	1.21		
	NRW ratio (%)	40%	47%	33%		
Peri-urban	System input (million m^3/year)	11.13	12.02	12.02	73.50%	70.90%
	Accounted volume (million m^3/year)	8.56	7.27	6.71		
	NRW volume (million m^3/year)	2.57	4.75	5.31		
	NRW ratio (%)	23%	40%	44%		
Total in Lusaka City	System input (million m^3/year)	74.63	70.51	71.06	74.10%	37.20%
	Accounted volume (million m^3/year)	48.21	49.97	47.22		
	NRW volume (million m^3/year)	26.4	20.52	23.85		
	NRW ratio (%)	35%	29%	34%		
Other Area	System input (million m^3/year)	9.34	10.08	9.71	-	96.40%
	Accounted volume (million m^3/year)	0.98	2.5	1.74		
	NRW volume (million m^3/year)	8.38	7.6	7.99		
	NRW ratio (%)	90%	75%	82%		
Transmission Facility	Leakage (Million m^3/year)	1.91	9.66	4.01	-	-
Lusaka Province Total	System input (million m^3/year)	85.88	90.25	80.37	-	64.60%
	Accounted volume (million m^3/year)	49.19	52.47	48.96		
	NRW volume (million m^3/year)	36.69	37.78	35.85		
	NRW ratio (%)	43%	42%	45%		

*1: Pipes which was installed more than 40 years ago or uncertain in 2015
*2: Unmetered accounted for water ÷water distribution volume x 100(%). Data from January to October in 2015
Source: JICA Study Team based on the monitoring data compiled by NRW Team, LWSC



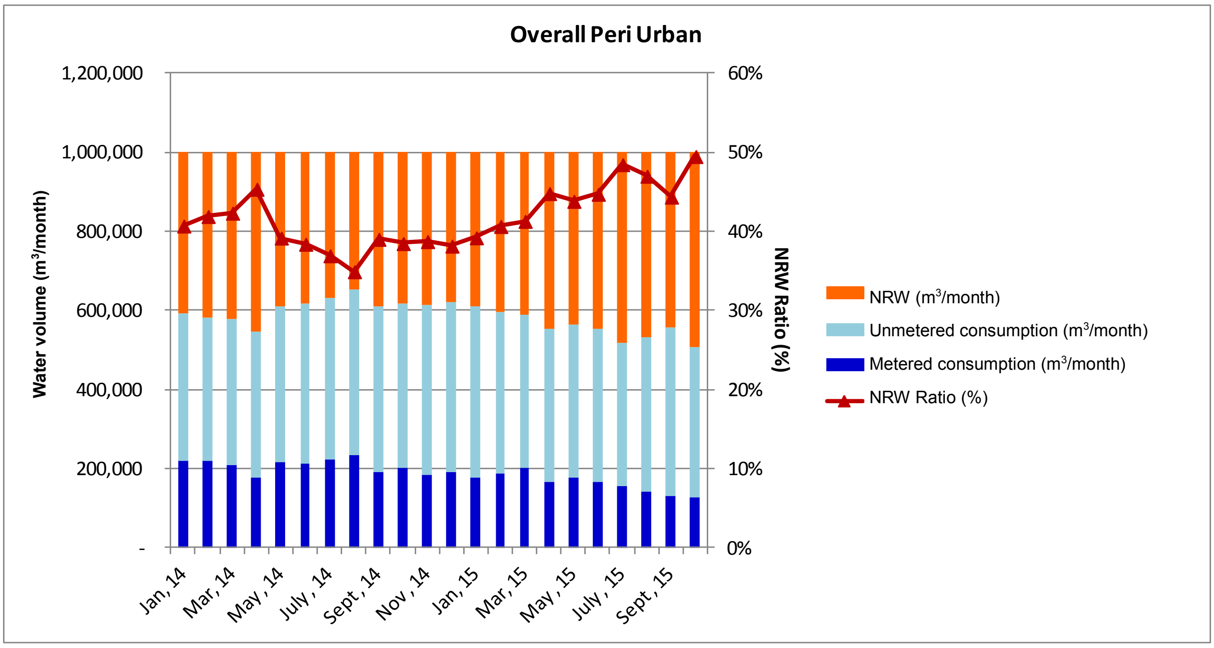
*: Figures for 2015 are the annual values converted from the data for 10 months up to October.
Source: JICA Study Team based on the monitoring data compiled by the NRW Team, LWSC

Figure 2.3.27 Monthly NRW Trend in the Entire Jurisdiction of LWSC



*: Figures for 2015 are the annual values converted from the data for 10 months up to October.
Source: JICA Study Team based on the monitoring data compiled by the NRW Team, LWSC

Figure 2.3.28 Monthly NRW Trend in the Central Branch



*: Figures for 2015 are the annual values converted from the data for 10 months up to October.
Source: JICA Study Team based on the monitoring data compiled by the NRW Team, LWSC

Figure 2.3.29 Monthly NRW Trend in the Peri-urban Area

(2) Composition of NRW

As described above, LWSC is still faced with difficulties in accurate estimation of NRW volume and ratio and is not at a stage to investigate the composition of NRW. The NRW Team of LWSC views from its experiences that about 40% of NRW ratio would comprise physical losses and commercial losses at 25% and 15%, respectively. Breakdown of NRW and its main causes are shown in Table 2.3.20.

Table 2.3.20 Breakdown and Main Causes of NRW

<table>
<tr><td rowspan="9">System Input Volume</td><td rowspan="4">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumption</td><td>Billed Metered Consumption</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Non-metered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption
(water used for fire fighting, etc)</td><td rowspan="7">Non-Revenue Water</td></tr>
<tr><td>Unbilled Non-metered Consumption
(free water distributed at standpipes)</td></tr>
<tr><td rowspan="5">Water Losses (Unaccounted for Water, UfW)</td><td rowspan="2">Apparent Losses (commercial Losses)</td><td>Unauthorized Consumption
(illegal use and connections)</td></tr>
<tr><td>Metering Inaccuracies
- No meters
- Meters not working
- Meters not recording accurately
- Meters misread</td></tr>
<tr><td rowspan="3">Real Losses (Technical Losses)</td><td>Leakage on Transmission and/or Distribution Mains</td></tr>
<tr><td>Leakage and Overflows at Utility's Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to Customers' Meters</td></tr>
</table>

Source: International Water Association (IWA)

In addition, corruption by the meter readers is sometimes reported and also causes commercial losses. LWSC used to exempt some water users including their staffs from paying for water and the consumptions in such users were a part of the commercial losses. At present, there is no water user exempted from paying for water anymore. Accordingly, unbilled authorized consumption, which is one of the components of NRW, only includes the volume for operation of LWSC and firefighting. LWSC staffs have a certain consumption limit free of charge but they need to pay for the excess consumption over the limit.

For accurate evaluation of NRW, measurement of water production and water consumption is essential. Measurement of water consumption in Lusaka needs to be significantly improved. LWSC needs to focus on the expansion of the water meter installation at present in spite of the need for maintenance and replacement of existing meters. On the other hand, the accuracy of water production measurement has been improved. Water production is measured by flow meter at the water transmission pumps at the Iolanda WTP even intermittently and a program to install flow meters at all wells is completed soon.

(3) Management System and Issues

The NRW Team, directly organized under the president of LWSC, is conducting the overall NRW countermeasures, controlling, and monitoring. In the meantime, other departments perform specialized activities for water leakage inspection and repair, measures against illegal connection, and water meter management.

The issues on the current NRW measures are described below.

- Rate of water meter installation for service connection remains at a low level. Bulk meter is not installed in all DMAs. Water balance of distribution and consumption is unknown. Effective countermeasure at exact location cannot be implemented.
- Deteriorated distribution mains, valves, and service connection pipes cause water leakage. Water leakage inspections and repairs are being conducted but do not attain substantial improvements as seen in the records of repair.
- Revenue water volume is far less than the actual volume of water consumption due to the low rate of water meter installation and deteriorated water meters.
- Illegal connections are being caught through rational approach; however, it is presumed that many illegal connections would exist and could not be found.
- Importance of NRW reduction is not fully understood among staffs and citizens in the LWSC service area. For example, LWSC staffs sometimes do not fix the water leakage promptly when they detect the visible water leakage.
- The manager of the NRW Team has enough knowledge of measures for NRW reduction as well as experiences through daily activities. However, the activities for NRW reduction should be related to the whole departments of LWSC and it is not possible for only three staffs of the NRW Team to

monitor all the relevant activities and educate other staffs. In addition, the NRW Team is separated from the other departments conducting practical activities and does not have the authority to educate other staffs.

2.3.8 Information Management System

(1) Customer Information and Facility Information Management System (EDAMS and ArcGIS)

1) Software

For management of the customer information and facility information, LWSC introduces EDAMS, which is a utility management software developed by a South African company, Hydro-Comp, and ArcGIS. LWSC purchased EDAMS in 2000 with the financial assistance by the World Bank. The software's functions are composed of three major packages, which are presented in Table 2.3.21.

Table 2.3.21 Major Functions of EDAMS, the Information Management Software Adopted by LWSC

No	Package	Function	Remarks
1.	Billing & Customer Information System: B&CI	Registration and update of customer profiles - Log of water consumptions of each customer - Calculation of bill - Log of payment record of each customer - Log of messages received from each customer	- Managed by the Commercial Service Division.
2.	Maintenance Management Systems: MMS	Registration and update of maintenance - Log of repair, rehabilitation and renewal of facilities and equipment	- Maintenance works are registered by the departments/sections which carried out the works.
3.	Asset Management & Infrastructure Systems: AMIPS	Registration and update of inventory data of pipes, reservoirs and pumping stations - Log of water flow and water pressure in the distribution network - Water balance analysis - Preparation of hydraulic model of water distribution network - Preparation of rehabilitation and renewal program taking into account life cycle cost	- GIS Team updates the inventory data by reflecting the registered maintenance information. - The function to prepare rehabilitation and renewal program is not used in LWSC.

Source: JICA Study Team based on interview with LASC Intelligence Technology Office and GIS Team

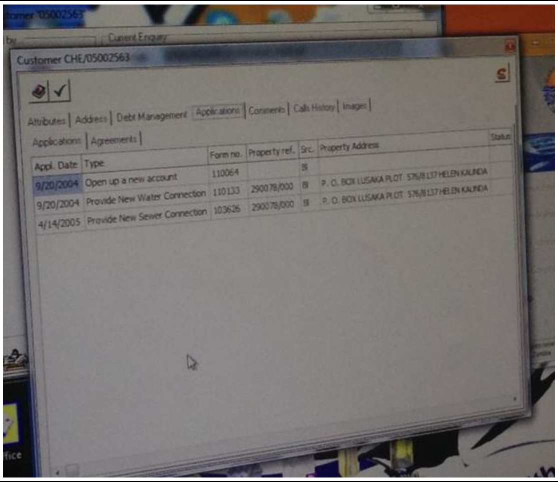
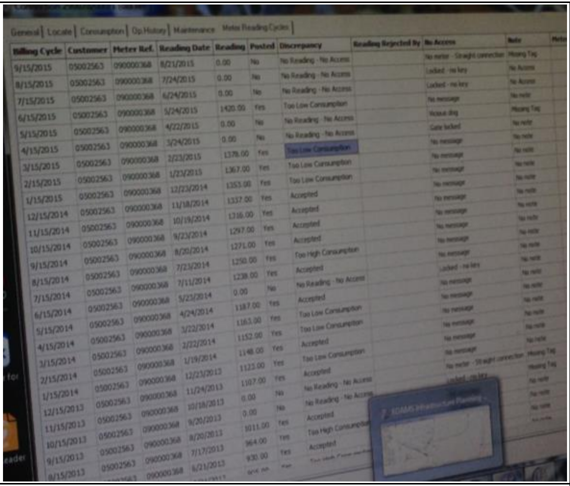
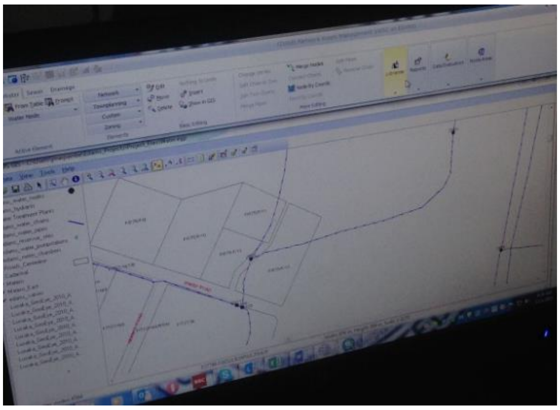
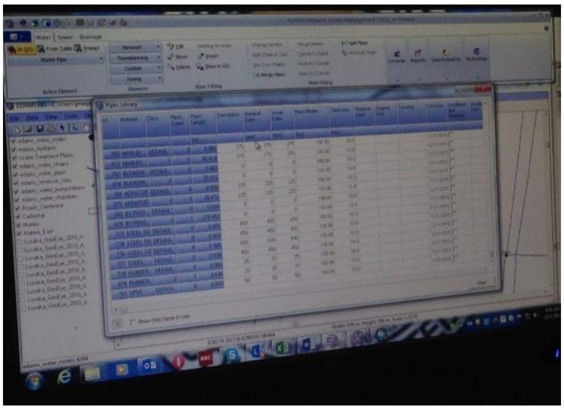
Of the three major functions of EDAMS, B&CI has been constantly utilized in LWSC since the installation in 2000. On the other hand, MMS and AMIP have not been utilized because LWSC has been faced with difficulties in transferring database from ArcGIS to EDAMS. In 2015, LWSC proceeded with the transfer of database for full-fledged operation of the remaining two functions because EDAMS is more capable of advanced asset management than ArcGIS.

According to the Intelligence Technology Office and GIS Team of LWSC, the major cause was the wide inconsistencies between the geographic information used in ArcGIS (existing leader maps) and that used in EDAMS (the satellite image of Google Earth). As a result, EDAMS did not recognize the water distribution network data imported from ArcGIS correctly. In addition, it took time to resolve unknown software bugs taking place in the process of the transfer of database. Such problems were resolved by technical support of the software supplier with the costs borne by LWSC in 2015.

2) Operational Condition of EDAMS and Issues

EDAMS is a sophisticated software that enables water utility to perform information management. LWSC has been utilizing the function of customer information management and is making efforts to fully utilize the other functions. As a result of the JICA Study Team's confirmation, the information on the existing facilities is almost complete, but the following issues exist regarding the customer information / facility information management system:

- The base map currently used in EDAMS is the satellite image of Google Earth in 2011, when the Water Supply Investment Plan was prepared by the consultant (Gauff Ingenieure). As Lusaka has been urbanized and expanded rapidly, the gaps take place between the base map and the actual geographic conditions. The base map should be updated but LWSC has not budgeted USD 10,000 for updating the base map.
- There are some errors in updating the registered data. The Engineering Department and branches are responsible for registration of repair and renewal logs to EDAMS. But sometimes the person in-charge fails the registration.
- Pipe inventory data include "unknown" information. Of the water distribution pipes in the Lusaka service area, 36.7% or 700 km of the pipes indicate "unknown" in diameter, material, or age. It is recommended that LWSC make efforts to supplement the "unknown" information by test excavation through the opportunities of construction works on water supply and sewerage network.
- In the pipe inventory, uPVC sections installed recently do not indicate the data on the year of construction. Such data are observed in Lumumba Branch for 187 km and peri-urban area for 25 km. It is presumed that these two branches would not register the data of year of construction.
- When old pipes are replaced with new ones, the data of unused old pipes are deleted from the inventory. It is recommended that such pipes should be kept in the inventory and indicated as "decommissioned". This manner of data management will facilitate the actions to be taken when unknown pipes are found during the construction works by LWSC or other utilities in the future.
- The GIS Team is still not familiar with MMS and AMIPS operation of EDAMS since they are still ongoing in EDAMS regular operation.

	
Customer Information (1/2) (Log of connection dates of the customers)	Customer Information (2/2) (Log of consumption and payment)
	
Map of the existing distribution network	Inventory data of the selected pipes on the map

Source: JICA Study Team

Photo 2.3.4 Screenshots of Information Management of LWSC in “EDAMS”

(2) Accounting and Asset Management Information System (SAGE 300ERP)

SAGE 300ERP software, which is developed by SAGE in South Africa, is used for the financial management of LWSC. LWSC installed SAGE 300ERP with the support of the World Bank and started its operation from 2012. LWSC uses SAGE 300ERP as both accounting database and asset management database. The accounting information in terms of order, payment, and budget is managed with the accounting database. The information of the assets owned by LWSC in terms of purchasing amount, its year, usage period, depreciation, insurance amount, and others are registered in the asset management database. LWSC has received periodic training and technical support from SAGE. At present, LWSC is not faced with any difficulty in its operation.

(3) Human Resources Information Management System (VIP)

LWSC has a plan to install the VIP software, which is developed by SAGE in South Africa, as the human resources management database in 2016. After the training to be provided by SAGE, LWSC will start the actual operation of VIP database for the information management of human relations and staff salary payment.

2.3.9 Client Service and Current Customer Complaints

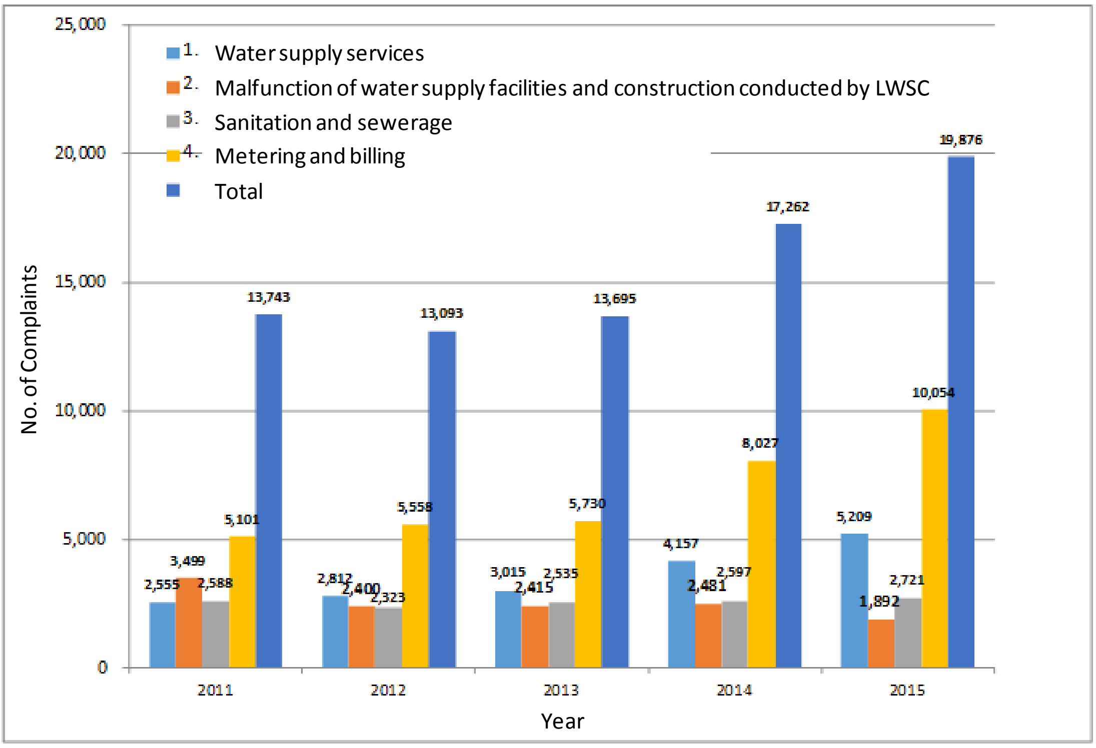
(1) Receiving Complaints and Procedures on Settlement

Complaints from the customers are received through customer windows as well as phone and e-mail contacts of LWSC headquarters and each branch. There is no dedicated call center or customer center. Once the customer complaint is received, it is classified and registered in EDAMS. EDAMS can be accessed from all LWSC offices and the department in-charge confirms and responds to the complaints though EDAMS. The information from the customers registered in EDAMS are not only complaints but also requests for suspending and resuming water service, leakage inspection inside housing lot (to be charged). Records of responding to complaints and requests are also registered in EDAMS.

(2) Number and Classifications of Complaints

Figure 2.3.30 shows the number of complaints and requests from the customers by classification through review of the data registered in EDAMS.

- Complaints related to water supply services (e.g., water volume, water quality, and water pressure)
- Complaints related to malfunction of water supply facilities (e.g., water leakage, visible damage of the facilities) and construction conducted by LWSC.
- Complaints related to sanitation and sewerage (e.g., overflow of wastewater, damaged and missing manhole cover)
- Complaints related to metering and billing (e.g., billing mistake, complaints about water tariff, damage and leakage of water meters).



*: Aggregate data from January to November in 2015
Source: JICA Study Team based on information of LWSC information management system EDAMS

Figure 2.3.30 Number of Complaints to LWSC in Lusaka City

The number of complaints has been increasing year by year since 2012. The total number of complaints for 11 months in 2015 has already reached 1.5 times for 12 months in 2012. In particular, the number of complaints related to metering and billing is the largest and has increased considerably. The major reason is related to the prepaid service introduced in 2014. Major complaints related to the prepaid services are troubles on the valve installed in the households and errors in the payment process (1,827 in 2014 and 2,392 in 2015). Other than the complaints related to the prepaid service, the complaints related to metering and billing indicated an upward trend as shown in Table 2.3.22.

The complaints related to water supply duration and water pressure have been increasing as well. Of these, the complaints related to insufficient water supply volume are predominant and increased obviously. The complaints on water pressure and water quality are not very common; however, the complaints on water quality have demonstrated a sharp increase in 2015 as shown in Table 2.3.23. The increase of complaints on water quality is concentrated in Peri-urban East Zone (181 complaints) and implies that some incident in the water distribution network took place.

The number of complaints related to failure of the water supply facilities and construction works by LWSC has stayed at a similar level since 2012 as shown in Table 2.3.24. The complaints on water leakages in service connections are predominant.

Table 2.3.22 Breakdown of the Complaints Related to Metering and Billing (Excluding those on the Prepaid System)

Contents	2011	2012	2013	2014	2015	Total
Excessive meter reading	2,458	3,053	2,979	2,783	2,492	13,765
Leakage from water meter	1,339	1,093	1,238	1,235	1,068	5,973
Fixed rate billing to metered customer	682	728	540	844	1,522	4,316
Excessive fixed rate	0	33	301	548	1,384	2,266
Broken water meter	347	248	253	239	239	1,326
Undelivered bill	178	168	169	95	181	791
Bill to closed or suspended account	0	60	88	157	469	774
Bills duplicated	45	145	112	132	108	542
Stuck water meter	0	0	0	72	120	192
Excessive billing	52	26	29	10	9	126
Bill to non-served household	0	4	21	39	59	123
Bill of sewerage to non-served household	0	0	0	16	6	22
Bill of commercial category rate to household	0	0	0	10	5	15
Total	5,101	5,558	5,730	6,180	7,662	30,231

※: Number of the complaints in 2015 is based on the data from January to November.
Source: JICA Study Team based on the registered information to EDAMS of LWSC

Table 2.3.23 Breakdown of the Complaints Related to Quality of the Water Supply Services in Lusaka City

Contents	2011	2012	2013	2014	2015	Total
Insufficient water volume	1,719	2,033	2,111	3,190	4,330	13,383
Low water pressure	811	756	879	933	669	4,048
Bad water quality	25	23	25	34	210	317
Total	2,555	2,812	3,015	4,157	5,209	17,748

*: Number of the complaints in 2015 is based on the data from January to November.
Source: JICA Study Team based on the registered information to EDAMS of LWSC

Table 2.3.24 Breakdown of the Complaints Related to Failures in Water Supply Facilities and to Poor Construction Works done by LWSC in Lusaka City

Contents	2011	2012	2013	2014	2015	Total
Leak from service pipe	2,795	1,866	2,076	2,090	1,604	10,431
Leak from distribution pipe	264	205	186	253	161	1,069
Valve damaged	430	323	148	121	111	1,133
Inappropriate backfilling after excavation work	10	6	5	17	16	54
Total	3,499	2,400	2,415	2,481	1,892	12,687

*: Number of the complaints in 2015 is based on the data from January to November.
Source: JICA Study Team based on the registered information to EDAMS of LWSC

2.4 Related Existing and Planned Project

2.4.1 Lusaka Water Supply, Sanitation and Drainage Project (MCC Project)

(1) Outline

The Lusaka Water Supply, Sanitation and Drainage Project (MCC project) is a grant aid from the Millennium Challenge Corporation (MCC) of the United States of America (USA),. MCC Project implements construction of water supply and sewerage facilities which are evaluated as high priority components in the Water Supply Investment Plan (July 2011) and Lusaka Sanitation Investment Master Plan (January 2011). The feasibility study on the MCC project, named as the Preparation of Feasibility Studies and Preliminary Design for Water Supply and Sanitation Projects (LWSSDP F/S), was completed in January 2012.

Table 2.4.1 shows the components and estimated cost of each contract package at the completion of LWSSDP F/S.

Table 2.4.1 Packaging, Components and Estimated Costs of MCC Project

<table>
<tr><th>Package</th><th>Component</th><th colspan="2">Estimated Cost at Completion of F/S (in million USD)</th></tr>
<tr><td>Lp1</td><td>Improvement of Iolanda WTP, transmission facilities and distribution centers</td><td>13.9</td><td rowspan="2">53.5</td></tr>
<tr><td>Lp6</td><td>Reinforcement of trunk distribution pipelines*</td><td>39.6</td></tr>
<tr><td>Ls1</td><td>Non-revenue water reduction</td><td>44.3</td><td>44.3</td></tr>
<tr><td>Ls3</td><td>Distribution network extension in Chelston Branch</td><td>38.5</td><td rowspan="2">63.9</td></tr>
<tr><td>CSE-44</td><td rowspan="2">Kuanda Square sewer network expansion and improvement</td><td rowspan="2">43.4</td></tr>
<tr><td>TU-5, TE-3, CSU-4</td><td rowspan="2">19.3</td></tr>
<tr><td>CSU-15</td><td>Chelston sewer network expansion and improvement</td><td>1.3</td></tr>
<tr><td colspan="2">Total</td><td colspan="2">181.0</td></tr>
</table>

*: Lp6 is a component to newly install water transmission pipe in Lusaka City. Here, it is called as "trunk distribution pipe" following that MCC F/S described it as "Primary Distribution Backbone".

Source: Preparation of Feasibility Studies and (30%) Preliminary Design for Water Supply and Sanitation Project, 2012

Afterwards, in the second field survey (February to March 2016), the JICA Study Team was provided by MCC with the information about the construction package in the bidding stage of MCC project. The components of each contract package (CP) are described in Table 2.4.2.

Table 2.4.2 Construction Package (CP) Components and Estimated Cost of MCC Project

Construction Package	Subproject in MCC Project F/S	Construction Period (At the time of contract)	Construction Cost (Million USD)	Components
CP-1	Lp1	From January 2016 to January 2018	46..0	Improvement of Iolanda WTP, transmission facilities and distribution centers
CP-2	Lp6			Reinforcement of trunk distribution pipelines
CP-3	Ls3	From January 2016 to January 2018	22.4	Distribution network expansion in Mtendere and Kamanga
	CSE-44, CSU-4, CSU-15			Sewer network expansion in Mtendere and Kaunda Square Renewal of sewerage pumping station in Chelstone areas
CP-4	TE-3, TU-5	From November 2015 to November 2017	10.0	Construction of Kaunda Square Waste Stabilization Ponds
CP-5	Ls2, Ls3	From February 2015 to February 2018	21.9	Distribution network expansion for Ng'ombe, SOS East, Chipata (Ls2) Distribution network expansion for Ndeke/Vorna Valley and Kwamwena (Ls3)
CP-6	Ls1	From March 2016 to March 2018	30.0	Non-revenue Water Reduction
CP-7	-	From November 2015 to February 2018	18.4	Improvement of Bombay Drainage System (north)
CP-8	-	From November 2015 to February 2018	17.8	Improvement of Bombay Drainage System (south)

Note: VAT is excluded in the construction cost.
Source: JICA Study Team based on the Final Bidding Documents (CP-1-8) provided by MCC

(2) Descriptions of Water Supply Components (As of January 2016)

The MCC Project component directly relation to the project is described below.

1) CP-1: Improvement of Iolanda Treatment Works, Transmission Facilities and Distribution Centers

This package will recover the original treatment capacity (110,000 m^3/day) of the Iolanda WTP and improve the water transmission system to Lusaka. The components in this package are listed as follows. Layout of the facilities is presented in Figure 2.4.1.

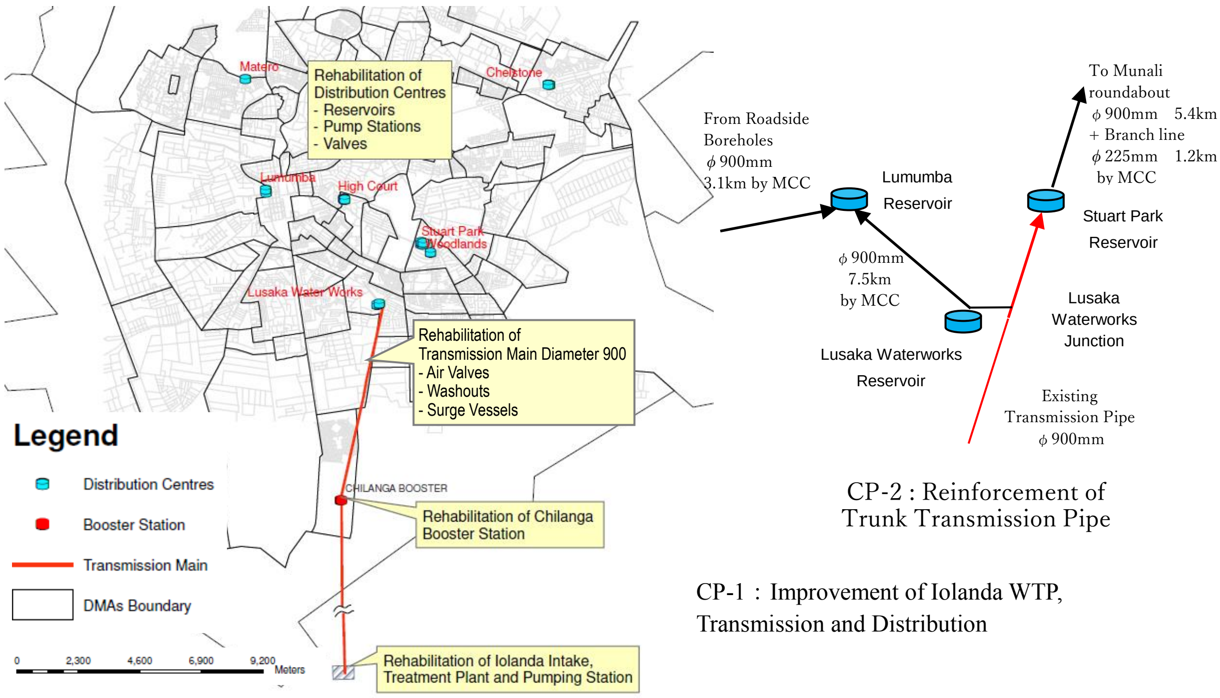
- Rehabilitation of Iolanda WTP: replacement of coagulant closing equipment and mixer
- Rehabilitation of Raw Water Intake facility: dredging intake canal, replacement of automatic traveling screen
- Rehabilitation and renewal of transmission pump
- Rehabilitation of Chilanga Booster Pumping Station: replacement of transmission pump and spare parts
- Rehabilitation of diameter 900 transmission main: replacement of associated facilities such as air valve, discharge valve, and surge tank

- Rehabilitation of distribution centers: repair and replacement of transmission and distribution pump, electric power receiving equipment, and other associated equipment, rehabilitation and installation of water level gauge at reservoir, rehabilitation of reservoir structure
- Extension of existing SCADA system

2) CP-2: Reinforcement of Trunk Distribution Pipelines

This package is to improves the trunk water distribution system in Lusaka to cope with the future water demand forecast in the Water Supply Investment Plan.

At present, since distribution pipes in Lusaka City have many branch pipes directly diverted. Therefore, the water from the Chilanga Booster Pumping Station is not transmitted to the Stuart Park Reservoir and Lumamba Reservoir. In order to ensure the transmission properly to the distribution centers, the package includes installation of dedicated transmission mains of diameter 1,200 mm, diameter 900 mm, and diameter 700 mm to the distribution centers and construction of elevated tank at each of the distribution centers. Layouts of the new transmission mains in this package are presented in Figure 2.4.1. Total pipe length is 21.5 km.



Source: JICA Study Team based on Water Supply Investment Master Plan 2011 (MCC M/P)

Figure 2.4.1 Layout Plan of the CP-1 and CP-2 Components of the MCC Project

New pipeline of CP-2 component is planned to be connected to the existing transmission pipeline from the Chilanga Booster Pumping Station at the point near the Lusaka Water Works. According to Lp6 plan, there is no regulating water tank at the connecting point. Water from the Chilanga Booster Pumping Station keeps water pressure in the transmission pipe and reaches the Stuart Park Distribution Center and Lumumba Distribution Center through the distribution pipelines to be constructed. However, after that, laying of water pipes from Lusaka Water Works Distribution Center to Stuart Park Distribution

Center was cancelled because existing water supply pipes were also deemed to be available for immediate water supply. The new pipeline has larger diameter and flow capacity than the existing pipeline (e.g., from existing diameter 900 mm to planned diameter 1200 mm). It is planned that the existing pipeline will not be used after the completion of the new pipeline, while actual management of the existing and new pipelines will be decided by LWSC.

Open cut method is planned for installation of the new pipeline. The Lumumba Reservoir is surrounded by a congested commercial and industrial area. For installation of the new pipeline to the Lumumba Reservoir, wayleave of a width of 30 m given to ZESCO is planned to be utilized. Procedure of prior confirmation in terms of environmental and social issues (ESIA) has completed. The new pipelines are scheduled to be placed in service from December 2017.

3) CP-6: Non-revenue Water Reduction

The NRW ratio was 48% at the time of the feasibility study on the MCC project. This package aims to reduce the NRW ratio to 25% by 2015. Table 2.4.3 shows the components of this package, as described in the MCC Project F/S report prepared in January 2012.

Table 2.4.3 CP-6 Components Designated at F/S Stage (MCC Project)

Construction Item	Description	Specifications
Renewal of distribution pipes	Renew the existing distribution pipes which are deteriorated or incapable to distribute design water volume	Length: 161 km Diameter: 75 mm–600 mm
Installation of Bulk meters and water meters	Install bulk water meters to set up district metered areas (DMAs) Install water meters to achieve 100% of the metered ratio.	Bulk meters: 300 locations Water meters: 23,000 locations
Provision of equipment for water leakage management	Provide equipment necessary for water leakage management	Ultrasonic flow meter Pressure logger Pipe detector Water leakage detector, etc.

Source: MCC Project F/S

DMAs are the divisions of water distribution area managed by LWSC in order to measure water distribution volume by each DMA. At present, bulk meters are not installed in any of the DMAs and DMA-based water distribution management cannot be performed.

In the MCC project, the existing LWSC service area was divided into 69 DMAs during the preparation of the MCC M/P (2011) and the detailed design and bidding for this package were conducted on the basis of 69 DMAs. On the other hand, LWSC has reorganized a part of the DMAs and then the number of DMAs became 66 at present.

Table 2.4.4 Number of DMAs in the Existing LWSC Service Area

Items	MCC Project (Planned in 2011)	Current Status of LWSC * (2016)
Number of DMA in the existing service area	69	66
Integrated DMA	Before integration: Kaunda Square 1 Kaunda Square 2	After integration: Kaunda Square
	Before integration: Woodland Extension New Woodland Extension	After integration: Woodland Extension
	Before integration: Mtendere Kalikiliki	After integration: Mtendere

*: Current area divided by LWS
Source: JICA Study Team based on the data provided by LWSC

MCC selected priority DMA for the MCC project among 69 DMAs during the detailed design after F/S. To select the priority DMA, 55 DMAs, with the exception of DMAs for implementation of distribution pipe expansion in other components (CP-5 and LS-3), were graded on the number of DMA connection points, water supply hours, pipe installation year, pipeline material, meter connection rate; and 35 DMAs were selected. Based on the result of the selection, MCC discussed with LWSC and reselected 14 DMAs. Table 2.4.5 shows the results of priority ranking of DMA prepared by MCC.

Table 2.4.5 Results of the Priority Evaluation of DMA NRW Reduction Project

No.	DMA	No. of interconnection conncetion points					Hours of Supply					Age of network					Pipe Material					Customer metering					Socring	Selection of 35DMA	Selection of 14DMA
		more than 9	7 - 8	5 - 6	3 - 4	1 - 2	less than 6 hrs	6 - 11 hrs	12 - 17 hrs	18 - 23 hrs	24 hrs	0 - 5 yrs	6 - 10 yrs	11 - 20 yrs	21 - 30 yrs	30 yrs	HDPE	PE/PVC	DI	GI	AC	less than 20%	21 - 40%	41 - 60%	61 - 80%	81 - 100%			
1	Chudleigh					4			2						3						4					4	17	○	
2	Nyumba Yanga				3					3					3						4					4	17	○	
3	Thorn Park					4			2							4					4				3		17	○	
4	Ibex Hill			2						3					3						4					4	16	○	
5	Chawama/Kuomboka		1						2							4					4					4	15	○	○
6	Mwambula		1						2							4					4					4	15	○	
7	Kabwata Estates	0							2							4					4					4	14	○	○
8	Luburma	0									4					4				3					3		14	○	
9	Matero	0							2							4					4					4	14	○	○
10	New Kamwala		1								4			2						3						4	14	○	
11	Handsworth		1						2							4			2							4	13	○	
12	Helen Kaunda				3				2												4					4	13	○	
13	Northmead	0							2							4				3						4	13	○	○
14	Woodlands Extension	0						1								4					4					4	13	○	
15	Chilenje South	0						1								4				3						4	12	○	○
16	Chunga					4			2					2							4	0					12	○	
17	John Howard			2					2							4					4	0					12	○	
18	Kalingalinga	0							2					2							4					4	12	○	
19	Libala	0							2							4				3					3		12	○	
20	New Kabwata		1								4										4				3		12	○	○
21	Rhodes Park	0							2							4			2							4	12	○	○
22	Town/Kabelenga	0							2							4			2							4	12	○	○
23	Chainama-Munali	0							2				1								4					4	11	○	
24	Marrapodi			2					2							4				3		0					11	○	○
25	Avondale	0							2												4					4	10	○	○
26	Chamba Valley			2					2												4			2			10	○	
27	Chelstone	0							2												4					4	10	○	○
28	Emmasdale Bank House	0							2												4					4	10	○	○
29	Garden	0							2							4					4	0					10	○	○
30	Kalundu	0							2												4					4	10	○	
31	Kaunda Square II		1						2												4				3		10	○	
32	New Woodlands Extension			2				1													4				3		10	○	
33	Olympia Extension		1						2												4				3		10	○	
34	Chainda				3				2												4	0					9		
35	Emmasdale	0							2												4				3		9		
36	George	0							2					2				1								4	9		
37	Kabanana				3				2												4	0					9		
38	Kabulonga	0						1													4					4	9	○	○
39	Olympia Park	0							2												4				3		9	○	
40	Prospect Hill	0							2											3						4	9		
41	Roma	0							2												4				3		9		
42	Shakespear	0							2											3						4	9		
43	State House	0							2											3						4	9		
44	Villa Elizabetha	0							2											3						4	9		
45	Government	0							2											3					3		8		
46	Kaunda Square I			2					2												4	0					8		
47	Chilenje	0						1												3					3		7		
48	Fairview	0							2									1								4	7		
49	Industries	0							2										2						3		7		
50	Unza	0							2										2						3		7		
51	Woodlands	0						1											2							4	7		
52	Chibolya	0							2												4	0					6		
53	Kalikiliki					4			2													0					6		
54	Sikanze	0							2									1							3		6		
55	Chandamali	0						1																	3		4		

Source： JICA Study Team based on LS-1 NRW Reduction Progress Report-1

After the MCC Master Plan, MCC reviewed and reorganized the NRW reduction component and renamed the component in the tender document: Ls1 to CP-6. The target of NRW reduction did not change as “decrease from 48% to 25%”; however, 14 high priority DMAs were selected as the target areas.

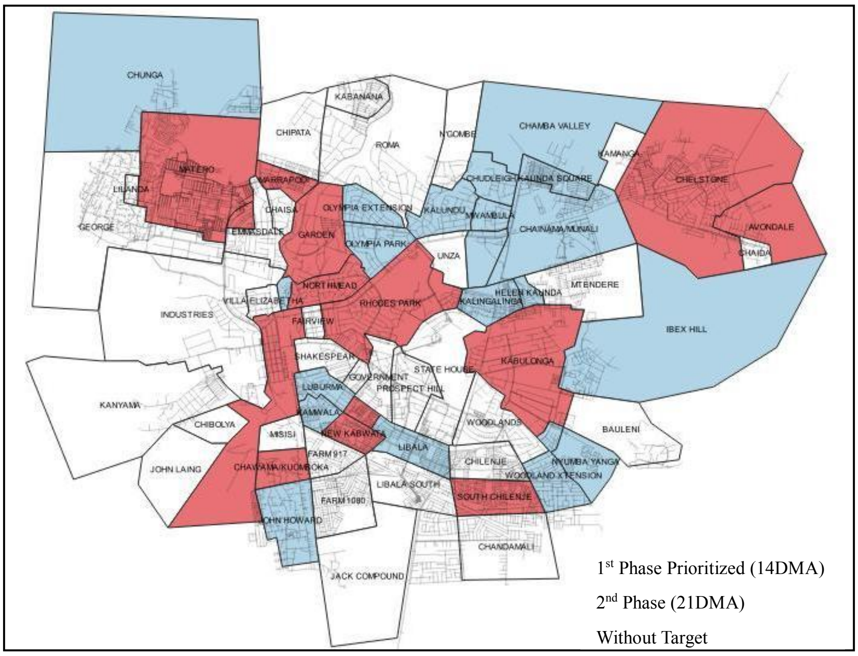
According to the interview with MCC, the MCC project will implement NRW reduction measures in the high priority 14 DMAs as first phase and consider further implementation in 21 DMAs as the second phase through review of results attained by the first phase. Since the construction of the 14 DMAs is delayed, there is a high possibility that 21 DMAs could not be handled. The 21 DMAs in the second phase are included in the 35 DMA candidates during the detailed design but are finally excluded from the priority DMA.

Table 2.4.6 and Figure 2.4.2 show the target DMAs where NRW reduction project is implemented.

Table 2.4.6 CP-6 List of Target DMA for NRW Component

First Phase (High priority 14 DMAs)		Second Phase (21 DMAs)	
1) New Kabawata House	12) Emmasdale Bank	1) Chudleigh	12) Libala
2) Chelston	13) Rhodespark	2) Nyumba Yanga	13) Chunga
3) Avondale	14) Kabulonga	3) Thom Park	14) John Howard
4) Northmead		4) Ibex Hill	15) Chainama-Munali
5) Chawama/Kuomboka		5) Mwambula	16) Kalundu
6) Chilenje South		6) Lubruma	17) Olympia Extension
7) Marrapodi		7) New Kamwala	18) Chamba Valley
8) Kabawata Estates		8) Handsworth	19) Kaunda Square 2
9) Matero		9) Helen Kaunda Extension	20) New Woodlands
10) Garden		10) Woodlands Extension	21) Olympia Park
11) Town/Kabelenga		11) Kalingalinga	

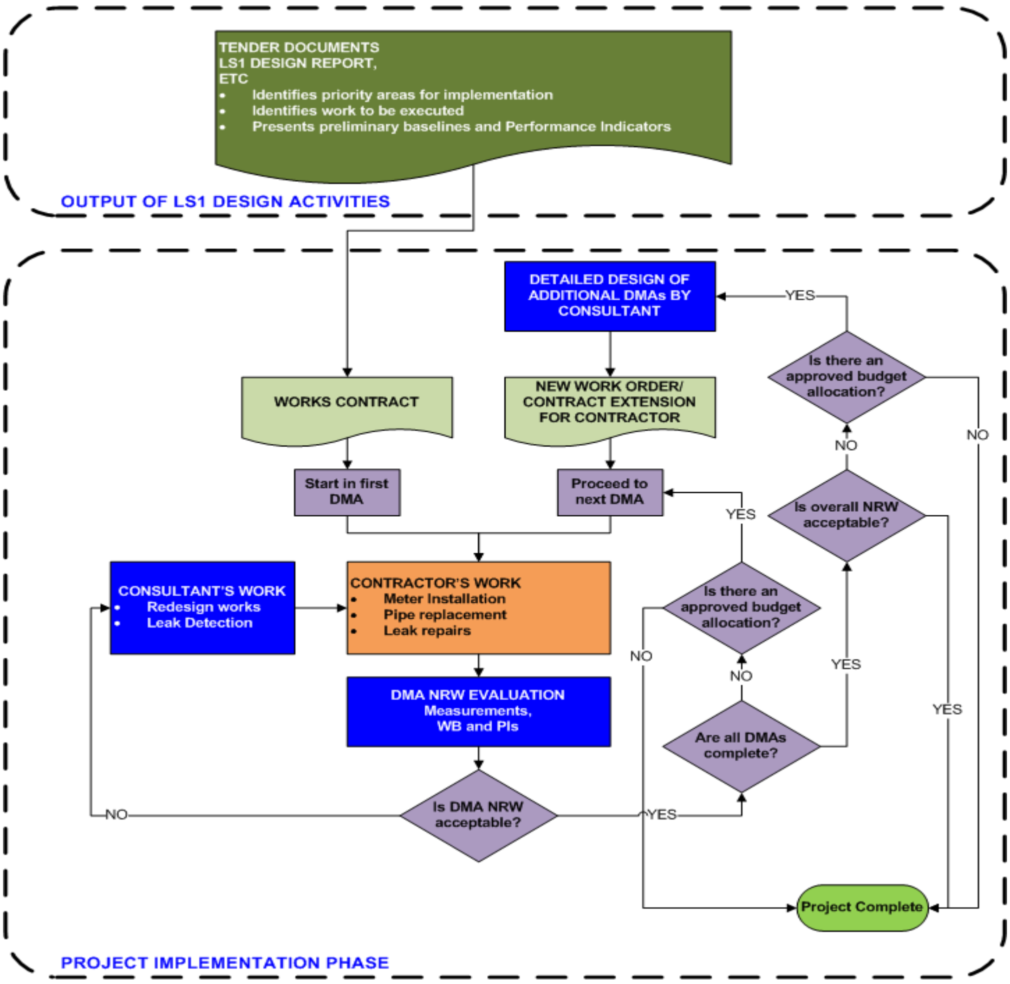
Source: Draft Bidding Documents, Technical Specification, CP6: NRW Reduction and Rehabilitation of the Distribution Network in Lusaka and the JICA Study Team based on LS-1 NRW Reduction Progress Report-1



Source: Draft Bidding Documents, Technical Specification, CP6: NRW Reduction and Rehabilitation of the Distribution Network in Lusaka and the JICA Study Team based on LS-1 NRW Reduction Progress Report-1

Figure 2.4.2 Location of DMA for CP-6 NRW Reduction Component

Figure 2.4.3 shows NRW reduction approach by CP-6. As shown in the “Project Implementation Phase” in the figure, the contractor conducts the works in DMA; improvement in the DMA is evaluated by flow measurement to confirm the achievement of target; then the contractor moves to the next DMA. If the achievement is not enough, the consultant implements design improvement while the contractor conducts the works for improvement. The project shall be completed with the achievement of the NRW reduction target or disbursement of all the budget for the works in this package.



*: Abbreviation in the figure, WB: Water Balance, PIs: Performance Indicator

Source: Draft Bidding Documents, Technical Specification, CP6: NRW Reduction and Rehabilitation of the Distribution Network in Lusaka

Figure 2.4.3 CP-6 Work Flow of NRW Reduction Measures Component

Table 2.4.7 shows the status of 14 DMAs as described in the tender documents prepared under the MCC project. In 14 DMAs, the service connections account for 41% of those in the existing LWSC service area. The pipeline length accounts for 23% of those in the existing LWSC service area. NRW rate is 47%.

Table 2.4.7 Baseline Data on the Prioritized 14 DMAs

No.	DMA Name	No. of Connections		Metering Ratio	Length of Network (Km)		Ave. Supply (m3/d)	Ave. Consumption (m3/d)	Baseline NRW (%)
1	New Kabawata	1,690	(2%)	70%	21.98	(1%)	11,112	6,916	38%
2	Chelston	2,796	(4%)	91%	82.68	(4%)	16,907	9,355	45%
3	Avondale	1,732	(2%)	81%					
4	Northmead	1,145	(2%)	81%	16.89	(1%)	3,873	2,071	47%
5	Chawama/Kuomboka	2,262	(3%)	31%	20.41	(1%)	4,772	2,215	54%
6	Chilenje South	2,700	(4%)	90%	28.11	(2%)	5,337	3,309	38%
7	Marrapodi	2,035	(3%)	85%	12.91	(1%)	2,831	1,465	48%
8	Kabawata Estates	1,509	(2%)	92%	10.26	(1%)	3,507	1,592	55%
9	Matero	7,109	(10%)	92%	73.44	(4%)	6,827	4,786	30%
10	Garden	1,442	(2%)	57%	23.16	(1%)	3,260	1,471	55%
11	Town/Kabelenga	937	(1%)	85%	24.90	(1%)	4,593	1,867	59%
12	Emmasdale Bank House	699	(1%)	88%	12.16	(1%)	3,805	943	75%
13	Rhodespark	1,500	(2%)	82%	42.95	(2%)	12,623	4,417	65%
14	Kabulonga	1,492	(2%)	87%	52.79	(3%)	4,032	3,694	8%
Total		29,048	(41%)	79%	423	(23%)	83,479	44,101	47%
		Lusaka city: 70,850	(100%)		Lusaka city:1,840km	(100%)			

Note: The number of connections is slightly smaller than the number of constructions in 2015 shown in Table2/2/4(2/2). It seems to be the data before 2015.

Source: Draft Bidding Documents, Technical Specification, CP6: NRW Reduction and Rehabilitation of the Distribution Network in Lusaka

Table 2.4.8 shows the work quantities for the pipe rehabilitation works and meter installation works that are mentioned in the Bill of Quantities compiled in the bidding documents. Work quantities of the pipe rehabilitation works consist of (i) works for reconfiguration of distribution network in DMA, (ii) works for improvement of hydraulic capacity, and (iii) works for reduction of leaks based on the leakage detection survey results.

The rehabilitation covers asbestos cement pipe and galvanized iron pipe. The total length of the rehabilitation is 207 km including 103 km in 14 DMAs and 104 km in other 21 DMAs. It was changed to install 32,500 water meters in the construction contract of CP-6.

Table 2.4.8 Bill of Quantities of the NRW Reduction Works (CP-6)

No.	DMA Name	Length of Pipe Rehabilitation (Km)											Customer Meters (Nos.)	Bulk Meters (Nos.)
		uPVC						Steel						
		75mm	90mm	110mm	160mm	225mm	280mm	300mm	400mm	450mm	500mm	600mm		
1	New Kabawata	3.83	0	1.97	0.14	0	0	0	0	0	0	0	510	2
2	Chelston	0.69	0	0	4.27	0.12	2.27	0	0	0	0	0	280	2
3	Avondale	0.78	0	0.73	2.04	0.01	2.46	0	0	0	1.47	2.95	370	2
4	Northmead	0.29	0.80	0	3.58	0.99	0	0	0	0	0	0	210	2
5	Chawama/Kuomboka	0	0	0	2.00	3.11	0	2.75	0	0	0	0	1,620	4
6	Chilenje South	2.04	0.27	0	6.70	2.75	0	0	0	0	0	0	290	2
7	Marrapodi	8.83	1.59	0	0	0.04	0.55	0	0	0	0	0	360	1
8	Kabawata Estates	0	0	0	0	0	0	0	0	0	0	0	120	2
9	Matero A	0	0	0	0.71	0	0.81	0	0	0	0	0	380	6
	Matero B	0	0.38	0	0.52	0	0.94	0	0	0	0	0	380	1
10	Garden	0.72	0.04	3.38	4.30	0.27	0.00	0	0	0	0	0	620	1
11	Town/Kabelenga	0.71	0	0.00	3.45	1.55	0.47	0	0	0.79	0	0	150	2
12	Emmasdale Bank House	0	0	1.79	0	0.12	0.21	0.95	0	0	0	0	100	1
13	Rhodespark	3.20	0.09	0.18	0.24	1.62	0.01	0	1.88	0	0	0	170	1
14	Kabulonga	1.72	5	2.44	0.47	1.08	0.00	0	0	0	0	0	240	3
(15)	(Longress/Massmedia)	0.14	0	1.77	0.58	0.47	0.02	0	0	0	0	0	110	2
i) Prioritized 14DMAs	Sub total	22.95	8.43	12.26	29.00	12.13	7.74	3.70	1.88	0.79	1.47	2.95		
	Total											***103***	***5,910***	***34***
ii) Rest of Lusaka	Sub total	13.77	5.36	11.33	38.91	12.51	11.97	4.37	1.84	0.23	0	3.68		
	Total											***104***	***15,400***	***0***
i) +ii)	Grand total											***207***	***21,310***	***34***

*: While the pipe rehabilitation quantities for Kabawata Estate DMA are not shown in the Bill of Quantities, it is assumed wrong in writing. On the other hand, the work quantities for Long/Mass Media are counted despite being not included in the prioritized DMAs.

Source: Edited by the JICA Study Team from the Draft Bidding Documents, Bill of Quantities, CP6: NRW Reduction and Rehabilitation of the Distribution Network in Lusaka

4) CP-3: Distribution Network Expansion in Mtendere and Kamanga

Table 2.4.9 and Figure 2.4.4 show the length and the target area of distribution pipe expansion in CP-3 respectively.

Table 2.4.9 Distribution Pipe Expansion in CP-3

DMA	Extension of Distribution Pipe (km)					
	63 mm	110 mm	160 mm	225 mm	315 mm	Total
Mtendre	51.2	3.9	-	1.1	2.3	58.5
Kamanga	8.2	3.1	3.1	-	-	14.4
Total	59.4	7.0	3.1	1.1	2.3	72.9

Source: Final Bidding Documents, Contract Package (CP) 3: Water and Sewer Reticulation in the Kamanga, Mtendere, Kaunda Square, and Chelston Areas

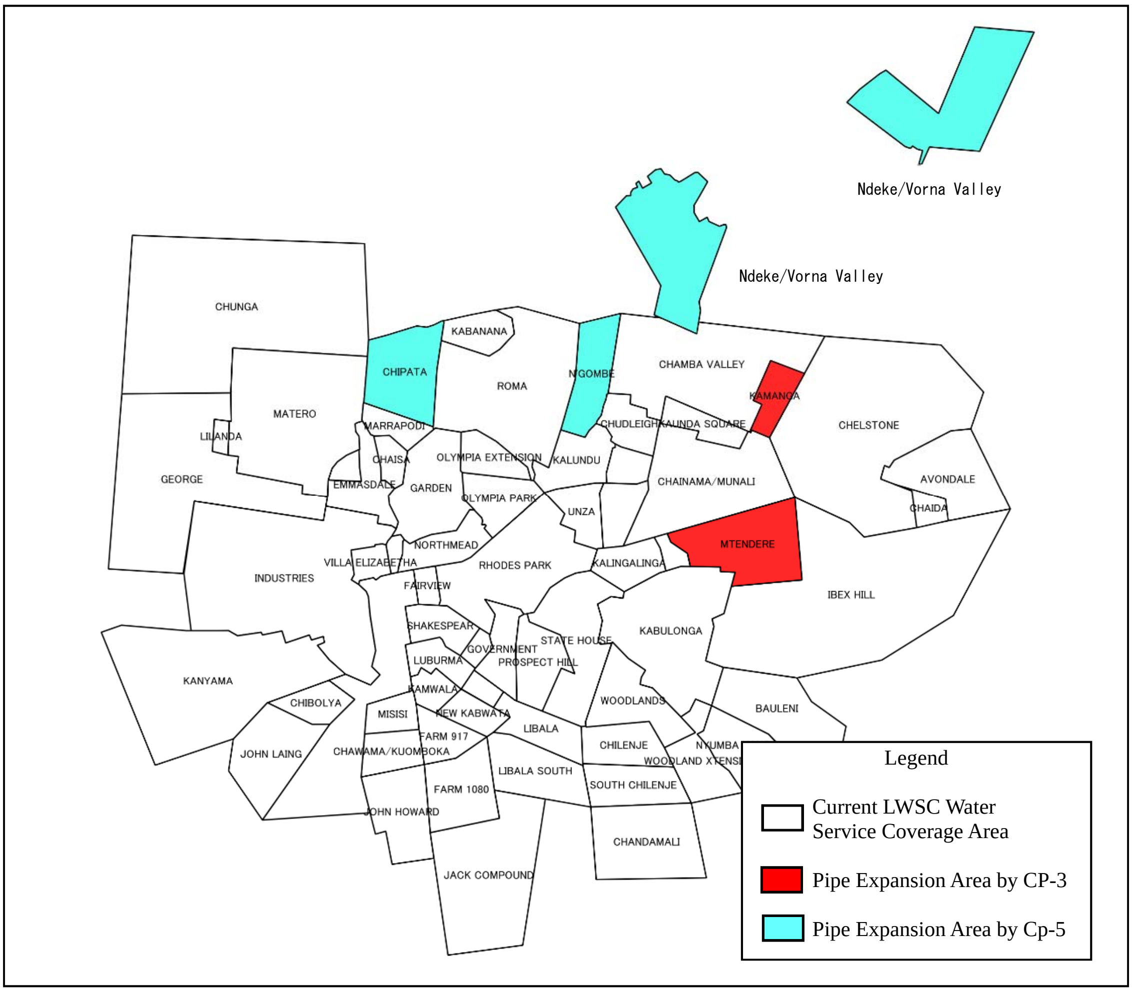
5) CP-5 : Expansion of Distribution Network in Chipata (Ls2) and Ndeke/Vorna Valley and Kwamwena (Ls3)

Table 2.4.10 and Figure 2.4.4 show the length and the target area of distribution pipe expansion in CP-5 respectively.

Table 2.4.10 Distribution Pipe Expansion in CP-5

DMA	Expansion of Distribution Pipe (km)											
	uPVC PN 10 (mm)							Steel PN 16 (mm)				Total
	63	90	110	160	225	250	315	100	200	350	400	
Ng'ombe, Chipata	37.9	2.1	8.4	0.5	4.7	0.7	4.0	-	-	-	-	58.3
Ndeke/ Vorna Valley, and Kwamwena	134.5	2.0	32.1	-	20.2	-	7.9	8.4	4.2	0.4	0.1	209.8
Total	172.4	4.1	40.5	0.5	24.9	0.7	11.9	8.4	4.2	0.4	0.1	268.1

Source: Final Bidding Documents Contract Package (CP-5)



Source: JICA Study Team

Figure 2.4.4 Target Area for Distribution Pipe Network Expansion (CP-3, CP-5)

2.4.2 Kafue Bulk Water Supply Project (KBWSP)

(1) General Information

The Kafue Bulk Water Supply Project (KBWSP) aims to 150,000 m^3/day of supply water from Kafue River to Stuart Park Distribution Center. The first phase for 50,000 m^3/day is being constructed from 2017 by Chinese Loan Project. The outline of KBWSP is described hereunder.

(2) Intake Facility and Raw Water Transmission Pipeline

An intake facility is planned to be constructed at around 80 m away from the existing Iolanda Intake Facility to the east. The components of the facility are described in Table 2.4.11 and Table 2.4.12.

Table 2.4.11 Intake Facility of KBWSP Phase 1

Item	Description
Intake flow rate	55,000 m^3/day Including self-consumption at WTP: 5% and head loss: 5%
Water level	HWL (High Water Level): AMSL 978m and LWL (Low Water Level): AMSL 972 m
Structure	Two compartments to take 150,000 m^3/day of raw water Intake tower equipped with access bridge (W=2.5 m and L = 95 m)
Gate	2,950 mm ×2,000 mm × 2 units
Pump	Q=2,750 m^3/hour, H=53 m, Output 560 kw× 2 units (one for stand-by) per compartment, two units to be installed in this phase, additional two units to be installed in the future phase.
Raw water transmission pipeline	Ductile iron pipe, φ800 mm ×1 lane, L= 2.2 km

Source: JICA Study Team based on the asset information of LWSC

Table 2.4.12 WTP Facility of KBWSP Phase 1

Item	Description
Treatment capacity	50,000 m^3/day
Sedimentation basin	Horizontal flow with inclined plate, two compartments, water depth; 3.6 to 4.2 m
Filter basin	Six basins, and filter thickness: 1.2 m Washing- method: air washing, backwashing, and surface washing Backwash pump: three units (one for stand-by) Blower: two units (one for stand-by) Chlorine dosing pump: three units (one for stand-by)
Treated water reservoir	Total volume: 3,500 m^3 × 2 reservoirs
Treated water transmission pump	Q = 875 m^3/hour, H = 250 m, Output: 850 kW × four units (one for stand-by)
Chemical building	Coagulant dosing (Coagulant: Poly aluminum chloride, Solution tank: 2.1 m (L) × 3.05 m (W) × 2.3 m (H) × three compartments Lime dosing equipment (Alkali agent: Slaked lime, Solution tank; 2.1 m (L) × 3.05 m (W) × 2.3 m (H) × three compartments) Chlorination room: one unit
Wastewater regulating tank	Capacity: 800 m^3 × depth 4 m (two compartments)
Others	Administration building, storage room, gate and guard room, and sub-station

Source: JICA Study Team based on the asset information of LWSC

(3) Transmission Facility

Transmission facilities in the first phase of KBWSP include transmission pumps that will be constructed in the new WTP, expansion of Chilanga Booster Pumping Station, water transmission pipeline from the new WTP to Stuart Park Distribution Center via Chilanga Relay Pump Station (pipe diameter: φ800 mm). The outline of each facility is shown in Table 2.4.13. The salient features of transmission facility are shown below.

- Storage capacity of treated water reservoir in Iolanda WTP is 7,000 m^3 equivalent to a volume for 3.4 hours under the transmission flow rate of 50,000 m^3/day.

- Storage capacity of treated water reservoir in Chilanga Booster Pumping Station is 3,190 m^3 equivalent to a volume for 1.5 hours under the transmission flow rate of 50,000 m^3/day.
- Flow velocity in the transmission pipeline of φ800 mm is 1.15 m/s under the transmission flow rate of 50,000 m^3/day. The transmission pipeline has a capacity for an increase of flow rate.
- The minimum earth cover thickness on the pipe is specified as 0.8 m. The drawings of longitudinal profile show the earth cover thickness ranging from 1.0 m to 1.2 m.
- Pipe jacking method is planned for railway crossing section. Earth cover thickness in this section is more than 2.5 m as shown in the drawings of longitudinal profile.

Table 2.4.13 Outline of the Transmission Facilities in the First Phase of KBWSP

Items	Outline
Transmission facility in Iolanda WTP	- Horizontal shaft type centrifugal flow pump: Discharge quantity 875 m^3/hour (0.243 m^3/second), Total head 256 m (Actual pump head 151.8 m), three regular use and one stand-by, Generator: Power 850 kW, Voltage 3.3 kV, Rotation 2,950 rpm, three regular use and one stand-by - Treated water reservoir: Capacity 7,000 m^3 (36.6 m×26.2 m× Effective water depth 4.0 m×2 tanks), Semi-underground type
Chilanga Booster Pumping Station	- Horizontal shaft type centrifugal flow pump: Discharge quantity 875 m^3/hour (0.243 m^3/second), Total head 243 m (Actual pump head 156.0 m), three regular use and one stand-by, Generator: Power 850 kW, Voltage 3.3 kV, Rotation 2,950 rpm, three regular use and one stand-by - Treated water reservoir: Capacity 3,190 m^3 (28.6 m ×19.6 m× Effective water depth 3.0 m×2 tanks), Semi-underground type
Transmission pipe	- Section from Iolanda WTP to Chilanga Booster Pumping Station: Pipe diameter φ800 mm, Length 29.3 km, Test pressure: 4 types of 1.6, 2.5, 3.0, and 3.2MPa, Steel pipe (Pipe thickness 2 types of 10 mm and 12 mm) and Ductile cast iron pipe (2 types of K10 and K12) - Section from Chilanga Booster Pumping Station to Stuart Park Reservoir: Pipe diameter φ800 mm, Pipe length 24.4 km, Test pressure 3 types of 1.6, 2.5, and 3.0MPa, Steel pipe (Pipe thickness 2 types of 10 mm and 12 mm) and Ductile cast iron pipe (2 types of K10 and K12)

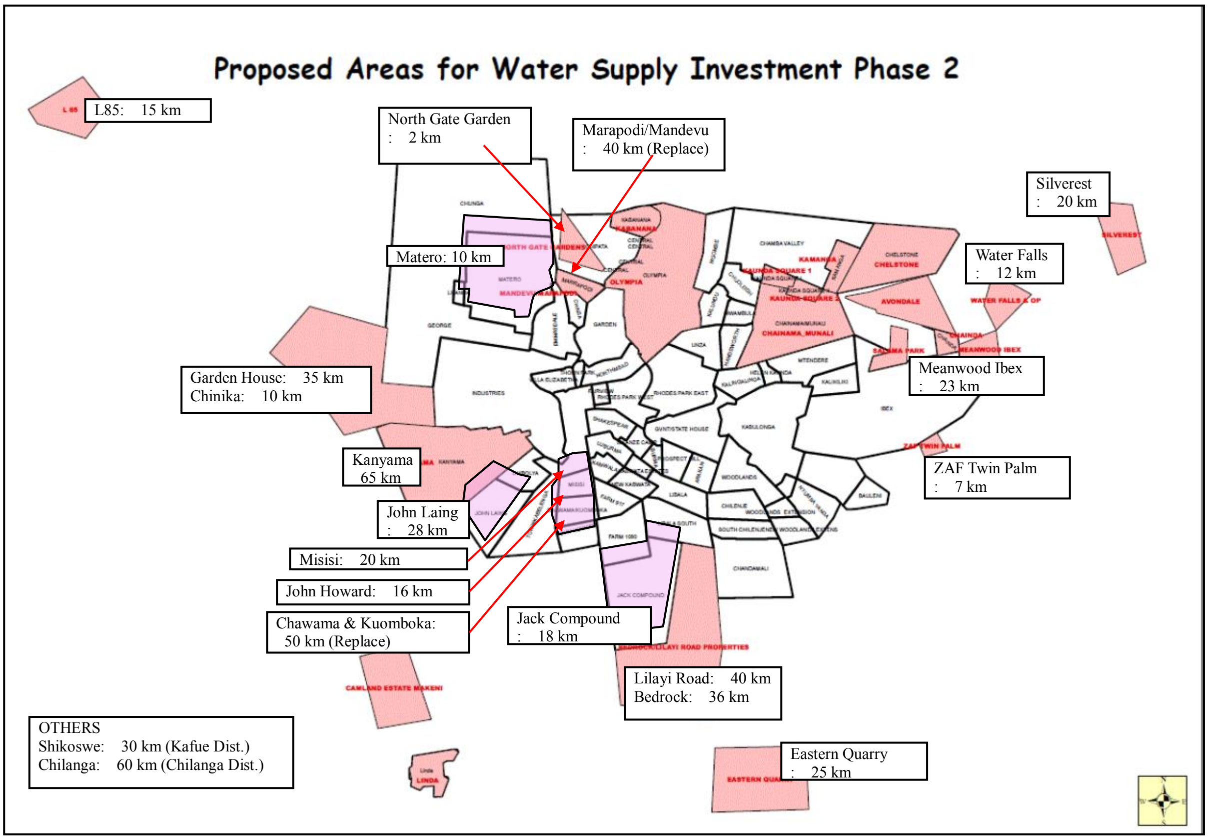
Source: JICA Study Team based on the data provided by LWSC

2.4.3 Lusaka City Water Supply Improvement Project Phase 2

Prior to the KBWSP for augmentation of water supply capacity, LWSC intends to initiate "Lusaka City Water Supply Improvement Project Phase 2" for expansion of water distribution network. The target areas of the project are shown in Figure 2.4.5. In these areas, the LWSC plans to develop a water distribution network through well construction for the time being in order to respond to newly generated water demand.

In Lusaka Water Supply Improvement Project Phase 2, water supply of 119,116 m^3/day is planned for 174,858 households and the project cost is estimated at ZMW 723 million (USD 76 million). It includes installation of distribution pipes with a total length of 562 km (including 90 km for renewal of the existing pipeline), six booster pumping facilities, five reservoirs and four power stations, wells, and bulk meters. The planned works for installation of distribution pipes are shown in Table 2.4.14.

LWSC considers dividing the project into several components to be implemented using private funds. LWSC has already contacted a Chinese company. In the meantime, LWSC also considers other financial sources such as the government or donors including JICA. This project will improve water distribution network which is part of the Lusaka Water Supply Improvement Project Plan Phase 2 (township excluding peri-urban).



Source: Project Plan of Lusaka Water Supply Improvement Project Phase 2 prepared by LWSC

Figure 2.4.5 Distribution Pipe Network Expansion Area in Lusaka Water Supply Improvement Project Phase 2

Table 2.4.14 Installation Length of Distribution Pipe in Lusaka Water Supply Improvement Project Phase 2

Current LWSC Water Service Coverage Area		Out of the Current LWSC Water Service Coverage Area	
Area	Distribution Pipe Length (km)	Area	Distribution Pipe Length (km)
Matero	10	Silverest	20
North Gate Gardens	2	Water Falls	12
Meanwood Ibex Hill	23	ZAF Twin Palm	7
Misisi/Kuku	20	Chinika	10
Jack Compound	18	Garden House	35
John Howard	16	L85	15
John Laing	28	Bedrock	36
Kanyama	65	Eastern Quary	25
		Lilayi Road	40
Marapodi/Mandevu	40 (Renewal)	Shikoswe	30
Chawama/Kuomboka	50 (Renewal)	Chilanga	60
Total in the Service Area	182 (New) 90 (Renewal)	Total out of the Service Area	290 (New)
		Grand Total	562

Source: Project Plan of Lusaka Water Supply Improvement Project Phase 2 prepared by LWSC.

CHAPTER 3 EXAMINATION OF PROPOSED PROJECT

3.1 Outline of Chapter 3

In this chapter, the Water Supply Investment Master Plan prepared by MCC, for Greater Lusaka (Lusaka City and its surrounding region: Kafue District, Chongwe District and part of Chilanga District) with a target year of 2035, (hereinafter referred to as MCC Master Plan or MCC M/P) was reviewed. After the review, the water demand was newly forecasted, and the Project was formulated based on the new demand forecast.

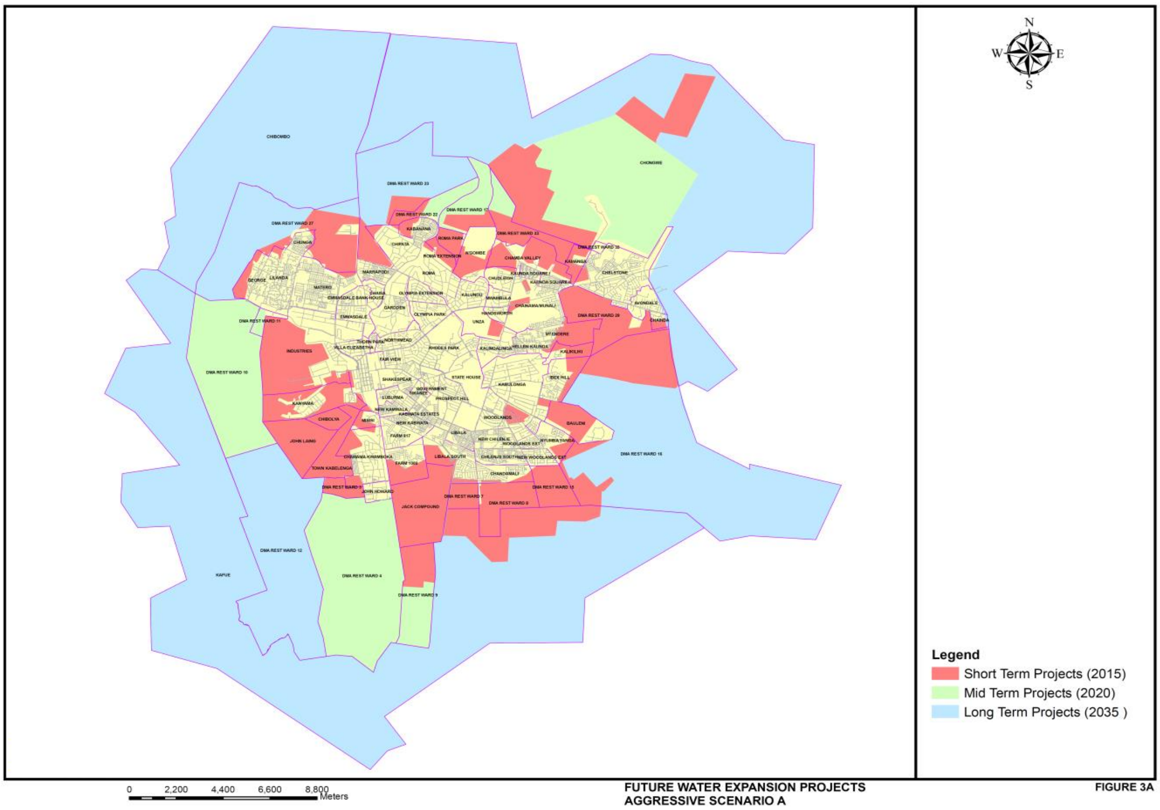
Section 3.2 shows the outline of the MCC M/P, and the differences between the forecast in the M/P and the actual situation in Greater Lusaka as of 2015. In Section 3.3, the Priority Area for the water supply system development in Lusaka City was proposed, considering the proposals in the MCC M/P and other plans and progress of relevant projects. In Section 3.4, the population and water demand forecasts in the MCC M/P were reviewed and new population and water demand forecasts were proposed. In Section 3.5, the Project was formulated as a yen loan project, to cover the water demand for the Priority Area in 2030. In Section 3.6, a water distribution plan in the Priority Area, which is expected to be realized after the Project's completion, was prepared. In Section 3.7, a plan for expansion of the water supply system to the entire area of Greater Lusaka was proposed.

3.2 Comparison Between the MCC Master Plan and Actual Situation

3.2.1 LWSC Water Service Area Proposed in the MCC M/P

The MCC M/P, which was prepared in 2011, proposed a water supply system development plan to supply water for the 4.38 million population of Greater Lusaka in 2035 as shown in Figure 2.2.6.

The proposed plan in the MCC M/P was to expand the current LWSC water service coverage area (hereinafter referred to as LWSC Service Area) to the entire Greater Lusaka by 2035. The water supply facility plan was formulated based on the expansion plan of the water service area as shown in Figure 3.2.1. For the expansion, it was proposed in the MCC M/P to install 1,507 km of water distribution pipes by 2015 and 1,964 km by 2035 as shown in Table 3.2.1. However, the pipes that have been installed since the year the MCC M/P was prepared until 2015 were only 114 km.



Source: Water Supply Investment Master Plan, 2011 (MCC M/P)

Figure 3.2.1 Expansion Plan of LWSC Service Area in the MCC M/P

Table 3.2.1 Proposed Distribution Pipe by 2020 as Proposed in the MCC M/P

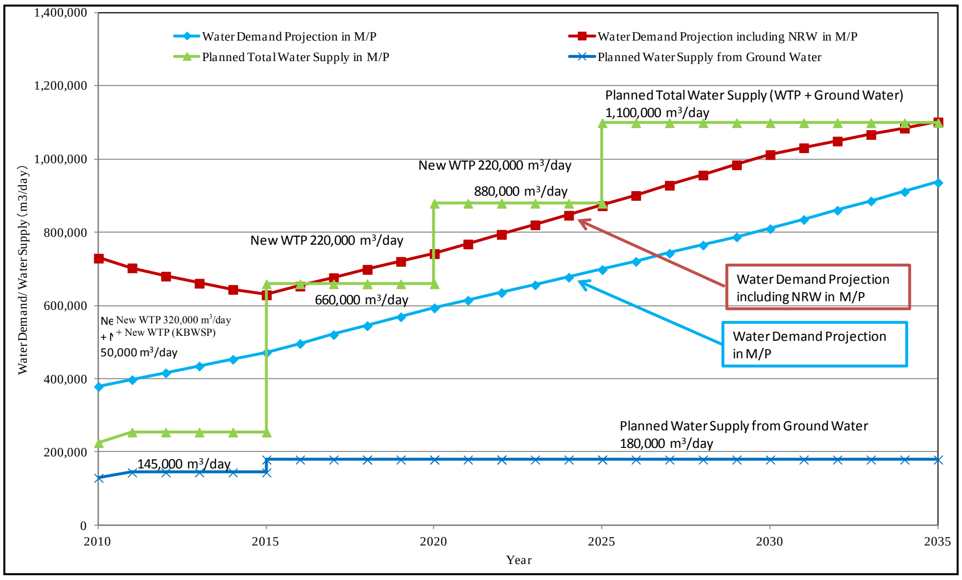
Type of Pipe, Dia.	2015	2020	2035	Total
uPVC Pipe (90 – 280 mm)	1,302 km	134 km	149 km	1,585 km
Steel Pipe (300 – 900 mm)	205 km	10 km	164 km	379 km
Total	1,507 km	144 km	313 km	1,964 km

Source: Water Supply Investment Master Plan, 2011 (MCC M/P)

3.2.2 Development Plan in the MCC M/P by 2035

The outline of the water demand and supply balance forecast and water source development plan in the MCC M/P are shown in Figure 3.2.2 and Table 3.2.2, respectively. The MCC M/P proposed to augment the existing water supply system, taking water from Kafue River, from a current capacity of 95,000 m^3/day to 920,000 m^3/day, and to develop a groundwater resource from a current capacity of 130,000 m^3/day to 180,000 m^3/day. However, LWSC has water right of only 855,750 m^3/day from Kafue River at present.

The MCC M/P planned to complete the three projects from 2000 to 2015. One of them is an expansion of the existing WTP (50,000 m^3/day). The others are the construction of a new WTP (320,000 m^3/day) and development of groundwater wells (35,000 m^3/day in total). These projects have not been implemented but a new WTP with a capacity of 50,000 m^3/day is under construction in the KBWSP Phase-1, with a financial assistance from the Chinese government.



Source: Water Supply Investment Master Plan, 2011 (MCC M/P)

Figure 3.2.2 Demand and Supply Curve in the MCC M/P

Table 3.2.2 Development Plan of Surface Water and Groundwater in the MCC M/P

Year	Water Production (m³/day)			Expansion Plan
	Total	Groundwater	Kafue River	
2010	225,000	130,000	95,000	
2011	255,000	145,000	110,000	+10 boreholes (15,000 m³/day)
2012 - 2014	255,000	145,000	110,000	
2015	660,000	180,000	480,000	+25 boreholes (35,000 m³/day) Expand the existing WTP by 50,000 m³/day Add a WTP of 320,000 m³/day
2016 - 2019	660,000	180,000	480,000	
2020	880,000	180,000	700,000	Add a WTP of 220,000 m³/day
2021 - 2024	880,000	180,000	700,000	
2025	1,100,000	180,000	920,000	Add a WTP of 220,000 m³/day
2026 - 2035	1,100,000	180,000	920,000	

Source: Water Supply Investment Master Plan, 2011 (MCC M/P)

3.2.3 Water Demand Forecast in the MCC M/P

(1) Future Service Population

The population forecast and planned service ratio in Greater Lusaka in the MCC M/P are shown in Table 3.2.3. The MCC M/P projected the total population will grow by 2.6 million from 2015 to 2035 and proposed to increase the service population by 2.6 million and those served through service connection by 2.5 million in the same period.

Table 3.2.3 Existing and Future Service Population and House Connection

Item	MCC M/P		
	Year 2015	Year 2025	Year 2035
Population	2,344,000	3,570,000	4,953,000
Population in LWSC Service Area	2,344,000	3,570,000	4,953,000
Water Service Population	2,344,000	3,570,000	4,953,000
Water Service Ratio	100%	100%	100%
Service Population through Household Connection	1,594,000	2,820,000	4,111,000
No. of Public Tap/Water Kiosk User	750,000	750,000	842,000
House Connection Ratio	68%	79%	83%

Note: Population of Greater Lusaka in 2015 is projected by the MCC M/P and the current service population in 2015 is the total service population of LWSC and Water Trusts.
Source: JICA Study Team based on Water Supply Investment Master Plan, 2011 (MCC M/P) and LWSC Data

According to LWSC, it was estimated that the population in the LWSC Service Area was around 1.92 million, the water service population was around 1.59 million, and service population through household connection was 0.83 million in 2015. There is a significant difference between LWSC's population estimate and the forecast in the MCC M/P.

(2) Unit Water Consumption

1) Domestic Water Use

In the MCC M/P, the unit consumption rate of domestic water was set for each housing type as shown in Table 3.2.4. Table 3.2.5 shows the population ratio of each housing type. In the MCC M/P, a significant increase of water demand was expected in Greater Lusaka due to the increase of household connection.

Table 3.2.4 Unit Water Consumption for Domestic Use

Type of House	Type of Connection	Consumption	
High Cost Housing	House Connection	280 Lpcd	Average* 135 Lpcd（2015） 145 Lpcd（2035）
Medium Cost Housing		150 Lpcd	
Low Cost Housing		100 Lpcd	
Informal Cost Housing	Public Tap Connection	40 Lpcd	

Note*: Weighted average by type of house as shown in Table 3.2.5.
Source: JICA Study Team based on Water Supply Investment Master Plan, 2011 (MCC M/P)

Table 3.2.5 Present and Planned Service Population Ratio by Type of House Connection

Type of Connection	Type of House	Present (2015)	MCC M/P	
			2015	2035
House Connection	High Cost Housing	52%	24%	24%
	Medium Cost Housing		24%	24%
	Low Cost Housing		19%	35%
Public Tap	Informal Cost Housing	48%	33%	17%
Total		100%	100%	100%

Source: JICA Study Team based on Water Supply Investment Master Plan, 2011 (MCC M/P)

2) Non-domestic Water Use

In the MCC M/P, unit consumption rates for public and commercial water demands were set as 14.00 Lpcd and 3.05 Lpcd, respectively. The total of both unit consumption (17.05 Lpcd) is around 0.11 - 0.13 times the average unit consumption rates for domestic water use (135-145 Lpcd: refer to Table 3.2.4). It is extremely smaller than the recent service ratio (average: 0.33, shown in Table 3.2.7).

As for the industrial water use, the unit consumption rate of 80,000 L/ha/day was adopted in the MCC M/P. Table 3.2.6 shows the result of industrial water demand forecast in the MCC M/P and the actual water supply amount for industrial use by LWSC. The actual water supply amount was estimated at around 1,500 m^3/day in 2015. The forecast amount in the MCC M/P is around 70 times larger than the actual water supply amount.

Table 3.2.6 Industrial Water Demand Forecast in the MCC M/P

Unit: m^3/day

	Actual Consumption by LWSC (2015)	MCC M/P		
		2015	2025	2035
Inside Existing LWSC Service Area	1,500	91,252	68,992	52,318
Outside Existing LWSC Service Area	0	16,570	38,473	60,376
Total	1,500	107,822	107,465	112,694

Source: Water Supply Investment Master Plan, 2011 (MCC M/P)

(3) Non-revenue Water：NRW Rate

In the MCC M/P, NRW rate was expected to decrease from 48% in 2010 to 20% by 2020, and to 25% by 2015. However, the current NRW rate in 2015 is still 45%. The progress of NRW reduction is far behind schedule.

Table 3.2.7 NRW Reduction Plan in the MCC M/P

	2010	2015	2020	2025	2030	2035
NRW rate	48%	25%	20%	20%	20%	15%

Source: Water Supply Investment Master Plan, 2011 (MCC M/P)

(4) Daily Peak Factor

In the MCC M/P, all the facilities were planned based on the daily average water demand (instead of the daily maximum water demand). A daily peak factor was not considered.

(5) Comparison Between Current Situation and Future Plan

Table 3.2.8 shows the comparison between the current situation of water supply service in Greater Lusaka in 2015 and the target of the MCC M/P.

Table 3.2.8 Comparison Between Current Situation and Future Plan in the MCC M/P

Item	Current Situation (2015)	Targets in MCC M/P			
		2015	2025	2030	2035
Population					
Population of Greater Lusaka	2,344,000	2,344,000	3,570,000	4,199,000	4,953,000
Population in LWSC Service Area	1,923,218	2,344,000	3,570,000	4,199,000	4,953,000
Service Population*1	1,589,584	2,344,000	3,570,000	4,199,000	4,953,000
Service Coverage	83%	100%	100%	100%	100%
Water Supply Volume*2					
Domestic Water (m^3/d)	102,879	324,677	530,449	631,472	739,761
Public and Commercial Water (m^3/d)	21,172	39,865	60,873	71,599	84,441
Industrial Water (m^3/d)		107,822	107,465	107,287	112,594
Total Water Supply (m^3/d)	124,048	472,463	698,787	810,359	936,896
Water Production Capacity					
Groundwater (m^3/day)	137,000	180,000	180,000	180,000	180,000
Surface Water (m^3/day)	96,000	480,000	920,000	920,000	920,000
Total Water Production Capacity (m^3/day)	233,000	660,000	1,100,000	1,100,000	1,100,000

Note:*1: Including service population in Water Trust Area

*2: Average value of LWSC NRW Dept. data in 2015 (Not including NRW)

Source: JICA Study Team based on Water Supply Investment Master Plan, 2011 (MCC M/P)

(6) Subjects to be Reviewed for the Project

From the gaps between the plans in the MCC M/P and the current situation, the following subjects should be considered to establish a realistic plan for the Project.

1) Expansion of service coverage area of LWSC has not proceeded as scheduled. To prepare a practical project scope, the Project will focus on the current LWSC Service Area.

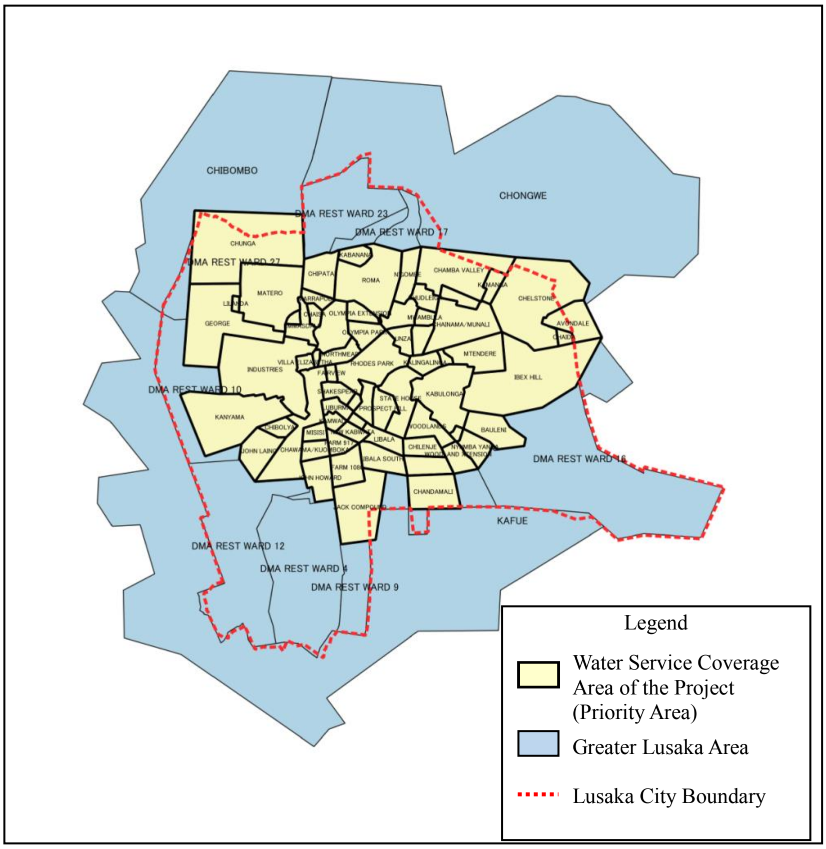
2) Projected service population and house connection population in the MCC M/P are much larger than actual conditions.
Based on the current conditions, more realistic forecast of service population and house connection population should be executed.

3) Unit water consumption rates should be examined based on the current water consumption data.

4) The water demand forecast in the MCC M/P regarded the overall NRW volume as water loss. The Study will recalculate the water demand by applying a more exact definition of water loss, where estimated leakage amount is regarded as the water loss volume.

3.3 Water Service Coverage Area in the Project

As discussed in the previous section, the MCC M/P proposed that the water service area will extened to the entire Greater Lusaka (822 km^2) soon; however, its implementation will need enormous cost and long construction period. Therefore, the Study focuses on the current LWSC service coverage area (263 km^2) as its Priority Area for the water supply improvement by the target year of 2030. Figure 3.3.1 shows the Priority Area which is the target area of the Project in Greater Lusaka.



Source: JICA Study Team

Figure 3.3.1 Water Service Coverage Area of the Project (Priority Area)

3.4 Forecast of Population and Water Demand

3.4.1 Population Forecast

(1) Forecast of Total Population in Greater Lusaka

In the Study, two existing reports have been reviewed regarding the population forecast in Greater Lusaka.

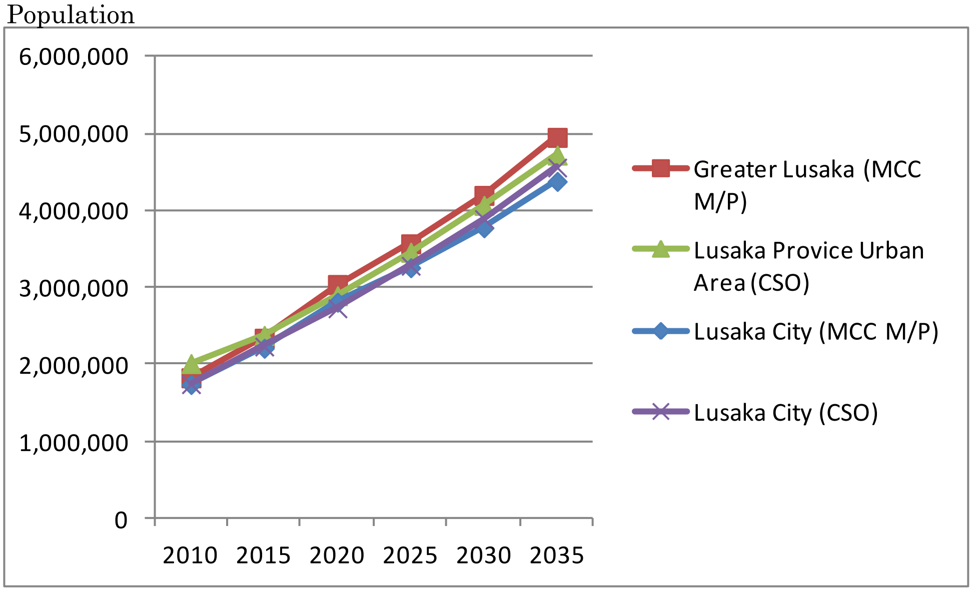
- MCC, Water Supply Investment Master Plan, Lusaka (MCC M/P): July 2011
- Republic of Zambia, Central Statistical Office, Population and Demographic Projections, 2011-2035 (CSO Report): July 2013

Table 3.4.1 and Figure 3.4.1 show the results of the population forecast in the abovementioned reports. Since the CSO Report does not show the forecast for Greater Lusaka, the forecast of Lusaka Province urban area is shown in the following table and figure. The population of Lusaka Province urban area is approximately the same as that of Lusaka City.

Table 3.4.1 Comparison of the Population Forecast in Greater Lusaka Between MCC M/P and CSO Report

Plan	Population					
	2010	2015	2020	2025	2030	2035
Urban Area in Lusaka Province						
CSO Report, 2013	2,015,000	2,381,000	2,896,000	3,461,000	4,070,000	4,723,000
Greater Lusaka						
MCC M/P, 2011	1,830,000	2,344,000	3,042,000	3,570,000	4,199,000	4,953,000
Lusaka City						
MCC M/P, 2011	1,743,000	2,214,000	2,812,000	3,260,000	3,779,000	4,381,000
CSO Report, 2013	1,747,152	2,236,000	2,732,000	3,285,000	3,893,000	4,561,000

Source: JICA Study Team based on Water Supply Investment Master Plan, 2011 (MCC M/P) and Central Statistics Office, Population and Demographic Projections, 2011-2013 (CSO Report)



Source: JICA Study Team based on Water Supply Investment Master Plan, 2011 (MCC M/P) and Central Statistics Office, Population and Demographic Projections, 2011-2013 (CSO Report)

Figure 3.4.1 Comparison of Population Forecast for Greater Lusaka

As shown in Figure 3.4.1, the trends of the population growth in the MCC M/P and CSO Report are very similar. Table 3.4.2 shows the comparison of the population growth rate. Population forecast in the CSO Report was carried out based on analysis of statistics data of age distribution, birth rate, and migration among cities until 2010. In the MCC M/P, population growth rate was set at 4.9% by 2020, which was the actual growth rate (4.9%) in Lusaka City from 2000 to 2010.

Table 3.4.2 Comparison of Population Growth Rate Between the MCC M/P and CSO Report

Area	Source	2007 - 2015	2015 - 2020	2020 - 2035
Greater Lusaka	MCC M/P	5.1%	5.4%	3.0%
Lusaka City		4.9%	4.9%	3.3%
Urban Area of Lusaka Province	CSO Report	3.4%	3.8%	3.3%
Lusaka City		4.9%	4.9%	3.0%

Source: JICA Study Team based on Water Supply Investment Master Plan, 2011 (MCC M/P) and Central Statistics Office, Population and Demographic Projections, 2011-2013 (CSO Report)

The population growth rate adopted in the MCC M/P was a bit higher than that in the CSO Report, which was prepared two years later after the completion of the MCC M/P, however, the water demand forecast in the Study applies the population forecast in the MCC M/P after 2020 for Greater Lusaka, Lusaka City, and the LWSC Service Area. On the other hand, the service ratio is newly estimated in the Study because the increase of service ratio to 100% had not been realized as expected in the MCC M/P.

(2) Forecast of Population and Service Population in Priority Area

The population forecast of the Priority Area was carried out as follows:

- ✓ Population forecast after 2020, applied the ones of the MCC M/P. For the current population in 2015, the LWSC estimation of 1,923,218 was adopted.
- ✓ In 2015, proportion of the population in the township and peri-urban was 32.3%:67.7%. The Study assumed that the proportion will not vary. The population of township in 2015, which was 620,804, would increase by 3.3% per year (MCC M/P population growth rate of Lusaka City from 2020 to 2035). Peri-urban population would be that in the Priority Area after deducting the township population in the same area. The average population growth rate from 2015 to 2035 is 2.2% per year. Proportion of population in township and peri-urban will be 39.5%:60.5% in 2035.

The service population forecast in the Priority Area was carried out as follows:

- ✓ Actual water service coverage rate in 2015 was estimated at 87.9% (Township: 91.0%, Peri-Urban: 79.1%). In the MCC M/P, water service coverage rate was planned to be 100% after 2015, however, it was not achieved.
- ✓ Water service coverage rate in the township is planned to be 100% by 2025.
- ✓ In the peri-urban area, expansion of the current water service coverage (79.1%) will not improve soon. Therefore, the water service coverage was assumed to be constant at 79.1% by 2035.

Table 3.4.3 shows the calculation results under the conditions shown above.

Table 3.4.3 Forecast of Population and Service Population of Township and Peri-urban

	2010	2015	2020	2025	2030	2035
Population in Lusaka City	1,743,000	2,214,000	2,812,000	3,260,000	3,779,000	4,381,000
Population in Priority Area	1,238,559	1,923,218	2,080,609	2,238,000	2,594,000	3,007,000
(Township)	619,162	620,804	730,224	858,930	1,010,321	1,188,395
(Peri-urban)	619,397	1,302,414	1,350,385	1,379,070	1,583,679	1,818,605
Ratio of Service Population	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
(Township)	50.0%	32.3%	35.1%	38.4%	38.9%	39.5%
(Peri-urban)	50.0%	67.7%	64.9%	61.6%	61.1%	60.5%
Service Population	1,050,903	1,595,171	1,765,828	1,950,463	2,263,802	2,627,820
(Township)	562,818	564,311	696,999	858,930	1,010,321	1,188,395
(Peri-urban)	488,085	1,030,860	1,068,829	1,091,533	1,253,481	1,439,425
Service Coverage	84.8%	82.9%	84.9%	87.2%	87.3%	87.4%
(Township)	90.9%	90.9%	95.5%	100.0%	100.0%	100.0%
(Peri-urban)	78.8%	79.1%	79.1%	79.1%	79.1%	79.1%

Source: JICA Study Team

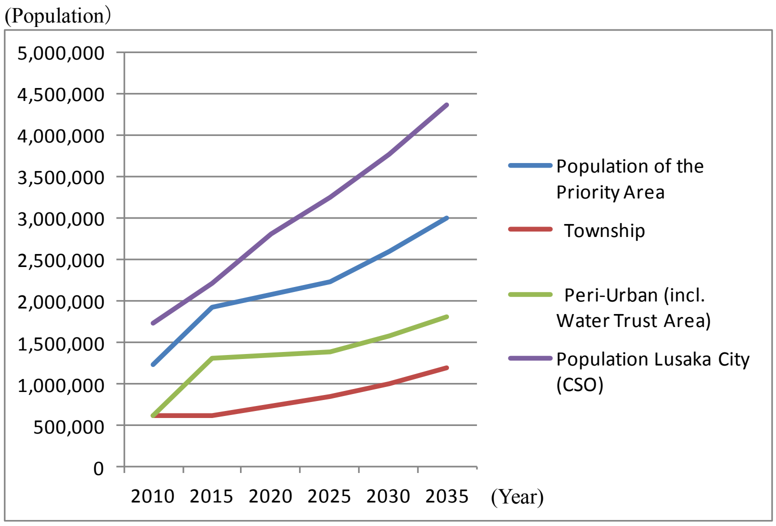
(3) Service Population through Household Connection in the Priority Area

The MCC M/P plans that household connection rates will be 100% in the township, 63% in the peri-urban, and 81% in the Priority Area by 2035. In the Study, household connection rate in township was presumed to be 100% constantly, while that in the peri-urban was presumed to have presented only a slight improvement from 26.7% to 30.0%. Table 3.4.4 and Figure 3.4.4 show the service population forecast through household by township and peri-urban.

Table 3.4.4 Forecast of Service Population of Household Connection of Township and Peri-urban in the Priority Area

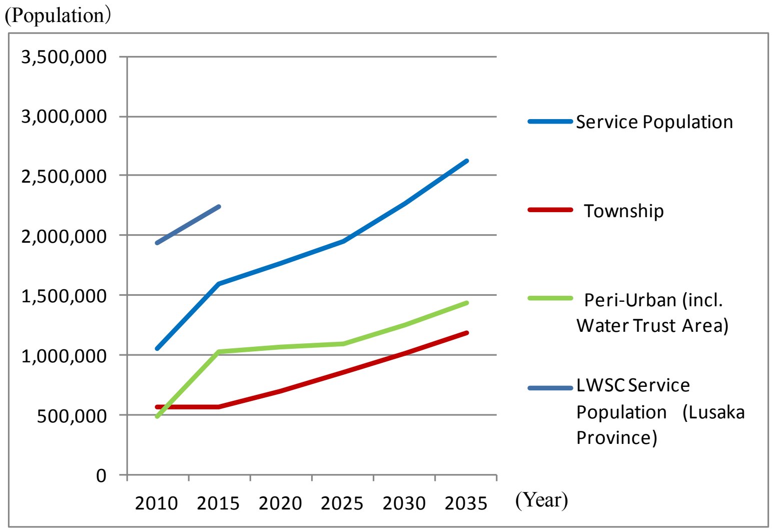
	2010	2015	2020	2025	2030	2035
Service Population	1,050,903	1,595,460	1,765,988	1,950,463	2,263,802	2,627,820
(Township)	562,818	564,600	697,169	858,930	1,010,321	1,188,395
(Peri-urban)	488,085	1,030,860	1,068,829	1,091,533	1,253,481	1,439,425
Service Population of Household Connection	693,137	839,660	982,360	1,186,390	1,386,365	1,620,223
(Township)	562,818	564,600	697,169	858,930	1,010,321	1,188,395
(Peri-urban)	130,319	275,060	285,191	327,460	376,044	431,827
Ratio of Household Connection	66.0%	52.6%	55.6%	60.8%	61.2%	61.7%
(Township)	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
(Peri-urban)	26.7%	26.7%	26.7%	30.0%	30.0%	30.0%

Source: JICA Study Team



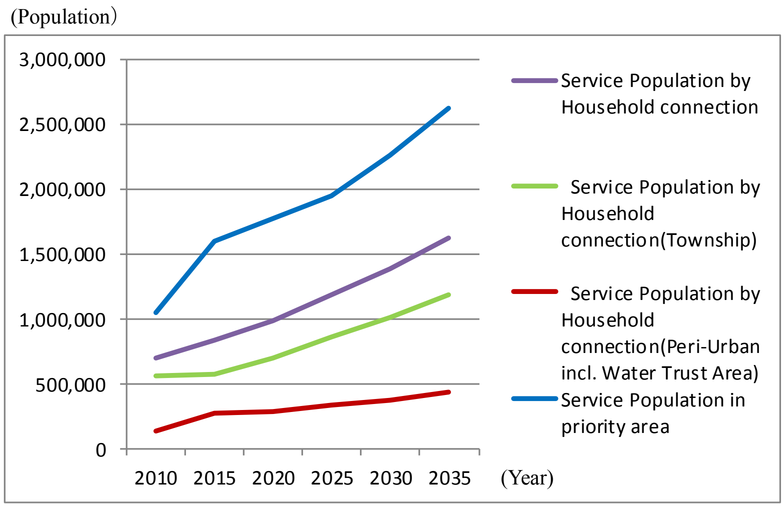
Source: JICA Study Team

Figure 3.4.2 Population Forecast of the Priority Area



Source: JICA Study Team

Figure 3.4.3 Service Population Forecast of the Priority Area



Source: JICA Study Team

Figure 3.4.4 Forecast of Service Population through Household Connection

3.4.2 Water Demand Forecast

(1) Water Demand for Domestic Water Use

Domestic water use accounts for approximately 70% of the current water supply amount by LWSC. Water demand for domestic water use will be a major portion of the total water demand. Per capita water consumption of house connection was determined at 150 Lpcd as a result of the discussion with the LWSC Infrastructure Planning and Design Division. Since 2008, LWSC has used 150 Lpcd for the domestic water demand with house connection for the design of the water supply facility. As shown in Table 2.2.8, water consumption rate of the domestic water use was estimated to be 154.6 Lpcd in the township, whose house connection is 100%. The value (150 Lpcd) being used by the LWSC seems to be in an appropriate range as the average unit water demand of the house connection water supply. Water demand per capita of public tap and water kiosk users was set at 40 Lpcd, which is the same as the assumption in the MCC M/P.

Table 3.4.5 Unit Water Demand for Domestic Water Use

Supply Method	House Connection	Public Tap/Kiosk
Unit Water Demand	150 Lpcd	40 Lpcd

Source: JICA Study Team

(2) Water Demand for Non-domestic Water Use

1) General

Water demand forecast for non-domestic use was carried out under the following conditions:

- ✓ Water demand forecast for non-domestic use was separately studied by. Public water use, commercial water use, and industrial water use.
- ✓ Water demands for public and commercial water uses were presumed to be proportional to the domestic water demand.
- ✓ Industrial water users supplied by LWSC exist only in a limited area (industrial area). Further industries are planned to be developed in two special economic zones, which are located outside of the Priority Area. Therefore, water demand for industrial water use in the Priority Area was presumed to be constant at the current volume.

2) Water Demand Rate of Industrial Water Use

In non-domestic water use, industrial water use has a low percentage. Table 3.4.6 shows the water supply of the non-domestic water use in December 2015. The annual records of the billed water amount by usage are not arranged by LWSC.

Table 3.4.6 Breakdown of LWSC Water Supply Amount for Non-domestic Water Use (Dec. 2015)

No	Type of User	Number of Connection	Water Supply Amount (m^3/day)	Percentage per Total Non-domestic Water Supply Amount
Industrial Water Use				
1	Soft Drinks/Breweries	10	1,244	4.6%
2	Manufacturing/Processing	30	308	1.1%
	Total of Industrial Water	**40**	**1,552**	**5.7%**
Other Non-domestic Water User				
1	GRZ Hospitals/Clinics	49	6,189	22.8%
2	Defence Force Property	10	3,798	14.0%
3	Shop/Private Office Block	1,014	2,423	8.9%
4	Admin. Office - GRZ	27	1,664	6.1%
5	Supermarkets/Shopping Mall	46	659	2.4%
6	Hotel/Motel/Lodges/Guest Houses	80	640	2.4%
7	GRZ Primary and Secondary School	103	601	2.2%
8	Restaurant/Bar/Tavern	294	452	1.7%
9	Churches	287	402	1.5%
10	Others	3,403	8,706	32.1%
	Total of Non-domestic Water Use	5,353	27,086	100.0%

Note: The figures in the table are the averages in December 2015, which are different from the averages of the whole year 2015 in Table 3.4.7.
Source: JICA Study Team based on the data of LWSC Billing Dept.

As for industrial water use, there are ten connections for Soft Drinks/Breweries, whose daily average consumption was 1,244 m^3/day, and 30 connections for Manufacturing/Processing, whose daily average water consumption was 308 m^3/day. Total water consumption of all the industries was about 1,500 m^3/day and it accounts for 6% of the total non-domestic water. The industrial water use is concentrated in one DMA (industrial area in Lumba).

Two special economic zones (Lusaka South Multi Facility Economic Zone and Lusaka East Multi Facility Economic Zone) are now being constructed outside the current LWSC Service Area in Greater Lusaka (refer to Figure 3.7.1). Major industrial centers in/around Lusaka City will be developed in the two economic zones. Therefore, new industrial developments in the current service area will not take place and so industrial water demand is expected to be not significant. Therefore, the Study presumes that the industrial water demand in the Priority Area in the existing industrial zone will be 2,000 m^3/day. It includes an increase of 30% from the current consumption.

3) Per Capita Water Demand of Public Water and Commercial Water

Table 3.4.8 shows the domestic water use and non-domestic water use amounts of three years (from 2013 to 2015) and ratio of domestic water use and non-domestic water use in the LWSC Service Area. The actual water supply amount for non-domestic use from 2013 to 2015 was 32,672 m^3/day in terms of daily average for the three years. It is equivalent to 0.33 times of the amount for domestic water.

Table 3.4.7 Domestic and Non-domestic Water Use Amount and Ratio

Year	Daily Average Water Supply Amount of Domestic Water (m^3/day)	Daily Average Water Supply Amount of Non-domestic Water (m^3/day)	Ratio of Domestic Water Use /Non-domestic Water Use
2013	94,361	37,745	0.40
2014	97,744	39,098	0.40
2015	102,879	21,172	0.21
Average	98,328	32,672	0.33

Source: JICA Study Team

From the average values in the table above, the Study presumes non-domestic water excluding industrial water (namely, total amounts of public and commercial water uses) to be 0.3 times of the supply amount for domestic water use. Based on the unit domestic water demand of 135 Lpcd, non-domestic water demand was calculated as 40.5 Lpcd. It is greater than the value in the MCC M/P (public water: 14.00 Lpcd, commercial water: 3.05 Lpcd, Total: 17.03 Lpcd).

4) Conclusion on the Water Demand for Non-domestic Use

From the studies above, water demand for non-domestic use in the Priority Area was set in Table 3.4.8.

Table 3.4.8 Estimate of Unit Water Demand for Non-domestic Water Use in the Priority Area

	Public / Commercial Use	Industrial Use
Water Demand in the Study	0.3 times of Domestic Water Use	2,000 m^3/day

Source: JICA Study Team

(3) Non-revenue Water Ratio and Water Leakage Ratio

In CP-6 of the MCC Project, the construction works for NRW reduction are being implemented in 14 DMAs since 2016. In addition to this, detailed design for further 21 DMAs is ongoing. The MCC Project expects the construction works in the 35 DMAs to achieve a reduction of 25% NRW ratio (refer to Chapter 2, Section 2.4.1).

However, implementation of the MCC Project is behind schedule, approximately by five years. Considering the significant delay of CP-6, the Study updates the NRW reduction target as shown in Table 3.4.9. Also, the Study presumes the current leakage ratio, which is the NRW volume after deducting the commercial loss volume, and its reduction target as shown in the same table.

Table 3.4.9 Improvement Plan of NRW and Leakage

Year	NRW Ratio	Leakage Ratio	Remarks
2016-2018	45–35%	30-25%	Achieve NRW ratio of 35% and leakage ratio of 25% after completion of the MCC Project (CP-6)
2019-2025	35 –25%	25-20%	Achieve NRW ratio of 25% and leakage ratio of 20% after completion of the Project
2026-2035	25%	20%	Keep NRW ratio of 25% and leakage ratio of 20% through continuous implementation of old pipes replacement

Source: JICA Study Team

The MCC M/P planned that the NRW ratio would improve to 20% by 2030 but the Study is apprehensive that the expectation is too optimistic. The MCC Project will decrease the NRW ratio but after completion of the KBWSP Project and the Project, increased supply amount and water pressure in the distribution networks will incur more water leakage from aged pipes. Therefore, the Study made a downward revision of the ultimate targets in 2035 for the NRW ratio and leakage ratio, and were set at 25% and 20%, respectively.

(4) Daily Peak Factor

For setting the peak factor, which is the ratio of the maximum daily water demand against the average daily water demand, seasonal variation of water consumption for the long term is usually analyzed by water consumption data. However, in the current LWSC Service Area, as the actual water supply amount chronically does not meet the water demand, water consumption trend does not indicate seasonal variation of water demand. Therefore, in Greater Lusaka, it is difficult to calculate the daily peak factor based on the existing.

In the Improvement of Water Supply Condition in Ndola City Project (JICA grant aid project), 1.2 (load factor 83.3%) was used as the daily peak factor. In the city, the average monthly water production in the dry season (from April to October) is 1.15-1.2 times as large as that in the rainy season (from November to March). Population in Greater Lusaka is over two million and it is larger than the water supply population in Ndola (0.4 million). It may relax the peak of water supply variation; however, daily peak factor of Greater Lusaka is set as 1.2, the same as that in Ndola City.

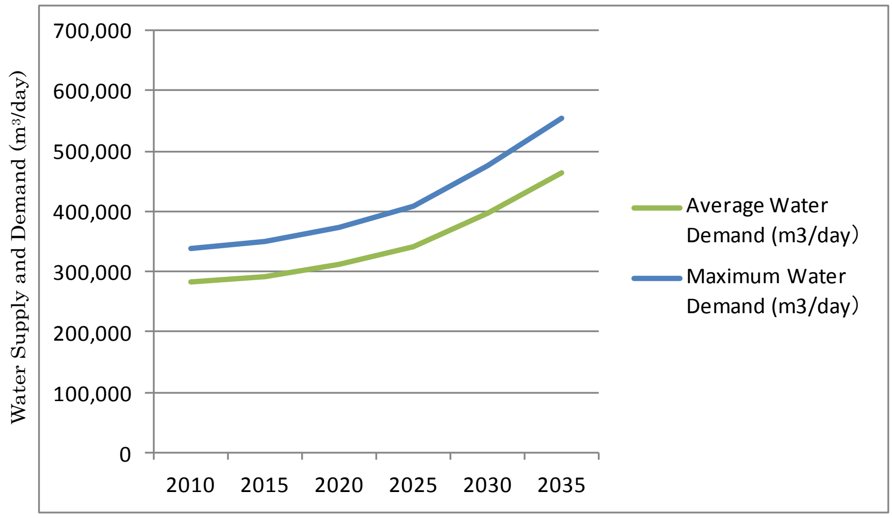
(5) Water Demand Forecast

Based on the above studies, the water demand forecast is shown in Table 3.4.10 and the calculation results are shown in Figure 3.4.5.

Table 3.4.10 Water Demand Forecast of Priority Area

Items	Unit	2010	2015	2020	2025	2030	2035
Population of Lusaka City (MCC M/P, 2011)	-	1,743,000	2,214,000	2,812,000	3,260,000	3,779,000	4,381,000
Population of Priority Area	-	1,238,559	1,923,218	2,080,609	2,238,000	2,594,000	3,007,000
Township	-	619,162	620,804	730,224	858,930	1,010,321	1,188,395
Peri-Urban (incl. Water Trust Area)	-	619,397	1,302,414	1,350,385	1,379,070	1,583,679	1,818,605
Population Ratio	-	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Township	-	50.0%	32.3%	35.1%	38.4%	38.9%	39.5%
Peri-Urban (incl. Water Trust Area)	-	50.0%	67.7%	64.9%	61.6%	61.1%	60.5%
Service Population in Lusaka Province	-	1,937,600	2,246,800				
Service Population	-	1,050,903	1,595,460	1,765,998	1,950,463	2,263,802	2,627,820
Township	-	562,818	564,600	697,169	858,930	1,010,321	1,188,395
Peri-Urban (incl. Water Trust Area)	-	488,085	1,030,860	1,068,829	1,091,533	1,253,481	1,439,425
Service Population Rate	-	84.8%	83.0%	84.9%	87.2%	87.3%	87.4%
Township	-	90.9%	90.9%	95.5%	100.0%	100.0%	100.0%
Peri-Urban	-	78.8%	79.1%	79.1%	79.1%	79.1%	79.1%
Service Population by Household connection	-	693,137	839,660	982,360	1,186,390	1,386,365	1,620,223
Township	-	562,818	564,600	697,169	858,930	1,010,321	1,188,395
Peri-Urban (incl. Water Trust Area)	-	130,319	275,060	285,191	327,460	376,044	431,827
Rate of Household connection	-	66.0%	52.6%	55.6%	60.8%	61.2%	61.7%
Township	-	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Peri-Urban	-	26.7%	26.7%	26.7%	30.0%	30.0%	30.0%
Service Population by Public Tap / Kiosk	-	357,766	755,800	783,638	764,073	877,437	1,007,597
Township	-	0	0	0	0	0	0
Peri-Urban (incl. Water Trust Area)	-	357,766	755,800	783,638	764,073	877,437	1,007,597
Rate of Public Tap / Kiosk	-	34%	47.4%	44.4%	39.2%	38.8%	38.3%
Township	-	0%	0.0%	0.0%	0.0%	0.0%	0.0%
Peri-Urban (incl. Water Trust Area)	-	73%	73.3%	73.3%	70.0%	70.0%	70.0%
Domestic Water Consumption by HC	m^3/day	103,971	125,949	147,354	177,958	207,955	243,033
Unit domestic water consumption by HC	plcd	150	150	150	150	150	150
Domestic Water Consumption by PT / Kiosk	m^3/day	14,311	30,232	31,346	30,563	35,097	40,304
Unit domestic water consumption by PT / Kiosk	plcd	40	40	40	40	40	40
Commercial Water Consumption	m^3/day	35,484	46,854	53,610	62,556	72,916	85,001
Ratio of Commercial : Domestic	-	0.3	0.3	0.3	0.3	0.3	0.3
Industrial Water Consumption	m^3/day	2,000	2,000	2,000	2,000	2,000	2,000
Total Water Consumption	m^3/day	155,766	205,035	234,309	273,078	317,968	370,338
Water losses	m^3/day	127,445	87,872	78,103	68,269	79,492	92,585
Water loss ratio	-	45.0%	30.0%	25.0%	20.0%	20.0%	20.0%
Average Water Demand	m^3/day	283,210	292,908	312,412	341,347	397,460	462,923
Peak factor	-	1.2	1.2	1.2	1.2	1.2	1.2
Maximum Water Demand	m^3/day	340,000	351,000	375,000	410,000	477,000	556,000

Source: JICA Study Team



Source: JICA Study Team

Figure 3.4.5 Water Demand Forecast in the Priority Area

3.5 Scope of the Project and Development Scenario

3.5.1 Current Facility Development Plan

(1) Surface Water Source

Kafue River is the only surface water source for Greater Lusaka. The existing facility is under rehabilitation by the MCC Project. Its current production capacity is 96,000 m^3/day and after the rehabilitation, production capacity is expected to recover to 110,000 m^3/day, which is the original design capacity. KBWSP Phase-1 is currently under construction and in 2018 the new WTP with a treatment capacity of 50,000 m^3/day capacity is to be completed. Table 3.5.1 shows the water supply amounts forecasting the existing water supply systems and KBWSP Phase-1 fed by Kafue River to Lusaka City. Total of the water production capacity is 160,000 m^3/day. LWSC has a water right of 855,750 m^3/day in Kafue River; therefore, about 700,000 m^3/day can be further developed.

Table 3.5.1 Production Capacity from Surface Water Source Kafue River for Lusaka City

System/Project	2010	2015	2020	2025	2030	2035
1) Existing System	96,000	96,000	110,000	110,000	110,000	110,000
2) KBWSP Phase-1	0	0	50,000	50,000	50,000	50,000
計	96,000	96,000	160,000	160,000	160,000	160,000

Source: JICA Study Team

(2) Groundwater Service (In the Current LWSC Service Area: Priority Area)

In the LWSC Service Area, three types of well are currently used. Namely 1) wells owned by LWSC, 2) wells owned by Water Trust and 3) wells privately owned by industrial companies. In the Study, usage trend of groundwater in the Priority Area is estimated as shown in Table 3.5.2.

Table 3.5.2 Groundwater Source in Current LWSC Service Area

Unit: m^3/day

Types of Well	2010	2015	2020	2025	2030	2035
1) Wells managed by LWSC	145,000	100,000	100,000	100,000	100,000	100,000
2) Wells managed by Water Trust	12,000	12,000	12,000	12,000	12,000	12,000
3) Private Wells	25,000	25,000	25,000	15,000	15,000	0
Total	182,000	137,000	137,000	127,000	127,000	112,000

Source: JICA Study Team

1) Wells of LWSC and Water Trust

The current situation and the future prospects of operation condition of wells which are managed by LWSC and Water Trust are described below.

- As shown in Figure 2.3.1, due to power failures pumping volume from wells, which are managed by LWSC, has been decreasing since 2014. However, from 2016 until the completion of the Project, LWSC plans to improve the pumping volume by new installation of generators to pumps.

- It had been observed that the quality of water does not meet the drinking water standards at wells of about 25,000 m^3/day (about 17% of the total water volume) at the wells managed by the LWSC. If groundwater contamination gets worse, some well will be closed. However, of sewerage improvement projects and installation of sanitation facilities are planned to be completed within two or three years. After the completion of the projects, groundwater contamination is expected to improved and will be able to keep the drinking water quality standard.
- As shown in Table 2.2.6, the wells in the Water Trust have approximately 12,000 m^3/day(11,903m^3/day) of production volume. The wells are to be used sequentially in the future. LWSC plans gradually to incorporate Water Trusts with lack of operation ability into the service area. The Study also plans the same.
- When the priority project is completed in 2022, LWSC is expected to have 112,000 m^3/day of production volume (currently LWSC wells 100,000 m^3/day and wells from Water Trust Area 12,000 m^3/day).

2) Private Wells

The current situation and the prospects of operation condition of private wells which are individually managed are described below.

- The present population in the Priority Area is 1.92 million (LWSC estimation). Population serviced by LWSC and Water Trust Area is 1.59 million. The remaining 0.33 million people use private wells. In addition, many people serviced by LWSC and Water Trust also use private wells. As there is no detailed data, about 25,000 m^3/day of groundwater was assumed to be used from private wells. It was assumed that 1 million people, including the 0.33 million people without water supply service, use the 25 Lpcd of groundwater from private wells.
- According to the prospect of LWSC, private wells are expected to gradually decrease their production capacity after 2023, due to the cost and trouble of operation and maintenance. The Study projected that groundwater usage from private wells will be 15,000 m^3/day in 2025 and 0 m^3/day in 2030 from the current 25,000 m^3/day.

3.5.2 Examination of the Scope of the Project

Water development capacity of 300,000 m^3/day in addition to the existing water supply systems of 272,000 m^3/day is required to satisfy the water demand of 556,000 m^3/day in 2035 at the current LWSC Service Area (Priority Area) in the Study Area.

The target year of the Project is 2030. In 2030, the water demand will be 477,000 m^3/day and 190,000 m^3/day of new water source will be development required to meet the water demand in 2030. In the Project, 200,000 m^3/day of new water production facilities is proposed. Table 3.5.3 and Figure 3.5.1 show the water supply development scenario in the Priority Area.

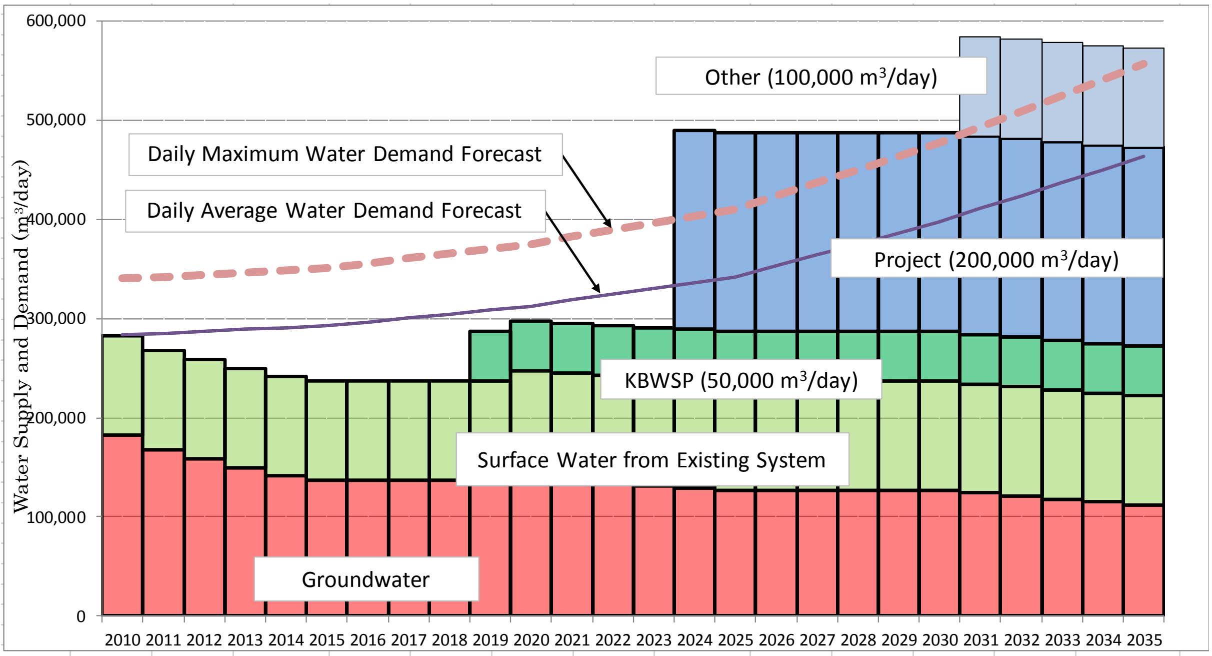
Table 3.5.3 Required Development Capacity for Priority Area

Unit: m^3/day

Items	2015	2020	2025	2030	2035
(1) Groundwater	137,000	137,000	127,000	127,000	112,000
(2) Surface Water (Kafue River)					
Existing System	96,000	110,000	110,000	110,000	110,000
KBWSP Phase-1	-	50,000	50,000	50,000	50,000
Project	-	-	200,000	200,000	200,000
Other Project	-	-	-	-	100,000
(3) Total	233,000	297,000	487,000	487,000	572,000
(4) Water Demand Forecast					
Average daily water demand	292,908	312,412	341,347	397,460	462,923
Maximum daily water demand	351,000	375,000	410,000	477,000	556,000

Source: JICA Study Team

Figure 3.5.1 shows the water demand forecast and development plan proposed in the Project by 2035.



Source: JICA Study Team

Figure 3.5.1 Water Demand Forecast and Development Plan

3.6 Examination of Distribution Facility After Project Completion

After the Project, 360,000 m^3/day (current: 110,000 m^3/day + KBWSP Phase-1: 50,000 m^3/day + the Project: 200,000 m^3/day) will be provided to the Priority Area.

Table 3.6.1 shows the water demand forecast of each 66 DMA in 2030. The maximum daily water demand is 477,000 m^3/day, which will be covered by 360,000 m^3/day from Kafue River and 117,000 m^3/day from groundwater source.

The water supply system will deliver 360,000 m^3/day of water from Kafue River to the 66 DMAs, through three distribution centers (Lusaka Water Works, Stuart Park Distribution Center, and Lumumba Distribution Center). To ensure water distribution to the target area, the following works are proposed for the Project:

- Expansion of distribution reservoir and distribution pump to the distribution center
- Expansion of distribution main
- Expansion of distribution pipe network
- Renewal of distribution pipe network

This will be discussed in detail in Chapter 4, Section 4.4. The details of the water distribution system will be described in Section 4.4.3.

Table 3.6.1 Water Demand Forecast of Each DMA (2030)

TOWNSHIP		Population				Average Demand (Lpcd)		Water Demand (m3/day)					Total (Including NRW)	Total (Daily Maximum)
		Total	Sevice Coverage	Household Connection 150Lpcd	Public Tap/ Kiosk 40Lpcd			Domestic Hosuhold Conne.	Domestic PT/Kiosk	Non Domestic	Industrial	Total		
CEN	Olympia	8,055	100%	100%	0%	150		1,208	-	362		1,571	1,963	2,356
	Olympia Park Extension	5,453	100%	100%	0%	150		818	-	245		1,063	1,329	1,595
	Kalundu	8,754	100%	100%	0%	150		1,313	-	394		1,707	2,134	2,560
	Roma	29,485	100%	100%	0%	150		4,423	-	1,327		5,750	7,187	8,624
	Rhodespark	41,513	100%	100%	0%	150		6,227	-	1,868		8,095	10,119	12,142
	Fairview	5,837	100%	100%	0%	150		876	-	263		1,138	1,423	1,707
	Northmead	10,846	100%	100%	0%	150		1,627	-	488		2,115	2,644	3,172
	Thornpark	7,078	100%	100%	0%	150		1,062	-	319		1,380	1,725	2,070
	Prospect Hill	8,864	100%	100%	0%	150		1,330	-	399		1,728	2,161	2,593
	Statehouse	18,395	100%	100%	0%	150		2,759	-	828		3,587	4,484	5,381
	Government	5,879	100%	100%	0%	150		882	-	265		1,146	1,433	1,720
	Sikanze	3,313	100%	100%	0%	150		497	-	149		646	808	969
CHE	UNZA	35,421	100%	100%	0%	150		5,313	-	1,594		6,907	8,634	10,361
	Handsworth	5,293	100%	100%	0%	150		794	-	238		1,032	1,290	1,548
	Chudleigh	11,851	100%	100%	0%	150		1,778	-	533		2,311	2,889	3,466
	Chainama	25,172	100%	100%	0%	150		3,776	-	1,133		4,909	6,136	7,363
	Helen Kaunda	10,159	100%	100%	0%	150		1,524	-	457		1,981	2,476	2,972
	Chelston-LC	63,178	100%	100%	0%	150		9,477	-	2,843		12,320	15,400	18,480
	Avondale Southend	17,903	100%	100%	0%	150		2,685	-	806		3,491	4,364	5,237
	Chamba Valley-MC	18,300	100%	100%	0%	150		2,745	-	824		3,569	4,461	5,353
	Kaunda Square-LC	18,114	100%	100%	0%	150		2,717	-	815		3,532	4,415	5,298
	Kaunda Square STG2	8,737	100%	100%	0%	150		1,310	-	393		1,704	2,130	2,555
KBL	Woodlands-HC	9,824	100%	100%	0%	150		1,474	-	442		1,916	2,395	2,874
	Woodlands Extension	7,701	100%	100%	0%	150		1,155	-	347		1,502	1,877	2,253
	Kabulonga & Sunningdale	17,444	100%	100%	0%	150		2,617	-	785		3,402	4,252	5,102
	New Ibex Hill-HC	4,261	100%	100%	0%	150		639	-	192		831	1,039	1,246
	Nyumba Yanga-LC	11,653	100%	100%	0%	150		1,748	-	524		2,272	2,840	3,409
	Chilenje South-LC	24,640	100%	100%	0%	150		3,696	-	1,109		4,805	6,006	7,207
	Chilenje-LC	20,977	100%	100%	0%	150		3,147	-	944		4,090	5,113	6,136
	New Woodlands Extension	4,480	100%	100%	0%	150		672	-	202		874	1,092	1,310
	Chandamali-MC	18,970	100%	100%	0%	150		2,845	-	854		3,699	4,624	5,549
KBT	Luburma	18,626	100%	100%	0%	150		2,794	-	838		3,632	4,540	5,448
	Libala	15,465	100%	100%	0%	150		2,320	-	696		3,016	3,770	4,524
	Kabwata	13,438	100%	100%	0%	150		2,016	-	605		2,620	3,276	3,931
	New Kamwala-LC	10,904	100%	100%	0%	150		1,636	-	491		2,126	2,658	3,189
	New Kabwata S/S	11,353	100%	100%	0%	150		1,703	-	511		2,214	2,767	3,321
	F1080	38,267	100%	100%	0%	150		5,740	-	1,722		7,462	9,328	11,193
	F917	24,588	100%	100%	0%	150		3,688	-	1,106		4,795	5,993	7,192
	Libala South	32,825	100%	100%	0%	150		4,924	-	1,477		6,401	8,001	9,601
LUM	Shakespear	9,373	100%	100%	0%	150		1,406	-	422		1,828	2,285	2,742
	Town/Kabelenga	81,617	100%	100%	0%	150		12,243	-	3,673		15,915	19,894	23,873
	Industrial Area	115,019	100%	100%	0%	150		17,253	-	5,176	2,000	24,429	30,536	36,643
	Villa Elizabetha	13,358	100%	100%	0%	150		2,004	-	601		2,605	3,256	3,907
MAT	Emmasdale	21,963	100%	100%	0%	150		3,294	-	988		4,283	5,353	6,424
	Matero	105,679	100%	100%	0%	150		15,852	-	4,756		20,607	25,759	30,911
	Emmasdale Bank Houses	10,294	100%	100%	0%	150		1,544	-	463		2,007	2,509	3,011
Total		**1,010,321**						**151,548**	**-**	**45,464**	**2,000**	**199,013**	**248,766**	**298,519**

PERI-URBAN														
PERI-URBAN EAST	Kalingalinga	55,611	79.1%	30.0%	70%	73		1,981	1,232	964		4,177	5,221	6,266
	Mtendere	158,886	79.1%	30.0%	70%	73		5,659	3,521	2,754		11,934	14,918	17,902
	Garden	130,832	79.1%	30.0%	70%	73		4,660	2,899	2,268		9,827	12,284	14,741
	Bauleni	43,942	79.1%	30.0%	70%	73		1,565	974	762		3,301	4,126	4,951
	Kamanga	21,692	79.1%	30.0%	70%	73		773	481	376		1,629	2,037	2,444
	Chainda	25,528	79.1%	30.0%	70%	73		909	566	443		1,918	2,397	2,876
	Ng'ombe	107,423	79.1%	30.0%	70%	73		3,826	2,381	1,862		8,069	10,086	12,103
PERI-URBAN SOUTH	Chawama	59,333	79.1%	30.0%	70%	73		2,113	1,315	1,028		4,457	5,571	6,685
	John Howard	33,339	79.1%	30.0%	70%	73		1,187	739	578		2,504	3,130	3,756
	Kanyama	250,700	79.1%	30.0%	70%	73		8,929	5,556	4,346		18,831	23,539	28,246
	Misisi/Kuku	45,362	79.1%	30.0%	70%	73		1,616	1,005	786		3,407	4,259	5,111
	Jahn Laing	78,650	79.1%	30.0%	70%	73		2,801	1,743	1,363		5,908	7,385	8,861
	Jack Compound	30,570	79.1%	30.0%	70%	73		1,089	677	530		2,296	2,870	3,444
	Chibolya	54,293	79.1%	30.0%	70%	73		1,934	1,203	941		4,078	5,098	6,117
PERI-URBAN WEST	George	264,688	79.1%	30.0%	70%	73		9,428	5,866	4,588		19,882	24,852	29,822
	Lilanda	13,177	79.1%	30.0%	70%	73		469	292	228		990	1,237	1,485
	Chunga	34,552	79.1%	30.0%	70%	73		1,231	766	599		2,595	3,244	3,893
	Kabanana	57,753	79.1%	30.0%	70%	73		2,057	1,280	1,001		4,338	5,422	6,507
	Chipata	86,873	79.1%	30.0%	70%	73		3,094	1,925	1,506		6,525	8,157	9,788
	Chaisa	30,475	79.1%	30.0%	70%	73		1,085	675	528		2,289	2,861	3,434
計		**1,583,679**						**56,407**	**35,097**	**27,451**		**118,955**	**148,694**	**178,433**

SUMMARY		Population Total	Service Population	Household Connection 150Lpcd	Public Tap/ Kiosk 40Lpcd	Average Demand (Lpcd)		Domestic		Non Domestic	Industrial	Total	Total (Including NRW)	Total (Daily Maximum)
Daily Average Water Demand	Township	1,010,321	1,010,321	1,010,321	-	150	-		151,548	45,464	2,000	199,013	248,766	298,519
	Peri-Urban	1,583,679	1,253,481	376,044	877,437	73	-		91,504	27,451	-	118,955	148,694	178,433
	Total (excluding NRW)	**2,594,000**	**2,263,802**	**1,386,365**	**877,437**	**107**			**243,052**	**72,916**	**2,000**	**317,968**	**397,460**	**477,000**
	Total (incluidng NRW 20%)								**303,815**	**91,145**	**2,500**	**397,460**		
Daily Maximum Water Demand (x 1.2)												**477,000**		

Source: JICA Study Team

3.7 Proposal on Service Coverage Area Expansion in Greater Lusaka

3.7.1 Water Demand Forecast in Greater Lusaka

(1) Water Service Population in Entire Greater Lusaka

Table 3.7.1 shows the forecast of the population and water service population of LWSC in Greater Lusaka.

Table 3.7.1 LWSC Service Population Forecast in Greater Lusaka

	2015	2020	2025	2030	2035
(1) Priority Area					
Population	1,923,218	2,080,609	2,238,000	2,594,000	3,007,000
Service population	1,595,460	1,765,998	1,950,463	2,263,802	2,627,820
Service coverage	83%	85%	87%	87%	87%
(2) Outside of Priority Area					
Population	420,782	876,391	1,332,000	1,605,000	1,946,000
Service population	0	88,000	200,000	401,000	1,557,000
Service coverage	0%	10%	15%	25%	80%
(3) Total of Greater Lusaka					
Population	2,344,000	2,957,000	3,570,000	4,199,000	4,953,000
Service population	1,595,460	1,853,998	2,150,463	2,664,802	4,184,820
Service coverage	68%	63%	60%	63%	84%

Source: JICA Study Team based on Water Supply Investment Master Plan, 2011 (MCC M/P). Population data of 2015 in Priority Area is based on the data from LWSC.

(2) Unit Water Demand

Unit water demand in the Priority Area is the same as that outside of the Priority Area. However, industrial water demand outside the Priority Area is separately calculated with the water demand of the special economic zone, as mentioned below.

Table 3.7.2 Unit Water Demand for Non-domestic Water Use in the Study

	Area	Public/Commercial	Industrial
Study	Priority Area	0.3 times of domestic water volume	2,000 m^3/day
	Outside Priority Area		6,000 - 20,000 m^3/day (See Table 3.7.3)
MCC M/P	Entire Area	17.05 Lpcd	107,465 - 112,594 m^3/day (See Table 3.2.6)

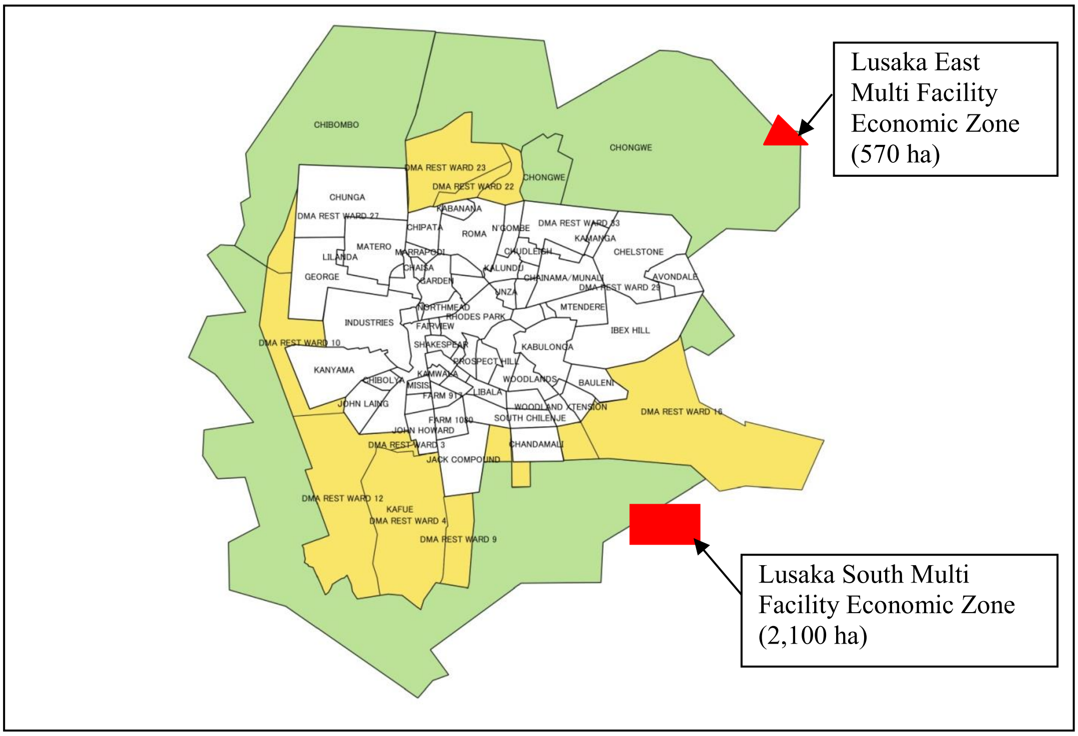
Note: * Industrial water demand outside Priority Area is separately calculated as water demand in the economic zone.
Source: JICA Study Team

Table 3.7.3 shows the water demand forecast in the special economic zones and as for the water demand in the Facility Economic Zone (LS-MFEZ), the estimate of JICA M/P of Lusaka South Multi Facility Economic Zone, 2009 is adopted. Also, water demand in Lusaka East Multi Facility Economic Zone (LE-MFEZ) is presumed to be the same as that of the LS-MFEZ.

Table 3.7.3 Water Demand Forecast in Special Economic Zones

Economic Zones	Water demand volume for each development stage		
	Until 2025 (1st Stage)	2030 (2nd Stage)	2035 (3rd Stage)
Lusaka South Multi Facility Economic Zone	3,000 m^3/day	6,000 m^3/day	10,000 m^3/day
Lusaka East Multi Facility Economic Zone	3,000 m^3/day	6,000 m^3/day	10,000 m^3/day
Total	6,000 m^3/day	12,000 m^3/day	20,000 m^3/day

Source: JICA Survey Team based on JICA M/P of Lusaka South Multi Economic Zone,2009



Source: JICA Study Team

Figure 3.7.1 Location Map of Multi Facility Economic Zone around Lusaka City

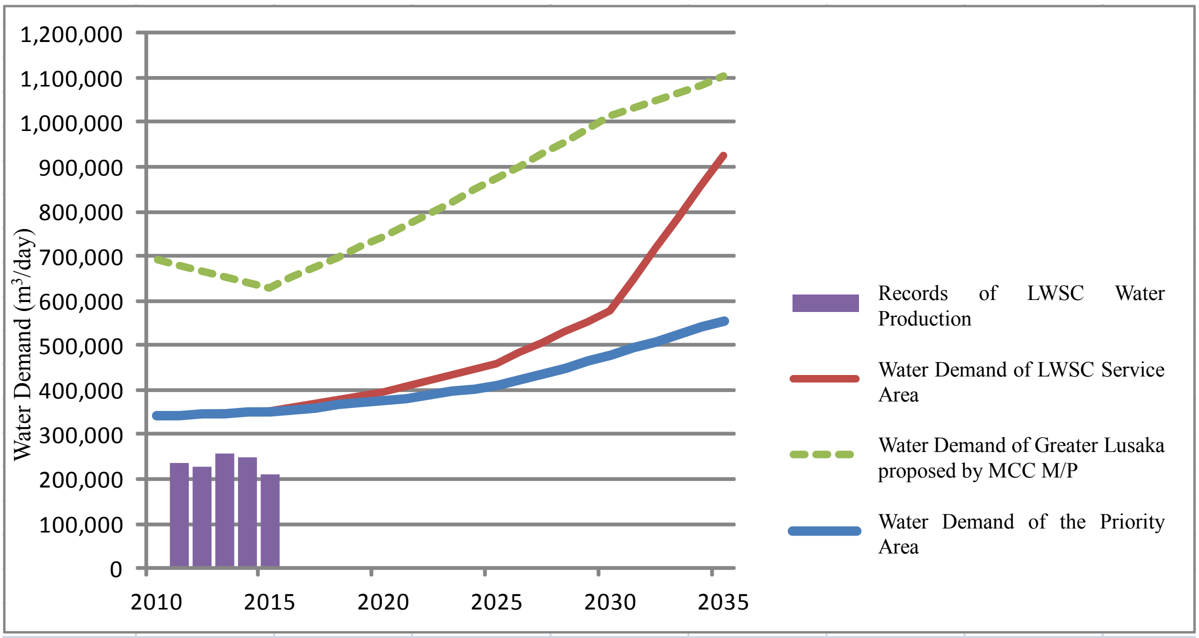
(3) Water Demand Forecast

Table 3.7.4 shows the calculation sheet of the water demand forecast in Greater Lusaka including the Priority Area. Figure 3.7.2 shows comparison of the water demand forecast in Greater Lusaka between proposals of JICA Study Team and MCC M/P.

Table 3.7.4 Water Demand Calculation Sheet for Greater Lusaka

	Present (2015)	2020	2025	2030	2035
(1) Priority Area					
Total Population	1,923,218	2,080,609	2,238,000	2,594,000	3,007,000
Service population	1,595,171	1,765,998	1,950,463	2,263,802	2,627,820
Service Coverage	83%	85%	87%	87%	87%
Service Population with Household Connection	839,371	982,360	1,186,390	1,386,365	1,620,223
Ratio of Hosehold Correction	53%	56%	61%	61%	62%
Service Population with Public Tap/ Kiosk	755,800	783,638	764,073	877,437	1,007,597
Ration of PT/ Kiosk Service	47%	44%	39%	39%	38%
Demand of Domestic Use : Household Connection (m^3/day)	125,906	147,354	177,959	207,955	243,033
(Unit Water Demand: Lpcd)	150	150	150	150	150
Demand of Domestic Use : TP/ Kiosk (m^3/day)	30,232	31,346	30,563	35,097	40,304
(Unit Water Demand: Lpcd)	40	40	40	40	40
Demand for Non-domestic Use (m^3/day)	46,841	53,610	62,556	72,916	85,001
(Ratio with Domestic Use)	0.3	0.3	0.3	0.3	0.3
Demand of Industrial Use (m^3/day)	2,000	2,000	2,000	2,000	2,000
Total Water Demand (m^3/day)	204,979	234,309	273,078	317,968	370,339
Leakage Water (m^3/day)	87,848	78,103	68,269	79,492	92,585
Leakage Ratio	30%	25%	20%	20%	20%
Daily Average Water Demand (m^3/day)	292,827	312,413	341,347	397,460	462,923
Daily Maximum Water Demand (m^3/day)	351,000	375,000	410,000	477,000	556,000
(2) Outside of Priority Area					
Total Population	420,782	876,391	1,332,000	1,605,000	1,946,000
Service population	0	88,000	200,000	401,000	1,557,000
Service Coverage	0%	10%	15%	25%	80%
Service Population with Household Connection	0	48,400	120,000	280,700	1,292,310
Ratio of Hosehold Correction	50%	55%	60%	70%	83%
Service Population with Public Tap/ Kiosk	0	39,600	80,000	120,300	264,690
Ration of PT/ Kiosk Service	50%	45%	40%	30%	17%
Demand of Domestic Use : Household Connection (m^3/day)	0	7,260	18,000	42,105	193,847
(Unit Water Demand: Lpcd)	150	150	150	150	150
Demand of Domestic Use : TP/ Kiosk (m^3/day)	0	1,584	3,200	4,812	10,588
(Unit Water Demand: Lpcd)	40	40	40	40	40
Demand for Non-domestic Use (m^3/day)	0	2,653	6,360	14,075	61,330
(Ratio with Domestic Use)	0.3	0.3	0.3	0.3	0.3
Demand of Industrial Use (m^3/day)	0	6,000	6,000	12,000	20,000
Total Water Demand (m^3/day)	0	17,497	33,560	72,992	285,764
Leakage Water (m^3/day)	0	5,832	11,187	18,248	50,429
Leakage Ratio	0%	25%	25%	20%	15%
Daily Average Water Demand (m^3/day)	0	23,330	44,747	91,240	336,193
Daily Maximum Water Demand (m^3/day)	0	26,000	49,000	100,000	370,000
(3) Total of Greater Lusaka					
Total Population	2,344,000	2,957,000	3,570,000	4,199,000	4,953,000
Service population	1,595,171	1,853,998	2,150,463	2,664,802	4,184,820
Service Coverage	68%	63%	60%	63%	84%
Demand of Domestic Use : TP/ Kiosk (m^3/day)	156,138	187,544	229,721	289,969	487,771
Demand for Non-domestic Use (m^3/day)	46,841	56,263	68,916	86,991	146,331
Demand of Industrial Use (m^3/day)	2,000	8,000	8,000	14,000	22,000
Total Water Demand (m^3/day)	204,979	251,807	306,638	390,960	656,103
Leakage Water (m^3/day)	87,848	83,936	79,456	97,740	143,014
Leakage Ratio	30%	25%	21%	20%	15%
Daily Average Water Demand (m^3/day)	292,827	335,742	386,094	488,700	799,116
Daily Maximum Water Demand (m^3/day)	351,000	401,000	459,000	577,000	926,000

Source: JICA Study Team



Source: JICA Study Team

Figure 3.7.2 Comparison of Water Demand of Greater Lusaka

3.7.2 Future Water Supply Capacity

The water supply capacity development in the Priority Area is described in Section 3.5.1, while the water supply capacity development outside the Priority Area is mentioned in this subsection.

By 2025, the distribution pipe expansion plan by LWSC (See Figure 2.4.5) plans to develop water distribution networks with a groundwater development of 20,000 m^3/day. The groundwater development is conducted almost outside the current LWSC Service Area. In CP-3 and CP-5 of the MCC Project (See Figure 2.4.4), well construction of 10,000 m^3/day will be conducted. In total, well construction of 30,000 m^3/day is already planned outside the current service area by 2025. Recently, housing development advances in various locations outside the Priority Area. With this, it is expected that a well construction would be implemented soon to increase water supply capacity by more than 30,000 m^3/day.

Table 3.7.5 shows the water source development plan outside the current LWSC service coverage area (the Priority Area). To meet the water demand forecast, necessary groundwater development plan will be 49,000 m^3/day by 2025, 100,000 m^3/day by 2030, and 170,000 m^3/day by 2035.

About groundwater development potential outside of the Priority Area, considering that the current total exploitation of groundwater in the Priority Area by LWSC, Water Trust, and individuals is 137,000 m^3/day, and the service expansion area is more than twice as large as the Priority Area, the Study presumes that the groundwater in the service expansion area will have sufficient potential to supply 170,000 m^3/day, which is 125% of the current groundwater exploitation in the Priority Area. It is assumed that the quantity of water that will not be served from the groundwater resources is around 170,000 m^3/day; thus, it will come from the surface water resources. It is expected that Kafue River will provide 200,000 m^3/day.

Table 3.7.5 Water Resource Development Plan Outside the Priority Area of Greater Lusaka

Year	Groundwater Resource	Surface Water Source
2010 - 2015	0 m^3/day	-
2016 - 2025	0 – 49,000 m^3/ day	-
2026 - 2030	49,000 - 100,000 m^3/ day	-
2030 - 2035	90,000 - 170,000 m^3/ day	200,000 m^3/ day

Source: JICA Study Team

3.7.3 Development Plan for Water Supply to Greater Lusaka

Table 3.7.6 shows the water demand forecast and water source development plan up to 2035 for Greater Lusaka including the Priority Area.

Table 3.7.6 Required Development Capacity for Greater Lusaka

Unit: m^3/day

	2025	**2030**	**2035**
(1) Priority Area			
Groundwater	137,000	127,000	112,000
Surface Water	360,000	360,000	460,000
・Existing System	110,000	110,000	110,000
・KBWSP Phase-1	50,000	50,000	50,000
・Project	200,000	200,000	200,000
・Additional Development Required	0	0	100,000
Sub-Total（Priority Area）	497,000	487,000	572,000
【Water Demand Forecast】	410,000	477,000	556,000
(2) Outside of the Priority Area			
Groundwater	49,000	100,000	170,000
Surface Water	0	0	200,000
・KBWSP Phase-2	0	0	100,000
・Additional Development Required	0	0	100,000
Sub-Total（Outside of Priority Area）	49,000	100,000	370,000
【Water Demand Forecast】	49,000	100,000	370,000
Total in Greater Lusaka			
Groundwater	178,000	217,000	282,000
Surface Water	360,000	360,000	660,000
・Existing System	110,000	110,000	110,000
・KBWSP Phase-1&2	50,000	50,000	150,000
・Project	200,000	200,000	200,000
・Additional Development Required	0	0	200,000
Total	538,000	577,000	942,000
【Water Demand Forecast】	459,000	577,000	926,000

Source: JICA Study Team

(1) Priority Area

To satisfy the water demand in 2030, the Study plans to develop a 200,000 m^3/day groundwater source in addition to the 50,000 m^3/day development in the KBWSP Phase-1. To satisfy the water demand in 2035, an additional development of 100,000 m^3/day is needed in the future.

(2) Outside Priority Area

Water demand forecast outside the Priority Area in 2035 is 370,000 m^3/day. Along with the 170,000 m^3/day of groundwater source, 100,000 m^3/day development in KBWSP Phase-2 and another 100,000 m^3/day development are needed.

(3) Overall Plan

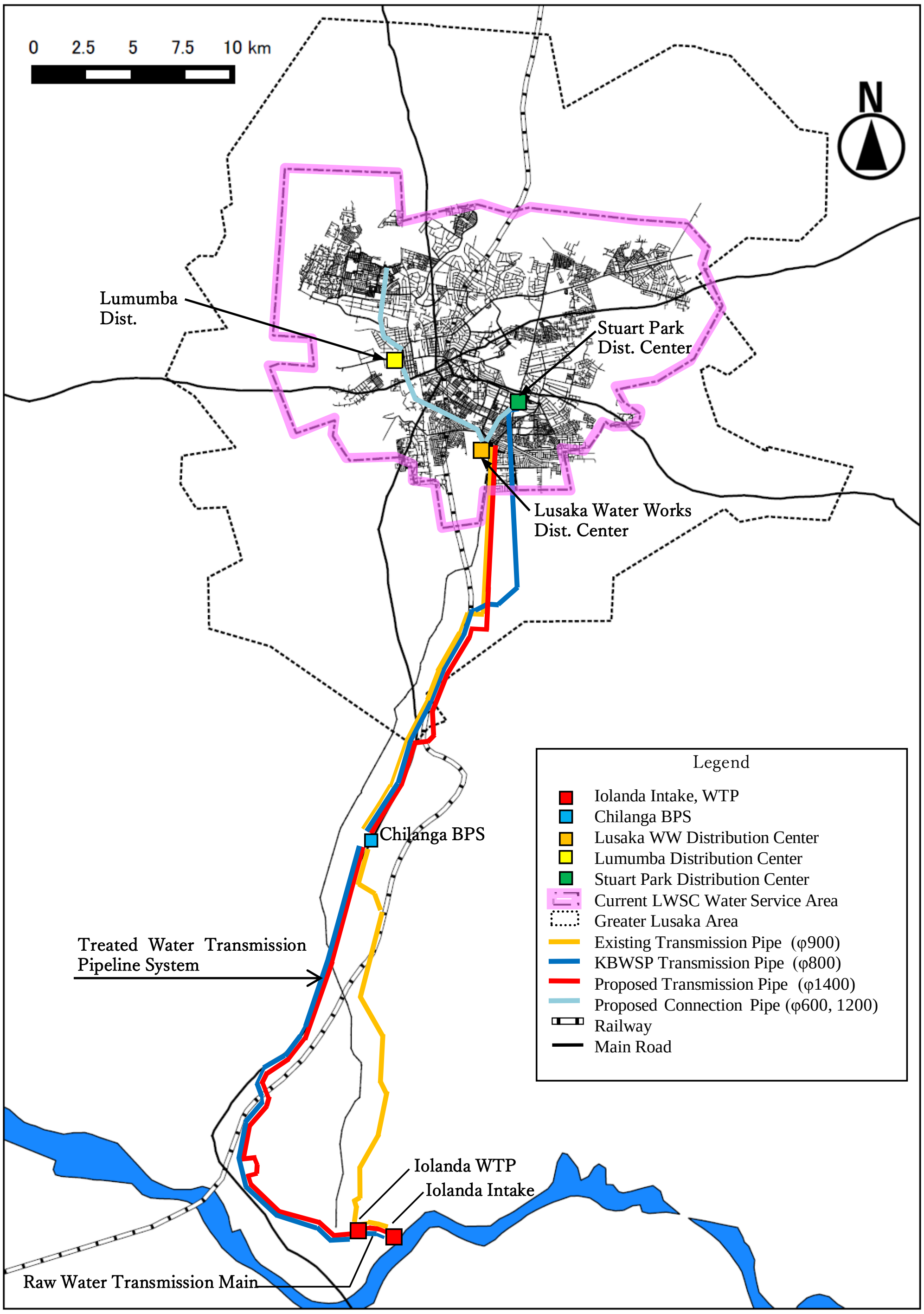
360,000 m^3/day (Priority Area: 360,000 m^3/day) and 660,000 m^3/day (Priority Area: 460,000 m^3/day and outside Priority Area: 200,000 m^3/day) of surface water source (Kafue River) should be developed to satisfy the water demand in 2030 and 2035, respectively.

To satisfy the water demand in 2030, the implementation of the current system (110,000 m^3/day), KBWSP Phase-1 (50,000 m^3/day) and the Project (200,000 m^3/day) is required. To meet the water demand in 2035, the 100,000 m^3/day in KBWSP Phase-2 and the additional development of 200,000 m^3/day are needed.

CHAPTER 4 FACILITY PLAN

4.1 Outline of the Project

The Project consists of water intake, raw water transmission pipeline, water treatment plant (WTP), treated water transmission, and distribution facilities. The outline of the Project is shown in Figure 4.1.1 and Table 4.1.1.



Source: JICA Study Team

Figure 4.1.1 Outline of the Project

Table 4.1.1 Outline of the Project

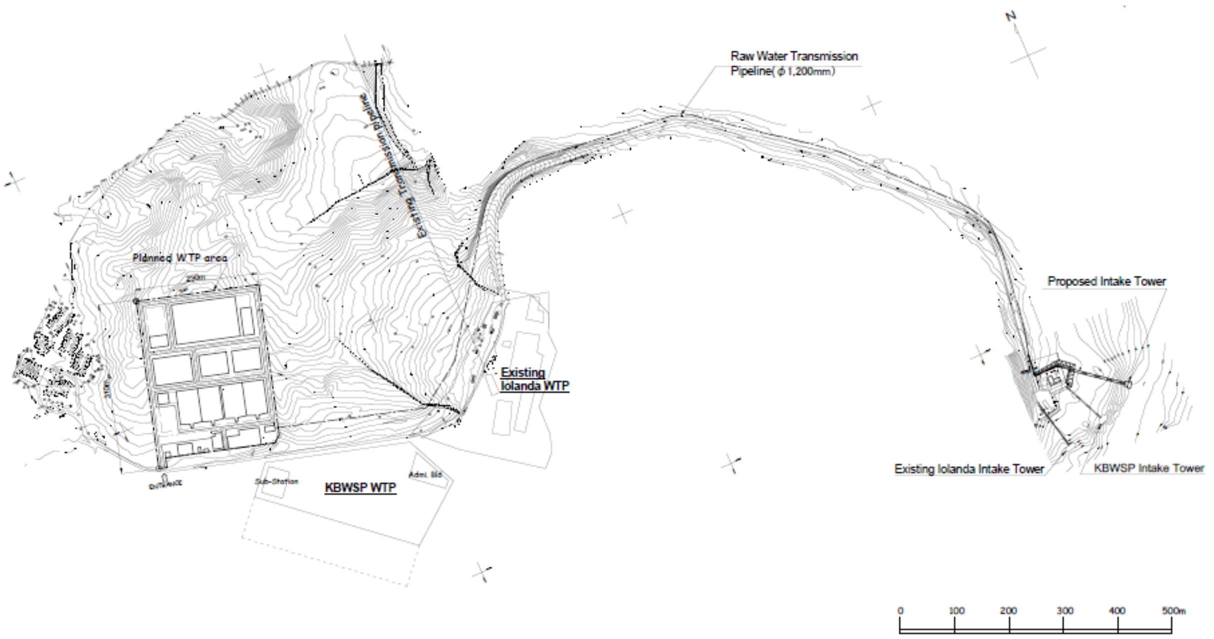
Proposed Facility	Principal Features
Intake Facility, Raw Water Transmission Pipeline, and Water Treatment Plant (WTP)	1) Intake Facility Intake capacity: 210,000 m^3/day Structure type: Intake tower（RC concrete） Pump type: Vertical mixed flow type, Total head: 36 m, Discharge: 48.6 m^3/min, 4 units (including one stand-by) Operation and electrical building: 1 no. 2) Raw Water Transmission Pipeline Material: Mild steel Diameter and Length: 1,200 mm x 2.2 km 3) Water Treatment Plant (WTP) Production capacity: 200,000 m^3/day Receiving well: 1 unit Mixing, Flocculation and Sedimentation Basin: 2 units x 2 lines Rapid sand filter: 8 cells x 2 lines Sludge treatment facility: 1 unit Chemical building: 1 unit, Chlorine building: 1 unit, Electrical building: 1 unit, Emergency generator house: 1 unit, Administration building: 1 unit, Maintenance work shop: 1 unit
Treated Water Transmission Facility	1) Transmission pump station in Iolanda WTP Pump type: Double suction volute pump - Discharge: 46.3 m^3/min, Total head: 184 m, 4 units (including one stand-by) Treated water reservoir: 8,400 m^3 2) Chilanga Booster Pump Station Pump type: Double suction volute pump - Discharge: 46.3 m^3/min, Total head: 190 m, 4 units (including one stand-by) Treated water reservoir: 8,400 m^3 Office and Store House: 1 no., Chlorination House: 1 no. 3) Treated water transmission pipeline From Iolanda WTP to Distribution Center of Lusaka Water Works (LWW) - Material: Mild Steel, Diameter and Length: 1,400 mm, 51.5 km From LWW to Stuart Park Distribution Center - Material: Mild Steel, Diameter and Length: 1,200 mm, 4.1 km From LWW to Lumumba Distribution Center - Material: Mild Steel, Diameter and Length: 1,200 mm, 7.0 km From Lumumba Distribution Center to Matero Reservoir - Material: Mild Steel, Diameter and Length: 450 mm, 4.7 km
Distribution Facilities (Reservoirs, Pump Stations, Chlorination Building)	1) Distribution Reservoir (Expansion) - Service Reservoir (21,000 m^3) in Lusaka Water Works - Service Reservoir (21,000 m^3) in Lumumba Water Distribution Center - Service Reservoir (3,000 m^3) in Matero Distribution 2) Pump Station (Expansion) - Pump station in Lusaka Water Works: 1 no. - Pump station in Lumumba Water Distribution Center: 2 no. (For distribution: 1 no., For transmission: 1 no.) - Pump station in Stuart Park Water Distribution Center: 1 no. - High Court Pump Station: 1 no. - Woodland Pump Station: 1 no. 3) Chlorination Building (Expansion) House - Lusaka Water Works: 1 no. - Lumumba Water Distribution Center: 1 no. - Stuart Park Distribution Center: 1 no.

Proposed Facility	Principal Features
Water Distribution System (Pipes)	1) New Construction Expansion of Distribution Main Material: uPVC, HDPE and Mild Steel, Diameter and Length: 150 mm - 800 mm, x 125 km Installation of DMA master meter: 66 locations LWW to Lumumba Reservoir 2) Replacement of Distribution Networks Material: uPVC, HDPE and Mild Steel, Diameter and Length: 75 mm – 600 mm x 270 km Replacement of Service Connection 12,500 nos. Replacement of Household Meter: 12,500 nos, New Household Meter: 8,500 nos. 3) Expansion of Distribution Networks Material: uPVC, HDPE and Mild Steel, Diameter and Length: 75 mm - 315 mm, 340 km Procurement of house hold meter: 35,000 nos
Others	- Integrated Remote Monitoring System: 1 lot - Maintenance Equipment (Vehicles, Tools, Flow Measuring Device, Water Quality Testing Equipment, etc.)

Source：JICA Study Team

4.2 Intake Facility, Raw Water Transmission Pipeline and Water Treatment Plant

The general layout of intake, raw water transmission pipeline, and water treatment plant proposed in the Project is shown in Figure 4.2.1. The intake facility of the Project is located near the existing Iolanda Intake Facility. Raw water collected from the intake is transmitted to the WTP through a raw water transmission pipeline with the length of approximately 2.2 km (diameter: 1,200 mm). The treatment capacity of the WTP is 200,000 m$^{3/}$day (daily maximum water supply volume is 200,000 m^3/day). The construction of the WTP for the Project was planned near the existing Iolanda WTP and KBWSP WTP.



Source: JICA Study Team

Figure 4.2.1 General Layout of Intake Facility, Raw Water Transmission Pipeline, and Water Treatment Plant

4.2.1 Design Standard

(1) Design Standard for the Facility

The Lusaka Water and Sewerage Company (LWSC) prepared a draft design standard on the water supply and sewerage network in October 2010. However, it was not completed as reported in the MCC F/S. Also, the design standard relating to the water supply facility has not been established either. Accordingly, the design of the water supply facilities complied with the design criteria of the Water Supply Facilities 2012 issued by the Japan Water Works Association in the Project, based on the discussion with LWSC.

(2) Water Quality Standard

According to the Design Review Report (Feb. 2013) of the MCC Project, both the World Health Organization (WHO) Drinking-water Quality Guideline and the Zambian Water Standard (ZS 190: 1990) were applied. On the other hand, in the KBWSP conducted by the China Civil Engineering Construction Corporation, the WHO Drinking-water Quality Guideline was applied. However, neither of the projects revealed issuing year nor revision number of the WHO Drinking-water Quality Guideline.

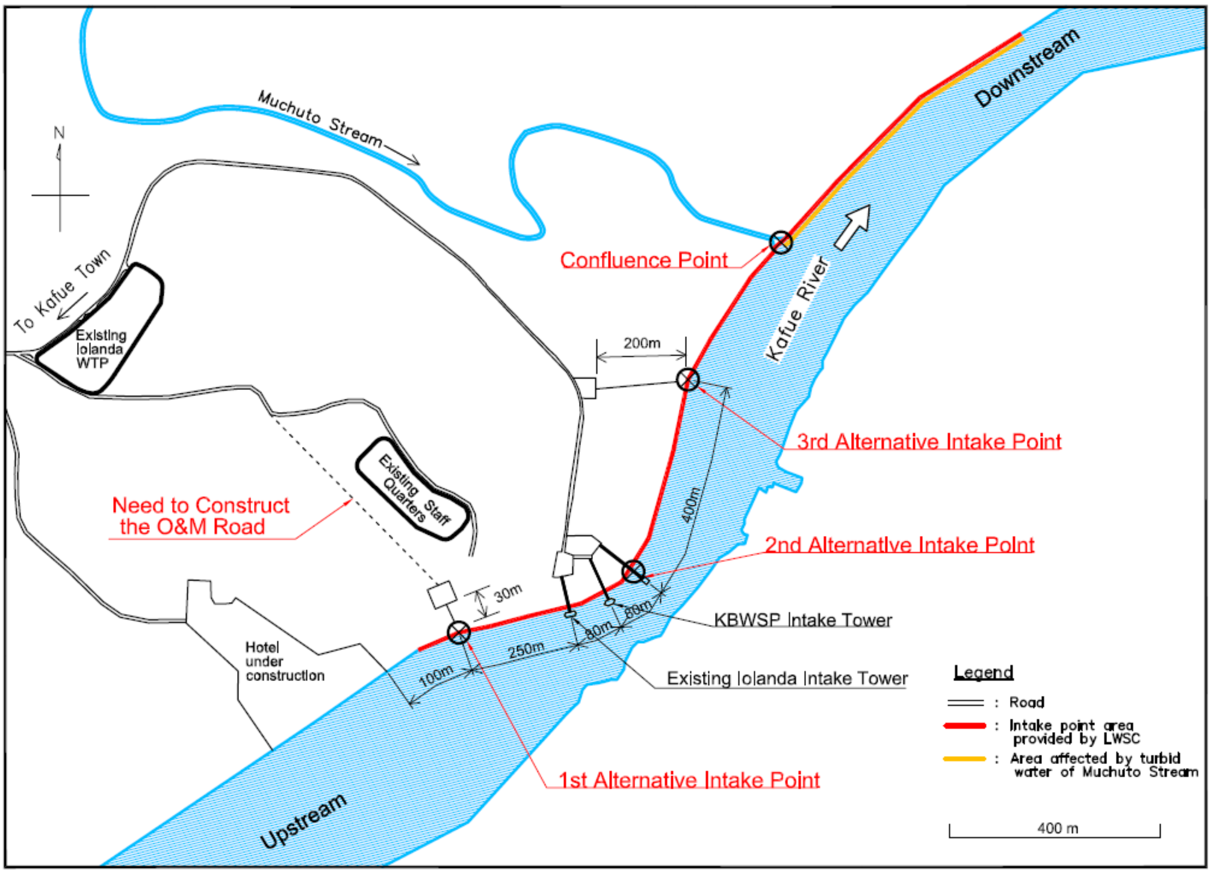
As shown in Table 2.2.1, there is no major difference between the Zambian Water Standard and the WHO Drinking-water Quality Guideline Fourth Edition. However, the WHO Drinking-water Quality Guideline does not clearly show the permissible values of color, pH level, etc. Accordingly, the Project adopted the Zambian standard (ZS 190: 2010) as its water quality standard.

4.2.2 Intake Facility and Raw Water Transmission Pipeline

(1) Intake Facility

1) Selection of Intake Facility

From the site situation and the result of the site survey, three alternative intake points within the area were selected as 1) the first alternative intake point nearby a hotel under construction (LWSC plan), 2) the second alternative intake point located approximately 80 m downstream of KBWSP intake tower, and 3) the third alternative intake point located approximately 400 m downstream of the second alternative intake point. Figure 4.2.2 shows the intake area to be provided by LWSC and the three alternative intake points. The downstream from confluence point where the Kafue River and Muchuto Stream merged was excluded from the nomination as an alternative point, since the downstream side has high turbidity of the Kafue River water due to storm water drainage of Muchuto Stream.



Source: JICA Study Team

Figure 4.2.2 Intake Area Provided by LWSC and Three Alternative Intake Points

Criteria of judging the alternatives are 1) impact to the Kafue River, 2) reliability in intake water volume, 3) raw water quality, 4) construction cost, 5) operation and maintenance (O&M) easiness, and 6) environmental impact due to construction. Each alternative evaluation result is shown in Table 4.2.1.

As a result of the comparative study from the integrated aspects, the second alternative point was selected as the optimum site for having the easiest O&M and better condition compared with the other alternatives.

Table 4.2.1 Comparison for Selection of Intake Facility Location

Evaluation Item	1st Alternative Point	2nd Alternative Point	3rd Alternative Point
Impact to the Kafue River	Impact to the Kafue River can be reduced by constructing an intake facility at the edge of the normal water flow area. In the case of the intake tower, it needs to construct the piers of the access bridge (30 m) in the flooded field, however, affection to the construction of access bridge is limited due to the low flow of velocity and shallow depth.	Impact to the Kafue River can be reduced by constructing an intake facility at the edge of the normal water flow area. In the case of the intake tower, it needs to construct the piers of the access bridge (82 m) in the flooded field, although, the location of the intake facility for the Project is out of the area influenced by the existing Iolanda and KBWSP intake facilities, so impact is limited.	Impact to the Kafue River can be reduced by constructing an intake facility at the edge of the normal water flow area. In the case of the intake tower, it needs to construct the piers of the very long access bridge (200 m) in the flooded field, so it affected the river flow compared with others where low flow velocity and shallow depth are even affected.
	A	A	C
Reliability in Intake Water Volume	Water intake from the Kafue River is secured throughout the year by the construction of the water intake inlet facility in response to the fluctuation of the water level.	Water intake from the Kafue River is secured throughout the year by the construction of the water intake inlet facility in response to the fluctuation of the water level.	Water intake from the Kafue River is secured throughout the year by the construction of the water intake inlet facility in response to the fluctuation of the water level.

Evaluation Item	1st Alternative Point	2nd Alternative Point	3rd Alternative Point
	A	A	A
Raw water quality	A small hotel is under construction at 100 m upstream. Raw water pollution risk is the highest in comparison with the two alternatives.	It is located 510 m downstream from the small hotel so that sewage is fully diluted. Raw water quality is not affected.	It is located 910 m downstream from the small hotel so that sewage is fully diluted. Raw water quality is not affected.
	C	A	A
Construction cost	Intake facility (including access bridge 30 m), 1.1 km raw water pipeline, and O&M access road Around USD 12 million	Intake facility (including access bridge 82 m) and 1.9 km raw water pipeline. Around USD 11 million	Intake facility (including access bridge 200 m) and 1.5 km raw water pipeline. Around USD 11 million
	B	A	A
Operation and maintenance (O&M) easiness	Although the existing Iolanda Intake and new intake are located at a 250 m distance, a cliff lies between them and they cannot access each other directly. Access distance is 2,700 m. As a result, each intake facility needs their own O&M staffs.	Planned intake is located next to the existing Iolanda Intake, O&M works can integrate for both facilities.	Although planned intake is located at 560 m from the existing Iolanda Intake, it is along the existing access road and access length shortens to 300 m. It allows to conduct relatively efficient O&M works.
	C	A	B
Environmental impact due to construction	It is planned upstream of the existing Iolanda and KBWSP intake facilities, the existing ones will be affected by turbid water from the construction works. Upstream hotel will be affected by the construction noise.	It is planned downstream of the existing Iolanda and KBWSP intake facilities, the existing ones will not be affected by turbid water. Although construction vehicles will affect to the O&M works, it will be minor.	It is planned downstream of the existing Iolanda and KBWSP intake facilities, the existing ones will not be affected by turbid water. It will be the least that the construction vehicles will affect to the O&M works.
	C	B	A
Selection	Not selected	Selected	Not selected

Note: A : Excellent, B : Good, C : Fair
Source: JICA Study Team

2) Selection of Intake Facility

With regard to the river water source, conceivable intake types are generally intake weir, intake tower, intake gate, and intake conduit. In the Project, intake tower is selected by the following reasons:

a) Intake weir: It will be a hindrance to navigation of ships around the intake point.

b) Intake gate: This type is used for small- to medium-scale volume of water intake requiring raw water conveyance canal. O&M will be complicated since intake gate will be submerged during the rainy season.

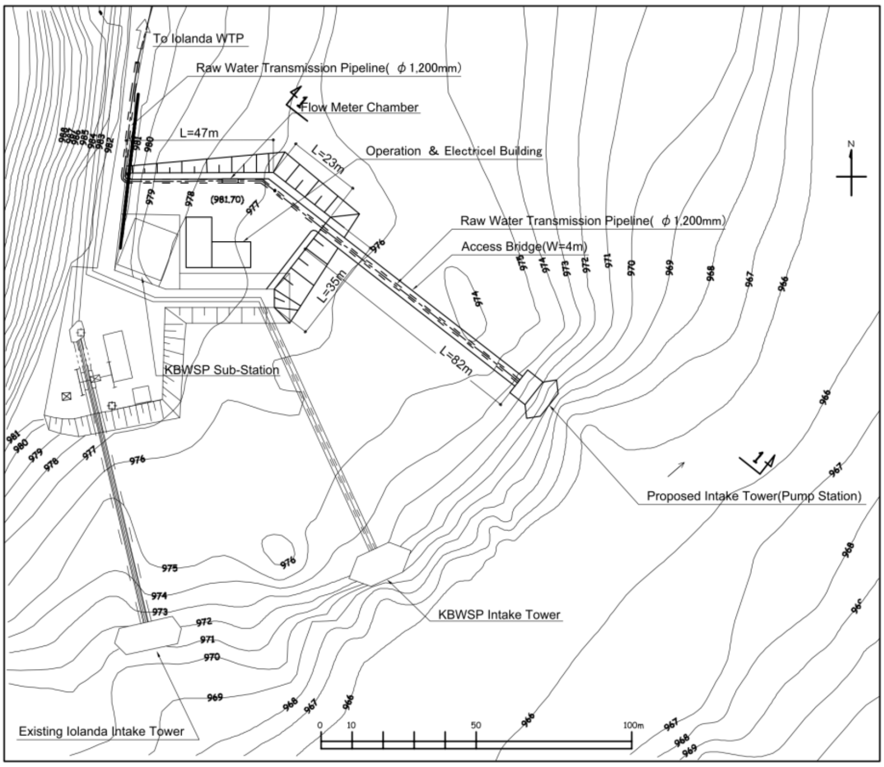
c) Intake conduit: This type is used for small- to medium-scale volume of water intake. O&M will be complicated since water suction pit and water conveying conduit are submerged in 3.9 m depth during the rainy season.

3) Design Water Intake Volume

Design intake flow rate is 210,000 m^3/day, which includes the daily maximum design water supply volume of 200,000 m^3/day and water volume for treatment loss and internal use of 10,000 m^3/day (5% of the daily maximum design water supply).

4) Water Intake Facility

The water intake facility of the Project is located near the existing intake and KBWSP intake. Figure 4.2.3 shows the location related among the existing intake, KBWSP intake and the intake of the Project.



Source: JICA Study Team

Figure 4.2.3 Location of the Intake Facilities Proposed in the Project and Other Intake Facilities

a) Structure of water intake tower

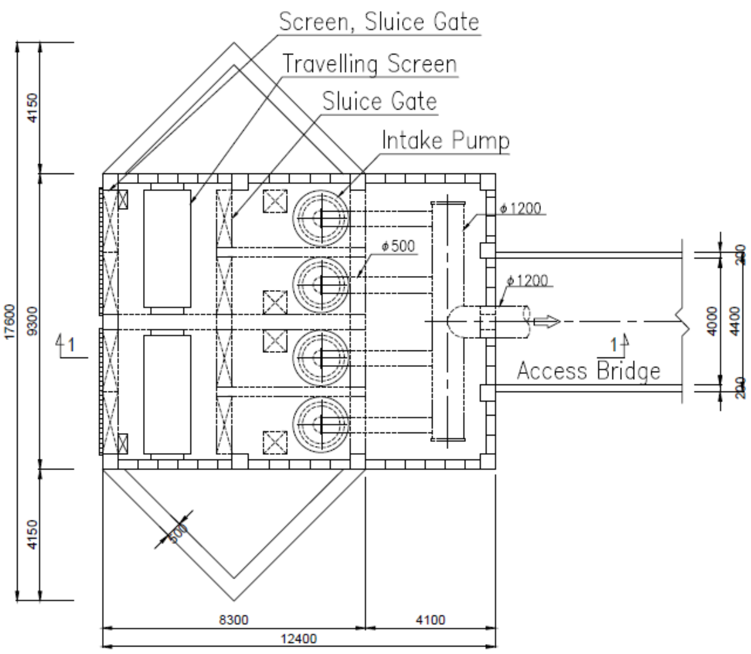
Structure of intake tower is shown below in consideration of the safe and stable water intake as well as O&M. Plan of intake tower is shown in Figure 4.2.4.

Type of structure: Reinforced concrete structure composed of intake inlets, travelling screen pit, and pump pit

Intake inlets: Multistage gate type consisting of two compartments with two intake inlets at upper portion and lower portion respectively (inlets in total), enabling different intake level equipped with coarse screen and intake gate.

Travelling screen pit: Screen pit is provided to remove foreign materials passing through the coarse screen. Two compartments are designed for O&M.

Pump suction pit: Four suction pits are designed so as to take the design water volume even during the maintenance period.

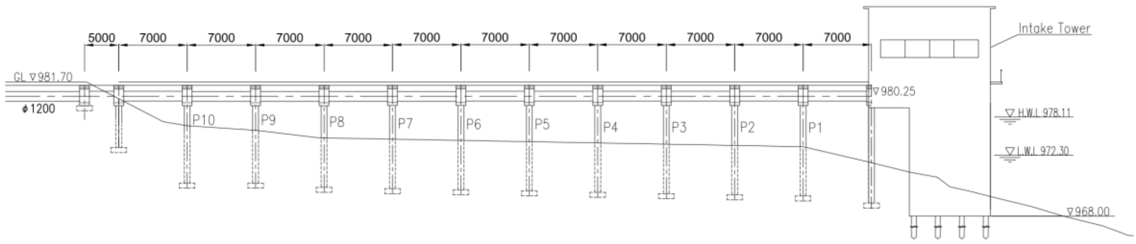


Source: JICA Study Team

Figure 4.2.4 Plan of Intake Tower

b) Access bridge of water intake tower

Since the bridge length of 82 m is considered to be rather long, the design of the access bridge was made enabling traffic ability of maintenance vehicle as well as O&M. The section of the access bridge is shown in Figure 4.2.5.



Source: JICA Study Team

Figure 4.2.5 Profile of Access Bridge

c) Operation and Electrical Building

Operation building was designed for the purpose of O&M works of intake facility, together with the electrical building for operation of machinery including pumps and travelling screen.

5) Design Water Level

Design high water level is 978.11 m above mean sea level at 100-year probability of the Kafue River. The water level data was obtained from the Water Resource Management Authority (WARMA) and LWSC. Design low water level is 972.30 m above mean sea level due to the same low water level of Kafue Gorge Dam. Table 4.2.2 shows the design high water level and design low water level of MCC and KBWSP. There is not much difference among those listed in the table except for the design high water level of MCC, the design water level of the Project is appropriate.

Table 4.2.2 Design High Water Level and Design Low Water Level of MCC Project, KBWSP and the Proposed Design Water Level in the Project

	MCC Project	KBWSP	The Project
Design High Water Level (Above mean sea level)	974.40 m	978.00 m	978.11 m
Design Low Water Level (Above mean sea level)	971.40 m	972.00 m	972.30 m

Source: JICA Study Team

6) Mechanical and Electrical Equipment

a) Pumping Facility

i) Intake pump

Selection of the intake pump is generally made by using the specific gravity (Ns). Ns is calculated as 440 under the pump utilization condition and it falls on the range between 400 and 1,200, which are appropriate for the mix pump. The suction head of the pump is -7.8 m, which is over the vacuum range of the horizontal pump (-5 m). Therefore, vertical mix flow pump is selected as same as the existing pump type.

Specification of the intake pump is as follows.

Type	:	Vertical mixed flow pump
Operation method	:	Operated from electrical room (allowing remote control from WTP as well)
Pump bore	:	600 mm
Discharge volume	:	70,000 m^3/day/pump (48.6 m^3/min)
Pump total head	:	36 m
Motor rated capacity	:	450 kW
Number of pumps	:	4 nos. including one stand-by

ii) Flow control

Flow control is basically made of a number of pumps. However, speed control will be considered in the detailed design in consideration of the actual water demand and water production of the existing and other water supply project.

iii) Countermeasure against water hammer

As a result of the calculation, it is confirmed that water hammer occurs in the raw water transmission pipe. Electric outages were recorded several times in a month in the existing system, and this is one of the reasons of the occurrence of the water hammer. In this situation, protection method for the raw water facility is required. The raw water pump equipped with flywheel is employed as one of the most reliable countermeasures especially for low negative pressure.

b) Power Receiving and Transforming Facility

The power receiving and transforming facility was constructed by the Zambia Electricity Supply Corporation Limited (ZESCO) near the WTP. In the Project, 3.3 kV was confirmed to be obtainable from ZESCO and was received by the high voltage panel in the electrical building of the intake facility. The power transmission line from the power receiving and transforming facility to the electrical building is constructed by the Project.

c) Flow Meter

Flow meter for raw water transmission pipeline was designed to be installed in a flow meter chamber. Flow rate is displayed in the monitor panels installed in the control building of the intake facility and water treatment plant.

Type	: Ultrasonic flow meter
Number of meter	: 1 no
Diameter	: φ1,200 mm
Material	: Stainless steel

(2) Raw Water Transmission Facility

The raw water transmission facility is used to transmit the raw water taken by the intake facility to the WTP. The facility is composed of raw water transmission pipes, air valve chambers, washout chambers and valve chambers. The existing Iolanda Raw Water Transmission Pipe Route was adopted considering the O&M and construction workability.

Pipe material shall be mild steel because of its good workability, reasonable price, and procurability from the neighbouring countries. The comparison of the pipe materials is described in Table 4.3.7.

For the selection of the raw water transmission pipe diameter, flow velocity of 2 m/sec was adopted for the design.

From the results of the preliminary design, specifications of the raw water transmission pipeline are as follows:

Materials of pipe	: Mild Steel
Pipe diameter	: 1,200 mm
Pipe length	: 2.2 km
Line of pipes	: 1 lane
Maximum covering depth	: 2 m
Valve chambers	: Air valve chamber: 3 nos., Washout chamber: 2 nos. and Sluice valve chamber: 1 no.

4.2.3 Water Treatment Plant (WTP)

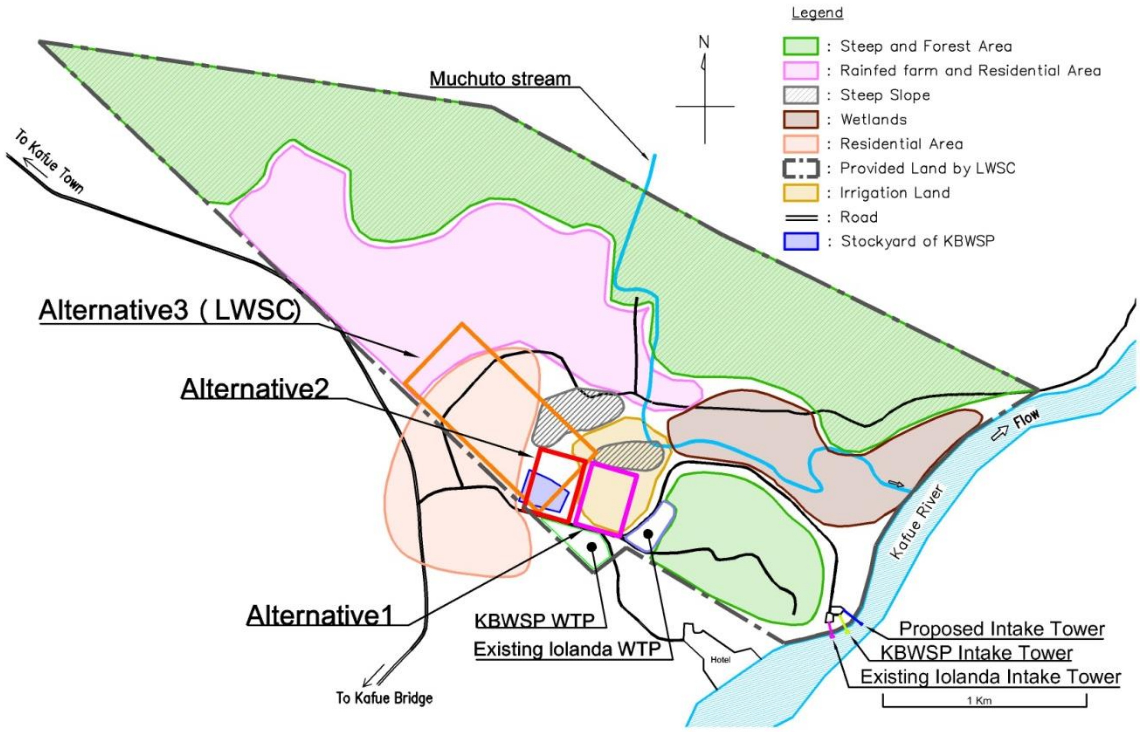
(1) Selection of Sites for the WTP

Figure 4.2.6 shows approximately an area of 600 ha for the WTP, which LWSC can provide for the Project. However, the area includes a steep slope, forest and swamp, which are not suitable for construction and operation of the plant. The other areas that meet the following three requirements are considered as Alternatives 1 and 2, and the area proposed by LWSC is considered as Alternative 3.

a) To avoid steep sloping area, forest, and swamp

b) To avoid surrounding areas of the Muchuto Stream

c) To avoid residential areas



Source: JICA Study Team

Figure 4.2.6 Candidate Sites for the WTP

Table 4.2.3 shows the results of the comparison among the three alternative sites for the WTP. As a result of the comparison, Alternative 2 shall be selected for the site of WTP, as it will not require resettlement of residents.

Table 4.2.3 Comparison for the Selection of the WTP Location

Evaluation Item	**Alternative 1**	**Alternative 2**	**Alternative 3（LWSC）**
Resettlement	No resettlement is generated.	No resettlement is generated.	It estimates that more than 100 households need resettlement.
	A	A	C
Impact to social environment	It was confirmed that 44 households cultivate vegetables in the area. Assuming that they are affected by the Project, they will have to change their work due to the loss of agricultural land.	It was confirmed that 10 households cultivate vegetables in the area. Assuming that they are affected by the Project, they will have to change their work due to the loss of agricultural land.	It assumes that the Project affects the resettled residents' income and life. Besides, the affected households are generated and have to change their work due to the loss of agricultural land. Furthermore, it assumes that the Project influences the social services in accordance with the resettlement of school.
	B	A	C
Impact on KBWSP Project	No impact	KBWSP plans to complete the construction works by September 2018. There is a risk of delay in the construction progress due to the availability of the land.	KBWSP plans to complete the construction works by September 2018. There is a risk of delay in the construction progress due to the availability of the land.
	A	C	C
Construction cost	The natural slope can be used in the design to save with the cost. However, the land has not been cleared yet, and so the construction cost will increase because of the on-site clearance work.	The natural slope can be used in the design to save with the cost. Land has already been cleared, and so it has the cheapest construction cost.	Due to the flat type of land, civil works and surplus soil transport shall be required to make a slope. The construction cost on earth works increases and so it has the highest cost.
	B	A	C
Cost on land acquisition/ compensation	Compensation cost shall be generated accompanying the abandonment of the farm land.	Compensation cost shall be generated accompanying the abandonment of the farm land. However, the abandonment scale is smaller than that of Alternative 1.	Compensation cost shall be generated accompanying the resettlement and abandonment of the farm land. The cost is the biggest since it includes resettlement cost.
	B	A	C
Operation easiness	The planned WTP stands next to the existing Iolanda and KBWSP WTP, and so O&M works are efficient.	The planned WTP is located near the existing Iolanda and KBWSP WTP, and so O&M works are efficient.	The planned WTP is located away from the existing Iolanda and KBWSP WTP. O&M works' efficiency are inferior to the other two alternatives.
	A	A	B
Point	9	10	0
Selection	Not Selected	Selected	Not selected

Note: A：Excellent, B：Good, C：Fair
Source: JICA Study Team

(2) Treatment Process

1) Selection of Water Treatment Method and Sludge Treatment Method

a) Water Treatment Method

Raw water quality (turbidity) of the water source is good according to the water quality test result, and so a slow sand filter or a rapid sand filter is considered for its filtration system. As a result of the discussion with the LWSC, rapid sand filtration method, which includes coagulation, sedimentation, and rapid sand filter, is adopted because the slow sand filter needs large lands to operate and is not common in large WTPs in Zambia. In addition, both the existing Iolanda WTP and KBWSP WTP adopted the same method. Thus, application of the method to the Project was judged to be appropriate.

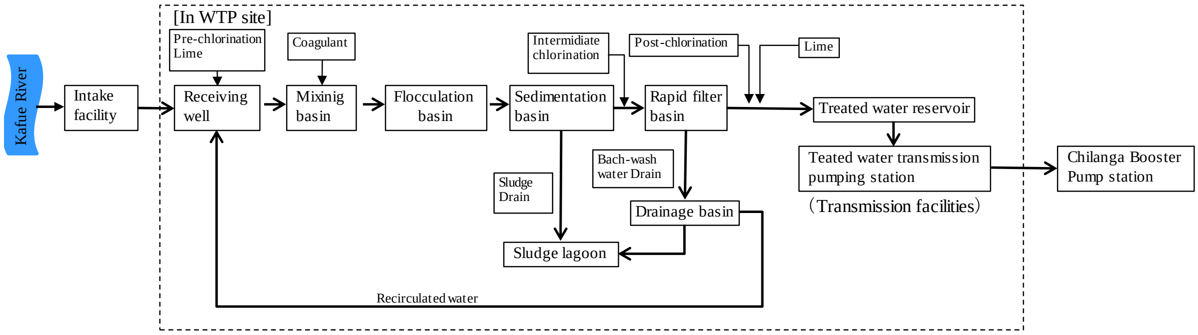
b) Sludge Treatment Method

Drain water from filter and sedimentation basin in the existing Iolanda WTP is directly discharged to the Kafue River without any treatment. The Project introduced the sludge treatment system to reduce the burden on the environment only for the new Iolanda WTP. Therefore sludge treatment system for the existing Iolanda WTP is out of scope in the Project.

Several sludge treatment methods were proposed including the drying bed, sludge lagoon, mechanical dewatering and thermal drying. After examining the water quality, ease of O&M, land acquisition and construction cost, the sludge lagoon treatment method was adopted. The sludge treatment method is composed of sludge lagoon and drainage basin.

2) Flow of Water Treatment

Figure 4.2.7 shows the flow of the water treatment.

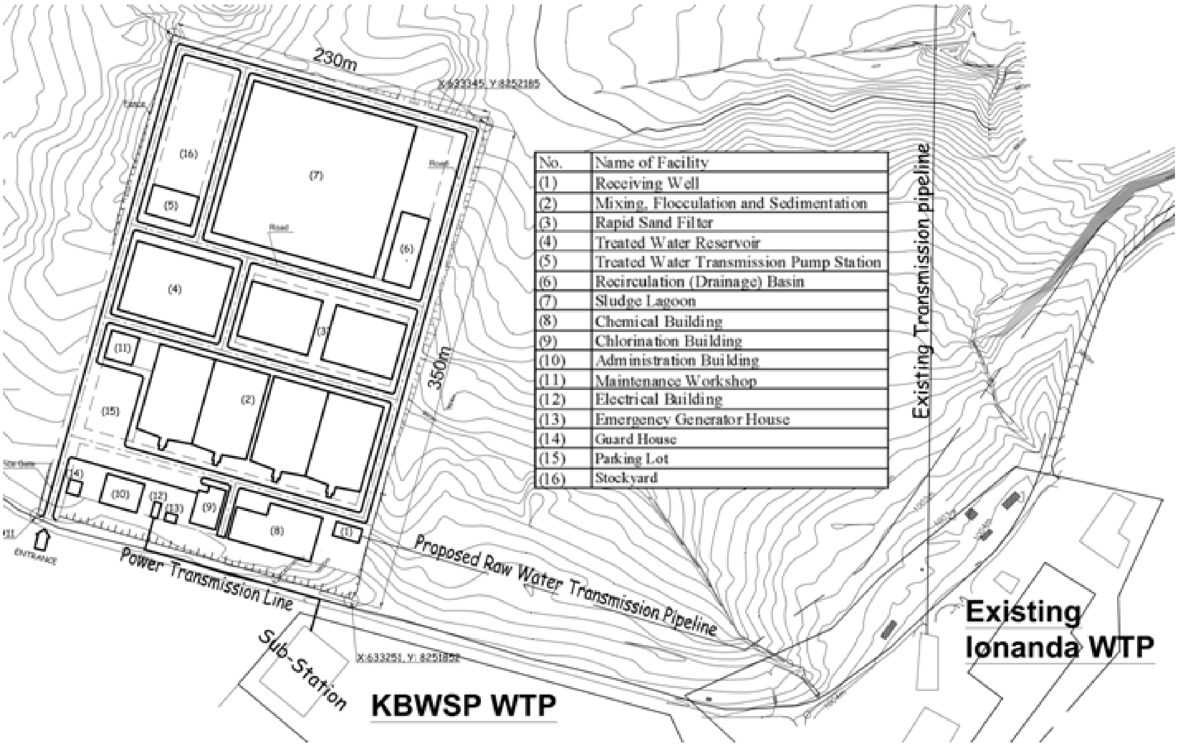


Source: JICA Study Team

Figure 4.2.7 Flow of the Water Treatment

(3) Design of Water Treatment Facility

Figure 4.2.8 shows the proposed general layout of the WTP for the Project. The water treatment facility is composed of a receiving well, mixing basin, flocculation basin, sedimentation basins, filters, sludge treatment system, chemical building, chorine building, emergency generator house and other appurtenant facilities. For the process of the treatment, two process flow line is adopted in consideration of the safety and O&M. The area of the water treatment plant is 80,500 m^2 (350 m x 230 m).



Source: JICA Study Team

Figure 4.2.8 General Layout of the WTP

1) Design Filtration Flow Volume

Design filtration volume is 200,000 m^3/day.

2) Receiving Well

Purpose of installing the receiving well is to stabilize the raw water level fluctuation, measure and regulate the raw water volume. Moreover, it has functions of injection of pH adjustment lime and pre-chlorination, distribution of raw water and receiving of re-circulated water. It is planned to be made of reinforced concrete structure.

3) Mixing Basin

Purpose of installing the mixing basin is to rapidly mix the coagulant with raw water. Coagulant is mixed by the rapid mixer applying around 2 minutes of mixing time for the design treatment volume. There are two lines of mixing basin, flocculation basins and sedimentation basins. The de-sludge system was designed as one structure. Main structure is constructed using reinforced concrete.

Aluminium sulphate is used for the coagulant, which can remove the turbidity and color of water. This is easily obtained in Lusaka City. According to the jar testing result done in the MCC Project, effectiveness of the aluminium sulphate for removing the turbidity and color was confirmed. In the existing Iolanda WTP, aluminium sulphate was used as a coagulant before, however, Sudfloc (chemically similar to PAC) is currently being used since the coagulant dosing system around the year 2010 failed. MCC report describes that Sudfloc is effective for reducing turbidity, but does not have an effect on the water's color. On the other hand, the use of PAC is planned in the KBWSP, however, it is not available in Lusaka City according to an interview survey with the sub-contractor of the water quality monitoring. Considering the efficiency of using the same chemicals, availability of PAC should be confirmed during the detailed design stage of the Project from the aspects of improving the efficiency of O&M works and the adopted chemicals should be determined. According to the LWSC, both aluminium sulphate and PAC are allowed.

4) Flocculation Basin

Purpose of installing the coagulation basin is to make an efficient floc formation using the coagulant. There are two kinds of flocculation basin. One is equipped with a mechanical type flocculator and another is a baffle type. The baffle type was adopted from the aspect of easy maintenance. Moreover, a de-sludge valve was installed to remove periodically the sludge at the bottom of the basin. Reinforced concrete structure is applied.

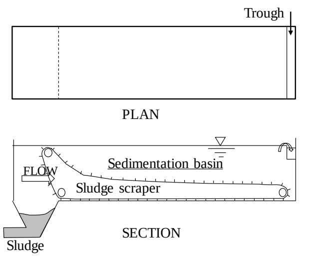
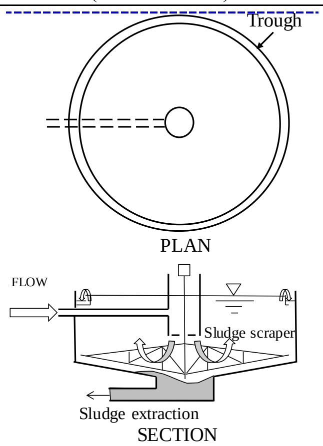
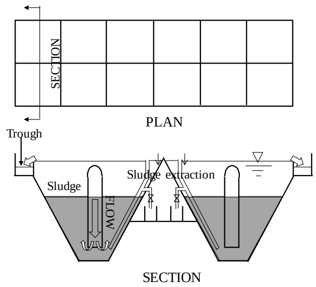
5) Sedimentation Basin

In consideration of the existing facilities, KBWSP's facilities and other facilities in African countries, there are three types of sedimentation basin mentioned in Table 4.2.4, namely: 1) rectangular horizontal flow type, 2) round horizontal flow, and 3) blanket hopper type (chemical clarification tank type in the existing Iolanda Treatment Plant) were compared.

In consideration of the flocculation effect, O&M, management, and workability, the first alternative (rectangular horizontal flow type sedimentation basin) was selected in the preliminary design. In the detailed design, detailed examination in consideration of the actual usage condition of KBWSP's sedimentation basin will be made for final judgement of the type of sedimentation basin.

The sludge collector of the rectangular horizontal type for sedimentation basin is a link belt type sludge collector, which has less failures and simple maintenance and is generally used for WTPs. The material of the link belt is plastic, and thus has excellent corrosion resistance.

Table 4.2.4 Comparison in the Selection for the Sedimentation Pond Alternatives

Evaluation	Rectangular Horizontal Flow Type (Alternative 1)	Circular Horizontal Flow Type (Alternative 2)	Blanket Hopper Type (Alternative 3)
Facility description			
Coagulation effect	It can be flexible to variation of turbidity and flow volume. Stable flocculation effect can be expected.	It becomes an unstable flowing status because flow direction moves and wind largely influences the flowing status.	Stable turbidity value is required. When raw water turbidity and flow volume fluctuate, flocculation effect decreases.
	A	B	B
Construction cost	It is estimated to be around USD 3.0 million with one sedimentation pond consisting of one concrete body and equipment.	The cost is cheaper than Alternative 1 because the mechanical equipment is simpler than that of the Alternative 1.	It is the cheapest alternative, because major mechanical equipment is not required, although the concrete works are complex.
	C	B	A
Construction workability	Construction is easy because of its rectangular shape.	It is more difficult than Alternative 1 because of its circular shape.	It is the most difficult one for construction due to its complicated shape.
	A	B	C
Operation	Sludge density control in the sedimentation pond shall not be required. Operation is easier than the other two alternatives.	Operation is more difficult than Alternative 1 due to its unstable flowing status.	Sludge density control in the sedimentation pond shall be required, and so operation is the most difficult. Floc passes through the sedimentation pond and it affects to filter process.
	A	B	C
Maintenance	Periodical maintenance on machines shall be required.	Periodical maintenance on machines shall be required.	Frequent maintenance shall be required due to valve and pipe clogging. Maintenance is most difficult in this alternative.
	A	A	C
Selection	Selected	Not selected	Not selected

Note: A: Excellent, B: Good, C: Fair
Source: JICA Study Team

6) Rapid Sand Filter

In the Project and in KBWSP, rapid sand filter was selected as an existing filter. Two process lines of rapid sand filter with constant filtration method were adopted. For the selection of the regulating system of the filter, the self-balancing self-back wash type (siphon type) widely used in Japan, and the conventional flow control type, which is used in many countries, were compared. For the washing method of the filter media, a combination of the back-washing and surface-washing type was adopted, as it is also commonly used in Japan.

As shown in Table 4.2.5, both filtration systems have their own advantageous features. Thus, there was an inability to determine which is more efficient. But as a result of the discussion with the LWSC, the self-balancing type (self-back wash type) filtration system was selected due to the non-necessity to equip and control the runoff system; and less electricity for the operation of the filter is needed.

Table 4.2.5 Comparison of the Filter Type

Item	Self-balancing Self-back Wash Type (Siphon Type)	Conventional Flow Control Type
Method of Flow Control	Inlet flow control type An outlet weir of which height is above the media surface level is provided at the outlet of the filtered water trough. The flow rate is maintained by gravity raising the water depth above sand surface as the head loss increases in the sand media.	Outlet flow control type In this system, measuring and flow regulating systems are provided on the outlet side of filter. The filtration flow rate is controlled by flow regulating system. As filtration proceeds and the clogging of the filter layer progresses, the valve is opened to cover the increase in head loss in the filter, and thereby the filtration flow rate is maintained constant.
Number of Cell	Eight cells are formed in one group	Optional
Filtration	1. Flow control The inflow water runs in from the inflow conduit via siphons, and the inflow volume is evenly distributed to the filter via the inflow weirs. Runoff is naturally operated by water level in the filter. This filter is possible without adjusting the filtration rate on the outlet side 2. Protection of negative pressure in the media The filter layer is not exposed to the air because outlet wear level is set above the sand level. 3. Quality of treated water Slow finishing backwashing and slow start filtration is good for proper treatment.	1. Flow control Flow control is made by the flow control meter and flow regulating valve. There is a need to maintain the constant water level in the filter and control the flow regulating valve operation ratio by water level (pressure) for constant flow rate. 2. Protection of negative pressure in the media Due to the treated water conduit level being lower than the media surface level, a negative pressure in the media when the media clogged is possible to occur. 3. Quality of treated water Water quality may be degraded due to the change in the filtration velocity when a control valve is operated.
Backwashing	1. Major equipment of backwash system Backwash system is composed of the siphon system and the surface wash pump. 2. Supply and drainage of backwash water Self-back washing is performed using the treated water that runs into the treated water conduit from the other filter, then washout water is collected by the effluent trough and drained through the siphon. 3. Pressure of the backwash water Backwash flow rate is determined by the height of the difference of the runoff weir and effluent trough edge. In case of changing the flow pressure, there is need to equip the adjustment runoff weir. 4. Volume of backwash water Due to the use of runoff water of the other filter during backwashing, and if the filtration rate is lower or available water for back washing is less than that the required for backwashing, an external supply of water is necessary. 5. The structure does not allow preliminary drain.	1. Major equipment of backwash system Backwash system is composed of motorized drain valve, motorized back wash valve, back wash pump, and surface wash pump. 2. Supply and drainage of backwash water Backwash water is supplied by the backwash pump. Washout water is collected by effluent trough and drained through a motorized gate. 3. Pressure of the backwash water Initial setting and periodical maintenance are required because the control of the backwash volume is through the pressure of the backwash pump. 4. Volume of the backwash water In having the individual backwash system, the filtration rate is not affected by the backwashing. 5. The structure allows preliminary drain.
Construction Cost	Construction cost of civil and earth works is higher because the filter is deeper. On the other hand, the cost of mechanical equipment is lower because a backwash pump is not necessary in using the self-back washing system. Total cost is almost the same with the conventional flow control type.	Construction cost of civil and earth works is lower compared with the siphon type, but the costs for the mechanical equipment, such as pumps and valves, are higher. So, the total cost is almost the same with the self-balancing type.
Operation	Operation is easy because clogging in the media is visible, flow control is easier because flow control is only for the inlet side and not in the outflow side. Also inflow control via inlet siphon can be operated by the solenoid valve. During the backwashing, the volume of the treated water of filters is decreased, causing difficulty in controlling chlorine feeding.	In case of unbalance runoff flow, water level fluctuates, and causing the over flow or exposing of the filter media. Therefore, it needs to equip the flow meter, flow regulation valve, and regulating meter. In addition, flow control setting is necessary so the operation is more complicated compared with the self-balancing filter.
Maintenance Cost	Due to the non-requirement of the backwash pump, this type is cheaper than the conventional flow control filter. Power consumption is about 25% compared with the conventional flow control filter	Backwash pump and surface wash pump are necessary so electric cost is higher than the self-balancing type (self-back wash). Power consumption is about four times larger compared with the self-balancing type (Self-back wash type).

Item	Self-balancing Self-back Wash Type (Siphon Type)	Conventional Flow Control Type
Maintenance Technology	In case of a breakdown in the siphon system, all of the filter under the same line will be stopped. Therefore, it is very important to have a professional O&M staff, and so adequate O&M training is essential.	This filter is basically the same as the existing one (fully manual operation system), new filter will be designed as electrically operated filtration system. Therefore, utilizing the conventional flow control type filter also needs adequate O&M training.
Selection	Selected	Not selected

Note: Backwash water of filtration flow control method is supplied by a backwash pump or a high-rise tank. In this table, backwash pump is assumed.

Source: JICA Study Team

7) Sludge Treatment Facility

a) Drainage Basin

Purpose of installation of the drainage basin is to receive the washout drain water of the filters and the sludge of sedimentation basin to separate supernatant water from the sludge and to transmit the supernatant to the receiving well. Wash out water from the filter and sludge from the sedimentation basin are transferred to the sludge lagoon and to the drainage basin by gravity. The drainage basin is equipped with functions of the recirculation pump system and the sludge removal system. The main structure was constructed using reinforced concrete.

b) Sludge Treatment Method

For sludge treatment method, a sludge lagoon, which does not require thickener and mechanical equipment, was adopted. It is constructed using the masonry method. Accumulated sludge in the sludge lagoon is removed by human and equipment and disposed near WTP within the LWSC compound. Some of sludge is planned to reuse for construction such as road embankment. Daily sludge volume is calculated as three ton. Treated water by sand is drained to Muchuto River.

8) Chemical Building

The chemical building is built to be equipped with the chemical feeding system together with a storage room for the chemicals. A storage room is a space to store the alum and limes, which are chemicals used for water treatment. The chemical feeding system includes dissolving tanks, dole-tanks, chemical transfer pumps, dosing pumps, and other equipment. Also, the chemical building is equipped with a water quality monitor room. The main structure is constructed of reinforced concrete with a floor space of approximately 1,400 m^2.

9) Chlorine Building

Chlorine building is built to equip the chlorination system for dosing of pre-chlorine, intermediate-chlorine and post-chlorine and consists of the chlorine injection facilities, chlorine storage facilities and a neutralization system. A liquefied chlorine (chlorine gas charged in a one-ton gas cylinder) is used as a chlorine agent as same as in the existing Iolanda WTP. The main structure was constructed using reinforced concrete with a floor space of approximately 400 m^2.

10) Electric Building

Electric building is built to equip the power incoming system and for receiving the 3.3 kV electricity from ZESCO. The main structure was constructed using reinforced concrete with a floor space of approximately 60 m^2.

11) Emergency Generator House

The emergency generator house is built to install the generator with a capacity of 200 kVA as a backup system of instrumentation and system control, assuming the power load of 90 kW for sludge scraper of sedimentation basin, neutralization system, emergency valves and internal water supply pumps, and 63 kW for building lighting, communication, control system and so on. The main structure was constructed using reinforced concrete with a floor space of approximately 50 m^2.

(4) Other Facilities

1) Administration Building

Supervising director for three WTPs is planned to be stationed in administration building of KBWSP and each WTP has director under supervision of supervising director. The administration building in the Project will be for the purpose of O&M for the intake and the WTPof the Project. The administration building includes management rooms, meeting room, water quality testing laboratory and etc. The main structure is constructed using reinforced concrete with a floor space of approximately 750 m^2.

2) Maintenance Workshop

Maintenance workshop is built exclusively for the WTP in the Project since the equipment installed in the adjacent WTPs is different from that of the adjacent WTP. Maintenance workshop consists of a maintenance room and a material and equipment storage yard. The main structure is constructed using reinforced concrete with a floor space of approximately 400 m^2.

(5) Electrical and Mechanical Facilities

1) Main Equipment

Table 4.2.6 shows the main equipment installed in the proposed WTP.

Table 4.2.6 Proposed Main Equipment in WTP

Item of Equipment	Number of Equipment	Specification
Rapid mixer	4 nos.	Mechanical agitating device with reduction gear
Sludge scraper	24 sets	Link belt type
Chlorination system	1 lot.	Injection equipment, injection pumps, chlorine cylinders, and neutralization system
Coagulant dosing system	1 lot.	Dissolving tanks, dole- tanks and chemical pumps
Alkaline agent dosing system	1 lot.	Dissolving tanks, dole- tanks and chemical pumps
Re-circulation pump	2 nos.	Wastewater submersible pump, 37 kW
Water supply pump	2 nos.	Single suction multistage volute pump, 11 kW
Sludge removal pump	2 nos.	Submersible sludge pump, 2.2 kW
Surface wash pump	3 nos.	Double suction volute pump, 110 kW (including one stand-by)
Siphon system	2 nos.	Siphon pipe, vacuum holding tank, valves, vacuum pump, (7.5 kW), compressor (3.7 kW)
Flow meter	1 lot.	Ultrasonic wave type
Valves	1 lot.	Gate valve, Flow amount adjustment valve, 400 mm - 1,400 mm
Main pipes in the WTP	1 lot.	Steel pipe, 400 mm to 1,400 mm
Electric equipment	1 lot.	Power distribution equipment, power facility and uninterruptible power source equipment
Emergency power generator	1 no.	200 kVA, indoor low noise type
Control monitoring system	1 lot.	Control monitoring equipment, information processing device, and transmission device
24 hours water quality monitoring device	1 lot.	pH meter, turbidity meter, residual chlorine meter, alkalinity analyzer, and thermometer
Water quality test equipment	1 lot.	Test instruments including water cohesion reaction tester, pH meter, and turbidity meter
O&M vehicle and equipment	1 lot.	Folk lift, truck (4 t), small wheel loader

Source: JICA Study Team

2) Power Receiving and Transforming Facilities

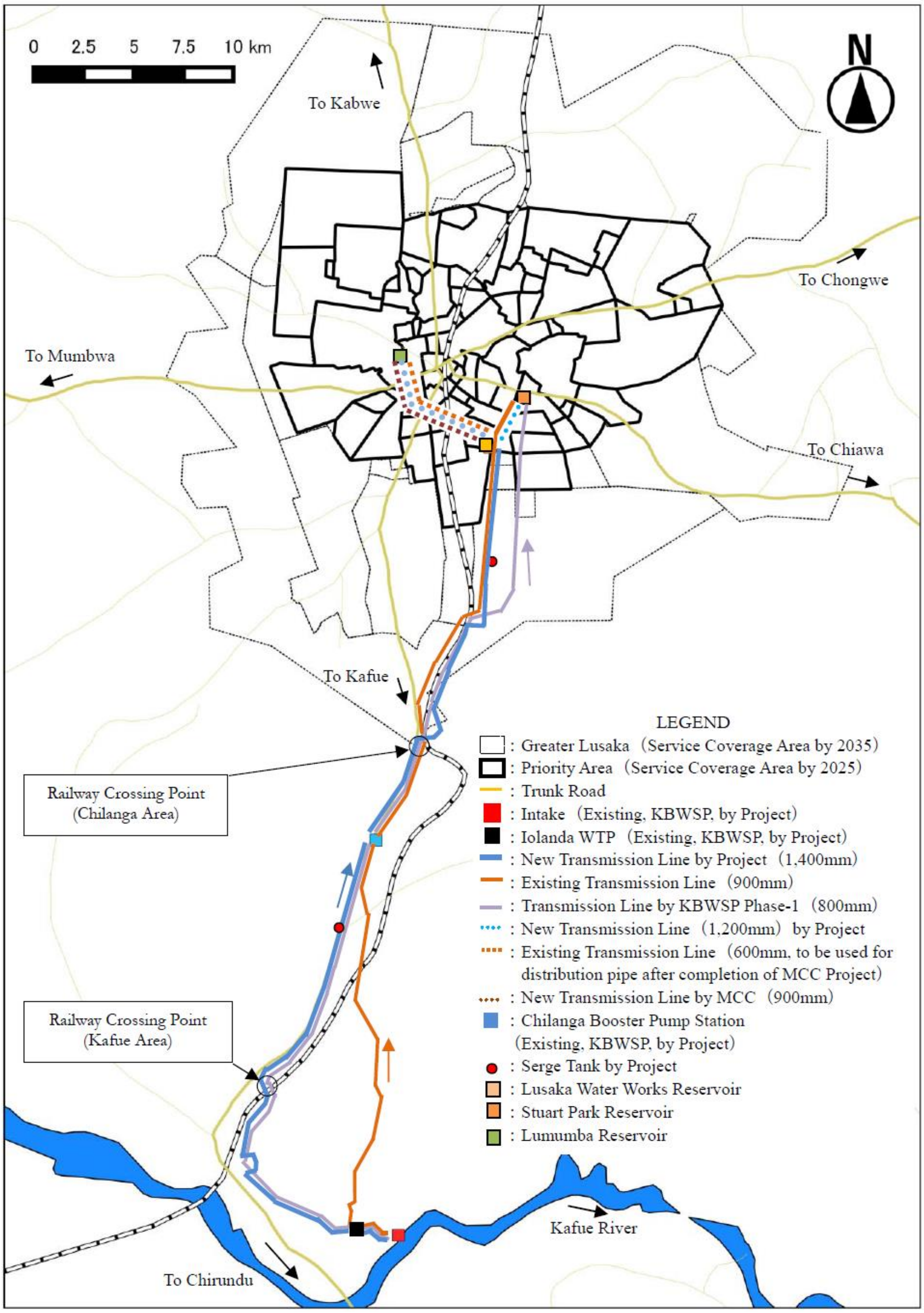
Power receiving and transforming facility shall be constructed by ZESCO in the area of KBWSP WTP. The 3.3 kV transmission line length of 200 m from transmission facility located in KBWSP WTP to electrical building in the WTP is constructed by the Project. The WTP is operated with a low voltage power supply, using 400 V for the treatment equipment and 230 V for the lighting and control system. The power receiving panel and transformer of the treatment plant are proposed to be installed in the electrical building.

4.3 Transmission Pipeline

4.3.1 Overall Layout

(1) Overall Layout of Transmission Pipeline System

The overall layout of planned transmission pipeline system of the Project, existing system, and the Kafue Balk Water Supply Project (KBWSP) Phase-1are shown in Figure 4.3.1.



Source : JICA Study Team

Figure 4.3.1 Overall Layout of Transmission Pipeline System

(2) Outline of Overall Transmission Pipeline System and Number of Transmission Pipeline

The existing transmission pipeline system consists of pipeline (Dia 900 mm) from the Iolanda WTP to Lusaka City and two pump stations, i.e., one is the pump station in Iolanda WTP and another one is the Chilanga Booster Pump Station, for transmitting 110,000 m^3/day to Lusaka City. The destinations of the existing transmission pipeline are three distribution centers, namely: Stuart Park Distribution Center Reservoir (hereinafter Stuart Park Reservoir) (High Water Level (HWL): 1,309 m), Lusaka Water Works Distribution Center Reservoir (hereinafter Lusaka Water Works Reservoir) (HWL: 1,288 m), and Lumumba Distribution Center Reservoir (hereinafter Lumumba Reservoir) (HWL: 1,285 m).

After the commencement of service proposed in the Project, the number of transmission pipeline will be three, i.e.: one existing pipeline (Dia. 900mm), one planning pipeline (Dia. 800 mm) by KBWSP Phase-1 Project, and one planning pipeline (Dia. 1,400mm in plan) by the Project. In the facilities plan, future expansion of Iolanda WTP and additional transmission pipeline are also considered. After the commencement of the service by the KBWSP Phase-1 Project as well as the proposed plan in the Project, the water transmission system will have backup for each pipeline during the maintenance period since more than two pipelines will be available in total.

As for the transmission pipeline route from Chilanga Booster Pump Station (BPS) to the three distribution centers in Lusaka City, the transmission pipe of KBWSP Phase-1 Project will be connected to Stuart Park Reservoir while the new transmission/connection pipes between Lusaka Water Works Reserboir and Lumumba Reservoir will be completed by MCC Project (CP-2 Package).

The main features of three distribution centers are shown as follows:

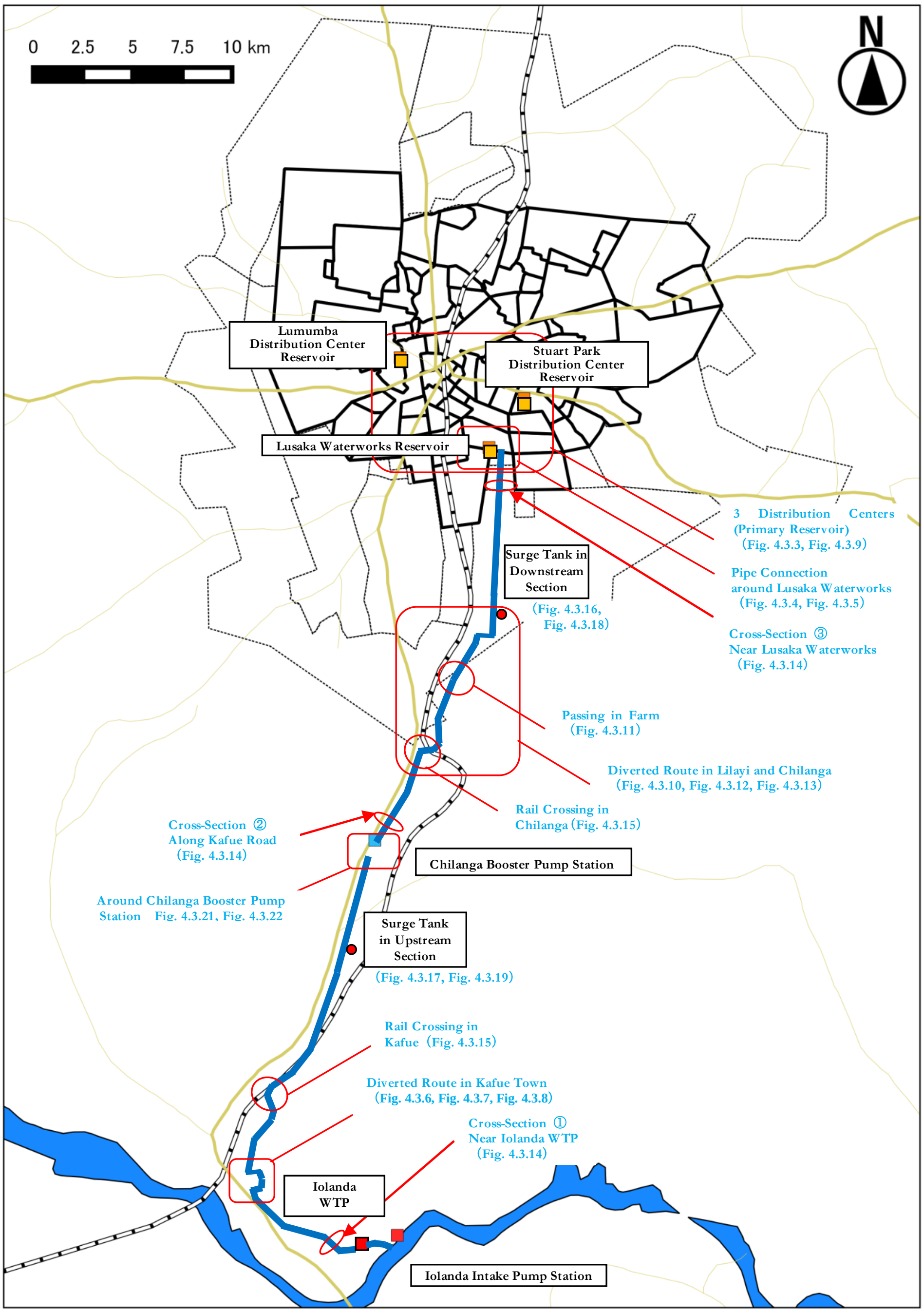
- Stuart Park Reservoir
  This reservoir has the largest storage capacity (90,920 m^3) in Lusaka City and its elevation is the highest among other reservoirs. For these conditions, it is possible to distribute water to wide area by gravity.

- Lusaka Water Works Reservoir
  This reservoir is the key distribution center for distributing water to the other reservoirs in Lusaka City through the pump station operated in the same yard. Lusaka Water Works Reservoir collects water not only from Iolanda WTP, but also groundwater sources in Lusaka City.

- Lumumba Reservoir
  This reservoir is located in the area which high water demand is expected due to increasing population growth and development of industrial area in the future.

Because these three distribution centers have important features distinct from each other, new transmission pipeline planned in the Project was designed for supplying water to all three distribution centers. Lusaka Water Works Reservoir is located at the branch point between two transmission pipeline sections directed to Stuart Park Reservoir and Lumumba Reservoir. Accordingly, the new transmission pipeline route was proposed as Lilayi area passing route, which is directly reaching to Lusaka Water Works Reservoir.

The layout of key points on the planned transmission pipeline system is shown in Figure 4.3.2.



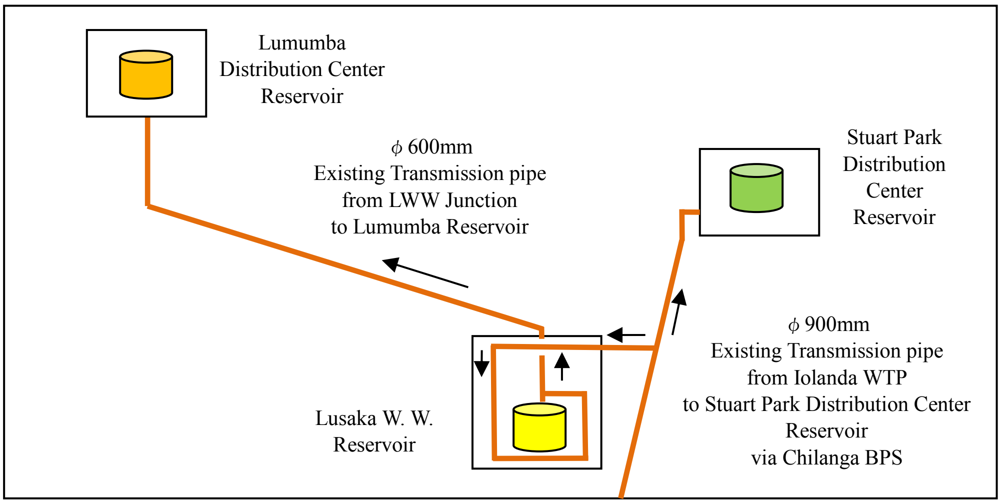
Source: JICA Study Team

Figure 4.3.2 Key Points on the Transmission Pipeline Route

(3) Transmission Pipeline System around Lusaka Water Works

1) Existing Condition of the Transmission Pipeline System

The existing condition of the transmission pipeline system around Lusaka Water Works Reservoir is shown in Figure 4.3.3. Treated water from Iolanda WTP is delivered to the Stuart Park Reservoir, Lusaka Water Works Reservoir, and Lumumba Reservoir.



Source: JICA Study Team

Figure 4.3.3 Existing Transmission Pipeline System among Main Distribution Centers (Present Condition)

2) Planned Condition of Transmission Pipeline System

The planned condition of the transmission pipeline system around Lusaka Water Works Reservoir is shown in Figure 4.3.5. Also, Figure 4.3.4 shows a transitional condition after MCC Project (CP-2 Package). New connection pipe (Dia. 900 mm) between the junction point near Lusaka Water Works and Lumumba Reservoir is under construction by MCC Project (CP-2 Package). This section is under construction work and will commence its operation prior to this Project.

New transmission pipeline proposed in the Project branches at the junction point around the Lusaka Water Works for distributing to the three main distribution centers. Planned transmision amount under the Project is 68,000 m^3/day for Lusaka Water Works Reservoir Reservoir, and 132,000 m^3/day for Lumumba Reservoir. On the other hand, transmission to Stuart Park Reservoir is made by the exisint facility and the KBWSP Phase-1 (see Figure 4.3.5 and Figure 4.3.20).

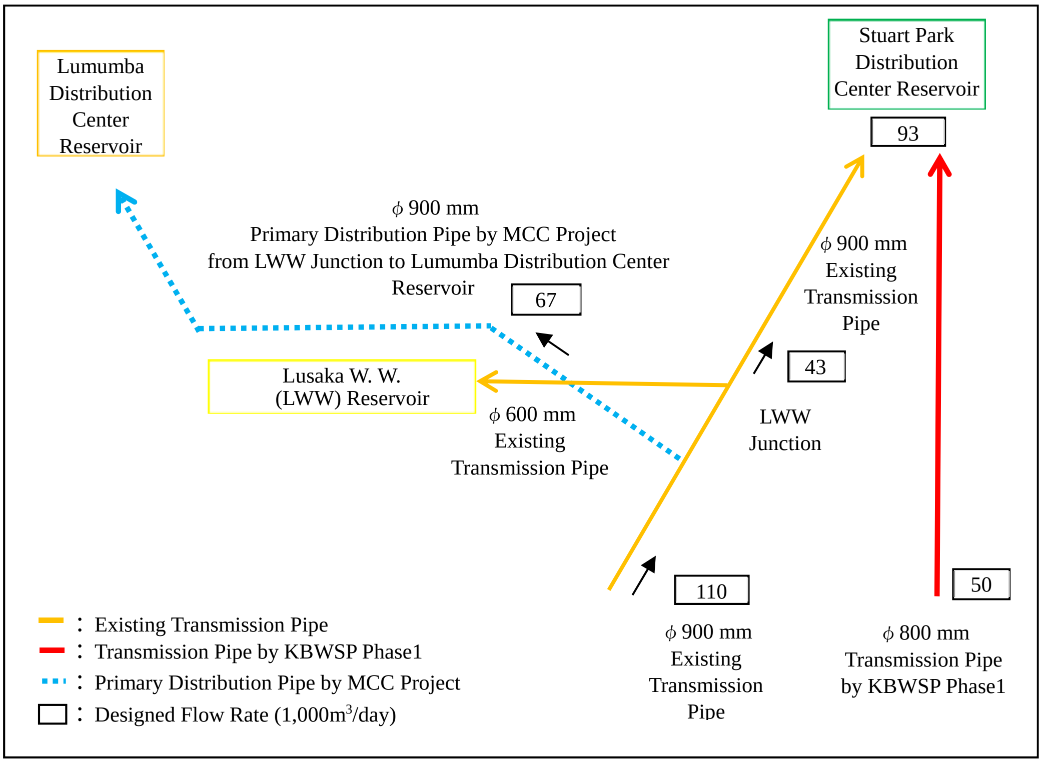
After the installation of transmission/connection pipes by MCC Project (CP-2 Package), 7.0km of new transmission pipe (Dia. 1,200 mm) is planned by the Project at the section between Lusaka Water Works and Lumumba Reservoir. Planned transmission amount will be transferred from Chilanga BPS to Lumumba Reservoir directly through this pipe and the abovementioned MCC pipe in parallel. However, the diameter of transmission pipe in this section will be reviewed in Detail Design Stage considering the future operation plan.

A connecting pipe between the new transmission pipeline (Dia. 1,400mm) by the Project coming up from Chilanga BPS and the new transmission pipeline (Dia. 1,200mm) by the Project going to Lumumba Reservoir, is installed in a section from the junction point near Lusaka Water Works to the branch point in front of Lusaka Water Works. The diameter of the pipe in this section is designed as 1,200 mm so as to pass the amount adding together the flow to Lusaka Water Works Reservoir and the flow to Lumumba Reservoir. A branch transmission pipe (Dia. 800 mm) to Lusaka Water Works Reservoir is planned in the compound of Lusaka Water Works. A sluice valve is set and closed off the connection between the existing transmission pipeline and transmission/connection pipes (Dia. 900 mm) installed by MCC Project (CP-2 Package). Alternatively, another short connection pipe (Dia. 1,200 mm) is set between the new transmission pipe (Dia. 1,400 mm) and the transmission/connection pipe (Dia. 900 mm) by MCC Project (CP-2 Package).

A new transmission pipe (Dia. 1,200mm) is planned from the junction point near Lusaka Water Works to Stuart Park Reservoir as a renewal of the existing transmission pipe in this section. A sluice valve is set on the existing transmission pipe at the junction point near Lusaka Water Works so as to close off the existing transmission pipeline to Stuart Park Distribution Center Reservoir. The section of the existing transmission pipe between the junction point near Lusaka Water Works and Stuart Park Reservoir will not be used as a transmission pipeline after the new transmission pipe (Dia. 1,200mm) is installed at the same section by the Project. However, according to the detailed design report of MCC Project (CP-2 Package), no branch distributing connection is at this section and it can be used continuously as the transmission pipe. Therefore, at the time of detailed design of the Project, confirmation of the progress of MCC Project (CP-2 Package) and review of possibility to use the existing transmission pipe as it is are to be done.

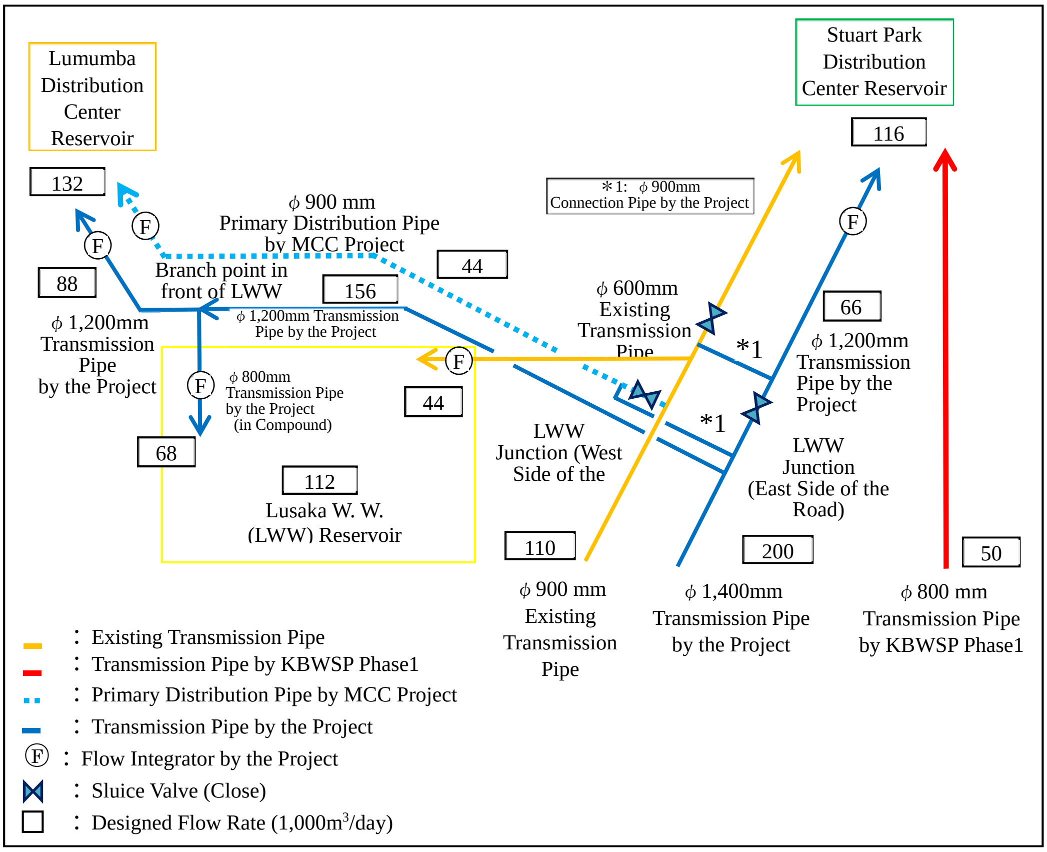
At the junction point near Lusaka Water Works, a sluice valve is set at the connecting point between the new transmission pipe (Dia. 1,400 mm) by the Project coming up from Chilanga BPS and the new transmission pipe (Dia. 1,200 mm) by the Project going up to Stuart Park Reservoir. These two new pipes are connected with this valve. Normally, this valve is closed.

In order to control and monitor flows as each pipe transfer the planned water distribution amount, diversion valves are installed at branch points of the transmission pipeline and integrating flowmeters are set at the inflow points of reservoir. It has a possibility that pipe connection work of the planned transmission pipeline requires a construction method without the suspension of water conveyance.



Source: JICA Study Team

Figure 4.3.4 Transmission Pipeline System around Lusaka Water Works (After MCC Project (CP-2 Package))



Source: JICA Study Team

Figure 4.3.5 Planned Transmission Pipeline System Around Lusaka Water Works

(4) Transmission Pipeline Route (Outline and Points for Comparison)

As shown in Figure 4.3.1, transmission pipeline installed by the Project starts from Iolanda WTP and reaches Lusaka City via Chilanga BPS. This pipeline route is divided into two sections: One is the “upstream section” from Iolanda WTP to Chilanga BPS and another is the “downstream section” from Chilanga BPS to Lusaka City. Pipeline route on each section was decided considering the distance of route, construction cost, land acquisition, construction conditions, access for maintenance, environmental and social issues. Key points on comparison of route plans are the following:

Distance of route and construction cost

Route plan of short distance connecting from treatment plant to distribution centers via booster pump station has an advantage in the points of construction cost.

Land acquisition for pipe installation

Use of public land space is a principle matter. Occupancy line at the side of main road was decided as it is on the outside of the planned road considering future road widening plan. The procedure of approval for land occupation by land owner on the section passing through private farm is necessary.

Construction condition for pipe installation work

Access of long trailer to the construction site, space, and traffic condition of the road for pipe installation work, rate of rock excavation, and railway crossingand other construction conditions were considered.

Operation and maintenance

It is preferable to install pipes along the main road in terms of O&M of pipeline such as detecting and repairing of leakages from pipes and maintainance of valves.

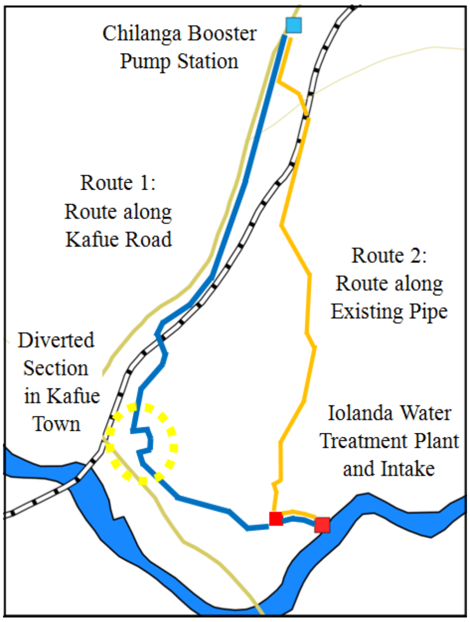
Environmental and social issues

Possibility of resettlement and diversion route at the section passing through the shopping area and residential area were studied.

(5) Transmission Pipeline Route (Comparison ①) upstreamsection: from Iolanda WTP to Chilanga BPS)

There are two routes for the section of transmission pipeline from Iolanda WTP to Chilanga BPS. The first one (Route 1) is the route along the existing pipeline and the other (Route 2) is the route along the highway (Kafue Road). Transmission pipeline of KBWSP Phase-1 Project is planned along Kafue Road. Although Kafue Road route is longer than the existing pipeline route, accessibility for maintenance work is easier. Rock excavation works in some places are expected during the pipe installation work on both routes.

As for the Route 1 along Kafue Road, the Road Development Agency (RDA), the authority for administration of road infrastructure in Zambia, LWSC and JICA Study Team held consultations on the location of the planned transmission pipeline (Dia. 1,400 mm) by the Project. As a result of that, RDA advised LWSC to install the transmission pipe in the position of 35 m on the outside from the centerline of Kafue Road in order to secure the space for future road widening. In the location passing through Kafue Town, some shops are standing on the road shoulder and houses are at the abovementioned advised position (35 m from center line). It is difficult to install the pipes at the indicated position. Therefore, in case of Route 1, it is necessary to circumvent the central part of Kafue Town as shown in Figure 4.3.6 and Figure 4.3.7.



Source:JICA Study Team

Figure 4.3.6 Location of Diverted Routein Kafue Town in Upstream Section

Source:JICA Study Team

Figure 4.3.7 Magnified View of Diverted Route in Kafue Town

Source: JICA Study Team

Figure 4.3.8 Roadside Conditions in Kafue Town

As a result of examination of two routes in terms of several aspects, Kafue Road Route was selected prioritizing easiness of maintenance as shown in Table 4.3.1.

Table 4.3.1 Comparison of Transmission Pipeline Route for Upstream Section (between Iolanda WTP to Chilanga BPS)

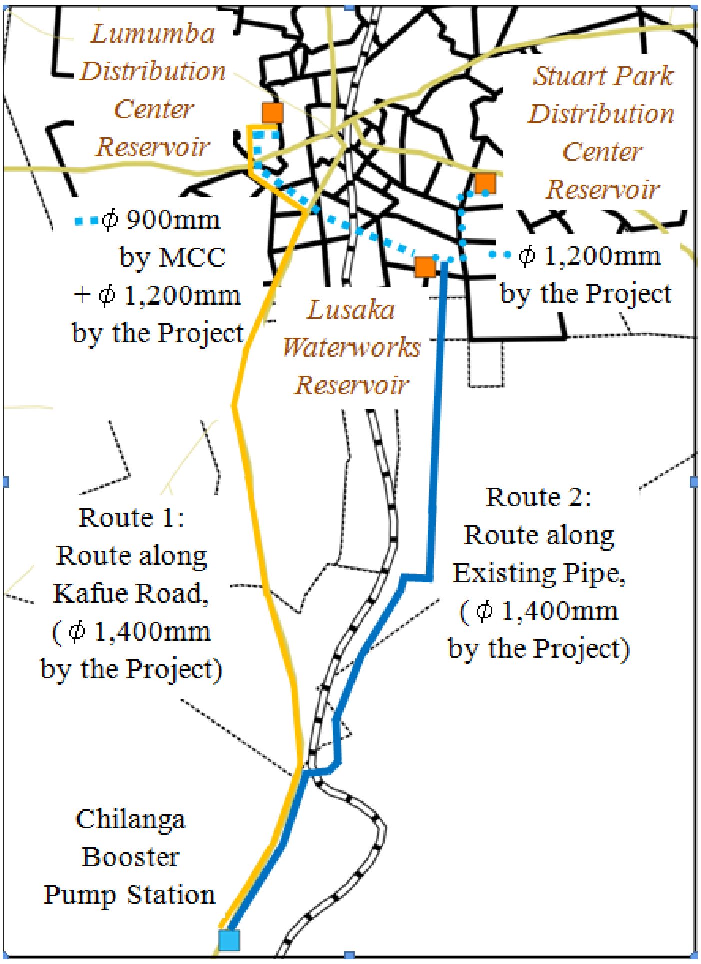
	Route 1: Along Kafue Road	Route 2: Along Existing Pipeline
Distance of Route	・30.0 km: longer than the existing pipeline route	・24.0 km: shortest route
	B	A
Construction Cost (*1)	・USD 51.9 million: higher than the existing pipe route	・USD 41.5 million: lowest cost
	B	A
Operation and Maintenance Cost (*2)	・Longer distance affects power cost because of pipe friction loss. Annual power cost for pumps: USD 1.80 million	・Power cost is lower than Route 1 because of lower friction loss. Annual power cost for pumps: USD 1.72 million
	B	A
Land Acquisition	・Wide area of road shoulder is available for pipe installation. ・There are some slope parts. ・There is a point crossing railway. ・Circumvention of Kafue Town is necessary.	・Wide area along mountain corridor is available for pipe installation. ・The route in mountain and foot of hills are curved. ・There is a point crossing railway. ・Border between road and private land is unclear. Therefore, it is difficult to determine the necessity of land acquisition.
	A	B
Condition of Construction, Influence by Construction	・Rock excavation section is expected. ・Road shoulder and side road can be used for construction and stockyard. ・Long pipe is available since the trailer can access to the construction site. ・There is a point crossing railway. ・Influence to the existing traffic condition is not serious since Kafue Road is a two-lane highway and traffic volume is not high.	・Rock excavation section is expected. ・Construction of temporary road is required for heavy vehicle operation in mountain side. ・Trailer cannot enter to unpaved road. Length of pipe material is limited up to 6m. ・There is a point crossing railway. ・Influence to the existing traffic condition is not serious since traffic volume is not high.
	A	B
Easiness of Maintenance	・It is easy to find and check pipes and valves since pipeline route is along the main road. ・Access and maintenance of pipe and valves are easy.	・It is difficult to find and check pipe and valves in grass field. ・It is difficult to record the installed pipe location using offset distance from structures.
	A	C
Influence to Environment and Social	・There is no possibility of resettlement. ・There is less environmental and social impact during construction period such as dust and traffic. These impacts can be managed.	・There is no possibility of resettlement. ・Tree cutting is required for construction of temporary road and installation of pipes.
	A	B
Evaluation	Periodical maintenance is required for transmission pipes. Route 1 is especially superior in terms of easiness of maintenance.	Although construction cost is lower than Route 1, O&M cost is almost same as Route 1, and easiness of maintenance and construction is less than Route 1.
	Selected	Not selected

Note: A: Excellent, B: Good, C: Fair
*1) Steel Pipe ϕ 1,400 mm *2) Unit of power cost is ZMW 0.38/kWh.
Source: JICA Study Team

(6) Transmission Pipeline Route (Comparison ②)(downstream section: destinations of transmission pipeline (distribution centers) and routes in Lusaka City)

There are two routes for the section of transmission pipeline from Chilanga BPS to the three distribution centers as shown in Figure 4.3.9. The first route is going to Lumumba Reservoir along Kafue Road and the other is the route separated around the Lusaka Water Works as same as the existing transmission pipeline route.

As a result of the examination of two routes mentioned in Table 4.3.2, Route 2 is selected. Route 2 is an option that will deliver water to the center of the three main distribution reservoirs. Because of the importance of water distribution balance for proceeding to future expansion plan in stages, Route 2 was prioritized.



Source: JICA Study Team

Figure 4.3.9 Transmission Pipeline Route in Downstream Section

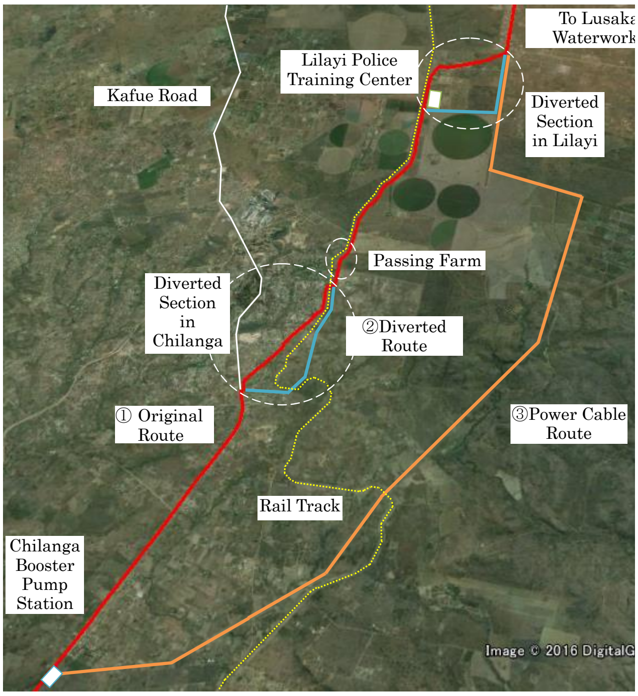
Table 4.3.2 Comparison of Transmission Pipeline Route for Downstream Section (betweenChilanga BPS to Distribution Centers)

	Route 1: Along Kafue Road	Route 2: Along Existing pipeline
Distance of Route	・24.8 km: (from Chilanga BPS to Lumumba Reservoir)	・21.5 km:(from Chilanga BPS to junction point near Lusaka W. W.) ・4.1 km: (from junction point near Lusaka W. W. to Stuart Park Reservoir) ・7.0 km:(from branch point in front of Lusaka W. W. to Lumumba Reservoir)
	A	B
Construction Cost (*1)	・USD 42.9 million: lower than existing pipe route	・USD 48.5 million: higher than Kafue Road route
	A	B
Operation and Maintenance Cost (*2)	・Water level of Lumumba Reservoir is 1,285 m. Pump total head and power cost are lower than the Route 2. Annual power cost: USD 1.77 million (from Chilanga BPS to Lumumba Reservoir)	・Due to the friction loss between Lusaka W. W. and Lumumba Reservoir, pump total head and power cost are higher than Route 1. Annual power cost: USD 1.97 million (Rate of flow from Chilanga BPS) to Lusaka W. W. Reserboir :6.8 to Lumumba Reservoir: 13.2
	A	B
Balance of Transmission System	・Flexibility on adjustment of flow to each distribution center is less than Route 2. ・Suitable route plan in case of water demand increasing in the west area distributed by Lumumba Reservoir.	・In point of operation of three distribution centers, this route has an advantage. Since water is sent to the center of three distribution centers, it is easy to distribute water to three distributuion centers through transmission/connection pipes by MCCProject (CP-2 Package).
	B	A
Land Acquisition	・Breaking pavement of side walk along Kafue Road is required at the commercial area in Lusaka City.	・Diverted route can be chosen in Lilayi commercial area and Chilanga residential area.
	B	A
Condition of Construction, Influence by Construction	・Rock excavation section is expected. ・Road shoulder and side road can be used for construction and stockyard. ・Long pipe is available since the trailer can access to the construction site. ・There is a point crossing railway. ・Night works or pipe jacking method should be considered since traffic volume of Lusaka City is high.	・Rock excavation section is expected. ・There is a section, around 800 m distance, passing through private ranch. ・Since the trailer cannot enter in narrow as well as up and down road, pipe length is limited up to 6 m. ・There is a point crossing railway. ・Most works can be done in daytime and open-cut method is applicable.
	B	B
Easiness of Maintenance	・It is easy to find and check pipes and valves since pipeline route is along main road. ・Access and maintenance of pipe and valves are easy.	・It is easy to find check pipes and valves since pipeline route is along main road. ・Access and maintenance of pipe and valves are easy.
	A	A
Influence to Environment and Social	・There is no possibility of resettlement. ・Influence of traffic restriction during construction period is serious in Lusaka City. Construction plan should be well-considered.	・There is no possibility of resettlement. ・There is less environmental and social impact during construction period such as dust and traffic. These impacts can be managed.
	B	A
Evaluation	There are disadvantages in terms of construction cost due to the works such as breaking pavement road and traffic restriction in Lusaka City. Additionally, it takes a long distance to distribute water to the east area of Lusaka City.	There is an advantage in terms of water distribution balance for distributing to the three distribution centers.
	Not selected	Selected

Note: A: Excellent, B: Good, C: Fair
*1 : Steel Pipe ϕ 1,400 mm *2 : Unit of power cost is ZMW 0.38/kWh.
Source: JICA Study Team

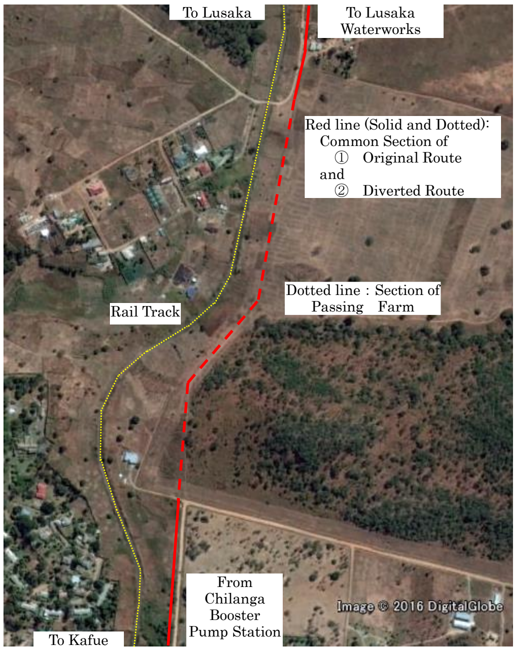
(7) Transmission Pipeline Route ③ (Diverted route for residential area in downstream section)

According to RDA, an area of 50 m width from the road centerline to road shoulder is defined as public land space. However, houses and shops are close to the road in some sections, currently. There are three options for passing the section between Chilanga BPS to Lusaka W. W., ① original route, ② diverted route circumventing the residential area, and ③ utilization of the power cable route, as shown in Figure 4.3.10. Figure 4.3.11 shows an enlarged view of the section where the Route ① and ② are passing through a farm land. Enlarged views of the diverted route circumventing the residential areas in Lilayi area (Figure 4.3.12) and Chilanga area (Figure 4.3.13) are also shown, respectively.



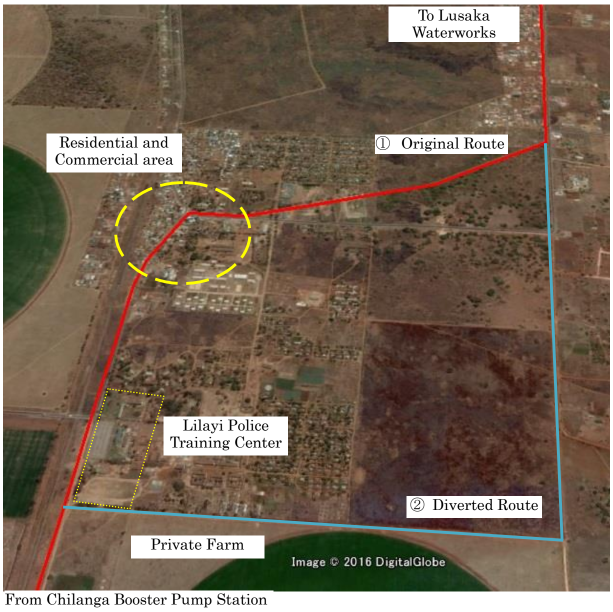
Source: JICA Study Team

Figure 4.3.10 Diverted Routes of Transmission Pipeline (Lilayi and Chilanga Areas)



Source: JICA Study Team

Figure 4.3.11 Section Passing a Farm (ChilangaArea)



Source: JICA Study Team

Figure 4.3.12 ②Diverted Route (LilayiArea)

Source: JICA Study Team

Figure 4.3.13 ②Diverted Route (ChilangaArea)

As a result of comparing routes and detailed examination, Route ② "diverted route circumventing the residential area" was selected. Although the pipe distance of Route ② is approximately 0.6 km longer than Route ①, Route ② is more advantageous in terms of easiness of maintenance, conditions of construction, and less effect on the environmental and social impacts. Comparison of transmission pipeline route in Lilayi and Chilanga areas is shown in Table 4.3.3.

Table 4.3.3 Comparison of Transmission Pipeline Route in Lilayi and Chilanga Areas

	Route ① Original Route	Route ② Diverted Route	Route ③ Power Cable Route
Construction Cost(*1, *2)	Distance: 20.9 km Cost : USD 36.2 million	Distance: 21.5 km Cost : USD 37.2 million	Distance: 23.0 km Cost :USD 39.8 million
	A	B	C
Land Acquisition	・Passing through the residential area and commercial area ・Passing in private ranch for the section of 800 m	・Passing through the residential area ・Passing in private ranch for the section of 800 m.	・Possible to use wayleaves of the power company.
	C	B	A
Easiness of Maintenance	・It is easy to find and check pipes and valves since pipeline route is along the main road.	・It is easy to find and check pipes and valves since pipeline route is along the main road.	・It is difficult to find pipes and valves in grass field and shrubs.
	A	A	C
Condition of Construction, Influence by Construction	・Earth retaining is required in the residential area. ・Safety management is important for works along Kafue Road. ・Rock excavation section is expected along Kafue Road. ・There is a point crossing railway.	・Earth retaining is required for trees and drain. ・Safety management is important for works along Kafue Road. ・Rock excavation section is expected along Kafue Road. ・There is a point crossing railway.	・Leveling and temporary road work under power cable are required. ・Trailer cannot enter to the temporary construction road since the road is up and down. ・Height of crane beam for hoisting pipe should be considered. ・There is a point crossing railway.
	B	A	C
Influence to Environment and Social	・There is no possibility of resettlement. ・Breaking walls and fences and passing in front of stores are needed at approx. 15 places.	・There is no possibility of resettlement. ・It has less influence to the private property.	・There is no possibility of resettlement. ・Trimming of shrubs is required in the land under power cable.
	C	A	B
Evaluation	Although it has the advantages on easiness of maintenance and cost, procedures on environmental and social aspects are required.	This route has an advantage on easiness of maintenance and influence on environmental and social points is not serious. There is little difference in cost compared with Route ①.	Since it is the longest and costly route compared with other routes, this route is one of the reserved route.
	Not selected	Selected	Not selected

Note: A: Excellent, B: Good, C: Fair

*1 : from Chilanga BPS to connecting point with transmission/connection pipes by MCC Project (CP-2 Package) near Lusaka W. W.

*2 : Steel Pipe ϕ 1,400 mm

Source: JICA Study Team

Chilanga District is located in outerward of the current LWSC water supply area as shown in Figure 2.2.4 and residents in this area use groundwater from deep well as their drinking water. LWSC has a future expansion plan of water supply system toward this area. The transmission pipeline (Dia. 1,400mm) proposed by the Projectis planned to pass through this area. Therefore, the Project provides a valve chamber for the future diversion to Chilanga District at the branch point on the transmission pipeline.

(8) Location of Transmission Pipes Planned in the Project and other Transmission Pipes

In the cross-section between Iolanda WTP to Kafue Road, three transmission pipelines are allocated. Typical cross-sections of transmission pipeline near Iolanda WTP (referred to cross-section ①), at Chilanga BPS (referred to cross section ②), and around Lusaka W. W. (referred to cross section ③) are shown in Figure 4.3.14.

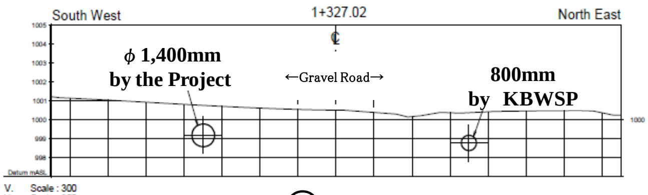
Cross-section ① shows the route between Iolanda WTP and Kafue Road. In this zone, existing transmission pipeline goes up through the other route in the mountain area toward Chilanga BPS as shown in Figure 4.3.1. Therefore, the number of pipeline in this zone is two. One is a pipe of KBWSP Phase-1 Project, and the other is the pipe installed by the Project. These two pipes are installed at each side of a gravel road in a parallel way. Since the pipe of KBWSP Phase-1 Project is installed at the north side (right side of flow direction) of road shoulder (in public space of road), the pipe planned by the Project is installed at the oppositeside (left side of flow direction) road shoulder of the same road (in public space of road). In the case of pipeline system expansion, a new pipe can be installed on the outside (far side from the road) of the planned pipe by the Project. There are few obstacles such as houses and structures in the present condition.

Cross-section ② shows the route along Kafue Road between Kafue Town and Chilanga area. There are three transmission pipelines that are installed around Chilanga BPS. Kafue Road has side road on both sides. The pipe of KBWSP Phase-1 is installed between Kafue Road and east side road (It is west side of the east side road.) (in public space of road). The existing transmission pipeline reaching Chilanga BPS through another route in the mountain area is located on the east side of east side road (in public space of road) in this zone. The pipe planned by the Project is also installed on the east side (far side from the road) of the existing pipe(in public space of road) in parallel with the above two pipelines. Although there are few obstacles in this zone, pipeline route has to be away from gutter and trees beside the road.

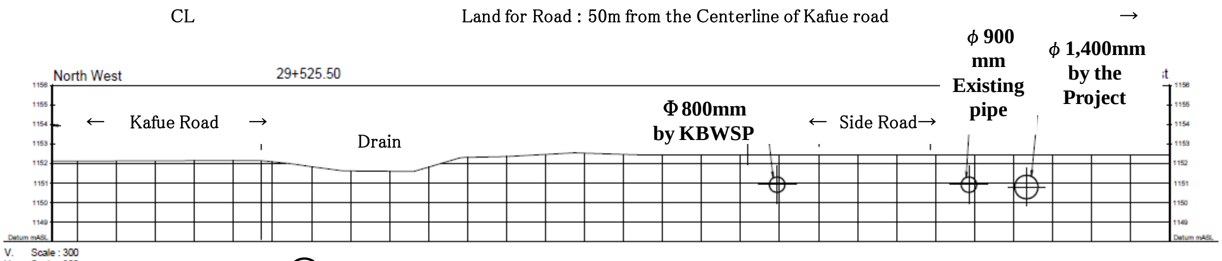
A space of 50 m in width for each side from the centerline of Kafue Road is a public space for road in general. RDA of Kafue Road indicated that the pipe of the Project should be installed at 35 m away from the centerline of Kafue Road. This line is outside of the future road widening plan and it will be not necessary to relocate the pipe. In the case of expansion, additional pipe can be installed on the outside (far side from the road) of the pipe planned by the Project.

Cross-section ③ shows the route between Lilayi area and Lusaka Water Works.Transmission pipes are toward the urban area in Lusaka City in this section. The pipe of KBWSP Phase-1 Project goes to

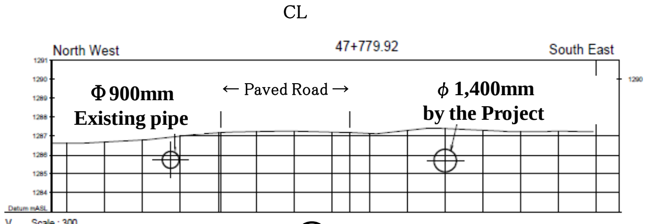
Stuart Park Reservoir directly without connecting to Lusaka Water Works as shown in Figure 4.3.1. Therefore, other two transmission pipes are shown in the cross-section ③. The existing pipe is located on the west side shoulder (in public space of road) of paved road located at 1.5 to 3 km east from Kafue Road. The pipe planned by the Project is installed at the opposite side (right side of flow direction) of the same road (in public space of road). Houses have increased in this area and there is a possibility that another new pipe is installed in the premises or occupies spaces under the road in case of future expansion.



Cross Section ① Around Iolanda WTP (Gravel Road)



Cross Section ② Around Chilanga BSP (Kafue Road and Side Road)



Cross Section ③ Around Lusaka Waterworks (Paved Road)

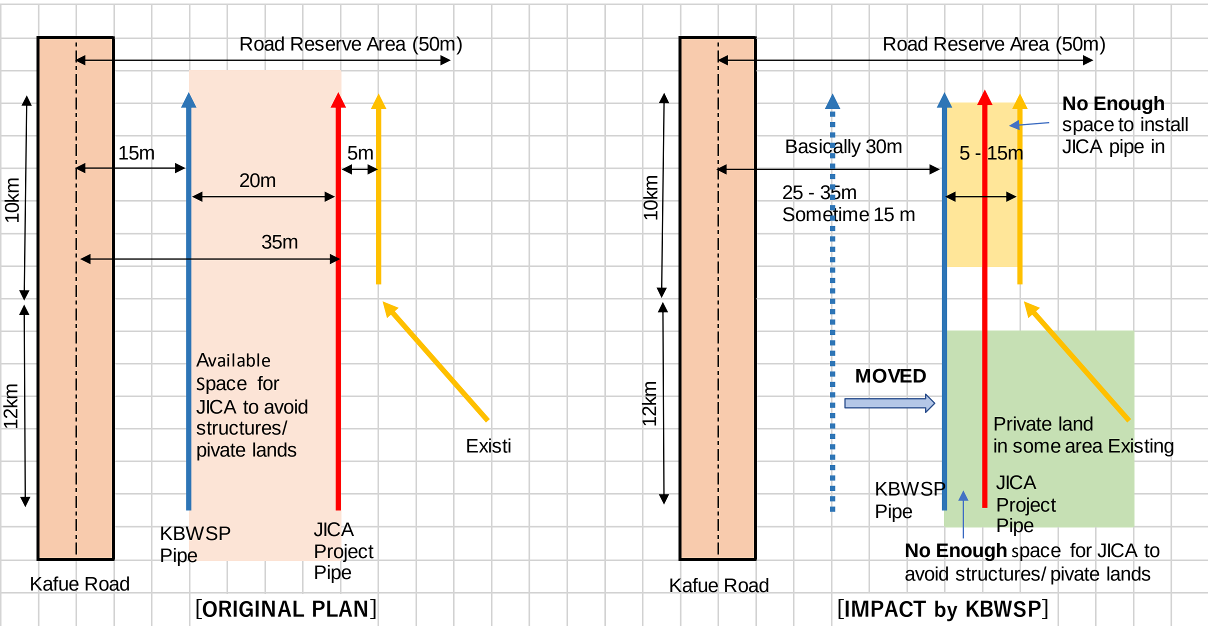
Source: JICA Study Team

Figure 4.3.14 Typical Cross-section of Transmission Pipeline Route at Principal Place

After preparation of the pipeline route plan of the Project as mentioned above, the pipeline route of KBWSP was changed at the construction stage in 2017. It gave a great impact on the project pipeline route.

As shown in the original plan in Figure 4.3.15, the pipeline of KBWSP had been planned to be installed 15 m far from the center of Kafue Road, and the pipeline of JICA project had been planned to be installed 35 m far from the center. There are around 20m width space between the both pipelines, and the space could be used for adjustment of both pipeline routes to avoid impacts on existing houses/ structures and private land.

However, RDA does not allow installation of the pipes within 15 m from the center, and the pipeline route of KBWSP has been moved around 30 m from the center, due to RDA's instruction. The space between KBWSP and JICA pipelines became much smaller, and it became impossible to move the pipeline to the road side for avoidance of impacts on existing houses/ structures. In some area where existing pipe was installed, the JICA project pipe cannot be installed on the original route, because no enough space between KBWSP pipe and existing pipe.



Source: JICA Study Team

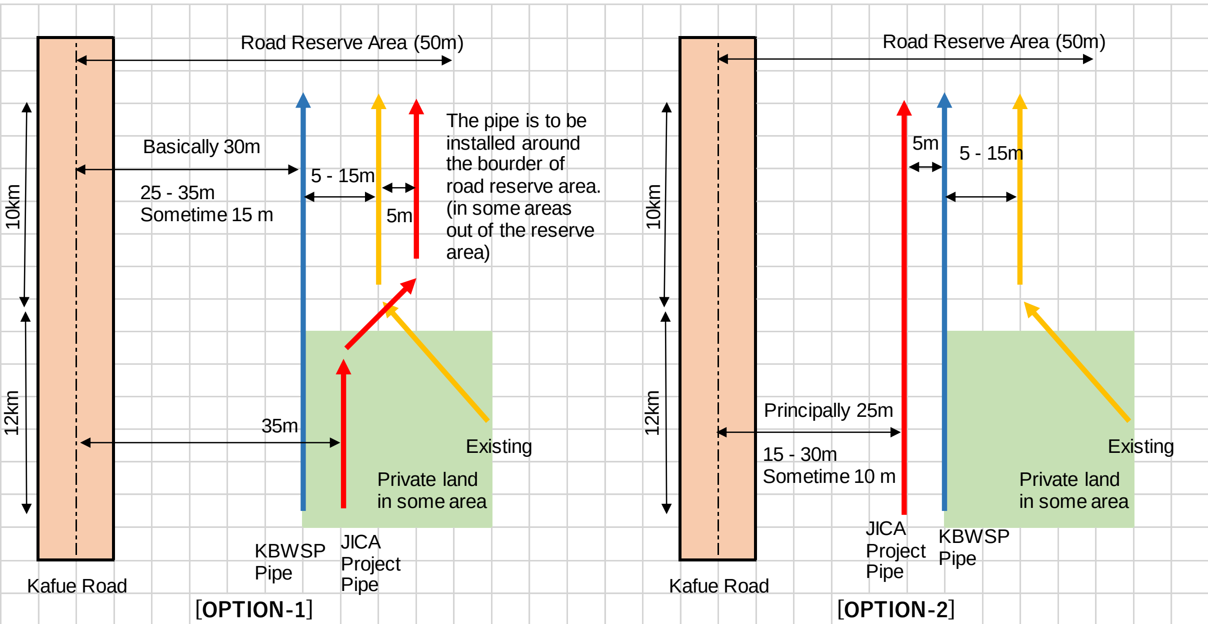
Figure 4.3.15 Original Plan of Transmission Pipiline Routes and Impacct by KBWSP

Under the situation mentioned above, there are two options for the pipeline route of the Project. (see Figure 4.3.16)

OPTION-1: It is to install the JICA project pipe far from the road, comparing with other two pipes. In the area where existing pipe was installed, the JICA pipeline will be installed around 45 - 50m from the center of the road, because no enough space on the original route. JICA project pipe may have to be installed in the private agriculture land, and the area where buildings/structures are existing along Kafue Road. In some area, JICA pipeline may have to be installed out of the road reserve area (more than 50 m from the center of road).

OPTION-2: It is to install the JICA project pipe near the road, comparing with other two pipes. The JICA project pipeline will be installed around 25 m far from the center. In this case, JICA project pipe will not be installed in the private agriculture land along the road, and the area where buildings/structures are existing, and out of the road reserve area. (A pipe installation under road is very common, though it is not so preferable from the view point of maintenance of road and pipe)

Ministry of Water Development, Sanitation, Environmental Protection (MWDSPE) and JICA Study Team recommended OPTION-2, however, RDA did not agree on it. OPTION-1 was selected as the result of discussion between MWDSPE and RDA.



Source: JICA Study Team

Figure 4.3.16 Option of Transmission Pipeline Route considering Construction of KBWSP

(9) Crossing of Railway

The rail track of Zambia Railways connects Lusaka City and Kafue Town. Planned transmission pipeline intersects with the rail track in Lilayi and Kafue. These two crossing points are shown in Figure 4.3.2 and plans of transmission pipeline at the crossing are mentioed below.

As for the construction method of railway crossing, KBWSP Phase-1 Project and MCC Project (CP-2 Package) adopt the pipe jacking method. The pipe installation method for the Project is also planned by the pipe-jacking method same as other project. Vertical shafts located at each side of crossing section are shown in Figure 4.3.17 as for reference. As for the route along Kafue Road, occupancy line at the road side is decided considering future road widening plan. At the rail crossing point in Chilanga, transmission pipe is installed at the space between rail track and field road.

Railway Crossing Point in Kafue **Railway Crossing Point in Chilanga**

Figure 4.3.17 Railway Crossing Point of the Transmission Pipeline

4.3.2 Hydraulic Design of Transmission Pipe

(1) Selection of Transmission Pipe Diameter

The diameter of transmission pipe was selected based on the examination in terms of the initial cost, O&M cost, life-cycle cost, and safeness of operation, since planning transmission volume was large at 200,000 m^3/day and also distance was long as almost 60 km.

(2) Friction Loss of Transmission Pipe

Friction loss of the transmission pipe is calculated with Hazen-Williams Formula as shown in Table4.3.4, since the pipe distance is long and pipe is straight in most part.

As for the Downstream section of the transmission pipeline, pump total heads are caluculated considering the case that total amount of the design transmission flow is sent through the 1,200mm pipe by the Project without using of the MCC transmission/connection pipes from Lusaka Water Works to Lumumba Reservoir.

Table 4.3.4 Friction Loss of Transmission Pipe

Upstream section : Iolanda WTP - Chilanga BPS 30.0km

Friction Loss	H loss	35.9 m	
	H = 10.666 × C^(-1.85) × D^(-4.87) × Q^(1.85) × L		
	H +10%	3.6	
Flow Coefficient	C	130	
Pipe Diameter	D	1.4 m	
Flow Rate	Q	2.31 m3/s	200,000m3/day
Pipeline Distance	L	30,000 m	
Altitude Differences	Actual H	144 m	
Pump Total Head	Total H	184 m	

Downstream section : Chilanga BPS - Lusaka WW φ1400mm, 21.5km
Lusaka WW - Lumumba Distribution Center Reservoir φ1200mm, 7.0km

Friction Loss	H1	25.7 m		
	H2	8.3 m		
	H = 10.666 × C^(-1.85) × D^(-4.87) × Q^(1.85) × L			
	H +10%	3.4		
Flow Coefficient	C	130		
Pipe Diameter	D1	1.4 m		
	D2	1.2 m		
Flow Rate	Q1	2.31 m3/s	200,000m3/day	
	Q2	1.53 m3/s	132,000m3/day	
Pipeline Distance	L1	21,500 m		
	L2	7,000 m		
Altitude Differences	Actual H	149 m	Lumumba	1285m
Pump Total Head	Total H	190 m	Reservoir	

(3) Examination of Appropriate Diameter of Transmission Pipe

As the condition of the examination of appropriate diameter, the flow velocity should be between 1.5 m/s and 2.5 m/s, the diameters of transmission pipeline can be 1,100 mm, 1,200 mm, or 1,400 mm. In order to identify the most appropriate diameter, comparative analyses of the transmission pipelines with three different diameters were done.

For the economic analysis, the total pump head, capacity of water volume, and Life Cycle Cost including the costs of installation, operation, and renewal were applied for grading. Also, the view of the safeness during operation was taken into account. The results indicated there are close margins in three cases of different diameter as shown in Table 4.3.5. Since the characteristics of transmission pipeline by the Project are quite long as around 60 km and high pressured, in order to decrease friction loss in pipe and reduce risks of leakage or pipe fracture, 1,400 mm of diameter was selected. In this case, the pipe friction loss is the lowest among the three kinds of diameter and maximum water pressure is less than 2.5 MPa.

Table 4.3.5 Comparison of Cost for Transmission System in Each Diameter

Design Flow Rate	200,000 m^3/day		
Diameter of Transmission Pipe	φ1,100 mm	φ1,200 mm	φ1,400 mm
Design Velocity	2.44 m/s	2.05 m/s	1.51 m/s
Pump Total Head (Chilanga BPS / Iolanda WTP)	260 m / 273 m	228 m / 228 m	190 m / 184 m
Cost for for Pump Stations ①	USD 17.10 million	USD 15.73 million	USD14.59 million
Cost for Transmission Pipeline ②	USD 65.68 million (USD 1,050/m)	USD 76.50 million (USD 1,260/m)	USD 100.71 million (USD 1,730/m)
Initial Cost ③＝①+② (Pump Station + Transmission Pipeline)	USD 82.78 million	USD 92.23 million	USD 115.30 million
Running Cost ④ (Power charge for 60 years)	USD 117.80 million (1.98 kWh/m^3)	USD 100.80 million (1.70kWh/m^3)	USD 84.18 million (1.42 kWh/m^3)
Cost for Renewal of Pump ⑤ (in each 20 years)	USD 6.16 million	USD 5.25 million	USD 4.50 million
Life Cycle Cost (LCC) ③+④+⑤	USD 206.74 million (104.3%)	USD 198.28 million (100.0%)	USD 203.98 million (102.9%)
Safeness (Design Water Pressure)	More than 2.5 MPa	More than 2.5MPa	2.4 MPa
Evaluation	C	C	A

Unit of Power Cost : ZMW 0.38/kWh (USD 0.040/kWh)
Note: A: Excellent, B: Good, C: Fair
Source: JICA Study Team

4.3.3 Pipe Material and Construction Method of Transmission Pipe

(1) Pipe Material of Transmission Pipe

Design conditions for the transmission pipe are shown in Table 4.3.6. Pipe material should be chosen as pipe body has sufficient strength that is applicable for pipe internal water pressure and embedding condition, quantity of pipes, procurement conditions, easiness of installation work, and so on. Static water pressure is calculated with altitude differences between the start point and end point of pipeline. Maximum pressure inside the pipe,which is the sum of static water pressure and water hammer, was calculated at around 2.4MPa in this Project.

To apply these conditions of pipe diameter and required pipe strength, steel pipe or ductile cast iron pipe can be generally chosen. Steel pipe has an advantage in cost and procurement from neighbouring countries. On the other hand, ductile pipe has advantage of construction since construction works can be conducted throughout the year including rainy season. In case of steel pipe, welding for pipe connectionon-site needs time. In view of these conditions as a whole, steel pipe was selected for this Project prioritizing in terms of strength and cost as shown in Table 4.3.7.

Table 4.3.6 Design Conditions of Transmission Pipe

Diameter, Distance, Flow Amount of Transmission Pipeline	DownstreamSection : Dia. 1,400 mm, 21.5 km (from Chilanga BPS to Branch point to Lumumba Reservoir, 200,000 m^3/day Dia. 1,200 mm, 7.0 km (from Branch point in front of Lusaka Water Works to Lumumba Reservoir), 132,000 m^3/day) Upstream Section : Dia. 1,400 mm, 30.0 km (from Iolanda WTP to Chilanga BPS), 200,000 m^3/day
Design Water Pressure	Downstream Section:2.4 MPa (Maximum static water pressure1.9 MPa + water hammer pressure 0.5 MPa) Upstream Section: 2.3 MPa (Maximum static water pressure 1.8 MPa + water hammer pressure 0.5 MPa) Design Water Pressure for both section is set as 2.4 MPa.
Pipe Installation	Earth covering depth: Min 1.0 m, Max 3.0 m, Unit weight of soil: 18 kN/m^3
Load Conditions	Wheel Load (Live Load): 245 kN×1 Truck (installing pipe under road shoulder)

Source: JICA Study Team

Table 4.3.7 Comparison of Material for Transmission Pipe

	Steel Pipe	Ductile Casting Iron Pipe
Applied Standard	ISO559	ISO2531
Required Thickness	14.2mm (Yield Stress: 225N/mm^2)	22.8mm (Tensile Stress: 420N/mm^2)
Strength	Applied Standard is commonly used, and it can be applied to the pressure less than 2.5MPa.	Applied Standard is commonly used, and it can be applied to the pressure less than 2.5MPa.
Pipe Joint	Installed pipes are connected by welding at the construction site.	Mechanical joint with bolts is applied to high pressured pipeline.
Procurement Conditions	Procurement from Africa (Tanzania, Botswana) is available.	DCIP is mainly procured from European countries or Japan.
Construction Conditions	Drainage for welding is necessary in the rainy season or at underground water discharging points.	Bolt joint is easy to connect pipes even in the rainy season and construction period is shorter than welding joint.
Durability	Inner painting and outer coating are required against electric and chemical corrosion.	Durability of pipe body is comparatively high. Rubber ring joint degrades over a long time.
Cost	USD 1,730/m (pipe, transportation, installation)	USD 3,240/m (pipe, transportation, installation)
Evaluation	Steel pipe has sufficient strength and it has advantage of cost and procurement in Africa. It is suitable for use in Zambia. [Adopted]	Ductile pipe has durability and it has advantage of construction period. Procurement for use in Zambia is limited and costly. [Not adopted]
	Selected	Not selected

ISO: International Organization for Standardization, API: The American Petroleum Institute
Source: JICA Study Team

(2) Joint Type of Transmission Pipe

Butt welding joint is chosen as the pipe connecting method basically since the steel pipe diameter is large and water pressure is high. Flange connection (applied standard: API Std605, API 5L) is chosen as the connection method of valves. As a measure of quality control on construction, the liquid penetrate inspection or x-ray check is applied for each welded point.

(3) Construction Method of Transmission Pipe

Minimum depth of earth covering on the buried pipeis adopted as 1.0 m for safety against loads of passing vehicles considering the pipe installation place is at the road shoulder. Sand bed is adopted for unevenness correction and uneven settling prevention. Excavation depth is the sum of pipe diameter, earth covering, and sand bed. Excavation depth would be more than 2.7 meters in most section of large diameter pipeline in the Project. In the excavation works, earth retaining would be conducted at the necessary place and safe slope would be secured. Working space for pipe installation and connection is necessary for both sides of the pipe. Measures against settlement and fall of wall or fence are required at the section of road shoulder excavation.

(4) Rock Excavation on Pipe Laying

As the result of site survey, following issues hs been identified.

- Limestone is exposed on the surface of excavation at some areas in Lusaka City.
- Outcrops are seen at the cut points on the hilltop along Kafue Road.
- Masses of rock lie on the road shoulder in Chilanga area.
- There is a quarry in the north of Kafue City.

As aresult of digging test pits along the planned transmission pipeline route, weathered rock is prospected in 25% of the section along Kafue Road (26 km) and other rocks is supposed in 20% of the section from Chilanga area to Lusaka Water Works (17 km). Considering these conditions, rock excavation is esteemed at approximately 20% in total transmission pipeline route.

(5) Countermeasure Against Water Hammer

Due to the nature of the Project, there is a possibility of water hammer effect on the transmission pipelines, therefore such possibility was examined. As a result, there are points where the maximum negative pressure was estimated as more than 10 m both in the downstream section at 15.3 km and in the upstream section at 22.1 km. It has the possibility that transmission pipes are affected at these points. Since the water hammer effect may seriously do damages on transmission pipes, the Project takes safe and secure measures to reduce the effect. As popular measures to reduce the water hammer effect, pump fly wheels, surge tanks, one-way surge tanks, air chambers, or air valves can be installed.

The salient features of this Project are: 1) a long distance pipelines with 21.5 km + 4.1 km (to Stuart Park Reservoir) / 21.5 km + 7.0 km (to Lumumba Reservoir) long in the downstream section and 30 km long in the upstream section; 2) the total pump heads in both sections are as high as almost 200 m; and 3) the downstream section of the transmission pipelines is rugged. In most cases where these characteristics are seen, taking a measure to reduce the maximum negative pressure alone cannot work sufficiently in terms of safety and security. Instead, a combination of several measures is usually applied to reduce the water hammer effect. In this Project, these measures are combined and applied.

Table 4.3.8 illustrates the results of a comparative analysis of different measures to reduce the water hammer effect. Based on the results, the Project selected to apply the combination of pump fly wheels, one-way surge tanks, and air chambers by maximizing the advantages of each of them. The fly wheels and air chambers will reduce the negative pressure in the rugged section from pump station to the maximum negative pressure point, meanwhile, one-way surge tanks and air valves will reduce the negative pressure in the section lower than the point where the maximum negative pressure is observed.

The results of countermeasure against water hammer are shown in Figure 4.3.18 (upstream section) and Figure 4.3.19 (downstream section). In case that one-way surge tank is set on the way of the transmission pipeline, negative pressure decreases and minimum pressure gradient rises near the ground level at tank installation point, also maximum pressure gradient falls to near hydraulic gradient. The proposed site of one-way surge tank in each section is shown in Figure 4.3.20 and Figure 4.3.21.

Table 4.3.9 shows the specifications of fly wheel, one-way surge tank, and air chamber.

Table 4.3.8 Comparison of Countermeasure against Water Hammer in Transmission Pipe

Item	Flywheel	Surge Tank	One-way Type Surge Tank	Air Chamber
Features	Flywheel mitigates rapid reduction of pump delivery pressure by increasing inertial effect when a pump is stopped.	Downstream side from a surge tank is separated from the water hummer. Surge tank absorbs pressure increasing and prevents negative pressure by supplying water.	One-way surge tank prevents negative pressure by supplying water. Full water filling of tank is necessary. One-way surge tank is smaller than a surge tank.	Pressure tank prevents pressure reduction of pipes with supplying water by controlling air pressure.
Safety Aspects	Flywheel is safe and reliable measure for relatively small negative pressure.	Surge tank is made by civil structure only. Most safe and reliable measure.	In case of water shortage of tank, one-way surge tank can not apply for negative pressure.	Accessories are necessary for pressurized steel vessel. In case of failure of accessories, it is not functioned.
O&M Aspects	Special maintenance is not required. Only pump maintenance is necessary.	Only cleaning of tank is required. O&M is most easy.	Periodic change of water is required for maintaining water quality. Continuous water level monitoring is required.	Maintenance is most complicated compared with other options. It is convenient to conduct periodic maintenance because the pressure tank is installed in pump station.
Construction Area	Not necessary.	Although construction area is almost the same as the case of one-way surge tank, height of surge tank is high.	In case of low height, construction area is relatively large. Necessary area is around 20 m x 20 m.	Construction area is smaller than the case of surge tank and one-way surge tank.

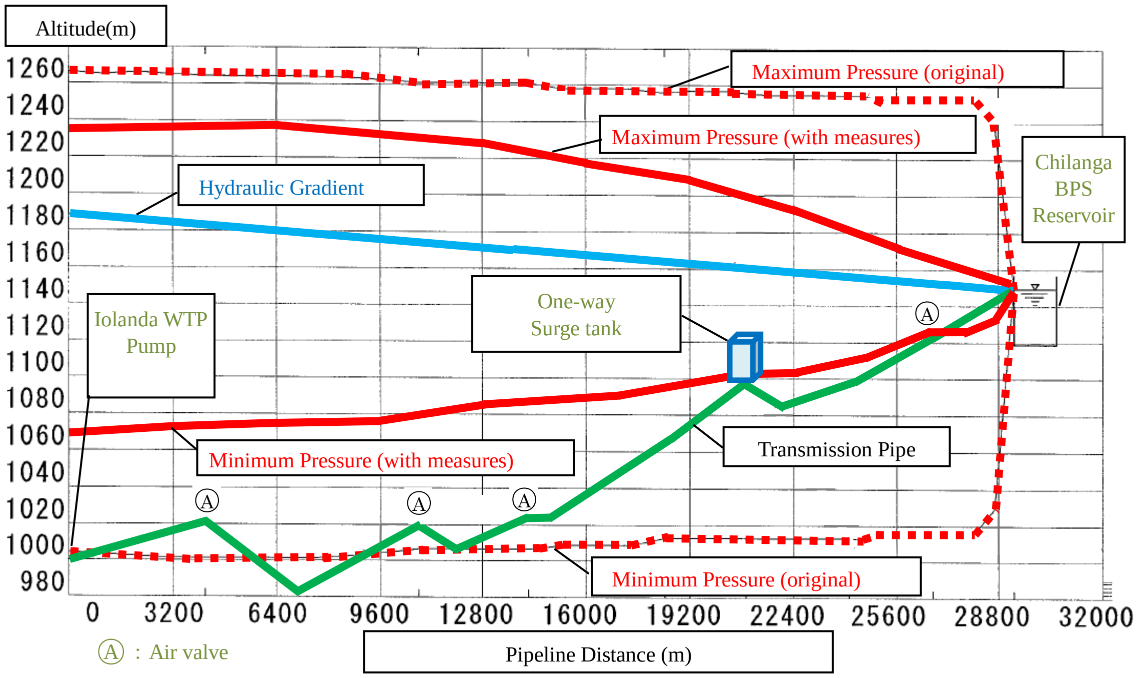
Item	Flywheel	Surge Tank	One-way Type Surge Tank	Air Chamber
Application to the Project	Independent use is difficult since actual pump head is high and transmission pipe distance is long in the Project. Flywheel can apply for lower and higher part of transmission pipe by mix use of other options. Scale of flywheel can be decreased by mix use with other options.	Height of surge tank is too high. Around 35 m in height for downstream section and around 90 m in height for upstream section are required, respectively. It is not a realistic option.	Independent use is difficult because of the characteristic of transmission pipeline. One-way surge tank can apply for the section between maximum negative pressure point and the last half section of transmission pipeline. Construction area can be decreased by mix use with other option.	Pressure tank can apply for negative pressure of the first half section of transmission pipeline by mix use with flywheel option. Scale of pressure vessel can be decreased by mix use with flywheel option.
Cost	Pump cost is high for special specification.	Construction cost is high because the structure height is high.	Lower than other options.	Construction cost is high because of pressurized vessel.
Selection	Selected as the measure for negative pressure of the first half section of transmission pipeline.	Not selected.	Selected as the measure for negative pressure of the section between maximum negative pressure point and the last half section of transmission pipeline.	Selected as the measure for negative pressure of the first half section of transmission pipeline.

Source: JICA Study Team

Table 4.3.9 Countermeasure Against Water Hammer

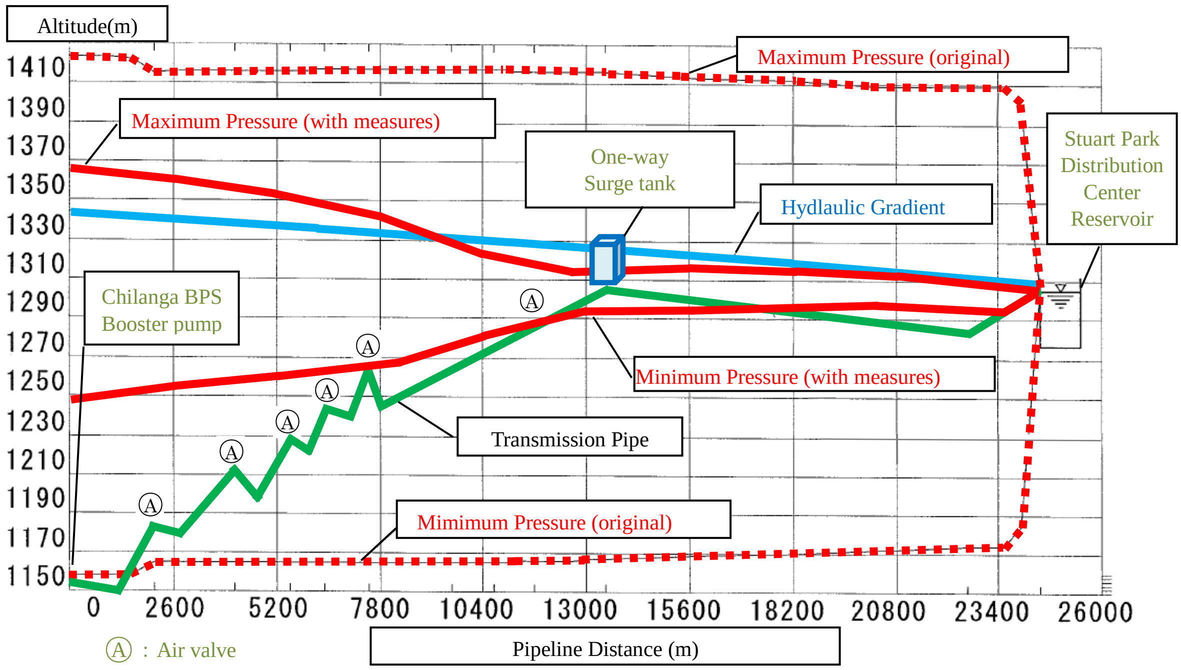
	Facilities
Upstream Section From Iolanda WTP to Chilanga BPS	− Fly wheel Set a fly wheel (GD^2=2,000 kgf･m^2) on each pump − One-way Surge Tank Location: 22.1km from Iolanda WTP, Altitude: 1,100 m, Effective Capacity: 100 m^3 − Air Chamber Location: Inside of Iolanda WTP, Altitude: 991.5 m, − Effective Capacity: 90 m^3
Downstream Section from Chilanga BPS to Stuart Park Reservoir via Lusaka Water Works	− Fly wheel Set a fly wheel (GD^2=2,000 kgf･m^2) on each pump − One-way Surge Tank Location: 15.3 km from Chilanga BPS, Altitude: 1,303 m, Effective Capacity: 200 m^3 − Air Chamber Location: Inside of Chilanga BPS, Altitude: 1,135.5 m, Effective Capacity: 70 m^3

Source: JICA Study Team



Source: JICA Study Team

Figure 4.3.18 Longitudinal Section of Transmission Pipe and Location of One-way Surge Tank (Upstream Section)



Source: JICA Study Team

Figure 4.3.19 Longitudinal Section of Transmission Pipe and Location of One-way Surge Tank (Downstream Section)

Source: JICA Study Team

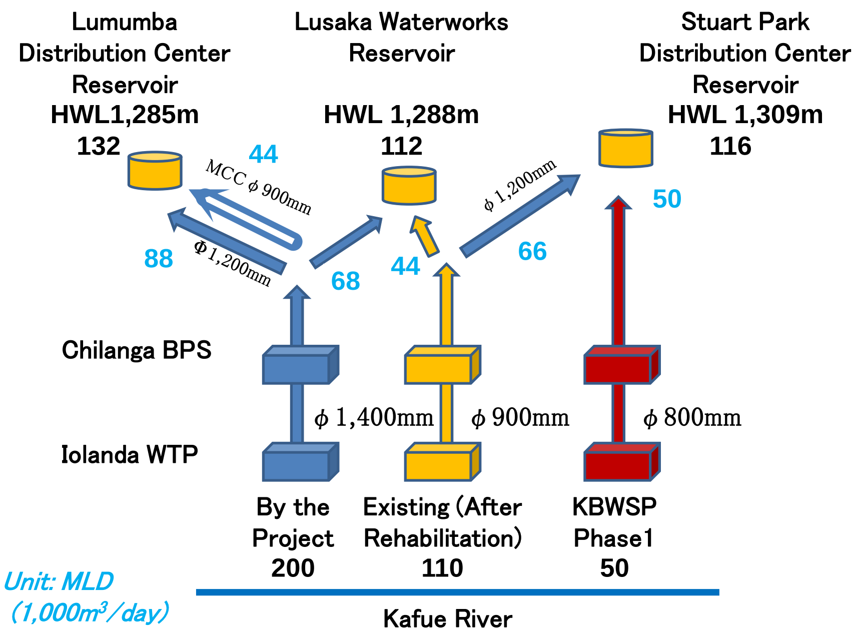
Figure 4.3.20 Proposed Site of One-way Surge Tank (Downstream Section)

Source: JICA Study Team

Figure 4.3.21 Proposed Site of One-way Surge Tank (Upstream Section)

4.3.4 Plan of Transmission Pipe System by the Project

As a result of the examination of pipe material, diameter, pipeline route, uses of transmission/connection pipe by MCC Project (CP-2 Package) among distribution centers and future expansion plan, the Project is finally planned as shown in Figure 4.3.22 and Table 4.3.10 as a transmission pipeline plan.



Source: JICA Study Team

Figure 4.3.22 Transmission Systemby the Project (2023)

Table 4.3.10 Transmission Pipeline Plan

Start Point	End Point	Pipe Material, Diameter (mm)	Distance
IolandaWTP	Chilanga BPS	SP ϕ 1,400	30.0 km
Chilanga BPS	Junction near Lusaka W. W. (at the east side of the road)	SP ϕ 1,400	21.5 km
Junction near the Lusaka Water Works (at the east side of the road)	Stuart Park Reservoir	SP ϕ 1,200	4.1 km
Junction near the Lusaka Water Works (at the west side of the road)	Lumumba Reservoir	SP ϕ 900 *	7.6 km *
Branch point in front of the Lusaka Water Works	Lumumba Reservoir	SP ϕ 1200	7.0 km

*: This section will be installed by the MCC Project (CP-2 Package) .
Source: JICA Study Team

4.3.5 Pump Equipment and Reservoir / Pumping Well in Iolanda WTP and Chilanga BPS

(1) Location of Facilities

The proposed location of the pump station at the beginning of transmission pipes was planned at the inside of the land of Iolanda WTP and the treated water reservoir in WTP was defined as a pumping well of the transmission pump. Booster pumps and their pumping well of similar specification with transmission pump station in Iolanda WTP was planned for Chilanga BPS which is located at the middle of transmission pipeline route.

(2) Pump Facilities

The number of pumps was decided considering the capacity range of general volute pump in order to prevent the limitation of procurement. Since the total head for high lift volute pumps in this Project is high at around 200 m, numbers of pumps in the pump station were decided with the condition of maximum discharge flow rate at 50 m^3/min per one unit. The specifications of pumps are given in Table 4.3.11.

Table 4.3.11 Pump Facilities of Transmission System

Item	Iolanda WTP	Chilanga BPS
Function	Transmission Pump	Booster Pump
Type	Horizontal Axis Centrifugal Pump	Horizontal Axis Centrifugal Pump
Pump Bore	Suction : 500 mm Discharge: 300 mm	Suction : 500 mm Discharge: 300 mm
Discharge Volume	46.3 m^3/min	46.3 m^3/min
Total Pump Head	184 m	190 m
MotorRated Capacity	2,800 kW	2,800 kW
Number of Pumps	Regular use: 3 nos. Standby : 1 no.	Regular use: 3 nos. Standby : 1 no.
Flow Control	Control by the number of operating pump	Control by the number of operating pump
Power Receiving and Transforming Facility	ZESCO transformer provides 3.3 kV power line.	ZESCO transformer provides 3.3 kV power line.
Flow Meter	Ultrasonic Flow Meter	Ultrasonic Flow Meter

Source: JICA Study Team

(3) Treated Water Reservoir and Pumping Well

The capacities of treated water reservoir in Iolanda WTP and pumping well in Chilanga BPS were designed with one-hour retention time. The reservoir was planned dividing into multiple units to enable cleaning work and fixing of internal paint of the reservoir. Chlorine mixing tank was planned to be installed at the upstream side of the reservoir. The dimension and capacity of the well and chlorine mixing tank are shown in Table 4.3.12.

Table 4.3.12 Treated Water Reservoir and Pumping Well of Transmission System

Design Flow Rate	200,000 m^3/day
Treated Water Reservoir, Pumping Well	54 m x 54 m x effective water depth 3.2 m (including chlorine mixing tank) There are two sections divided in the treated water reservoir / pumping well. Storage volume: 8,400 m^3
Chlorine Mixing Tank	Chlorine mixing space is located at the upstream point of the treated water reservoir / pumping well. Width: 4.2 m x Length: 24.7 m x Water depth: 3.4 m (Depth from low water level)
Piping	Inlet pipe, outlet pipe to pump equipment, overflow pipe, and drain pipe are connected to treated water reservoir / pumping well.

Source: JICA Study Team

(4) Location of Chilanga BPS

Figure 4.3.23 shows the planned construction site of the new Chilanga BPS by the Project. The existing Chilanga BPS is located between Iolanda WTP and distribution centers in Lusaka City. The site is halfway of the whole transmission pipeline in distance; and also with respect to altitude differences. It is possible to reduce high pressure in the pipe at the pump well of the booster pump station located at the middle point of the pipeline route. In KBWSP Phase-1 Project, a new booster pump station is planned near the existing station.

The existing pump station and transmission pipe are located on the east side of Kafue Road. Occupancy of land space for the pump station in the Project will be 3 ha and LWSC is ready to acquire the land in the south of the existing pump station.

Source: JICA Study Team

Figure 4.3.23 Planned Site for ChilangaBoosterPump Station

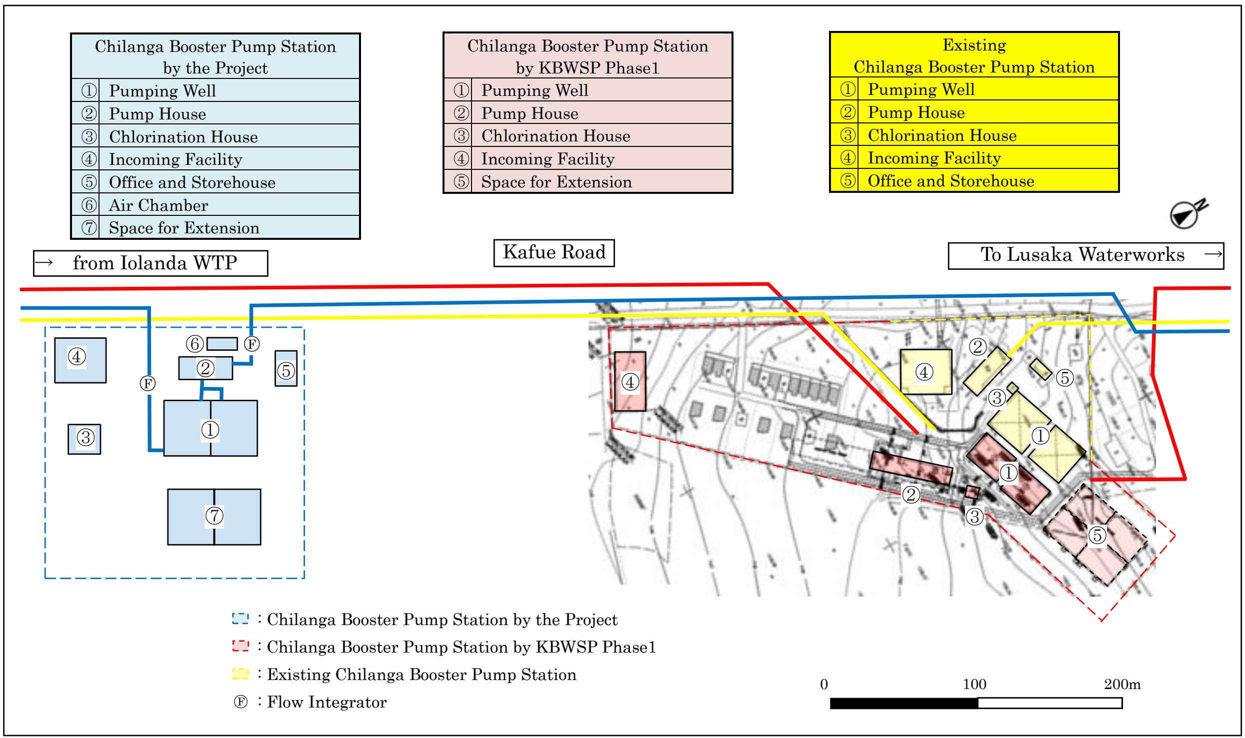
Because of site location of the new Chilanga BPS by the Project, comparing the upstream and the downstream section of transmission pipeline, the distance of pipeline and difference of elevation are not exactly equal. Therefore, there is a difference of pump total head between the transmission pump in IolandaWTP (for the upstream section) and the booster pump in Chilanga BPS (for the downstream section).

(5) Layout of Facilities in Chilanga BPS

Figure 4.3.24 shows the locational relation among three Chilanga BPSs, i.e.; planned by the Project, KBWSP Phase-1 Project, and the existing one.

The following facilities are equipped in Chilanga BPS planned by the Project.

- Pumping well, pump house, chlorination house, incoming facility, administration building, and air chamber were planned in the land of pump station. Space for substation owned by the Power Company and space for pumping well for future expansion were also planned in the pump station site. The pumping well was planned to be located at the upstream side of the pump house so that the required pump suction head can be obtained by difference of elevation.
- In the pump house, pumps and equipment including motors, valves (manual butterfly valve, motor-operated cone valve, check valve), drain pump, overhead crane, ventilation fan, and electric panels (incoming panel and pump operation panel) were planned,.
- As for measuring device, water level meter was planned to install at each section in the pumping well. Flow integrator was planned to install at the starting point of transmission pipeline in Iolanda WTP and both inflow and outflow of Chilanga BPS.



Source: JICA Study Team

Figure 4.3.24 Layout of Chilanga BPSof Each Project

(6) Power Receiving and Transforming Facility

Power receiving and transforming facility of Chilanga BPS shall be constructed by ZESCO and the power of 3.3kV from ZESCO will be received in Chilanga BPS. The scope of the Project for power transmission line is from secondary side of power receiving and transforming facility to incoming facility in the Project. The power source of Chilanga BPS is low voltage range of 400V for pumps and other equipment and 230V for the lightning and control system. The incoming panel and transformer for pump station are installed at the space in the pump house.

4.4 Distribution Facilities

4.4.1 Objective of Distribution Facility Plan

Distribution facility plan is designed to meet the water demand in 2030. Since the expansion and replacement of the distribution facility is currently being conducted in the MCC Project, the Project should avoid the duplication of the scope of the MCC Project.

4.4.2 Basic Concept

(1) Basic Concept

1) Target Area and Distribution Amount

The 66 DMAs of the Priority Area are the target area. Distribution amount is set at 477,000 m^3/day, same as the water demand in 2030. The amount is made up of 360,000 m^3/day of surface water from the Kafue River and 117,000 m^3/day of groundwater.

2) New Water Distribution Main

The Project plans to install a DMA master meter in each of the 66 DMAs and construct new distribution mains, from the three distribution centers and four distribution reservoirs, to reach directly each of the 66 DMAs without having to connect the existing distribution pipes.

3) Expansion of Water Distribution Network

The Project includes the expansion of the water distribution network in order to increase the water supply rate to 100%. The MCC Project currently extends 131 km of water distribution network in the Priority Area. The Project targets the township area which is not covered in the MCC Project. Although the water distribution network expansion in the peri-urban area is not covered in the MCC Project nor the Project, it will be conducted by the LWSC.

4) Replacement of Water Distribution Networks and Installation of Water Meters

The MCC F/S set a goal to reduce the non-revenue water (NRW) ratio to 25% by renewing the water distribution network and installing water meters. In the 14 DMAs, the most prioritized area in the 66 DMAs, the MCC Project includes a total of 103 km of distribution pipe replacement, water meter installation and construction for dividing the water distribution networks into districts as DMAs based on the MCC F/S. The MCC Project also includes the detailed design of the 21 DMAs, being the second highest priority area, however, the construction will not be implemented due to a limit in the budget. Therefore, the Project covers the replacement of the aging distribution pipes, installation of water meters and establishing district metering for the 21 DMAs. Prior to the construction, the detailed design will be conducted again based on the latest site condition. Distribution pipe replacement for the rest of the 31 DMAs will be covered by the LWSC.

5) Enhancement of Distribution Reservoirs and Distribution Pumps

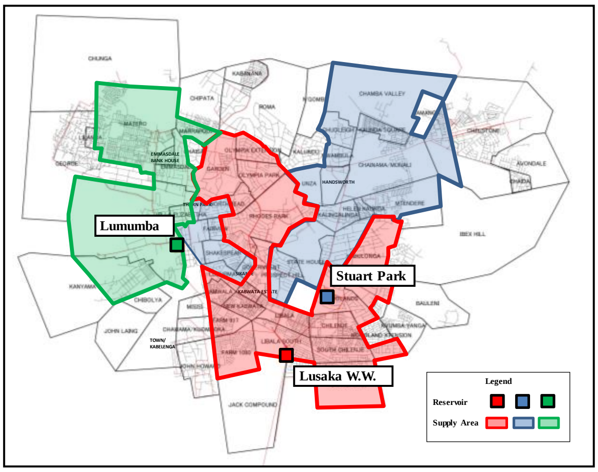
The Project plans to enhance the distribution reservoirs and distribution pumps in response to the increase in the amount of distributed water. The MCC Project did not include the enhancement of the distribution reservoirs and distribution pumps.

4.4.3 Distribution Area and Distributed Amount

(1) Existing and Future Distribution Area

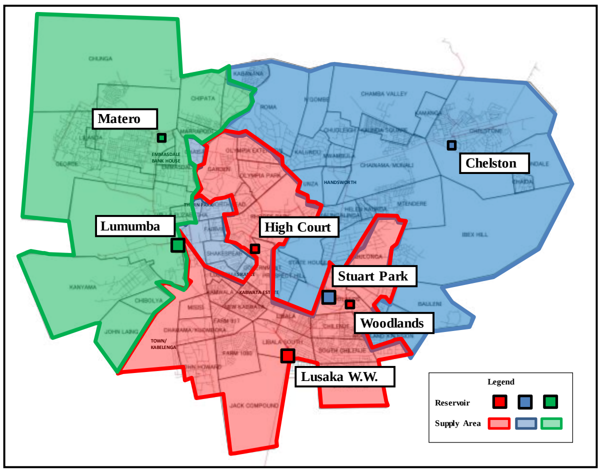
Treated water from the existing Iolanda WTP is distributed to the LWSC Service Area (Priority Area) around Lusaka City. There are three distribution systems centering each distribution center, namely: 1) Lusaka Water Works System (Lusaka Water Works, High Court Distribution Reservoir and Woodlands Distribution Reservoir) in the city center, 2) Lumumba Distribution System (Lumumba Distribution Reservoir and Matero Distribution Reservoir) in the northwestern part, and 3) Stuart Park System (Stuart Park Distribution Center and Chelston Distribution Reservoir) in the northeastern part. In other areas, groundwater is distributed from a small-sized distribution network separated from the three abovementioned distribution networks.

Figure 4.4.1 shows the current distribution area of each distribution system. The Project plans to expand the water distribution network with three distribution systems to cover the entire Priority Area. Along with the distribution pipe network expansion, distribution area of each distribution system is also expanded as shown in Figure 4.4.2.



Source: JICA Study Team based on the data of the LWSC

Figure 4.4.1 Current Distribution Area for Each Distribution System

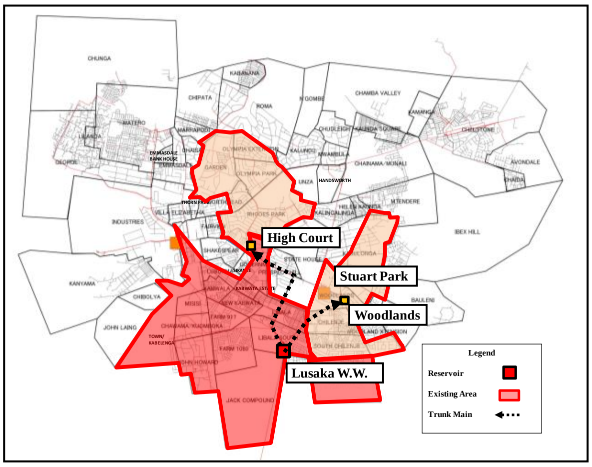


Source: JICA Study Team based on the data of the LWSC

Figure 4.4.2 Distribution Area for Each Distribution System After the Project

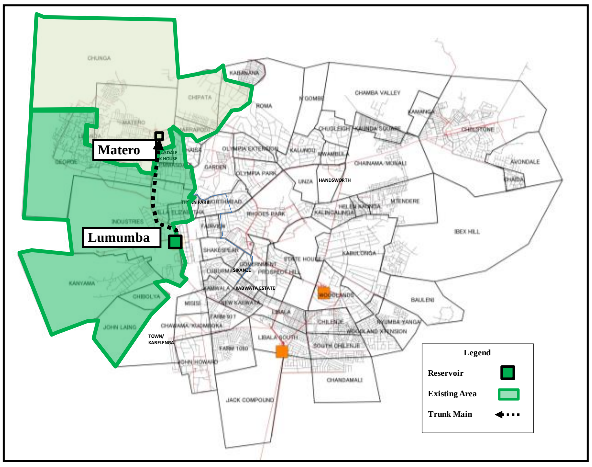
(2) Service Area in Each Distribution System

In each distribution system, both the distribution center and secondary distribution reservoir located downstream of the center cover each of the service area. Figure 4.4.3 shows the service areas of the Lusaka Water Works System after the Project. Figure 4.4.4 shows the service areas of Lumumba System after the Project. Figure 4.4.5 shows the service areas of Stuart Park System after the Project.



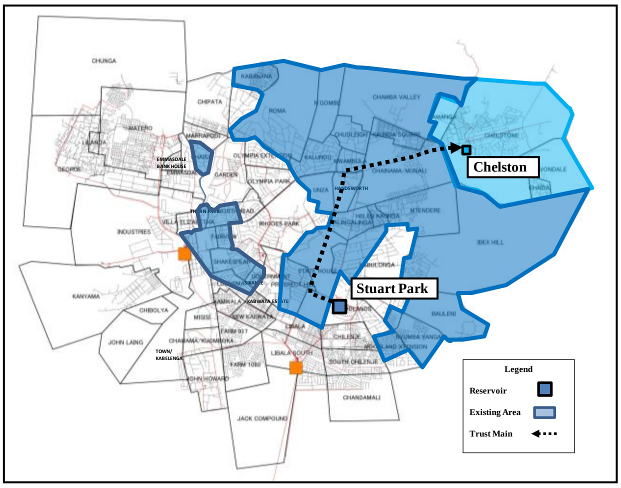
Source: JICA Study Team

Figure 4.4.3 Service Areas of Lusaka Water Works System After the Project



Source: JICA Study Team

Figure 4.4.4 Service Areas of Lumumba System After the Project



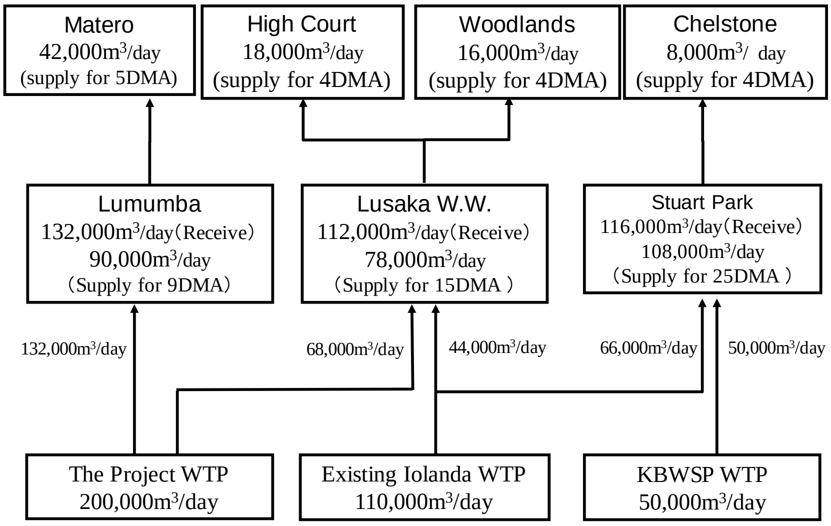
Source: JICA Study Team

Figure 4.4.5 Service Areas of Stuart Park System After the Project

(3) Water Transmission Amount and Water Distribution Amount

1) Allocation of Each Distribution Reservoir

Figure 4.4.6 shows the water transmission allocation to each distribution reservoir after the Project. Each distribution center distributes water to the service area and transmits water to the secondary distribution reservoir located downstream. Water transmission systems of the distribution reservoirs do not need to be changed, however, water amount will increase in response to the water demand in 2030.



Note: Ground water amount is not included.

Source: JICA Study Team

Figure 4.4.6 Water Allocation to Distribution Reservoirs from Each WTP in 2030

2) Water Distribution Amount of Each DMA

Table 4.4.1 shows the water demand, water distribution amount from well, distribution reservoir and maximum hourly amount (calculated per day) of each of the 66 DMAs in 2030. Total water demand is 477,000 m^3/day. The water distribution amount from the three distribution systems is 360,000 m^3/day, which is also the water transmission amount from Iolanda WTP. The water distribution amount from the well is 117,000 m^3/day which is the amount of the total water demand minus 360,000 m^3/day.

In DMA having wells, water is distributed from the well for a maximum capacity of the LWSC existing well. Water demand exceeding the capacity of the existing well is designed to be satisfied by the surface water from the distribution system. In the nine DMAs (Libala, John Howard, Jack Compound, Woodlands-HC, Olympia, Fairview, Chudleigh, Kabulonga & Sunningdale-HC, Chunga) where well satisfy the water demand, surface water will not be distributed.

To increase the water distribution efficiency, DMA was reexamined and new distribution areas were proposed as shown in Figures 4.4.3, 4.4.4, and 4.4.5. Kabulonga & Sunningale DMA of Woodlands Distribution Area is integrated into Kabulonga & Sunningale DMA of Stuart Park Distribution Area. New Woodland Extension DMA of Lusaka Water Works Distribution Area is integrated into Woodland Extension DMA of Woodlands Distribution Area. Town/Kabelenga DMA of Stuart Park Distribution Area was changed into Lusaka Water Works Distribution Area and Roma in Lumumba Distribution Area was changed into Stuart Park Distribution Area.

Table 4.4.1 Water Demand and Water Source Plan of Each Distribution System and DMA

No.	DMA	Demand (m3/day)	Supply Amount			No.	DMA	Demand (m3/day)	Supply Amount		
			Borehole	Water Supply System					Borehole	Water Supply System	
			Capacity*1 (m3/day)	Daily Max*2 (m3/day)	Hourly Max*3 (m3/day)				Capacity*1 (m3/day)	Daily Max*2 (m3/day)	Hourly Max*3 (m3/day)
Lusaka Water Works						**Stuart Park**					
1	Government	1,720	0	1,720	2,580	35	Helen Kaunda	2,972	0	2,972	4,457
2	Chandamali-MC	5,549	0	5,549	8,323	36	Chamba Valley-MC	5,353	0	5,353	8,029
3	Luburma-	5,448	0	5,448	8,172	37	Kaunda Square	7,854	0	7,854	11,781
4	Libala	4,524	4,524	0	0	38	Kabulonga & Sunningdale-HC	5,102	5,102	0	0
5	Kabwata	3,931	0	3,931	5,896	39	Shakespear	2,742	0	2,742	4,112
6	New Kamwala-LC	3,189	0	3,189	4,784	40	Roma	8,624	0	8,624	12,937
7	New Kabwata S/S	3,321	0	3,321	4,981	41	Kalingalinga	6,262	0	6,262	9,393
8	F1080	11,193	826	10,367	15,550	42	Mtendere	17,890	2,410	15,480	23,220
9	F917	7,192	1,607	5,585	8,378	43	Kalundu	2,560	0	2,560	3,841
10	Libala South	9,601	5,807	3,794	5,691	44	New Ibex Hill-HC	1,246	941	305	458
11	Chawama	6,681	0	6,681	10,021	45	Nyumba Yanga-LC	3,409	1,722	1,687	2,531
12	John Howard	3,754	3,754	0	0	46	Bauleni	4,948	1,400	3,548	5,321
13	Misisi/Kuku	5,108	0	5,108	7,662	47	Kabanana	6,503	1,010	5,493	8,239
14	Jack Compound	3,442	3,442	0	0	48	NG'OMBE	12,096	0	12,096	18,144
15	Town/Kabelenga	23,873	298	23,575	35,362		**Sub-total**	**126,191**	**18,000**	**108,191**	**162,287**
	Sub-total	**98,525**	**20,258**	**78,266**	**117,400**						
						Chelston					
Woodlands						49	Chelston-LC	18,480	15,104	3,376	5,064
16	Woodlands-HC	2,874	2,874	0	0	50	Avondale Southend-MC	5,237	4,965	272	407
17	Woodlands Extension-MC	3,563	0	3,563	5,344	51	Chainda	2,874	0	2,874	4,312
18	Chilenje South-LC	7,207	918	6,289	9,433	52	Kamanga	2,443	1,212	1,231	1,846
19	Chilenje-LC	6,136	0	6,136	9,204		**Sub-total**	**29,033**	**21,281**	**7,753**	**11,629**
	Sub-total	**19,779**	**3,792**	**15,988**	**23,981**						
						Lumumba					
High Court						53	Chaisa	3,431	0	3,431	5,147
20	Olympia-	2,356	2,356	0	0	54	Industrial Area	36,643	29,289	7,354	11,031
21	Olympia Park Extension	1,595	0	1,595	2,393	55	Villa Elizabetha	3,907	0	3,907	5,861
22	Rhodespark	12,142	10,903	1,239	1,859	56	Emmasdale	6,424	0	6,424	9,636
23	Garden	14,732	0	14,732	22,097	57	Emmasdale Bank Houses S/S	3,011	0	3,011	4,517
	Sub-total	**30,825**	**13,259**	**17,566**	**26,349**	58	Kanyama	28,229	0	28,229	42,343
						59	Jahn Laing	8,856	0	8,856	13,284
Stuart Park						60	George	29,804	6,886	22,917	34,376
24	Fairview	1,707	1,707	0	0	61	Chibolya	6,113	0	6,113	9,170
25	Northmead	3,172	0	3,172	4,758		**Sub-total**	**126,418**	**36,175**	**90,243**	**135,365**
26	Thornpark	2,070	0	2,070	3,106						
27	Prospect Hill	2,593	0	2,593	3,889	**Matero**					
28	Statehouse	5,381	0	5,381	8,071	62	Matero	28,911	184	28,727	43,091
29	Sikanze	969	138	831	1,247	63	Marrapodi	2,000	0	2,000	3,000
30	UNZA	10,361	0	10,361	15,541	64	Chipata	9,782	0	9,782	14,673
31	Handsworth	1,548	0	1,548	2,322	65	Lilanda	1,484	0	1,484	2,226
32	Chudleigh	1,733	1,733	0	0	66	Chunga	3,891	3,891	0	0
33	Mwambula	1,733	0	1,733	2,600		**Sub-total**	**46,067**	**4,074**	**41,993**	**62,989**
34	Chainama	7,363	1,836	5,527	8,290		**Total**	**476,839**	**116,839**	**360,000**	**539,999**

Note: *1: Water supply amount directly to DMA from well, *2: Daily maximum supply water amount to DMA from distribution reservoir
*3 : Daily maximum water supply amount (1.5 times the daily maximum water supply amount is set as the daily amount)

Source: JICA Study Team

4.4.4 Examination of the Water Distribution Capacity in the Existing Water Distribution Network

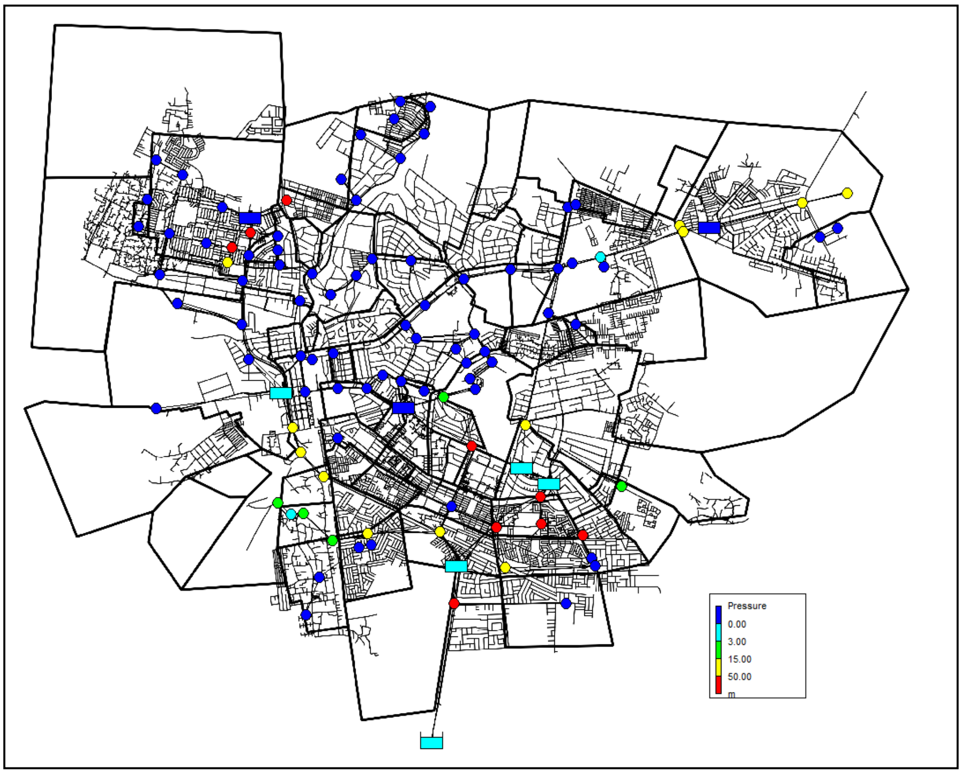
Prior to the planning of the water distribution pipe construction in the Project, water distribution capacity of the existing distribution pipe network for year 2030 was examined. As shown in Figure 4.4.7, hydrodynamic pressure in most of area does not meet 3 m which is the minimum requirement of Zambia Standard, so it is confirmed that capacity of existing distribution network is insufficient. Therefore, to secure the minimum water pressure, enhancement of the water distribution pipes is required in the Project.

For the calculation of the hydrodynamic pressure, a public domain software (EPANET2), developed by the US Environment Protection Agency was used. The computational condition is as follows;

- In each DMA, water demand point was set. In each of the demand point, ground elevation and water demand amount were also set.
- Hazen-Williams Formula was adopted for the calculation of the friction head loss. Flow velocity

coefficient was set as 110.

- The minimum hydrodynamic pressure of each DMA was designed to meet 15 m.



*: Since hydrodynamic pressure is less than 3 m at many points, the capacity of the existing distribution pipes is insufficient.

Source: JICA Study Team

Figure 4.4.7 Examination Result of the Distribution Capacity of the Existing Distribution Pipe in 2030

4.4.5 Construction of a New Water Transmission Pipe Between Distribution Reservoirs

As shown in Figure 4.4.6, in transmitting water from the three distribution centers to the four distribution reservoirs (Woodlands, High Courts, Chelston, and Matero), possibility of whether the existing water transmission systems can transmit design water transmission amount is confirmed. Using the pipe diameter and length of the existing water transmission pipes, head loss for transmitting design water transmission amount was calculated and whether the pump head exceeds a sum of head loss difference and elevation difference was confirmed.

As shown in Table 4.4.2, the existing system can transmit the design transmission water except for the transmission pipe between the Lumumba Distribution Center and Matero Distribution Reservoir. The construction of a 450 mm diameter water transmission pipe was proposed as an addition to the existing water transmission pipe between Lumumba Distribution Center and Matero Distribution Reservoir.

As shown in Table 4.4.3, necessity of expansion of pump capacity is confirmed through comparison of planned transmission amount and existing pump capacity. As a result, the transmission pumps from Lusaka Water Works to Woodlands reservoir and High Court reservoir have an allowable capacity of 1.3 to 1.5 times compared to the planned transmission amount, therefore these pumps have sufficient capacity. On the other hand, the capacity of transmission pump from Lumumba to Matero reservoir is

36,000 m^3/day compared to the total planned transmission amount 42,000 m^3/day (existing water transmission pipe: 21,000 m^3/day, proposed water transmission pipe: 21,000 m^3/day), thus capacity of the existing transmission pumps is insufficient. The capacity of existing transmission pump is 36,000 m^3/day, so the pump is utilized for transmitting the planned transmission amount (21,000 m^3/day) for the existing transmission pipe as current operation condition. Planned transmission amount for proposed water transmission pipe is supplied by an additional pump facility. The capacity of the new pumps is set as 36,000 m^3/day as same capacity of existing transmission pump.

Table 4.4.2 Checklist of Transmission Pipe Capacity to Distribution Reservoirs

Route Pipe Line	Planned water Transmission Amount (m3/day)	Status	Diameter (m)	Length (m)	Head Loss (m)	Elevation Difference (m)	Required Pump Head (m)	Existing Pump Head (m)	Velocity (m3/s)
Lusaka W. W. - Woodlands	16,000	Existing	0.450	3,100	8.8	34.0	42.8	44.0	1.16
Lusaka W.W.- High Court	18,000	Existing	0.450	4,200	14.8	10.0	24.8	58.0	1.31
Stuart Park - Chelston	8,000	Existing	0.375	9,000	17.1	-62.0	-44.9	44.0	0.84
Lumumba - Matero (1)	21,000	Existing	0.450	4,700	22.0	16.0	38.0	45.0	1.53
Lumumba - Matero (2)	21,000	New	0.450	4,700	22.0	16.0	38.0	45.0	1.53

Source: JICA Study Team

Table 4.4.3 Checklist of Pump Capacity to Distribution Reservoirs

Distribution System	Route	Pump Name	Pump Capacity (m^3/hr)	Pump Capacity (m^3/day)	Planned Transmission Amount (m^3/day)	Additional Capacity (m^3/day)
Lusaka W.W.	Lusaka W.W. to High Court	LWW Plant 1-H/CRT 1	510	* 24,480	18,000	No need
		LWW Plant 1-H/CRT 2	510			
		LWW Plant 1-H/CRT 3	510			
	Lusaka W.W. to Woodlands	LWW Plant 1-W/L 1 4	510	* 24,480	16,000	No need
		LWW Plant 1-W/L 1 5	510			
		LWW Plant 1-W/L 1 6	510			
Lumumba	Lumumba to Matero	Lumumba Matero No. 1	750	* 36,000	42,000	36,000
		Lumumba Matero No. 2	774			
		Lumumba Matero No. 3	750			

Note: * Total pump capacity is calculated with two duties and one standby.
Source: JICA Study Team

4.4.6 Construction of New Distribution Mains

(1) Design Policy

In the Project, for the 66 DMAs, the new distribution mains were designed under the following policies:

- The distribution mains should be designed to create districts in each DMA.
- The distribution mains should meet the water demand of each DMA.

- In a DMA meeting water demand by LWSC wells, DMA master meter with the minimum diameter was planned to be installed as a backup.

(2) Design Method and Design Result of New Distribution Main

1) Design Method

The plan was for the distribution mains to connect the distribution reservoir to each DMA master meter directly and not diverge it to the distribution pipe network plan to be installed along the road. The distribution main route was designed to connect the distribution reservoir to each DMA in the distribution area with the shortest possible distance.

Diameter of the pipe was decided through the pipe network analysis done using EPANET2. Analysis conditions are as follows:

- There are 66 DMAs in the entire Priority Area including the DMAs for the MCC Project and LWSC plan, which are the target areas.
- Water demand point (master meter installation point) is set in each DMA and at each demand point; ground elevation and demand amount are set. The water demand in 2030 in each DMA was used. To secure the minimum hydrodynamic pressure in all DMAs, pump head requiring the existing distribution centers and distribution reservoirs is set.
- Hazen-Williams Formula is adopted for the calculation of friction head loss, and the flow velocity coefficient was set as 110.
- The minimum hydrodynamic pressure[1] in each DMA was designed to meet 15 m. 15 m is the lowest amount, although 3 m is the minimum standard in Zambia. While 12 m is the head loss and height difference of the DMA meter and public water tap.
- The minimum diameter of the distribution main is 160 mm, same as the existing distribution pipe.

2) Design Result

As a result of the design based on the above method, the total length of distribution mains is approximately 125 km and diameter is from 160 mm to 800 mm, as shown in Table 4.4.4. Pipe material is Unplasticized Polyvinyl Chloride (uPVC) pipe (ISO 1452-1: 2009) or High-density Polyethylene (HDPE) pipe (ISO 4427-1: 2007) for up to 315 mm, and steel pipe from 350 mm up to 800 mm.

Figure 4.4.8 shows the pipe network analysis of the designed diameter and pump head. As shown in the figure, at all the DMA master meter points, the minimum hydrodynamic pressure of 15 m is secured.

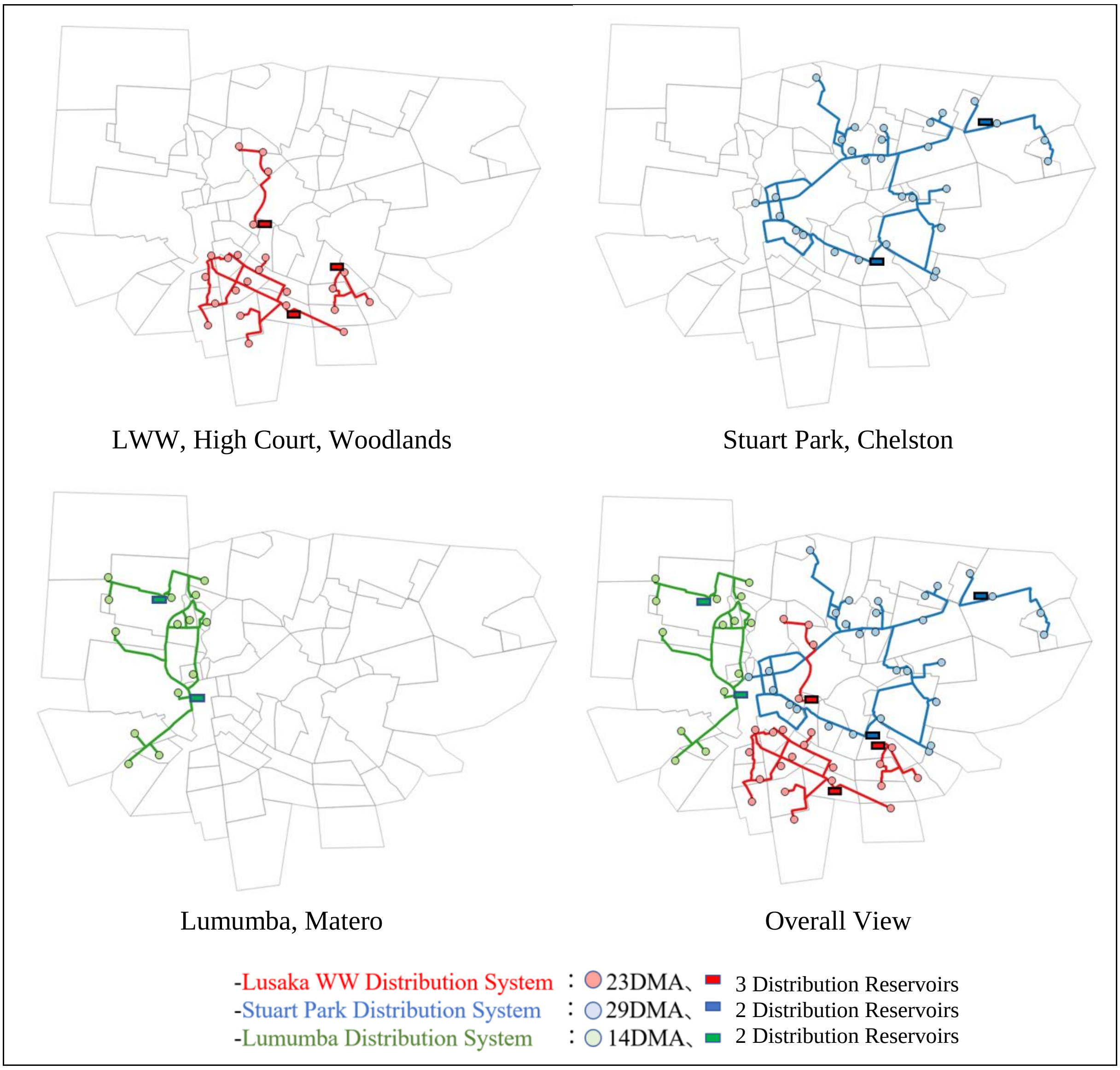
New distribution mains are recalculated based on the conditions and the latest distribution pipe data in the detailed design for the design of the distribution pipe network holding appropriate internal pressure. The control aspect, such as the number of pumps and revolving speed control, should be considered in the design.

[1] The point of the minimum hydrodynamic pressure is at the house hold connection or public tap.

Table 4.4.4 Length by Diameter of the New Distribution Main for Water Demand in 2030

No.	Water Distribution Area	Distribution Main Diameter (mm)										
		160	225	280	315	350	400	450	500	600	800	計
Length (m)	LWW	2,797	986	921	7,019	2,939	1,837	2,250	4,632	1,631	766	25,778
	Woodlands	110	518	1,391	3,656	0	0	0	0	0	0	5,675
	High Court	304	0	0	0	0	2,274	2,912	0	0	0	5,490
	Stuart Park	2,867	1,736	1,353	12,708	2,053	8,693	2,304	5,813	7,734	4,852	50,113
	Chelston	109	2,319	5,931	0	0	0	0	0	0	0	8,359
	Lumumba	0	4,164	2,655	1,831	2,655	392	0	6,037	0	3,233	20,967
	Matero	1,444	253	0	3,598	710	0	2,117	0	144	0	8,266
	Total	7,631	9,976	12,251	28,812	8,357	13,196	9,583	16,482	9,509	8,851	124,648

Source: JICA Study Team



Source: JICA Study Team

Figure 4.4.8 Route of the New Distribution Main and Hydrodynamic Pressure at the DMA Master Meter for Water Demand in 2030

4.4.7 Expansion of Water Distribution Network

(1) Design Policy

In the Project, expansion of the distribution network is designed under the following policy.

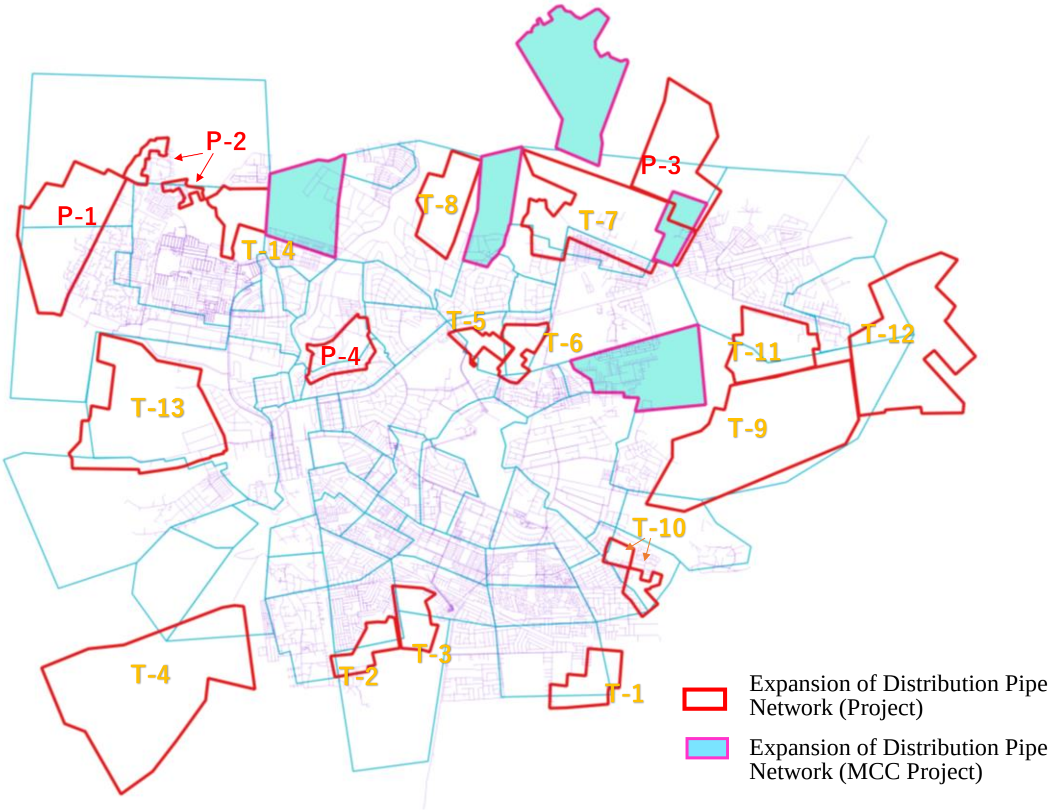
- To increase water supply rate to 100%, distribution pipe network is expanded for high-density residential area, low-density residential area with land readjustment, and maintained road and prospective development area of township except for existence of the distribution network area and the MCC Project area.
- In the peri-urban area, water distribution network is expanded for high-density residential area and maintained road area proposed by LWSC.

(2) Design Method and Result

Figure 4.4.9 shows the expansion area of the water distribution network in the Project in consultation with LWSC. In the figure, the existing distribution pipe network area and pipe network expansion area by the MCC Project are also shown to confirm that the expansion area by the Project avoids the existing area and MCC Project area. For the rest of the expansion area, LWSC will develop the distribution pipe network with their own budget.

Table 4.4.5 shows the distribution pipe length for the expansion of the Project calculated in the survey. Total length for expansion of the Project is approximately 340 km as shown in Table 4.4.5. Distribution pipe diameter is from 75 mm to 315 mm as same as the diameter of the existing pipes recently constructed and generally used in the MCC Project. Pipe material is uPVC pipe (rubber ring acceptor) or HDPE pipe.

For water distribution network expansion, distribution pipe route and diameter are decided after the recalculation based on the latest distribution pipe information, site condition, and housing development status in the detailed design.



Source: JICA Study Team

Figure 4.4.9 Distribution Pipe Network Expansion Plan

Table 4.4.5 Distribution Pipe Diameter for Expansion in the Project

No.	Area	Status	Diameter (mm)						Length (m)
			75	90	110	160	225	315	
T-1	Chandamali-MC	Township	9,684	135	1,883	135	1,076	538	13,450
T-2	F1080	Township	6,514	90	1,267	90	724	362	9,048
T-3	Libala South	Township	6,325	88	1,230	88	703	351	8,785
T-4	Town/Kabelenga	Township	22,313	310	4,339	310	2,479	1,240	30,990
T-5	UNZA	Township	3,795	53	738	53	422	211	5,271
T-6	Handsworth	Township	1,379	19	268	19	153	77	1,916
T-7	Chamba Valley-MC	Township	21,979	305	4,274	305	2,442	1,221	30,526
T-8	Roma	Township	9,257	129	1,800	129	1,029	514	12,857
T-9	New Ibex Hill-HC	Township	25,578	355	4,974	355	2,842	1,421	35,525
T-10	Nyumba Yanga-LC	Township	5,290	73	1,029	73	588	294	7,347
T-11	Chelston-LC	Township	16,321	227	3,174	227	1,813	907	22,668
T-12	Avondale Southend-MC	Township	37,590	522	7,309	522	4,177	2,088	52,208
T-13	Industrial Area	Township	13,046	181	2,537	181	1,450	725	18,120
T-14	Matero	Township	7,672	107	1,492	107	852	426	10,656
P-1	Balaston Area	Peri-Urban	15,879	221	3,088	221	1,764	882	22,054
P-2	Chunga Overspill	Peri-Urban	9,837	137	1,913	137	1,093	546	13,662
P-3	Obama Area	Peri-Urban	28,664	398	5,573	398	3,185	1,592	39,811
P-4	Chilulu Luangua Area	Peri-Urban	3,396	47	660	47	377	189	4,717
Total			244,519	3,396	47,545	3,396	27,169	13,584	339,609

Source: JICA Study Team

4.4.8 Replacement of Distribution Pipes

(1) Design Policy

To achieve the NRW rate of 25% by year 2030, distribution pipes are replaced based on the MCC F/S plan.

(2) Design Method

Measures against NRW conducted in CP-6 of the MCC Project are divided into the first stage for the first priority (14 DMAs) and the second stage for the second priority (21 DMAs). DMAs' measures against NRW are shown in Figure 2.4.2.

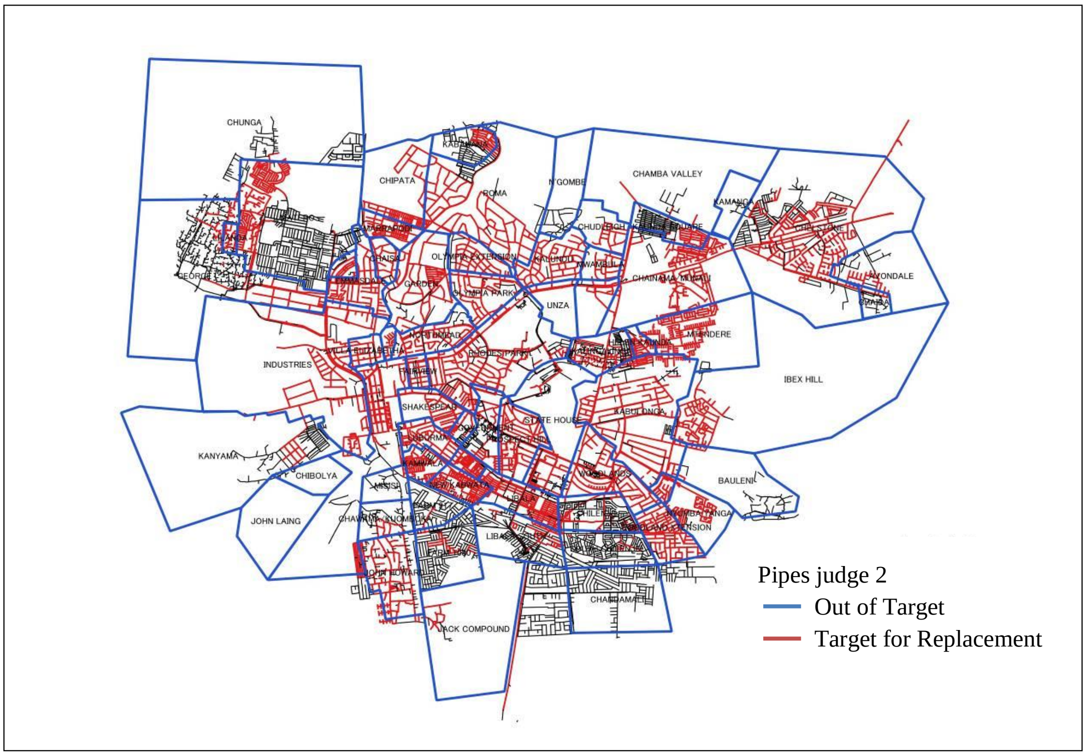
Areas included in the Project are the 21 DMAs for the second stage, where replacement is not conducted by the MCC Project due to a limit in budget. In the survey, the following methods were adopted for the design of the distribution pipes replacement.

- Although the 21 DMAs are the target for the Project, pipe length for replacement in all 66 DMAs is calculated to propose future replacement to LWSC.
- Distribution pipes for replacement are pipes which are expected to last for over 50 years after installation in 2030 and all asbestos cement pipes.
- Pipe diameter after replacement is still of the same size as before, however, pipes having a diameter 63 mm or less will be changed to 75 mm diameter pipes.
- Pipe materials are uPVC pipe or HDPE pipe from 75 mm up to 315 mm, and steel pipe from 350 mm to 600 mm.
- The Project includes water meter replacement and installation, and formation of districts of DMAs. As well as distribution pipe replacement to achieve NRW reduction target.

(3) Design Result

1) Distribution Pipes Required for Replacement in the Entire Priority Area

Figure 4.4.10 shows the distribution pipes that are required to be replaced in all 66 DMAs of the Priority Area. Distribution pipes for replacement are pipes which are expected to last for over 50 years after installation in 2030 and all asbestos cement pipes. The total length is 930 km.



Source: JICA Study Team

Figure 4.4.10 Distribution Pipes Required for Replacement in All 66 DMAs of the Priority Area

2) Distribution Pipe Length for Replacement, Water Meter Replacement and Establishment of District Metering Area (DMAs)

Figure 4.4.11 shows the areas of the Project for distribution pipe replacement. These areas have the existing pipes required for replacement. The total pipe length for replacement is 270 km. As shown in the figure, the areas do not overlap with the 14 DMAs of the MCC Project area. In association with the distribution pipe replacement, distribution was divided into 21 DMAs in the Project. In the 21 DMAs, 12,500 household connections out of the 21,000 house connections of water supply pipes and water meters are planned to be replaced. For the rest of the 8,500 water meter connections, which are not yet installed or are deteriorated, new water meters and meter boxes are planned to be installed in the Project.

Specification of the distribution pipe replacement is decided after confirmation of the latest distribution pipe material, site condition, housing development status, and pipe network calculation in the detailed design.

Table 4.4.6 (1) Length of Distribution Pipes Required to be Replaced

	DMA \ Length	Required to be Replaced (m)	Toal (m)
(1) 14 DMA for MCC Project			
1	AVONDALE	9,160	19,655
2	GARDEN	25,771	33,046
3	KABULONGA	55,952	63,204
4	EMMASDALE BANK HOUSE	11,945	12,160
5	MATERO	32,519	164,880
6	MARRAPODI	16,910	19,542
7	CHAWAMA/KUOMBOKA	3,171	11,001
8	KABWATA ESTATES	17,649	17,649
9	NORTHMEAD	11,534	12,592
10	RHODES PARK	40,334	61,469
11	CHELSTONE	53,778	86,981
12	SOUTH CHILENJE	1,809	49,633
13	TOWN/KABELENGA	21,030	28,244
14	NEW KABWATA	10,276	15,572
	Sub-Total	**311,838**	**595,626**
(2) 21 DMA for the Project			
1	CHUNGA	3,725	27,793
2	THORN PARK	2,690	2,984
3	LUBURMA	9,159	10,262
4	KAMWALA	11,176	13,101
5	OLYMPIA EXTENSION	10,192	10,371
6	CHAMBA VALLEY	6,791	13,707
7	CHUDLEIGH	5,402	5,951
8	KALUNDU	16,618	17,658
9	MWAMBULA	6,449	6,814
10	HANDSWORTH	3,444	3,769
11	CHAINAMA/MUNALI	51,314	57,786
12	IBEX HILL	19,288	19,548
13	KALINGALINGA	9,728	20,183
14	HELEN KAUNDA	10,667	12,353
15	LIBALA	16,125	21,113
16	WOODLAND EXTENSION	15,288	22,041
	New WOODLAND EXTENSION	-	-
17	NYUMBA YANGA	15,248	15,738
18	KAUNDA SQUARE	11,006	26,567
19	JOHN HOWARD	25,296	35,047
20	VILLA ELIZABETHA	17,674	18,917
	Sub-Total	**267,280**	**361,703**

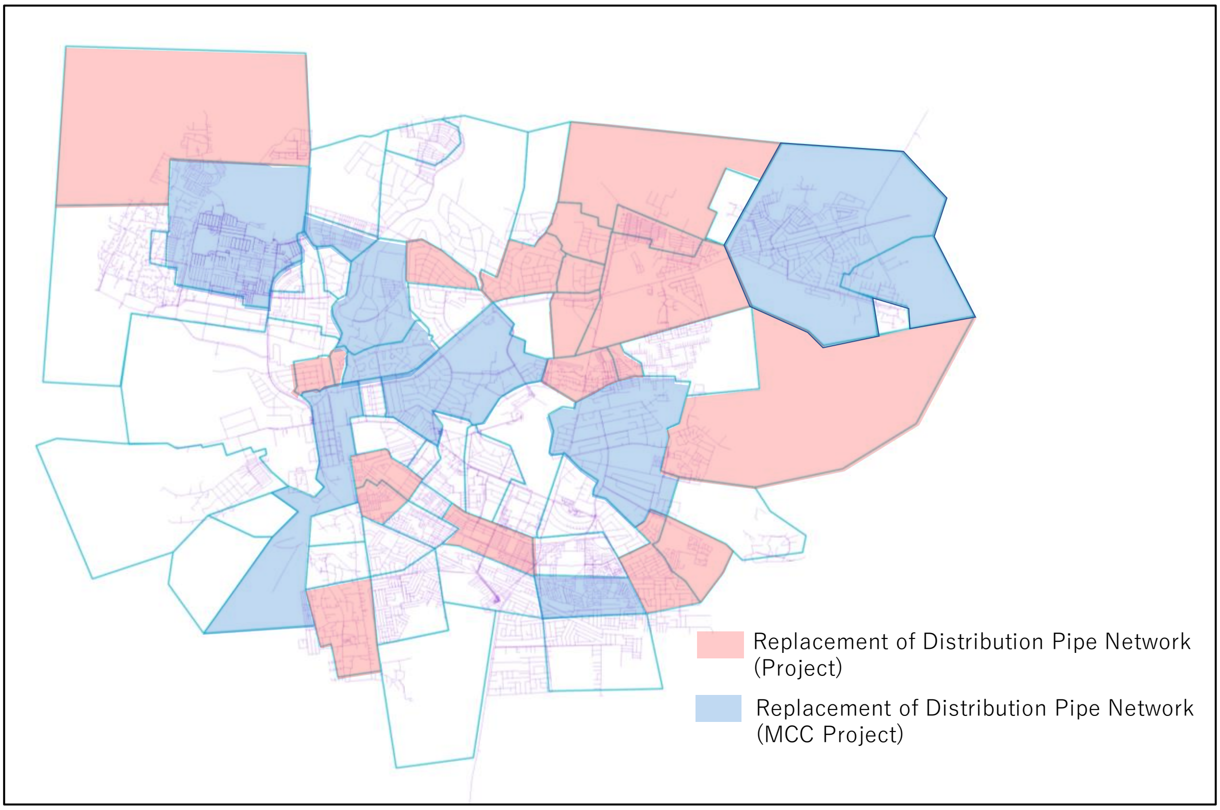
	DMA \ Length	Required to be Replaced (m)	Toal (m)
(3) Remaining DMA			
1	OLYMPIA PARK	15,975	17,978
2	WOODLANDS	23,871	32,623
3	LILANDA	785	2,087
4	GEORGE	28,826	69,173
5	INDUSTRIES	39,763	46,887
6	CHIBOLYA	0	0
7	MISISI	510	5,007
8	EMMASDALE	8,605	10,526
9	N'GOMBE	2,432	9,710
10	CHIPATA	23,122	23,122
11	CHAISA	6,352	8,209
12	ROMA	36,055	41,770
13	UNZA	0	968
14	MTENDERE	19,520	21,389
15	STATE HOUSE	26,645	38,375
16	PROSPECT HILL	19,917	25,610
17	BAULENI	1,564	12,296
18	CHILENJE	17,772	51,320
19	CHANDAMALI	0	23,332
20	FARM 1080	4,607	37,952
21	JACK COMPOUND	7,237	8,784
22	KANYAMA	4,050	22,794
23	JOHN LAING	0	0
24	GOVERNMENT	18,837	31,406
25	SIKANZE	2,830	10,993
26	SHAKESPEAR	17,476	17,493
27	FAIRVIEW	9,494	11,223
28	FARM 917	1,704	19,003
29	LIBALA SOUTH	4,043	36,470
30	KABANANA	3,669	19,425
31	KAMANGA	2,007	7,611
32	CHAIDA	0	0
		2,387	63,214
	Sub-Total	**350,056**	**726,749**
	Total	**929,175**	**1,684,079**

Source: JICA Study Team

Table 4.4.6 (2) Length of Distribution Pipe under the Project

DMA	Material	Diameter (mm)										Total (m)
		75	90	110	160	225	280	315	400	450	600	
21 DMA under the Project	uPVC or HDPE	69,577	5,306	52,669	71,204	28,280	13,503	7,434	0	0	0	247,973
	Steel Pipe	0	0	0	0	0	0	0	5,922	7,140	6,245	19,307
Total (m)		69,577	5,306	52,669	71,204	28,280	13,503	7,434	5,922	7,140	6,245	267,280

Source: JICA Study Team



Source: JICA Study Team

Figure 4.4.11 Areas for Replacement in the Project and MCC Project

3) Pipe Length Required for Replacement Except for the Project

Table 4.4.7 shows the pipe length required for replacement except for the Project.

Due to deterioration of distribution pipes, the LWSC needs to replace the old pipes through their own effort to be able to sustain the 25% NRW rate in the future. If the pipes expected to last for over 50 years after installation in 2030 and all asbestos cement pipes are replaced, the pipe length required for replacement in all the DMAs of the Priority Area is 930 km, as presented above. Deducting the pipe length replaced in the MCC Project and the Project, the pipe length which LWSC needs to replace is about 557 km. 557 km is 33 % of the entire existing length of pipes in the Priority Area (1,700 km).

In the 14 DMAs of the MCC Project, the MCC Project replaces 103 km of pipes and the LWSC needs to replace 207 km of pipes. In the 31 DMAs, which are not included in the MCC Project and the Project, LWSC needs to replace 350 km of pipes.

Table 4.4.7 Distribution Pipe Length Required to be Replaced until 2030 by LWSC

Pipe Length	Priority Area (66 DMAs)			
	14 DMAs	21 DMAs	31 DMAs	Total
Total pipe length required for replacement	310 km	270 km	350 km	930 km
Pipe length replaced by the MCC Project	103 km		-	103 km
Pipe length replaced by the Project		270 km	-	270 km
Pipe length required to be replaced by LWSC	207 km	-	350 km	557 km

Source: JICA Study Team

4.4.9 Expansion of Distribution Reservoirs and Distribution Pumps

(1) Expansion of Distribution Reservoir

According to the Japanese design standard (Design Criteria for Water Supply Facility 2012), the standard effective capacity of the distribution reservoir is considered to be 12-hour of the design daily maximum supply amount. Since earthquake seldom occurs and many houses in Zambia have water storage tanks, the storage capacity for emergency and time-varying adjustment will be smaller than that of the Japanese design standard. Therefore, 8-hour of the design daily maximum supply amount is adopted for the effective capacity of distribution reservoir in the Project. The required effective capacity and the effective capacity of the existing distribution reservoirs were compared. If the required effective capacity exceeds the existing effective capacity, the difference is set as the expansion effective capacity.

Table 4.4.8 Required Expansion Capacity of the Main Distribution Reservoirs

Distribution System	Distribution Reservoir	Design Distribution Amount (m^3/day)	Required Effective Capacity (m^3)	Existing Effective Capacity (m^3)	Effective Capacity for Expansion (m^3)	New Reservoir Capacity (m^3)
Lusaka W.W.	Lusaka W.W.	78,266	26,089	5,416	20,673	21,000
	Woodlands	15,988	5,329	5,870	No need	No need
	High Court	17,566	5,855	11,364	No need	No need
Stuart Park	Stuart Park	108,191	36,064	90,920	No need	No need
	Chelston	7,753	2,584	5,980	No need	No need
Lumumba	Lumumba	90,243	30,081	9,090	20,991	21,000
	Matero	41,993	13,998	11,000	2,998	3,000
Total		360,000	120,000	139,640	44,661	45,000

Source: JICA Study Team

As discussed above, Lusaka Water Works, Lumumba Distribution Center, and Matero Distribution Reservoir are targeted for expansion.

Since lands of Lusaka Water Works, Lumumba Distribution Center, and Matero Distribution Reservoir are all owned by the LWSC, there is no social impact such as land acquisition and resettlement of inhabitants. Considering easy O&M, the new distribution reservoir is constructed in the premise of the existing reservoir. For the Matero Distribution Reservoir, site of the old and unused distribution reservoir will be used in the construction of the new distribution reservoir.

Standard effective depth of distribution reservoir is 3-6 m, considering ease of construction and economic efficiency. To reduce space as much as possible, the effective depth of the new distribution reservoir is set as 6 m. Table 4.4.9 shows the specification of the new distribution reservoir.

Table 4.4.9 Specification of New Distribution Reservoir

Distribution System	Reservoir	Effective Capacity (m^3)	Length (m)	Width (m)	Height (m)	Structure Type
Lusaka W.W.	Lusaka W.W.	21,000	60	60	6	Semi-ground
Lumumba	Lumumba	21,000	45	82	6	Semi-ground
	Matero	3,000	25	20	6	Semi-ground

Source: JICA Study Team

(2) Expansion of the Existing Chlorination Building

Along with the water distribution capacity expansion, existing chlorine feeding facilities installed in Lusaka Water Works, Lumumba Distribution Center and Stewart Park Distribution Center were expanded.

(3) New Water Distribution Pump

1) Calculation of New Distribution Pump

For the calculation of the new distribution pumps, the maximum hourly supply amounts in Table 4.4.1 were used. As shown in Table 4.4.10, pump expansion capacity is the difference between the total pump discharge quantity and the design distribution amount.

Table 4.4.10 Comparison of Required Pump Capacity and Existing Pump Capacity

Distribution System	Purpose	Name of Pump	Pump Discharge (m^3/hr.)	Pump Discharge (m^3/day)	Distribution Amount (m^3/day)	Additional Amount (m^3/day)
Lusaka W.W.	Lusaka W.W. Distribution Pump	LWW Plant 2 New Libala 1	510	36,720	117,400	80,680
		LWW Plant 2 New Libala 2	510			
		LWW Plant 2 New Libala 3	510			
	Woodlands Distribution Pump	Woodlands LLR 1	160	11,520	23,981	12,461
		Woodlands LLR 2	160			
		Woodlands LLR 3	160			
	High Court Distribution Pump	High Court No. 1	200	23,088	26,349	3,261
		High Court No. 2	200			
		High Court No. 3	200			
		High Court No. 4	200			
		High Court Tower No. 1	54			
		High Court Tower No. 2	54			
		High Court Tower No. 3	54			
Lumumba	Lumumba Distribution Pump	Lumumba Service No. 1	560	40,320	135,365	95,045
		Lumumba Service No. 2	560			
		Lumumba Service No. 3	560			
Stuart Park	Stuart Park Distribution Pump	Stuart Park East No. 1	600	57,600	162,287	104,687
		Stuart Park East No. 2	600			
		Stuart Park West No. 1	600			
		Stuart Park West No. 2	600			
	Chelstone Distribution Pump	Chelstone Booster No. 1	445	32,160	11,629	No Need
		Chelstone Booster No. 2	445			
		Chelstone Booster No. 3	450			

Source: JICA Study Team based on LWSC information

After the examination, it is confirmed that sufficient pump capacity is secured in the existing Chelston Distribution Pump. On the other hand, capacity of water distribution pumps in the other five distribution reservoirs (Lusaka Water Works, Lumumba Distribution Center, Stuart Park Distribution Center, High Court Distribution Reservoir, and Woodlands Distribution Reservoir) is insufficient and expansion of the pumps is required.

2) Specification of New Water Pump

Table 4.4.11 shows the specification of the new pump facility. Six new pump stations were constructed in the premise of the existing distribution reservoirs. For the purpose of transmission from the Lumunba Distribution Center to Matero Reservoir, new transmission pump were designed. For selecting the pump equipment, the volute type pump was adopted and the number of pumps is 3-5 nos, considering the design water supply amount and inspection and maintenance.

To minimize the inspection and malfunction of pump impact to the water supply, standby pumps are prepared. Discharge rate is calculated by the number of pumps. The existing pump head is adopted from the total pump head. Figure 4.4.12 to Figure 4.4.17 show the locations of the new pump stations and distribution reservoirs. Each site of the distribution reservoir has enough construction space and there is no need for land acquisition. Specification of the new distribution pump was reexamined based on the distribution pipe network calculation in the detailed design.

Table 4.4.11 Specification of New Distribution Pump

Purpose	For Distribution					For Transmission
Items	LWW	Lumumba	High Court	Woodlands	Stuwart Park	Lumumba
Type of Pump	Double Suction Pump	Double Suction Pump	Sigle Suction Volute Pump	Double Suction Pump	Double Suction Pump	Double Suction Pump
Pump Bore	350 mm	350 mm	100 mm	200 mm	400 mm	350 mm
Discharge	14.0 m^3/min	16.5 m^3/min	1.1 m^3/min	4.3 m^3/min	18.2 m^3/min	12.5 m^3/min
Total Head	58 m	45 m	25 m	20 m	44 m	45 m
Motor Output	210 kW	190 kW	7.5 kW	25 kW	200 kW	170 kW
Number of Pump	Duty: 4 nos. Stand by: 1 no.	Duty: 4 nos. Stand by: 1 no.	Duty: 2 nos. Stand by: 1 no.	Duty: 2 nos. Stand by: 1 no.	Duty: 4 nos. Stand by: 1 no.	Duty: 2 nos. Stand by: 1no.
Flow Control	Controlled by number of pump and speed control	Controlled by number of pump and speed control	Controlled by number of pump	Controlled by number of pump	Controlled by number of pump and speed control	Controlled by number of pump
Power	AC380 x 50 Hz	AC380 x 50 Hz	AC380 x 50 Hz	AC380 x 50 Hz	AC380 x 50 Hz	AC380 x 50 Hz
Power Receiving	3.3 kV supplied by ZESCO	3.3 kV supplied by ZESCO	Low voltage power supplied by ZESCO	High voltage power supplied by ZESCO	3.3 kV supplied by ZESCO	3.3 kV supplied by ZESCO

Source: JICA Study Team

: New distribution tank
: New distribution pump station
: New Chlorination Building

Source: JICA Study Team

Figure 4.4.12 Locations of the New Pump Station and Distribution Reservoir in Lusaka Water Works Distribution Center

: Transmission Pump to Matero

Source: JICA Study Team

Figure 4.4.13 Locations of the New Pump Station and Distribution Reservoir in Lumumba Distribution Center

: New Stuart Park Pumping Station
: New Chlorination Building
: Stuart Park Pumping Station site
: Stuart Park Pumping Station site for expansion

Source: JICA Study Team

Figure 4.4.14 Locations of the New Pump Station and Distribution Reservoir in Stuart Park Distribution Center

: High Court Pump Station
: New distribution pump station
Source: JICA Study Team

Figure 4.4.15 Locations of the New Pump Station and Distribution Reservoir in High Court Pumping Station

: Woodland Pump Station
: New distribution pump station
Source: JICA Study Team

Figure 4.4.16 Locations of the New Pump Station and Distribution Reservoir in Woodlands Pumping Station

: New Matero Distribution Reservoir
: Matero Distribution Reservoir
Source: JICA Study Team

Figure 4.4.17 Locations of the New Pump Station and Distribution Reservoir in the New Matero Distribution Reservoir

4.4.10 Distribution Facilities for the Project

Table 4.4.12 shows the components of the distribution facilities for the Project. Table 4.4.13 shows the quantity of each work item of the distribution pipe expansion and replacement for each project (the Project, MCC Project, LWSC Project). Figure 4.4.18 shows the areas of the distribution pipe construction.

Table 4.4.12 Distribution Facility for the Project

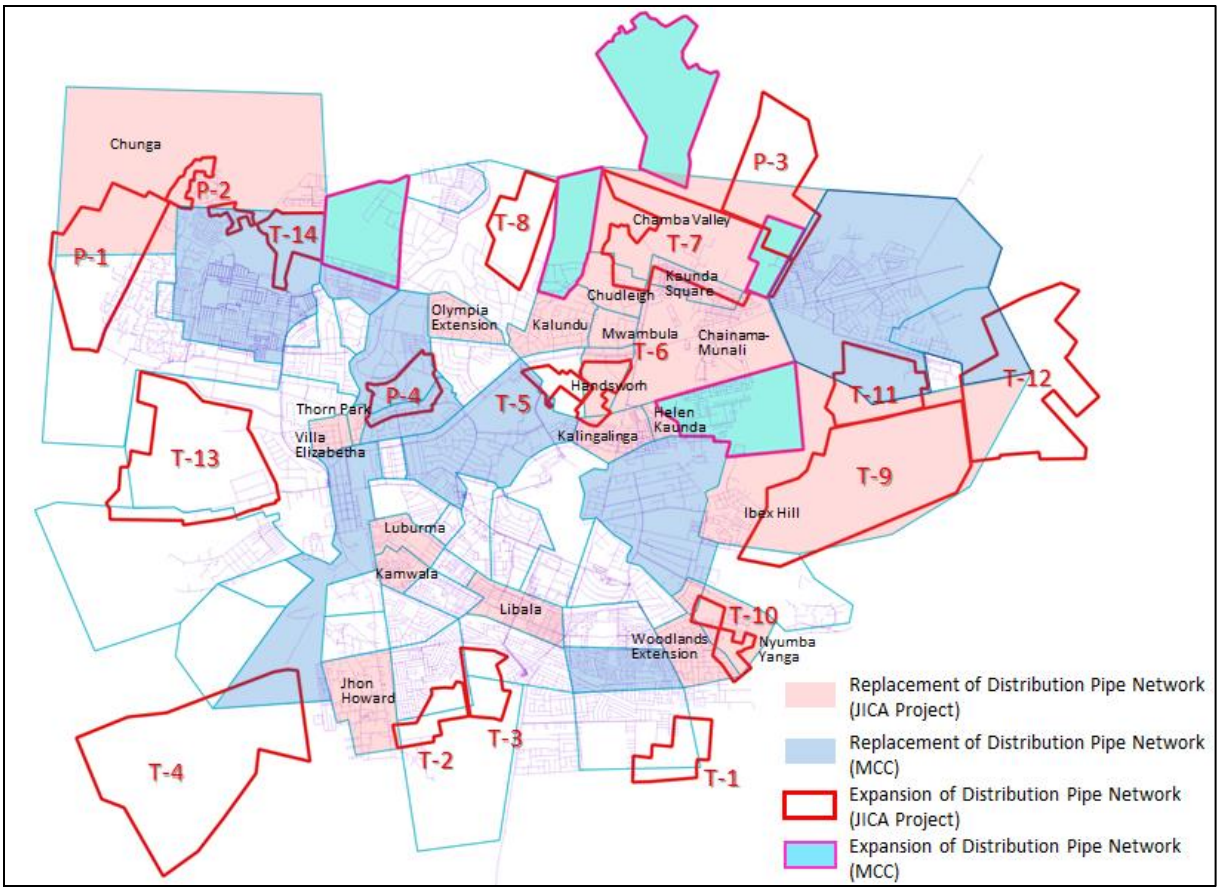
Components of the Project	Outline
New Distribution Main Construction	66 DMAs: material uPVC and Steel, Diameter and Length: 150 mm – 800 mm x 125 km DMA master meter：66 nos.
Expansion of Water Distribution Network	Materials: uPVC, HDPE and Steel Diameter and Length: 75 mm – 315 mm x 340 km House hold meter for expansion: 35,000 nos.
Replacement of Water Distribution Network	Material: uPVC and steel, Diameter and Length: 75mm – 600 mm x 270 km Service connection: 12,500 nos. Household meter for replacement: 12,500 nos. House-hold meter for new installation: 8,500 nos.
Expansion of Distribution Reservoir	Lusaka Water Works: 21,000 m^3 Lumumba Distribution Center: 21,000 m^3 Matero reservoir: 3,000 m^3
Expansion of Distribution Pump	Lusaka Water Works Pump Station: 1 no. Lumumba Pump Station: 2 nos. (For distribution:1no. For Transmission: 1 no.) Stuart Park Pump Station: 1 no. High Court Pump Station: 1 no. Woodland Pump Station: 1 no.
Expansion of Chlorine System	Lusaka Water Works. : 1 no. Lumumba Distribution Center: 1 no. Stuart Park Distribution Center: 1 no.

Source: JICA Study Team

Table 4.4.13 Quantity of the Distribution Pipes for Expansion and Replacement in the 66 DMAs in Each Project

Improvement Work	MCC Project	The Project	LWSC
Expansion and New Water Distribution Main	-	125 km (New)	-
Expansion of Water Distribution Pipe	131 km (Township, Peri-urban)	340 km (Township)	Peri-urban Area excluding the MCC target area
Replacement of Water Distribution Pipe	103 km (14 DMAs)	270 km (21 DMAs)	31 DMAs

Source: JICA Study Team



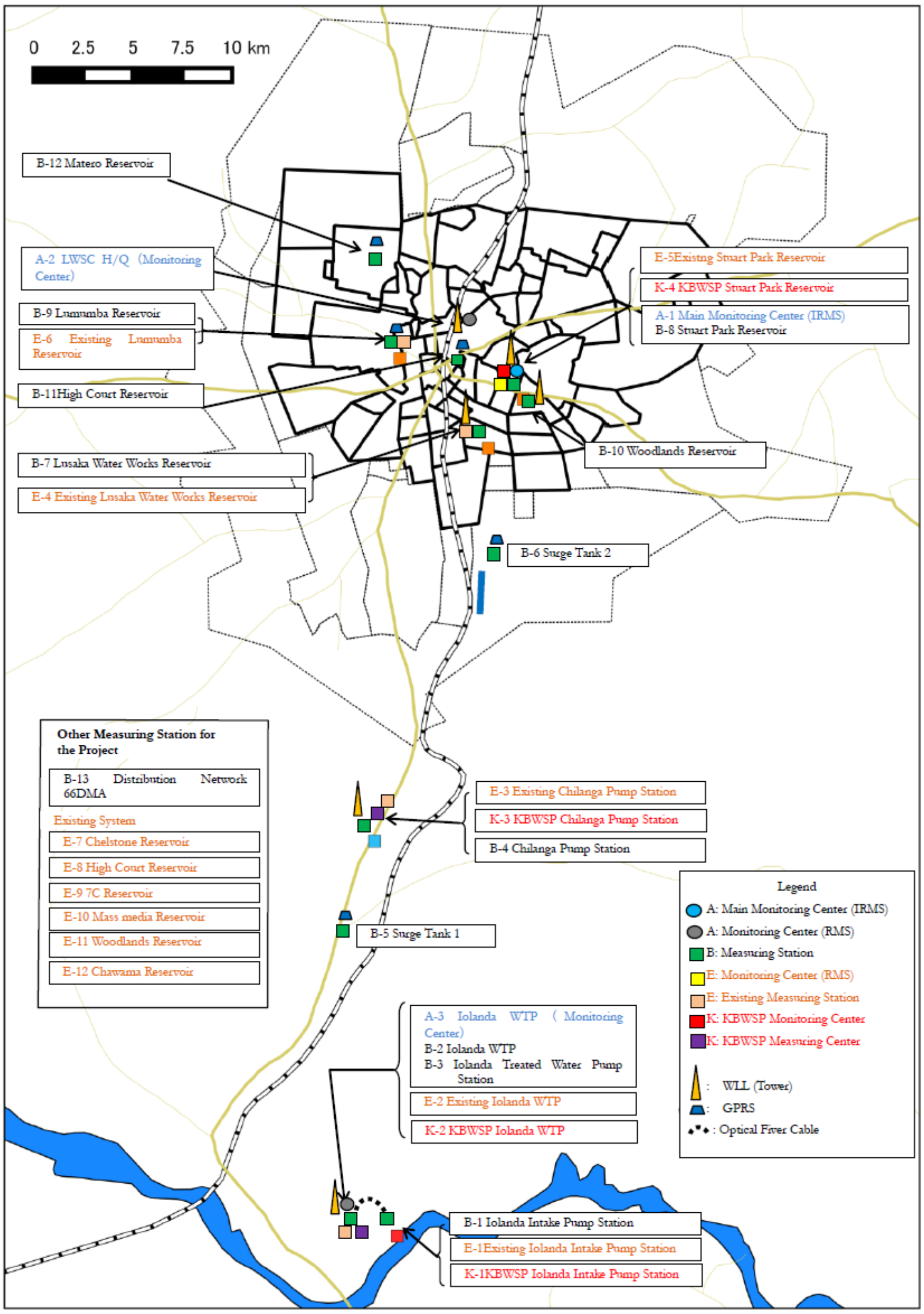
Source: JICA Study Team

Figure 4.4.18 Areas of the Expansion and Replacement of Distribution Pipes in the Project and in the MCC Project

4.5 Integrated Remote Monitoring System

4.5.1 General

Figure 4.5.1 shows the outline of the Integrated Remote Monitoring System (IRMS) applied in the Project. The Remote Monitoring System (RMS) has already been introduced in the existing water supply facility, however, it has malfunctioned and was planned to be repaired in the MCC Project. As for the KBWSP, RMS was also planned to be installed in their facilities. The various operational information of the Project is monitored by the IRMS installed at the Stuart Park Distribution Center. Besides, the IRMS to be installed by the Project is also planned to monitor the information of the existing water supply facilities and KBWSP.



Source: JICA Study Team

Figure 4.5.1 Integrated Remote Monitoring System Applied in the Project

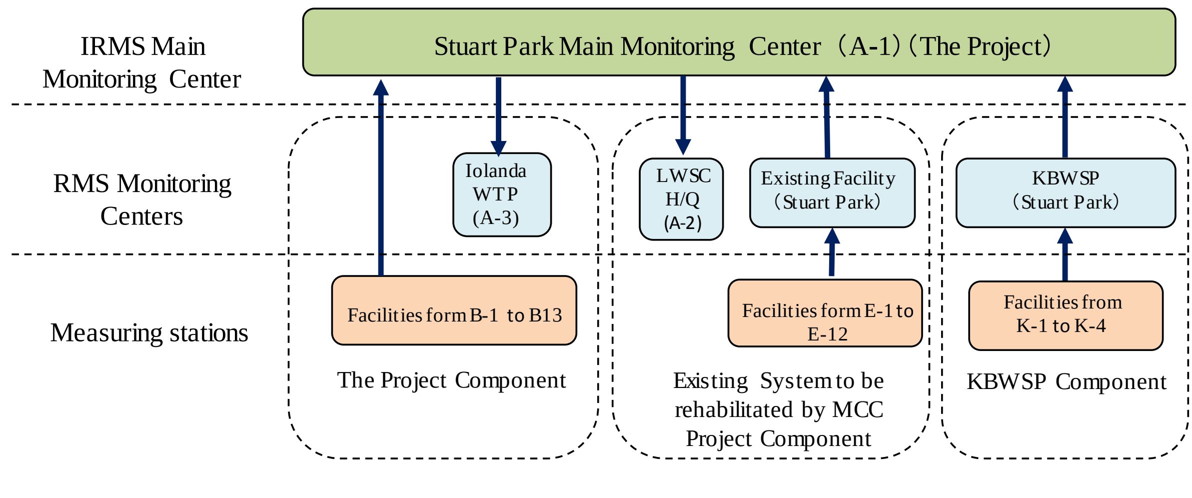
4.5.2 Integrated Remote Monitoring System Planning Strategy

(1) Objective of Development

The employment of the IRMS aims to integrate the data of the Project facilities, existing facilities, and KBWSP. Remote monitoring for the facilities is conducted by the IRMS for improvement of the O&M efficiency of LWSC and optimization of the water production amount as well as water supply amount.

(2) Features of the Integrated Remote Monitoring System

The RMS, which is to be replaced in the MCC Project, and RMS to be installed by KBWSP are planned to be utilized individually. As a result, there is a difficulty in the operation because a total of 3 RMS, including the Project's RMS, is needed to be monitored by the LWSC. Therefore, the Project plans to develop the IRMS incorporating the two systems. The IRMS is able to acquire all the necessary data and monitor the operation status for all water supply facilities at the Main Monitoring Center. Figure 4.5.2 shows the diagram of the IRMS. Table 4.5.1 shows the IRMS Monitoring Center and branch (A-1 to 3), Monitoring Station (B-1 to 13, E-1 to 12, K-1 to 4).



Source: JICA Study Team

Figure 4.5.2 Diagram of the Integrated Remote Monitoring System

Table 4.5.1 IRMS, Monitoring Center and the Implementing Project

No.	Target Facility	Implementing Project	No.	Target Facility	Implementing Project
A-1	Stuart Park Main Monitoring Center	The Project	E-1	Existing Iolanda Intake Pump Station	MCC Project
A-2	LWSC H/Q Monitoring Branch	MCC Project	E-2	Existing Iolanda WTP	MCC Project
A-3	Iolanda Monitoring Branch	The Project	E-3	Existing Chilanga Pump Station	MCC Project
B-1	Iolanda Intake Pump Station	The Project	E-4	Existing Lusaka W.W. Reservoir	MCC Project
B-2	Iolanda WTP	The Project	E-5	Existing Stuart Park Reservoir	MCC Project
B-3	Iolanda Treated Water Pump Station	The Project	E-6	Existing Lumumba Reservoir	MCC Project
B-4	Chilanga Pump Station	The Project	E-7	Existing Chelstone Reservoir	MCC Project
B-5	Surge Tank 1	The Project	E-8	Existing High Court Reservoir	MCC Project
B-6	Surge Tank 2	The Project	E-9	Existing 7C Reservoir	MCC Project
B-7	LWW Distribution Center	The Project	E-10	Existing Mass Media Reservoir	MCC Project
B-8	Stuart Park Distribution Center	The Project	E-11	Existing Woodlands Reservoir	MCC Project
B-9	Lumumba Distribution Center	The Project	E-12	Existing Chawama Pump Station	MCC Project
B-10	Woodlands Reservoir	The Project	K-1	KBWSP Iolanda Intake Pump Station	KBWSP
B-11	High Court Reservoir	The Project	K-2	KBWSP Iolanda WTP	KBWSP
B-12	Matero Reservoir	The Project	K-3	KBWSP Chilanga Pump Station	KBWSP
B-13	Distribution Networks 66 DMA	The Project	K-4	KBWSP Stuart Park Reservoir	KBWSP

Note: In B-13 Distribution Network 66 DMAs, flow meter for 14 DMA are planned to be installed by MCC Project, however, the master is unknown, so the Project planned to install the 66 master meters to build the bloc DMA.
Source: JICA Study Team

(3) Components of the IRMS

The IRMS of the Project consists of one main monitoring center, one monitoring center, and 13 measuring stations, while 12 measuring stations and one monitoring center in the MCC Project; and 4 measuring stations in the KBWSP.

1) IRMS Main Monitoring Center and Monitoring Branch

The IRMS Main Monitoring Center for real time monitoring is established in the Stuart Park Distribution Center. Necessary information of the MCC Project and the KBWSP will be obtained from both the RMS through a Local Area Net Work (LAN) located in the Stuart Park Distribution Center. In order to make the IRMS stable and safe, two monitoring centers will be established other than the Main Monitoring Center.

Table 4.5.2 shows the locations, name, and function of each monitoring center. For Iolanda WTP, individual SCADA system for operation and monitoring will also be equipped.. LWSC Headquarter Monitoring Branch has a system where the manager and engineer can monitor the water supply system's operation status on their PC screen.

Table 4.5.2 Function of Each Monitoring Station

No.	Location	Name	Function
A-1	Stuart Park Main Center	Central Station	Real time integrated monitoring of measuring stations shown in Table 4.5.1
A-2	LWSC Headquarter Monitoring Blanch	Branch Station	Integrated monitoring of measuring stations shown in Table 4.5.1
A-3	Iolanda WTP Monitoring Branch	Branch Station	Integrated monitoring of measuring stations shown in Table 4.5.1

Source: JICA Study Team

2) Function of Each Measuring Station

Table 4.5.3 shows the function of each measuring station. The 13 water supply facilities under the Project are planned to be controlled by IRMS, which include the water supply facilities, distribution station, and distribution networks. Thirteen water supply facilities in the MCC Project and four facilities in the KBWSP facility are not included because signal will directly be obtained in the Stuart Park Main Center.

Table 4.5.3 Function of Each Measuring Station

No.	Location	Name	Function
B-1	Iolanda Intake Pump Station	B-1 Measuring Station	Data transmission
B-2	Iolanda WTP	B-2 Measuring Station	Data transmission
B-3	Iolanda Treated Water Pump Station	B-3 Measuring Station	Data transmission
B-4	Chilanga Booster Pump Station	B-4 Measuring Station	Data transmission
B-5	Surge tank 1	B-5 Measuring Station	Data transmission
B-6	Surge tank 2	B-6 Measuring Station	Data transmission
B-7	LWW Distribution Center	B-7 Measuring Station	Data transmission
B-8	Stuart Park Distribution Center	B-8 Measuring Station	Data transmission
B-9	Lumumba Distribution Center	B-9 Measuring Station	Data transmission
B-10	Woodlands Reservoir	B-10 Measuring Station	Data transmission
B-11	High Court Reservoir	B-11 Measuring Station	Data transmission
B-12	Matero Reservoir	B-13 Measuring Station	Data transmission
B-13	Distribution Networks 66 DMA	B-14 Measuring Station	Data transmission

Source: JICA Study Team

4.5.3 Signal Transmission Method

Table 4.5.4 shows the comparison of each SCADA system transmission method. In principle, the current transmission method is applied to the system. In case there is no existing transmission system in the facilities, comparison in the view point of reliability, workability, and cost will be made and the most appropriate facilities will be selected. As a result of the comparison, the monitoring system transmission method was selected as the optical fiber line, Local Area Network (LAN) system, Wireless Local Loop (WLL), and General Packet Radio Service (GPRS).

Table 4.5.4 Comparison of Each Transmission Method and Applied Facilities

Transmission Method	Optical Fiber System	LAN System	Single Pair High Bit Rate Digital Subscriber Line (SHDSL)	Wireless Local Loop (WLL)	General Packet Radio Service (GPRS)
Feature	Wired communication system using optical fiber line	Wired communication system to establish the exclusive line within the facility	Wired communication system using telephone line (within 10 km distance)	Long distance wireless communication system with fixed radio frequency	Wireless communication system using mobile phone company internet network
Current Status for Existing System	Not utilized	Available in LWSC headquarter and Stuart Park Main Center	Not utilized	Radio tower stand is available at Iolanda WTP, Chilanga BPS, LWSC HQ, LWW, Woodland and Stuart Park, and WLL is available among them.	Not utilized
Reliability	Most reliable system compared with others.	Higher reliable system compared with wireless.	Higher reliable system compared with wireless.	This system was utilized without problem.	Due to the transmission speed not being stable, less stability compared with wire transmission is observed.
Workability	Due to the underground facilities, this is inferior to the others in workability.	It has better workability compared with the other wired system, but inferior to the wireless system.	Due to the flyover cable, it has better workability compared with the other wired systems.	This is the easiest because radio tower is already equipped.	It is not necessary to install the private line, so it is easy.
Price	It will be expensive in case of long distance.	Cheaper method	It is cheaper compared with the optical fiber cable.	It is cheaper than the wired method because existing radio tower can be used.	Cheapest method
Places to be Applied	Apply for short distance and in between the facilities	Apply for inside of the facilities	Cannot be applied because of its less workability and high price compared with GPRS	Apply for existing tower available	Apply for none availability existing transmission system and where difficulty for installing the private line
Facilities to be Applied	Between Iolanda WTP and intake facility	Inside of Iolanda WTP and pump station	None	Between Stuart Park Main Station and Iolanda WTP, Chilanga BPS, LWSC HQ, LWW and Woodland	Between Stuart Park Main Station and High Court, Chelstone and Matero
Selection	Applied	Applied	Not applied	Applied	Applied

Source: JICA Study Team

4.5.4 Integrated Remote Monitoring System Specifications

(1) Specifications of IRMS

Table 4.5.5 shows the specification of the IRMS for each monitoring station and Table 4.5.6 shows the specifications of the measuring stations for the water supply facility. The measuring data is saved by the Master SQL Server at the Stuart Park Main Center which includes all data monitoring and their data saving and control. The monitoring centers of Iolanda WTP functioned for monitoring of all information, saving the internal data and management. Function of the LWSC headquarter branch center is only for the monitoring of the measurement of the data for each facility since it has no water supply facilities.

In the Stuart Park Reservoir and Lusaka Water Works, the sharing of the equipment with the Project and other projects can be considered. However, sharing of those equipment with the Project is not appropriate due to operational and technical point of view, therefore, the Project employed an individual system in each facility.

Table 4.5.5 IRMS Specifications for Each Monitoring Station

No.	Monitoring Station	Equipment	Function or Objective
A-1	Stuart Park Main Control Center	WLL device, router	Wireless network receiving device
		Master server	Preparation of daily and monthly reports
		Master database server	Data storage for one year
		GPRS server	Receiving mobile network data from reservoir
		WEB server	Communication to internet
		HMI	Interface for monitoring and controlling
		Monitor, colored printer, UPS	Operation terminal and accessories
A-2	LWSC Head Quarter	WLL device, router	Wireless network receiving device
		HMI	Interface for monitoring and controlling
		PC, monitor, colored printer, UPS	Operation terminal and accessories
A-3	Iolanda WTP (Monitoring center)	WLL device, router	Wireless network receiving device
		Local server	Data distribution to HMI
		Local database server	Local data storage for one year
		HMI	Interface for monitoring and controlling
		Monitor, colored printer, UPS	Operation terminal and accessories

Source: JICA Study Team

Table 4.5.6 Specifications of the Measuring Station for Each Water Supply Facility

No.	Water supply facility	Equipment	Function or Objective
B-1	Iolanda Intake Pump Station	Optical fiber equipment	Communication equipment
		RTU, PLC, Touch Panel, UPS	System operation terminal and accessories
B-2	Iolanda WTP	Optical fiber equipment	Communication equipment
		RTU, PLC, Touch Panel, UPS	System operation terminal and accessories
B-3	Iolanda WTP Pump Station	Optical fiber equipment	Communication equipment
		RTU, PLC, Touch Panel, UPS	System operation terminal and accessories
B-4	Chilanga Booster Pump Station	WLL device, Router	Wireless communication receiving device
		RTU, PLC, Touch Panel, UPS	System operation terminal and accessories
B-5	Surge tank1	Electrical cabling, RTU	Communication equipment
		RTU, PLC, Touch Panel, UPS	System operation terminal and accessories
B-6	Surge tank 2	GPRS	Communication equipment
		RTU, PLC, Touch Panel, UPS	System operation terminal and accessories
B-7	LWW Distribution Center	WLL device, Router	Wireless communication receiving device
		RTU, PLC, Touch Panel, UPS	System operation terminal and accessories
B-8	Stuart Park Distribution Center	PLC, Touch Panel, UPS	System operation terminal and accessories
B-9	Lumumba Distribution Center	GPRS	Communication equipment
		RTU, PLC, Touch Panel, UPS	System operation terminal and accessories
B-10	Woodlands Reservoir	WLL device, Router	Wireless communication receiving device
		PLC, Touch Panel, UPS	System operation terminal and accessories
B-11	High Courts Reservoir	GPRS	Communication equipment
		RTU, PLC, Touch Panel, UPS	System operation terminal and accessories
B-12	Matero Reservoir	GPRS	Communication equipment
		RTU, PLC, Touch Panel, UPS	System operation terminal and accessories
B-13	66 DMAs	GPRS	Communication equipment
		RTU, PLC, UPS	System operation terminal and accessories

Source: JICA Study Team

(2) Measuring Device of Water Supply Facilities and Measuring Items

Table 4.5.7 shows the measuring device and measuring items at each water supply facility.

Table 4.5.7 Measuring Device and Measuring Items at Each Facility

No.	Facility	Measuring Place	Measuring Device	Measuring Item
B-1	Iolanda Intake Pump Station	River	Water level gauge	Water level
		Traveling screen	Control panel	On/off sign, operation time, fail
		Pump	Control panel	On/off sign, operation time, ampere, fail
		Transmission pipe	Water flow meter	Pressure, flow rate
		Panels	WH meter	Electricity consumption
B-2	Iolanda WTP	Receiving well, Sedimentation basin	Chlorine density meter	Chlorine density
		Receiving well, Sedimentation basin	Turbidity meter	Turbidity
		Receiving well, Sedimentation basin	pH meter	pH
		Receiving well, Sedimentation basin	Alkali meter	Alkalinity
		Receiving well	Thermometer	Temperature
		Inlet flow meter	Flow meter	Inlet flow volume
		Splits flow meter	Flow meter	Splits flow volume
		Receiving well, sedimentation basin, filter, drainage pit	Water level gauge	Water level
		Receiving well, sedimentation basin, filter, drainage pit	Valves, level sensor, flowmeter	Operation condition
		Mechanical and electrical facilities	Mixer, sludge scraper, pump, blower	Operation condition
		Panels	WH meter	Electricity consumption
B-3	Iolanda WTP Treated Water Pump Station	Treated water reservoir	Water level gauge	Water level
		Treated water reservoir	Choline meter	Residual chlorine
		Treated water reservoir	Turbidity meter	Turbidity
		Treated water reservoir	pH meter	pH
		Treated water reservoir	Alkali meter	Alkalinity
		Pump	Control panel	On/off sign, operation time, ampere, fail
		Discharge pipe	Discharge valve	Valve angle
		Flow meter chamber	Flow meter	Flow rate
		panels	WH meter	Electricity consumption
B-4 B-7 B-9	Chilanga Booster Pump Station LWW Distribution Center Lumumba Distribution Center	Pump	Control panel	On/off sign, operation time, ampere, fail
		Treated water reservoir	Water level gauge	Water level
		Outlet pipe	Outlet valve	Valve angle
		Inlet flow mete chamber	Flow meter	Inflow
		Outlet flow meter chamber	Flow meter	Out flow
		Treated water reservoir	Choline meter	Residual chlorine
		Chlorine building	Valve, level meter, flow meter	Operation monitoring
		Panels	WH meter	Electricity consumption
B-5	Surge tank 1	Surge tank	Water level gauge	Water level
B-6	Surge tank 2	Surge tank	Water level gauge	Water level
B-8	Stuart Park Distribution Center	Pump	Control panel	On/off sign, operation time, ampere, fail
		Inlet flow mete chamber	Flow meter	Flow rate
		Outlet flow meter chamber	Flow meter	Flow rate
		Chlorine Building	Valve, water level, flow meter	Operation
		Panels	WH meter	Electricity consumption
B-10	Woodlands Reservoir	Pump	Control panel	On/off sign, Operation time, Ampere, Fail
		Panel	WH meter	Electricity consumption
B-11	High Courts Reservoir	Pump	Control panel	On/off sign, operation time, ampere, fail
		Panels	WH meter	Electricity consumption
B-12	Matero Reservoir	Treated water reservoir	Water level gauge	Water level
		Inlet flow mete chamber	Flowmeter	Inlet flow
		Outlet flow meter chamber	Flow meter	Outlet flow
B-13	66 DMA distribution net works	DMA Flow meter chamber	Flow meter and pressure meters	Flow rate and pressure

No.	Facility	Measuring Place	Measuring Device	Measuring Item
E-1	Existing Iolanda Intake Pump Station	River	Water level gauge	Water level
		River	pH meter and turbidity meter	pH and turbidity
		Pump	Control panel	Pump monitoring
		Outlet pipe	Pressure meter	Pressure, flow rate
		Panels	WH meter	Electricity consumption
E-2	Existing Iolanda WTP	Treated Reservoir	Water level gauge	Water level
		Treated Reservoir	pH meter and turbidity meter	pH and turbidity
		Outlet flow meter chamber	Flow meter	Pump monitoring
		Outlet pipe	Pressure meter	Pressure, flow rate
		Panels	Electrical meter	Electricity consumption
E-3	Existing Chilanga Pump Station	Transmission pipe	Pressure gauge	Pressure
		Treated Reservoir	Level gauge	Water level
		Inlet flow mete chamber	Flow meter	Flow rate
		Outlet flow meter chamber	Flow meter	Flow rate
		Panels	WH meter	Electricity consumption
E-4 E-5 E-6 E-7 E-8	Existing LWW, Existing Stuart Park, Lumumba, Chelstone, High Court	Treated Reservoir	Water level gauge	Water level
		Treated Reservoir	pH meter and turbidity meter	pH and turbidity
		Inlet flow mete chamber	Flow meter	Flow rate
		Outlet flow meter chamber	Flow meter	Flow rate
		Distribution pipe	Pressure gauge	Pressure
		Panels	WH meter	Electricity consumption
E-9 E-10 E-11 E-12	Existing 7C Reservoir, Mass media Reservoir Woodlands Reservoir Chawma Reservoir	Treated Reservoir	Water level gauge	Water level
		Treated Reservoir	pH meter and turbidity meter	pH and turbidity
		Pump	Control panel	Pump monitoring
		Inlet flow mete chamber	Flow meter	Flow rate
		Distribution flow meter chamber	Flow meter	Flow rate
		Panels	WH meter	Electricity consumption
		Regional pressure	Pressure meter	Pressure
K-1	KBWSP Iolanda Intake Pump Station	River	Water level gauge	Water level
		River	pH meter and turbidity meter	pH and turbidity
		Pump	Control panel	Pump monitoring
		Outlet pipe	Pressure meter	Pressure, flow rate
		Outlet valve	Outlet valve	Valve angle
K-2	KBWSP Iolanda WTP	Treated reservoir	Water level gauge	Water level
		Treated reservoir	pH meter and turbidity meter	pH and turbidity
		Outlet flow meter chamber	Water flow meter	Outlet flow rate
		Pump discharge pipe	Pressure gauge	Pressure
		Panels	WH meter	Electricity consumption
K-3	KBWSP Chilanga Pump Station	Transmission pipe	Water flow meter and pressure meter	Pressure, flow rate
		Treated reservoir	Water level gauge	Water level
		Pump	Control panel	Pump monitoring
		Pump discharge pipe	Pressure gauge	Pressure
		Outlet valve	WH meter	Valve angle
K-4	KBWSP Stuart Park	Distribution reservoir	pH meter and turbidity meter	pH and turbidity
		Flow meter chamber	Flow meter	Inflow rate

Source: JICA Study Team, Preparation of Feasibility Studies and (30%) Preliminary Design for Water Supply and Sanitation Projects and year 2012（MCC F/S） and KBWSP Preliminary Design

(3) Other Necessary Procurement Items

The following services shall also be required in addition to the above devices' procurement to establish the IRMS. The contractor, which will procure the devices and software, shall conduct the following tasks.

1) Software

Procurement and installation of each device and software for operation of the IRMS by its provider

2) Commissioning and Operation Training

The contractor will conduct the following commissioning and operation training;

- Commissioning prior to commencement
- Initial instruction for one month after commencement
- Periodical monitoring for every three months up to one year after commencement (a total of four times)