PART II

MASTER PLAN

CHAPTER 1 PLANNING BASIS

1.1 Master Plan Targets

1.1.1 Outline of Existing Water Supply Conditions

The existing water supply conditions are described in Chapter 5 of Part I. The five types of water supply services as follows are provided in the Study Area.

- House connections of UWC customers
- Public tap of UWC customers
- Public hand pumps equipped to wells
- Water venders (Water tanker and jerry can bicycle venders)
- Private wells

As of the end of April 2009, no safe and clean water was supplied to the residents in Juba as the existing old water treatment plant was aged and malfunctioned, in which the water is not virtually treated and the water produced was not suitabke for human consumption. In addition, the working capacity of the water treatment plant was only about 3,000 m^3/d and it is very low compared to the current increasing water demand.

The reconstruction of the existing new water treatment plant has been implemented and completed in May 2009, and thereafter the capacity of the water treatment plant has been increased to 7,200 m^3/d. Even after the completion, the production capacity is still very small and has large deficit from the water demand. In addition, most of the produced water will not reach the customers as the existing network is comprised of very old asbestos and galvanized pipes and thus leakage of the existing network is assumed to be very large.

There are more than 400 public hand pumps in the Target Service Area. These hand pumps have several drawbacks in terms of water quality; high salinity in many wells, and possible man-caused pollution in some wells. Therefore, many of the public hand pumps are not suitable as water source for drinking purpose.

The source of water for private water venders of tanker and bicycle vender is raw water of the Bahr el-Jebel. Although chlorine is added to tank water for disinfection, it is not suitable for human consumption. In addition, the price of water is very expensive.

As a consequence, safe and clean water in adequate quantity is not supplied to most of the residents in the Target Service Area.

1.1.2 Target of Water Supply Service

The Study Team and Southern Sudan sides discussed on the future target coverage of treated water supply service and reached the consensus that it is not possible to achieve 100% coverage by 2015 considering the factors such as budget constraint, technical ability and rapid expansion of city. Finally, both sides concluded that as a basic policy of the Master Plan, safe and clean water or treated water shall be supplied to all the people in Juba area or the Target Service Area by 2025, and the service coverage targets for years 2015 and 2020 in the transitional period were set up as 80 % and 90 %

In addition, it is generally understood that it is very difficult to achieve 80 % and 100 % of service coverage in 2015 and 2025 by house connection only, considering the existing conditions of UWC's water supply facilities, the current small number of UWC customers (2,765 connections in 2007) and rapidly increasing population. Therefore, it is considered that the coverage targets shall be achieved by means of public taps connected to network and private venders. The source of water for all supply methods should be safe and clean water or adequately treated water.

The overall target water supply service of the Master Plan until 2025 are set as follows.

Target Water Supply Conditions

All the people in Juba can assess safe and clean water supply by 2025 by means of house connection, public tap or private water vender with following target coverages. Safe and clean water means adequately treated water for human consumption and of potable quality.

Target Coverage of Treated Water Supply

	2009	2015	2020	2025
Target coverage	**about 8 % (estimated)**	**80 %**	**90 %**	**100 %**

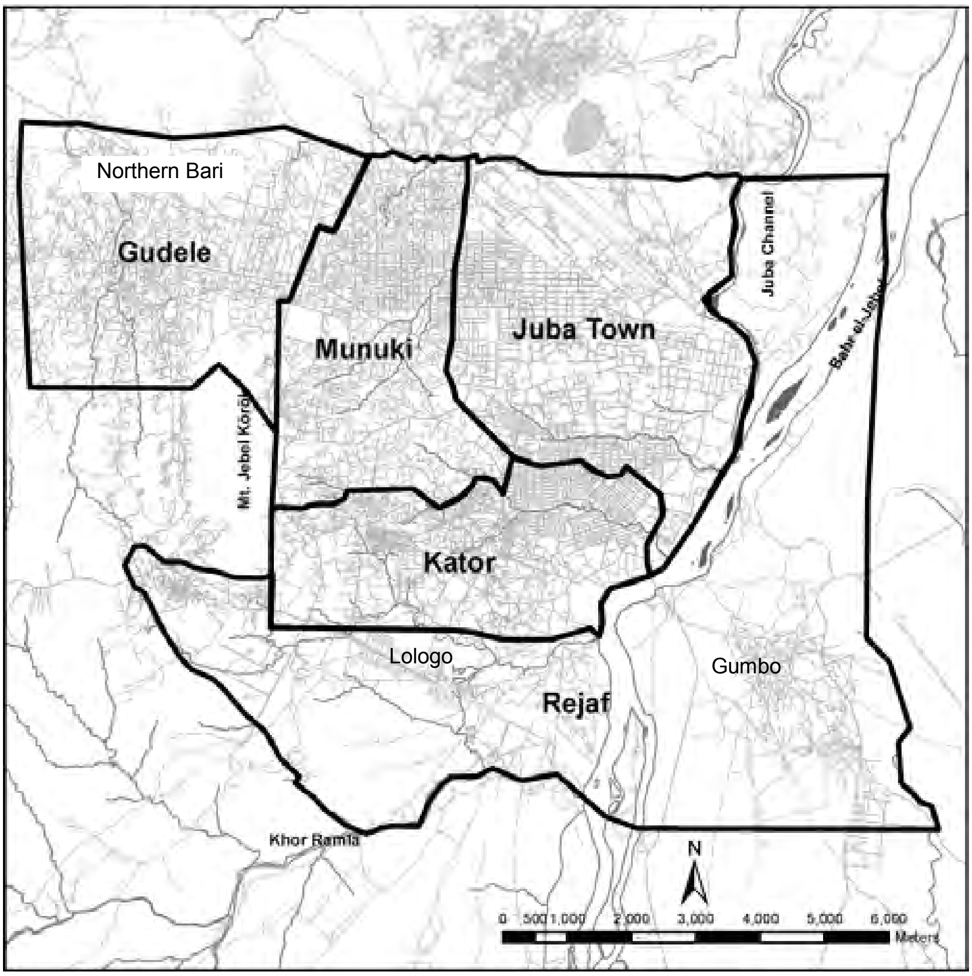
1.1.3 Target Service Area of Water Supply Service

Central Equatoria is composed of 6 Counties comprising of Juba, Yei, Terakeka, Kajo Keji, Lainya, and Morobo. Juba County comprises of 11 payams. Out of these payams, Juba Town, Kator and Munuki are expected to form Juba Municipality. On the other hand, the urbanized area of Juba has expanded to the outside of these three payams, i.e., Rejaf and Gudele. The latter area is located in the western zones of Munuki and belongs to Northern Bari.

The target area of water supply service is set as the existing major urbanized area including Juba

Town, Kator and Munuki, and future expected urbanized areas including Rejaf and Gudele. This area will form the Juba Capital Region.

Target Service Area of Water Supply



1.2 Population and Water Demand Projections

1.2.1 Methodology of Future Water Demand Estimation

In the Study, the water demand is categorized into domestic and non-domestic demands and estimated up to 2025 at 5 year intervals. The demand is composed of the following user groups:

- Domestic: House connection, Public taps and Water vender (Water tanker)
- Non-domestic: Commercial & business, Industrial, and Institutional

The flowchart of future water demand estimation is explained in Figure 1.1. The water demand is estimated using the following steps:

(1) Domestic Water Demand

1) Projection of total population and areal distribution up to 2025 based on land use plan
2) Estimation of service population by domestic demand category by delineating piped water network development area
3) Setting up of target domestic water consumption per capita
4) Estimation of total domestic water demand
5) Distribution of total domestic water demand to service area according to the population distribution

(2) Non-domestic water demand

1) Setting up the ratio of domestic and non-domestic water consumption
2) Calculation of total non-domestic water demand based on this ratio and estimated domestic water demand
3) Distribution of total non-domestic water demand to service area according to the areal extent of non-domestic users based on land use plan

(3) Water demand for facility planning

1) Estimation of total water demand and its areal distribution by summing up domestic and non-domestic water demands
2) Setting up of target leakage ratio and estimation of daily average water demand
3) Setting up of maximum daily coefficient (or seasonal peak factor) and estimation of maximum daily water demand

Future land use and population and water demand projections are discussed in Appendix-C.

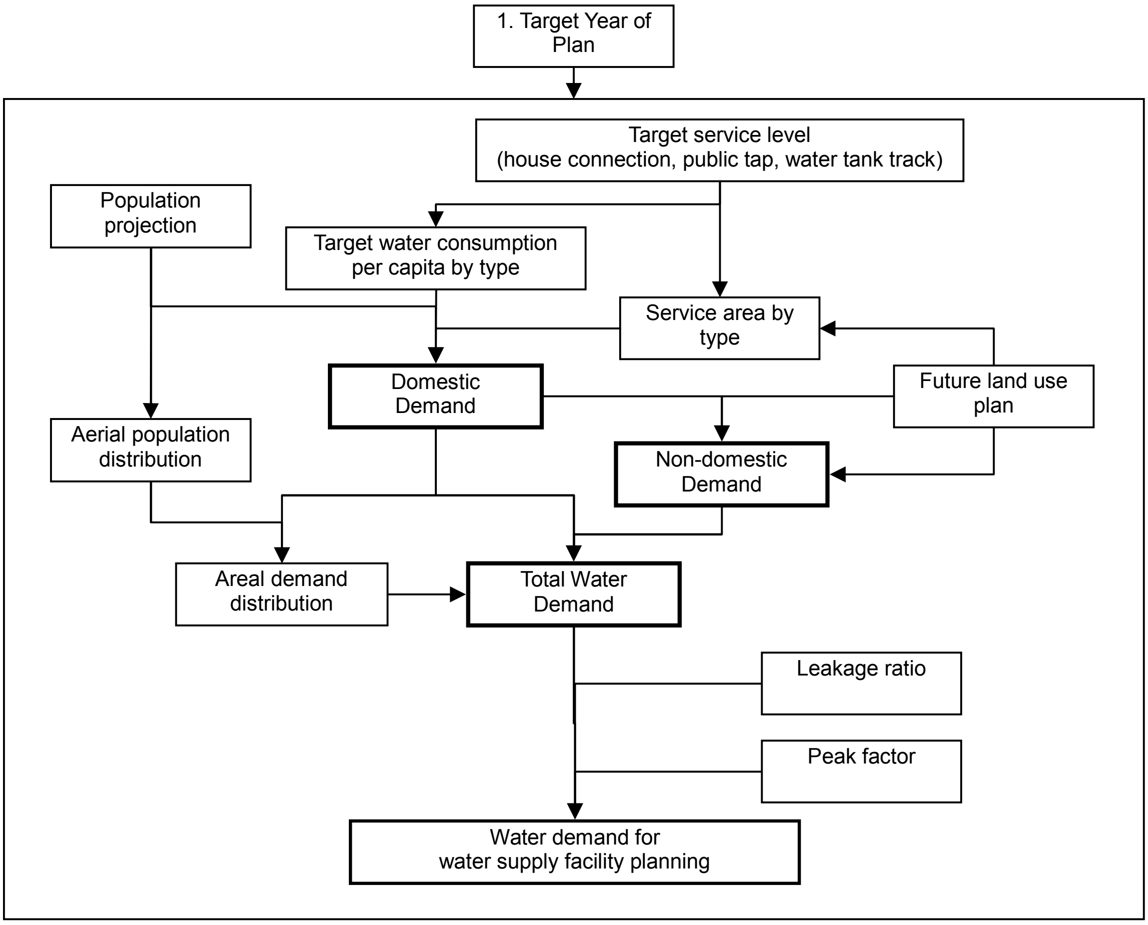


Figure 1.1 Flowchart of Water Demand Estimation

1.2.2 Future Population Projection

The trend of past and current populations and other population projection for Juba were studied and the details are given in Chapter 3 of Part I. The population in the Target Service Area in 2009 is estimated as 406,000 and the past populations are summarized in Table 1.1. The estimated population in the Target Service Area has increased at the rate of 12.9 % per annum after 2005. This drastic increase is attributable more to the socio-dynamic patterns than to natural causes as many refugees and internally displaced persons (IDPs) have returned to Southern Sudan, especially to Juba area, after the signing of CPA.

Table 1.1 Past Population and Estimated Growth Rate

	1977	1994	2005	2009
Population	71.5 [*1]	156 [*2]	250 [*3]	406 [*4]
Annual growth rate (%)		4.7%	4.4%	12.9%

Source:
*1: JICA Emergency Study
*2: United Nations head count census
*3: Juba Assessment Town Planning and Administration, USAID
*4: the Study Team estimate

The GIBB Africa forecasted in 2005 that the high growth trend of Juba area will continue up to 2011. The Study Team assumed that the current trend of high population increase will not continue after 2012 because the recent drastic increase is attributed mainly to the migration. The growth rate will eventually drop to the level of natural increase similar to the trends in the cities of the neighboring countries. Considering the factors analyzed in Chapter 3 of Part I and above, three growth scenarios have been assumed for the future population growth rate for Juba as shown in Table 1.2.

Table 1.2 Scenario of Future Population Growth Rate for Juba Population Forecast

Scenario	2010	2011	2015	2020	2025
High estimate	13%	13%	7%	6%	5%
Medium estimate	13%	13%	6%	5%	4%
Low estimate	13%	13%	5%	4%	3%

Based on these growth rates, the future population has been estimated and presented in Table 1.3 and Figure 1.2. Based on this estimate, the population of the Target Service Area in 2025 will be 1.16 million, 1.02 million and 0.89 million for high, medium and low estimates, respectively. The Study Team and Southern Sudan side agreed to adopt the high estimate as the future population for Juba. Consequently, the adopted population of the Target Service Area in 2015 and 2025 are 680,000 and 1,162,000, respectively.

Table 1.3 Future Population Forecast with Different Growth Trends

(Thousand persons)

Scenario	2010	2015	2020	2025
High estimate (adopted)	**459**	**680**	**910**	**1,161**
Medium estimate	459	655	836	1,017
Low estimate	459	631	768	890

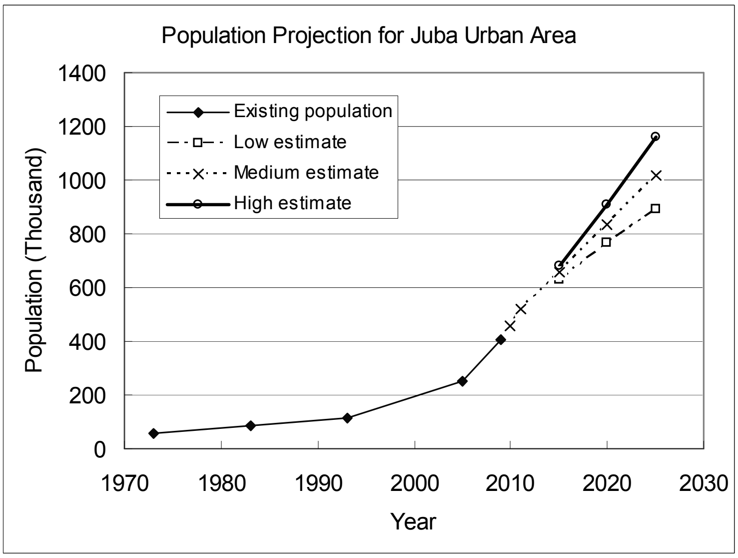


Figure 1.2 Future Population Forecast for Juba Urban Area

Based on the model prepared in Appendix-C, future total population was distributed over the Target Service Area, and the result of the estimated population distribution to sub-district up to 2025 is shown in Figure 1.3.

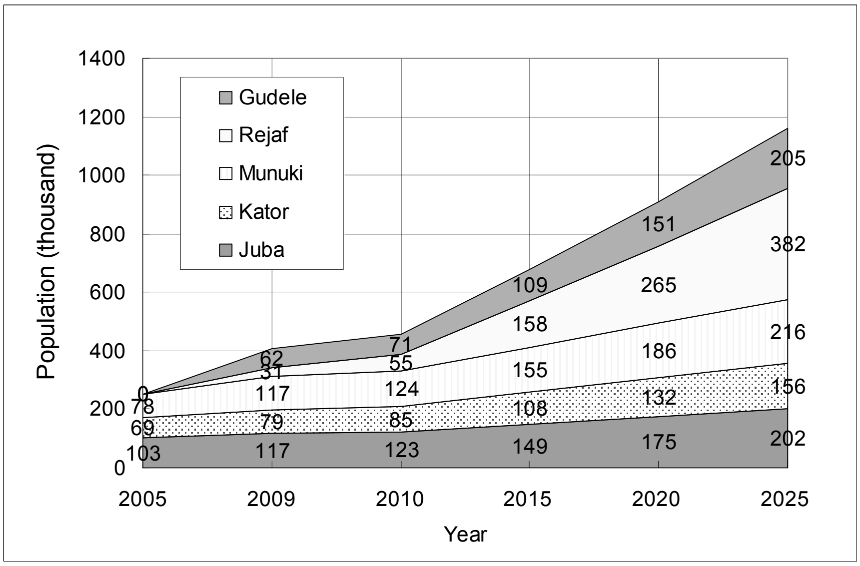


Figure 1.3 Population Distribution by Payam in Target Service Area

The population increase in Juba Town and Kator Payam is relatively low because most of these areas have been already developed. On the contrary, the population growth in Rejaf and Gudele is high because these areas have a lot of open space and high potential to be developed as residential areas. This growth trend coincides with the direction of recent expansion of urbanized area and new residential areas on future land use.

1.2.3 Water Demand Projection

(1) Unit Water Consumption

The procedure of estimation of future water demand was prepared in the previous section. The analysis of water consumption in neighboring countries was studied as reference of unit water consumption for Juba. Finally, future water demand for the Target Service Area was estimated based on these studies.

The current per capita water consumption of house connection, public tap and water tanker supply was calculated based on the result of socio-economic survey by the Study Team (see Chapter 5 of Part-I). The current average water consumption per capita of domestic users (house connection, public tap and tanker supply) is estimated as 33 L/c/d.

The design or target water consumption per capita for domestic users is set up as shown in Table 1.4, considering those of other areas in Sudan and other countries. The target water consumption per capita for 2025 is set at 120 L/c/d, with 105 L/c/d for 2020 and 90 L/c/d for 2015.

Table 1.4 Design Domestic Water Consumption per Capita

(L/c/d)

Users/ main water sources	Current water use	Target in 2015	Target in 2020	Target in 2025
- House connection	26 (53) *[1]	90	105	120
- Public tap	32.5	40	40	40
- Tanker	35.5	40	40	40

Note: * 26 L/c/d, which is estimated from the results of socio-economic survey by the Study Team, is the consumption level before the inauguration of rehabilitation of the existing water treatment plant and 53 L/c/d is estimated as the consumption level after the inauguration.

The ratio of water consumption of domestic and non-domestic users for 2025 are set as 70 % and 30 %, respectively, assuming the institutional water consumption will be reduced from the current 28 % as the public sector in Juba will relatively decrease in future and considering the typical ratio of total water consumption in a large city, i.e. 20 to 30 %.

The total percentage of the non-domestic water consumption was distributed to each non-domestic user group as shown in the table below. As explained above, the share of institution/government is assumed to reduce in future. The share of commercial & business and industry is set as 10 % and 3 %, respectively and is assumed to stay same in future. The low industrial water consumption rate was assumed considering that industry will use own water supply source or other public water supply exclusively for industry. The future water demand is estimated based on these ratios of the domestic consumption.

Table 1.5 Design Ratio of Non-Domestic Water Consumption

(%)

Class/main water sources	Current water use	Target		
		in 2015	in 2020	in 2025
1. Domestic	**63**	**62**	**66**	**70**
2. Non-domestic	**37**	**38**	**34**	**30**
- Commercial & business	9	10	10	10
- Industry	0	3	3	3
- Institution/government	28	25	21	17

(2) Service Coverage

The service coverage for 2015 and 2025 is planned as presented in Table 1.6 and Table 1.7, and the assumed coverage area by the network in 2015 is shown in Figure 1.4.

Table 1.6 Service Coverage Assumption for 2015 and 2025

Year	Service coverage assumptions
2015	• The border of covered area of water distribution network is delineated along the existing organized urban area and its surrounding. • In the network covered area, existing and potential organized urban area is supplied by house connection and unorganized urban area is supplied by public taps. The water source for both types of supply is piped water. • The area outside of the covered area is supplied by tanker. The water source in this case is also piped water.
2025	• The coverage of house connection in the existing main city areas (Juba Town, Kator and Munuki) will be 80 % and that of the remaining area (Rejaf and Gudele) will be 60 %.

Table 1.7 Service Coverage Projection

Payam	2015				2025			
	House connect (UWC)	Public tap (UWC)	Water tanker	Non-treated	House connect (UWC)	Public tap (UWC)	Water tanker	Non-treated
Juba Town	57 %	24 %	11 %	8 %	80 %	10 %	10 %	0 %
Kator	42 %	34 %	14 %	10 %	80 %	10 %	10 %	0 %
Munuki	37 %	50 %	8 %	5 %	80 %	10 %	10 %	0 %
Rejaf	0 %	0 %	60 %	40 %	60 %	10 %	10 %	0 %
Gudele	0 %	0 %	60 %	40 %	60 %	10 %	10 %	0 %
Total	28 %	22 %	30 %	20 %	70 %	15 %	15 %	0 %
Population covered	188,000	150,900	204,400	136,300	811,300	174,900	174,900	0

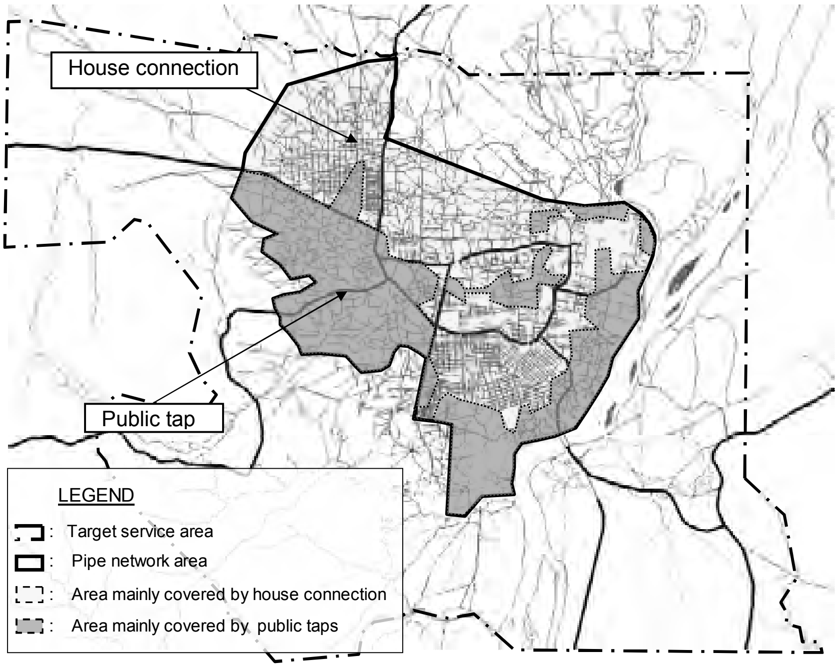


Figure 1.4 Assumed Service Area in 2015

(3) Estimation Conditions of Water Demand

In estimating the water demand, following factors are considered:

1) Ratio of continuous use of existing wells equipped with public hand pump

It is assumed that even after 2015, the use of existing wells equipped with public tap will be continued by the following percentage of users. In the assumption, it is considered that the current users of household connection do not use existing wells whereas some fraction (presented in Table 1.8) of the users of public tap and tanker will continue using existing wells.

Table 1.8 Ratio of Continuous Use of Existing Wells Equipped with Public Hand Pump

Category	Target		
	2015	2020	2025
House connection	0 %	0 %	0 %
Public tap and tanker	30 %	20 %	10 %

2) Leakage ratio

At the early stage of improvement project of water supply facilities in the water supply master plan, the first priority is given to the rehabilitation of existing distribution network and all existing network will be upgraded by replacement. This intervention is assumed to complete before 2015. Considering this conditions, the leakage ratio in 2015 is set as 20 %, and after 2015, the leakage ratio is assumed to be maintained at 20 % by appropriate leakage management measures.

3) Seasonal peak /daily maximum factor

The Study Team regards the design water consumption per capita set up in the previous section as annual average water consumption. Therefore, maximum daily coefficient or seasonal peak factor is used to estimate maximum daily water demand.

The result of the socio-economic survey by the Study Team indicated that the water consumptions per capita in dry and rainy seasons are 36 L/c/d and 30 L/c/d, with average of 33 L/c/d. Therefore, seasonal variation of water consumption is 20 % between dry season and rainy season. In other words, it can be said that the dry season's consumption is 1.1 times of the annual average consumption. In this case, therefore, the maximum daily coefficient is 1.1. The current water consumption is suppressed due to scarcity of water, especially in dry season, when the water is scarce. Therefore, if the water consumption is not suppressed, the peak factor would be higher.

Usually, peak factor tends to be high in the area that experiences very hot dry season. This is applicable to Juba. On the other hand, peak factor of the larger city tends to be low because water consumption tends to be flattened due to different consumption patterns of different human activities including office, commercial and industry. The maximum daily water demand coefficient of the larger city falls in the range of 1.1 and 1.2 in Japan. Considering very hot dry season in Juba, the maximum daily water demand coefficient is set as 1.2.

(4) Future Water Demand Estimation

With the conditions set above, the future water demands are estimated up to 2025 at 5 year interval and distributed over the Target Service Area. Domestic demand is distributed according to estimated future population distribution and the target level of water supply service. Non-domestic demand is distributed according to current land use and future land use plan. The result is shown in Table 1.9 and Figure 1.5.

The maximum daily water demand in 2015 and 2025 is estimated as 69,000 m^3/d and 236,500 m^3/d, respectively. In 2015, the water demand of Juba is the largest and that of Gudele is the smallest. Toward the year 2025, the increase in water demand of Rejaf and Gudele are getting significant and that of Juba, Kator and Munuki is getting smaller.

Table 1.9 Average and Maximum Daily Water Demand Estimation

(m^3/d)

Payam	Average daily demand			Maximum daily demand		
	2015	2020	2025	2015	2020	2025
Juba	20,900	29,200	41,000	25,000	35,100	49,300
Kator	10,900	18,300	29,400	13,100	21,900	35,300
Munuki	13,400	22,900	36,300	16,100	27,500	43,600
Rejaf	8,300	26,700	59,300	9,900	32,100	71,100
Gudele	4,100	14,100	31,000	4,900	16,900	37,200
Total	**57,600**	**111,200**	**197,000**	**69,000**	**133,500**	**236,500**

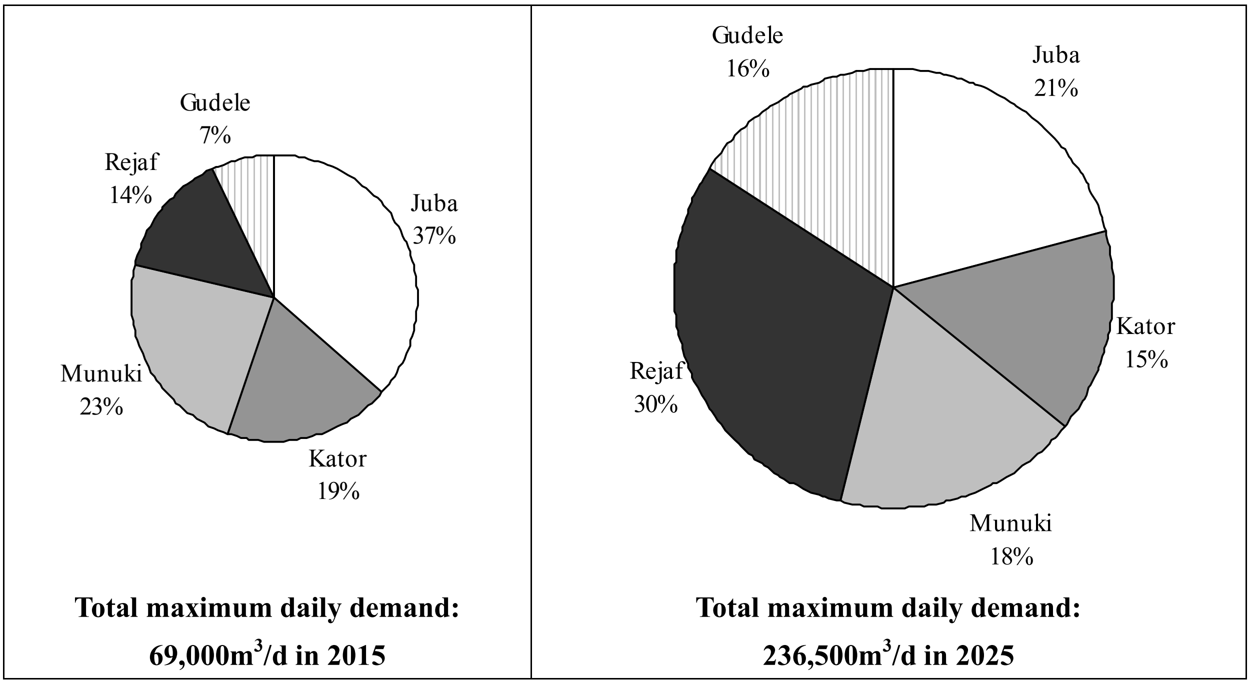


Figure 1.5 Estimated Maximum Daily Water Demand and Distribution by Payam

1.3 Selection of Water Supply Source

1.3.1 Existing Wells in Juba Urban Area

1) Well Yield

In the Target Service Area, the data of 439 wells are recorded by the MWRI and the data of 417 wells are analyzed. All wells are equipped with tube-well and hand-pump and used for drinking and other domestic purposes. The yield ranges from 0.1 m^3/h to 7.2 m^3/h with an average of 1.67 m^3/h. The maximum yield is equivalent to 173 m^3/d and it is quite small quantity for urban water supply.

2) Water Quality

The water samples of 89 existing wells were analyzed using on-site water quality analysis kit, which analyzes pH, TDS, salinity and EC. The result shows that 43 % of the samples exceed the draft Southern Sudan guidelines for drinking water quality in term of EC and TDS, and the same percentage of the samples have salty taste and not acceptable.

The water samples of 18 existing wells were collected and 27 parameters were analyzed in Central Water Testing Laboratories of Ministry of Water and Irrigation of Republic of Kenya. The result of laboratory test is tabulated in Chapter 4 of Part I and Appendix B, and summarized below. Seven (7) parameters out of the 27 parameters exceed the guideline values.

Table 1.10 List of Parameter Exceeding Guideline Value

Parameter	Guideline value	Number of Exceeding Samples	Percentage of exceeding samples	Range
Antimony (Sb)	0.005 mg/l	1	5.6 %	0 - 0.01 mg/l
Chloride(Cl)	200 mg/l	3	16.7 %	3 - 405 mg/l
Fluoride	1 mg/l	2	11.1 %	0.25 - 1.6 mg/l
Nitrate (NO3)	30 mg/l	3	16.7 %	0.12 to 260 mg/l
Nitrite (NO2)	0.5 mg/l	1	5.6 %	0 - 0.62 mg/l
Sodium (Na)	100 mg/l	14	77.8 %	35.5 to 754 mg/l
TDS	1,000 mg/l	4	22.2 %	369 to 2,300 mg/l

1.3.2 Potential Groundwater Source in Tokiman Paleochannel

A previous study by IFRC reported that the aquifer in Tokiman Paleochannel may have very high potential of groundwater discharge. This study result added that the aquifer with high discharge is composed of very thick alluvial deposits more than 150 m, connected to the Bahr el-Jebel, and directly recharged from the river. However, the result of the test boring by the Study Team indicates that groundwater is distributed only in following three types of small aquifers and no such thick aquifer has been identified.

- Groundwater level exists in relatively shallow (2 to 5 m) subsurface. Un-confined groundwater is distributed in alluvial deposit which forms Aquifer 1, and it is reddish-brown color and Fe and Mn exceed the guideline values.
- Also groundwater exists in un-confined weathered zone of gneiss with very small yield, which forms Aquifer 2.
- Confined fissure water is distributed in fractured zone of gneiss which forms Aquifer 3. EC of the groundwater is extremely high and exceeds the guideline value significantly.

Table 1.11 Summary of Results of Test Wells

Test well	Aquifer	Approx. depth	Type of groundwater	Water yield	Water parameters exceeding the guidelines	
					Field kit test	Laboratory test
Test well-1	1	50m	Un-confined	11.7 m^3/h (280 m^3/d)	Colored Fe: 5.4 mg/L Mn: 0.62 mg/L	Antimony Irion, Managanese, Sodiun, and TDS
Test well-2	3	200m	Fissure water	17.5 m^3/h (420 m^3/d)	EC: 4,630 µS/cm Fe: 0.47 mg/L Mn: 0.63 mg/L	Antimony, Iron, and Nitrite
Test well-3	2	100m	Un-confined	3.0 m^3/h (72 m^3/d)	Fe: 0.53mg/L	Antimony, Hardness, Chloride, Nitrate, Sodium, Sulfate and TDS

1.3.3 Surface Water

(1) River Flow

The other alternative water supply source for the Target Service Area is the surface water of the Bahr el-Jebel. For the evaluation purposes, river flow observation data measured by Dam Implementation Unit (DIU) at the upstream of the Juba Bridge between January and September 2008 using ADCP has been collected and analyzed. The minimum and maximum flow rates during this period are 1,125 m^3/s or 97.2 million m^3/d and 1,742 m^3/s or 150.5 million m^3/d, respectively. The depth of water in the river ranges between 4.0 m to 6.5 m from the bed.

(2) Water Quality

Water samplings from surface water of the Bahr el-Jebel during the rainy and dry seasons were carried out at existing water treatment plant intake in Juba Channel, midstream and upstream of the Bahr el-Jebel in the Juba stretch by the Study Team and analyzed in the laboratories and filed test kit. The results of water quality analysis were compared with the WHO guidelines (WHOGDW) and draft Southern Sudan guidelines (DSSGDW) for drinking water quality. In general, the qualities of surface water at 3 sampling points indicate that the water is good as a source for conventional water treatment, although the following parameters exceed the guideline values.

- Aluminum at all 3 sites in rainy season
- Antimony at the existing water treatment plant sites
- Iron at the existing water treatment sites in rainy season

The concentration levels of aluminum and iron could be reduced below the guideline values after conventional water treatment with using coagulation, sedimentation and rapid filtration.

In terms of the dry season results, only antimony exceeds at existing water treatment site. Comparing with the WHO guidelines, however, Antimony in the dry season is below the guideline value. It is recommended that these three parameters be monitored periodically and treatability of these parameters be assessed.

As a reference, a water sample from the existing water treatment plant site in May 2009 was collected and Antimony was analyzed in Tokyo, Japan. The result is below 0.005 mg/l.

As of microbiological parameters, the river water was evaluated as a good source of drinking water using conventional water treatment. The concentration of agro-chemicals analyzed was below the detectable level and pollution by agro-chemical cannot be identified in surface water samples analyzed in this Study.

1.3.4 Evaluation of Water Sources as Urban Water Supply Source

The feasibility of groundwater of existing wells and Tokiman Paleochannel and surface water is evaluated and summarized as urban water supply source in Table 1.12.

Based on the evaluation result, the surface water is feasible for urban water supply source but the groundwater in Tokiman Paleochannel is not feasible in terms of water quality and quantity. Groundwater of existing wells that complies with the draft Southern Sudan guidelines for drinking water quality can be continuously used as a supplemental water source for piped water supply.

Table 1.12 Evaluation of Water Source as Urban Water Source

Items	Evaluation guidelines	Surface water	Groundwater	
			Existing wells	Tokiman Paleochannel
Water quantity	Required water quantity is 237,000 m^3/d for 2025. *1	The minimum flow in 2008 was 97 million m^3/d. The required water quantity is equivalent to about 0.25 % of the minimum flow.	The average yield is 1.7 m^3/h (40 m^3/d) and the maximum yield is 7.2 m^3/h (170 m^3/d). These yields are far less than the required water quantity.	The yields of three test wells range in 72 – 420 m^3/d. These yields are far less than the required water quantity.
Water quality	Shall comply with Draft Southern Sudan Water Quality Guidelines.	In general, water quality is suitable for conventional water treatment.	In general, TDS is very high and some other parameters exceed the guidelines	The shallow groundwater has high iron and manganese values; the deep groundwater has high salinity contents (or TDS, EC); and the groundwater in intermediate depth has generally good water quality although the Iron level slightly exceed the SS Guideline.
Impacts on the source	-	Nearly no impact of river water abstraction on the river is foreseeable because the abstraction volume is quite little.	Excessive water withdrawal may cause lowering of groundwater table and reduced yield.	Excessive water withdrawal may cause lowering of groundwater table and reduced yield.
Feasibility as urban water source	-	Feasible	Not feasible	Not feasible
Recommenda-tion	-	Some parameters (Aluminum, Iron and Antimony) shall need periodical water quality monitoring.	Groundwater of wells complying with the guidelines can be used as a supplemental source for urban piped water supply.	Intermediate groundwater can be used for local water supply only although iron content slightly exceeds the guidelines.

Note: *1 Water quantity guideline for evaluation is set based on the estimated water demand in 2025.

1.4 Basic Policy of Water Supply Facility Planning

(1) Ensuring of Reliability of Water Supply and Lowering Risk of Failures

Water is an essential element for city activities including living, production and business activities and water supply system is one of the most important infrastructures in the city. Without it, all city activities could be stopped, especially when the city residents rely mainly on water supply system. Therefore, it is of vital importance to consider preventive measures against failure of water supply system such as large pipe break and accident of aqueduct-bridge in not only ordinary time but also emergency time and avoid fatal and long period disruption of water supply. In addition, future possible water quality degradation should be studied in deciding the location of water intake and reduce the risk of future potential water contamination of the source of water supply.

In order to strengthen the water supply system against failures and enhance the reliability of the system, following measures or concepts are effective and shall be adopted for planning policy.

- Usage of gravity water distribution
- Introduction of multiple transmission systems and mutual backs-up, if one system fails
- Decentralization of water supply facilities
- Introduction of District Metered Areas (DMAs) and mutual backs-up among DMAs
- Location of water intake to the water pollution free area in future

In planning, multiple alternatives of water supply system is prepared and compared to decide the best one. If the alternatives do not have significant cost difference, the alternative that includes these measures or concepts is adopted.

(2) Enabling of Staged Facility Construction

The water supply master plan (the Master Plan) is prepared for the target year 2025. Up to 2025, the water supply facilities will be constructed in stages to meet the required water demand at times. In general, it is relatively easy to add to the capacities of the facilities such as treatment plant, reservoirs and pumping stations. On the other hand, it is rather difficult to expand the capacities of pipelines consisting of transmission and distribution network, once they are installed. Therefore, the former facilities are planned to be constructed in stages but the construction of latter facilities are planned to meet the water demand in the target year of 2025. However, if any, the measures to reduce initial investment cost as much as possible shall be considered. These measures may include planning of multiple systems and implementation of system-wise implementation.

(3) Utilization of Topographic Advantage

Basically, water supply zoning and facility locations are planned considering advantage of topography of the area concerned. The Target Service Area is separated into two large areas by the Bahr el-Jebel: west and east banks. In the west bank, the topography of the Target Service Area is rather simple. The urbanized area has mainly developed in the east of Mt. Jebel Körök starting from the foothill of the mountain and reaching to the Bahr el-Jebel, where the land gently slopes down from 550 m to 450 m towards the river (see Figure 1.6). There are five small seasonal streams, which flow into the Bahr el-Jebel but these streams do not separate the Study Area due to their narrowness. In the east bank, the Target Service Area is much small than the west bank and the terrain is flat with low hill in the center of the Gumbo Town. To prepare a distribution zoning plan for the Target Service Area, these topographic characteristics are considered.

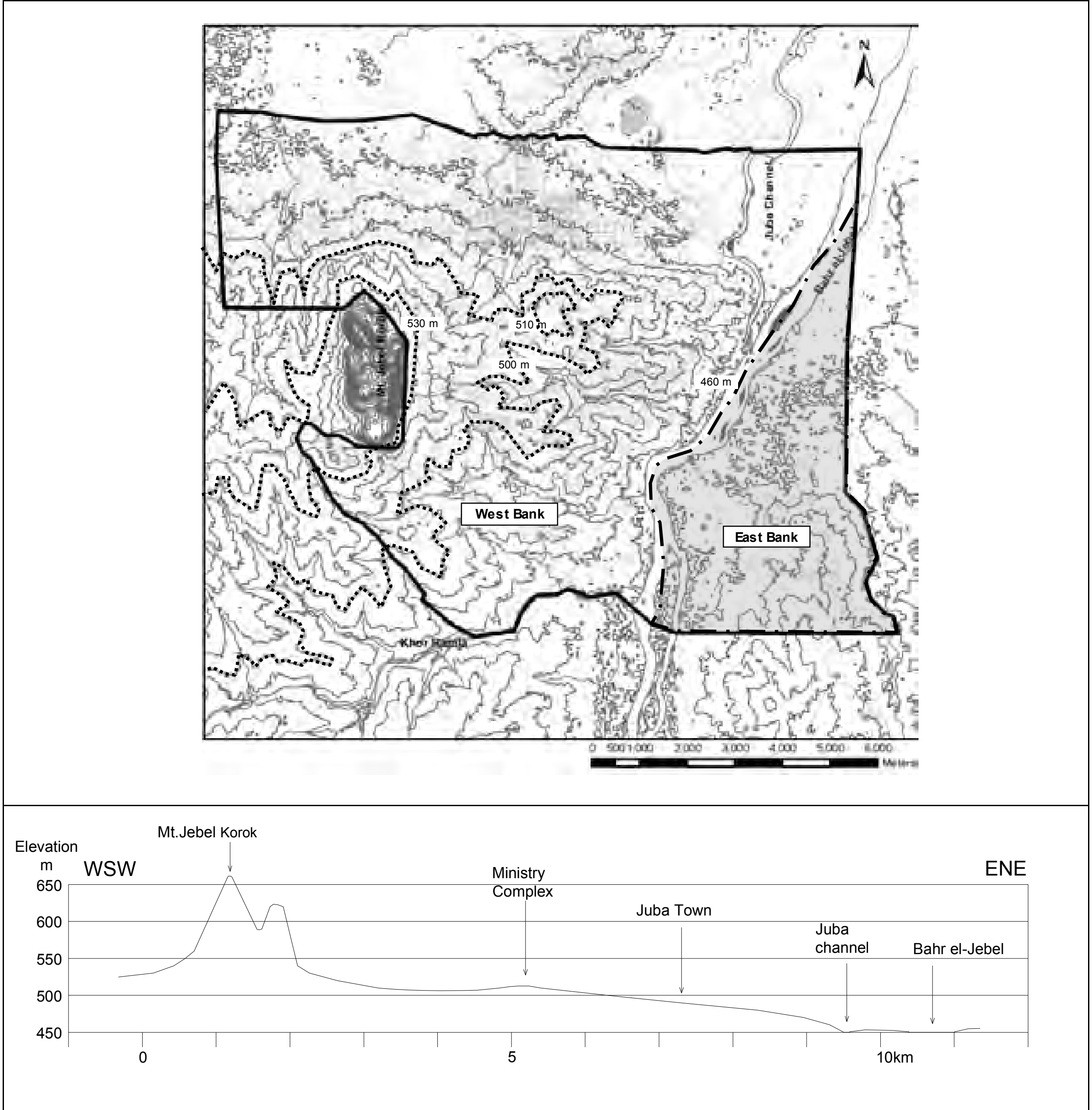


Figure 1.6 Topography in the Study Area

The gravity distribution of water in the supply area is an ideal distribution method, by which management of distribution is easy without the use of distribution pumping facilities, and the operation and maintenance cost can be optimized.

(4) Selection of Distribution Method

The following four options are considered to distribute water in a distribution zone. Basically, option 4 is recommended if the high elevated areas can be found in the distribution area because the control of water distribution is easiest in this case. If the high elevated area is not found in the area, option 2 and 3 is recommended and the operation is relatively easy; only switching on and off of pumps is required according to the water level of the elevated tank. If there is land acquisition problem or construction of service reservoir is not possible, in such cases option 2 should be adopted. In option 3, the control of water distribution (flow and pressure) is rather difficult and sophisticated pumping equipment is required for effective management of water distribution.

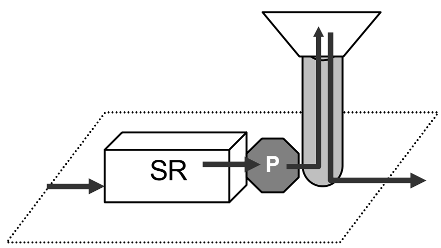
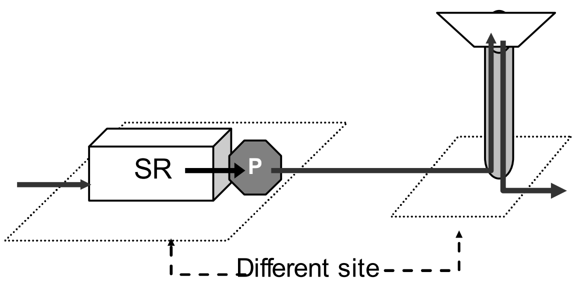
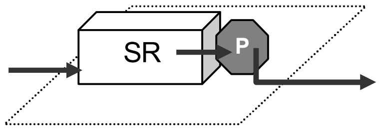
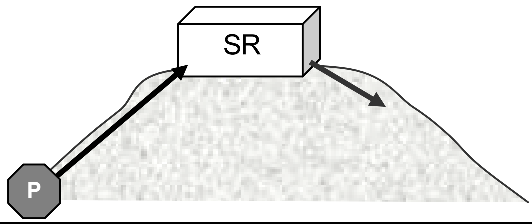
Option 1	Option 2
	
Combination of service reservoir, pump and elevated tank (Moderate operation difficulty)	Combination of service reservoir and pump, and remote elevated tank (The case that the land is limited for service reservoir)
Option 3	**Option 4**
	
Combination of service reservoir and distribution pump (Difficult operation: It requires sophisticated equipment to control water discharge according to the hourly fluctuating demand.)	Pump in water source and service reservoir on higher point (Easiest Operation)

Figure 1.7 Water Distribution Method from Service Reservoir

The mountain or high elevated area is located in the west of the Target Service Area and the terrain slopes gently from west to east. This topography is advantageous to distribute water from high area to low area by gravity. Therefore, gravity distribution of water shall be adopted as distribution method.

(5) Separation of Distribution Network from Transmission Line

In an attempt to improve water supply system in terms of providing adequate pressure and quantity, it is necessary to create the zoning system.

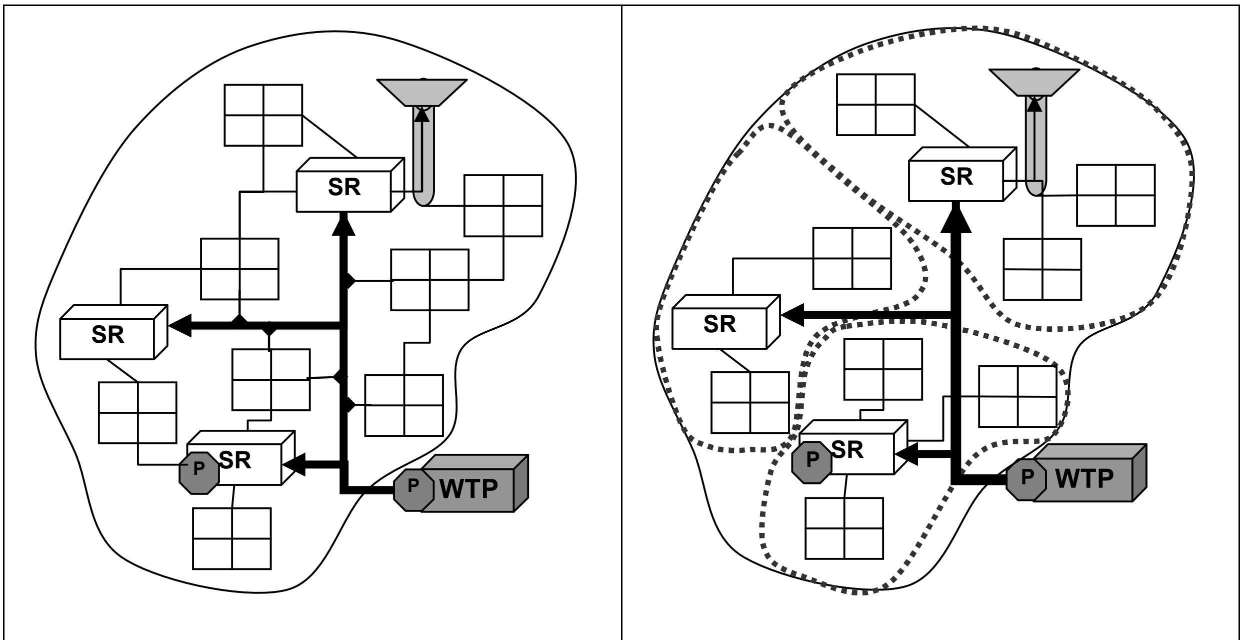
In the existing distribution network, the transmission and distribution mains are not separated but mutually connected. This makes the functions of the transmission and distribution mains unclear and the operation and maintenance complicated. Also, it is difficult to monitor the water distribution conditions (flow and pressure) and to control water distribution in the system.

The following are advantages of the system where distribution system is separated from transmission system.

- It is easy to monitor water supply conditions in transmission and distribution system
- It is easy to manage the water allocation to each distribution zone
- The pipe size of transmission system is smaller

Using the separated system, the transmission and distribution systems are planned to meet maximum daily and peak hour water demand, respectively. On the contrary, without application of the separated system, both systems should be planned to meet peak hour water demand, which results in larger capacity of water supply facilities.

For efficient water distribution management in a large water supply system, the separation of distribution system from transmission system and distribution zoning are proposed for future water supply system (see Figure 1.8). Distribution zoning also makes it easy to implement leakage control measures.



Transmission and Distribution Integarated System	Transmission and Distribution Separated System

Figure 1.8 Concept of Transmission and Distribution System

(6) Hierarchy of Distribution Zoning and Water Supply Facilities

This section describes the concept and the terminology and hierarchy for zoning system. Distribution zones, each of which has different functions, are categorized as shown in Table 1.13, considering water distribution management, and operation and maintenance.

Table 1.13 Hierarchy of Distribution Zoning

Category	Explanation
Distribution zone	Water is transmitted from water sources to distribution service reservoirs through transmission pipe, and then distributed from each service reservoir to respective distribution zone, each of which is basically independent from other distribution zone by valves. The water distribution pressure is mainly controlled in the zone so that the pressure in the zone remains in the specific range.
Sub-distribution zone	Sub-distribution zones are divided considering geological features and administrative or manmade boundaries and are a unit of operation and maintenance of distribution network.
District metered area (DMA)	District metered area is divided by several valves connecting DMA to distribution main and sub-main pipelines. The minimum area, which can be independent and the consumption can be measured, is defined as “District metered area”.

The existing distribution network is almost dilapidated with high leakage ratio. To reduce leakage and monitor the system by clusters, the concept of District Metered Areas (DMA) management should be introduced to the distribution network. DMA is a minimum area, which can become independent from adjoining DMA by valves and inlet and outlet flow of the area is measured. Followings are benefits of DMA.

- Adequate hydraulic pressure is assured.
- Leakage point and amount of leakage water can be grasped easily.
- When carrying out water rationing, it becomes an independent unit.
- The area of influence can be limited when the water must be stopped during repair work etc.
- Restoration becomes easier at the time of disasters.

Hierarchy of transmission and distribution system is defined as shown in Table 1.14 and Figure 1.9.

Table 1.14 Hierarchy of Transmission and Distribution System

Category	Function
Transmission main (TM)	Transmission mains consist of components that are designed to convey large amounts of water over great distances, typically between major facilities within the system, for example, between a treatment plant and a service reservoir, one service reservoir and another, or a pumping station to a service reservoir. Individual customers are not served from transmission mains.
Transmission pump (TP)	Transmission pumps are used for increasing water pressure within the transmission system.
Service reservoir (SR)	To store the treated water for distribution.
Distribution pump (DP)	Distribution pumps are used for increasing water pressure within the distribution system.
Distribution main (DM)	Distribution mains are trunk mains to transmit water in distribution pressure zone and an intermediate step toward delivering water to the end customers. Distribution mains are smaller in diameter than transmission mains. Frequently, distribution mains are connected to service reservoirs.
Distribution sub-main (DSM)	Distribution sub-main is branched off from distribution mains.
Distribution tertiary (DT)	Distribution pipes to be taped for house connection
House connection (HC)	Small diameter pipes branched off from distribution pipe to houses or end customers

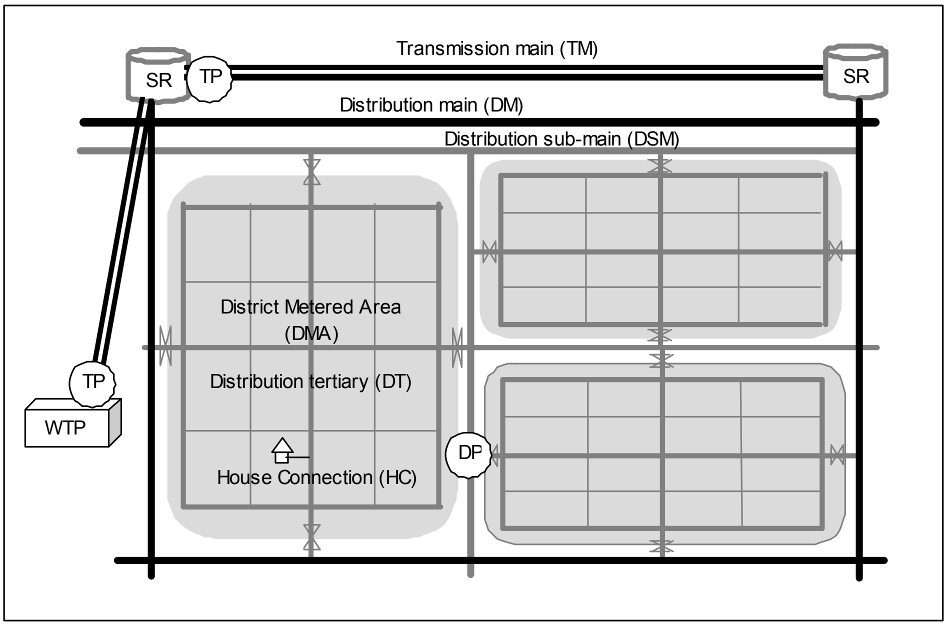
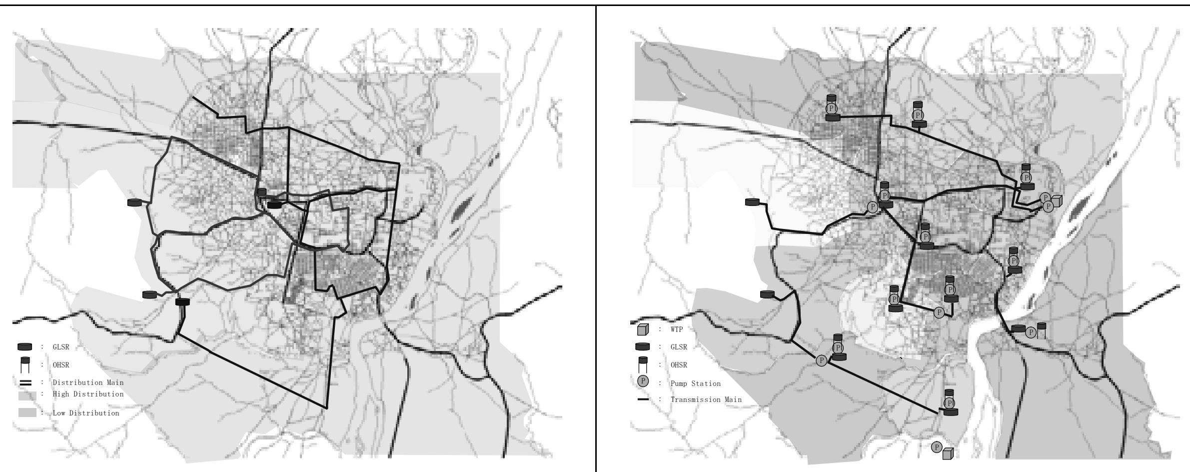


Figure 1.9 Transmission and Distribution System

1.5 Arrangement of Distribution Main Facilities

To distribute water in a distribution zone by gravity, distribution service reservoirs should be located at higher elevation than the supply area. On the other hand, if there is no such high area the water should be distributed by pump from the service reservoir. These service reservoirs and pumping facilities are called distribution main facilities.

To decide the appropriate arrangement of distribution main facilities, centralized or decentralized water distribution systems are to be compared. The characteristic of two water distribution systems are summarized in Table 1.15and conceptual arrangement of centralized and decentralized distribution systems in the Target Service Area is shown in Figure 1.10.



Centralized Distribution System	Decentralized Distribution System

Figure 1.10 Example of Conceptual Alignment of Centralized and Decentralized Distribution System

Table 1.15 Comparison of Centralized and Decentralized Distribution System

Item	Centralized distribution	Decentralized distribution
Zoning	A few large distribution zones are delineated according to topography and water is distributed from a few reservoirs. It is suitable for relatively flat land.	Many distribution main facilities are scattered according to allocation of demand. It is suitable for undulating land, where many zones can be made according to the difference in elevation and topography.
Distribution main facilities	O&M is simple as the number of distribution main facilities is a few.	O&M is rather complicated as there are many distribution main facilities.
Distribution pipeline	Diameter of distribution network is relatively large because water is distributed to relatively large area.	Diameter of distribution network is relatively small because water is distributed to relatively small area.
Influence area and mutual back-up	Influenced area of problems such as leakage is relatively large as a distribution zone is large. But this can be overcome by establishing district metered area (DMA). Mutual backup for water distribution between zones is relatively easy.	Influenced area of problems such as leakage is relatively small as a distribution zone is small. Mutual backup for water distribution between zones is relatively difficult.
Staged implementation	Staged implementation is relatively difficult as the system of each zone is large.	Staged implementation is relatively easy as each system is small and independent.

Centralized distribution method is adopted for the Study Area considering operation and maintenance easiness owing to the advantage of gravity water distribution. As for disadvantage of centralized distribution in terms of staged implementation, it can be overcome by selecting 2 transmission systems and utilizing the existing elevated tanks. This will be discussed later. In case of decentralized distribution, distribution pumps and/or elevated tanks are required in each distributing zone considering the study area's topography, which results in complicated operation and maintenance as many distribution main facilities are located.

1.6 Target Years of Major Project Scheme

The master plan period up to the target year in 2025 after the completion of this study in 2009 is 16 years. Considering the following conditions, the four project schemes up to the target year are prepared in Table 1.16,

- Trial operation scheme of the rehabilitated water treatment plant of Multi-Donor Trust Fund (MDTF) will be completed in 2010.
- Considerable period and large investment are required for construction of a new water supply system including new water treatment plant. To get benefits of the projects as early as possible, a short term and quickly implementable project shall be prepared before the start of implementation of construction of the new water supply system, which shall be started immediately after the completion of trial operation of MDTF scheme.
- Long term plan shall be divided into two major projects; priority projects and long term master plan scheme.
- The priority project components shall be components of the long term master plan.

Table 1.16 Establishment of Target Year and Major Project Components

Scheme	Target year	Major Projects
1. Current MDTF	2010	· Trial operation of rehabilitated WTP
2. Urgent Improvement	2012	· WTP expansion (up to 14,000 m^3/d) at existing WTP site · Urgent rehabilitation of distribution network in existing network area
3. Priority Project	2015	· Initiation of construction of a new water supply system · The system is the part of long-term Master Plan.
4. Long-term Master Plan	2025	· Completion of proposed water supply system in M/P · Expansion of future water supply area

CHAPTER 2 WATER SUPPLY FACILITY PLAN

2.1 Distribution Zoning

(1) Basic Conditions of Delineating Distribution Zoning

To delineate distribution zones, the following are preconditions:

- The location and the height of service reservoirs or elevated tanks are selected so as to distribute water directly to 2 stories buildings. Therefore, the minimum hydraulic pressure in the network should be not less than 1.5 kgf/cm^2 (equivalent to 15 m water head) in principle. However, in the hydraulically disadvantageous areas such as the remote area from service reservoir or near service reservoir, it shall be not less than 1.0 kgf/cm^2.
- Main roads, drains, streams, and routes of existing main distribution pipelines are considered in delineating distribution zones.

(2) Large Gravity Zoning

Water distribution zoning system is planned considering the topography of the area concerned. In Target Service Area, the following two salient features of topography are considered:

- Separation by the Bahr el-Jebel into two area
- Elevation difference in the west bank

The Target Service Area is divided into 2 main zones; west and east banks. In the east bank, the area forms one zone as the area is small and rather flat. In the west bank, the area can be separated into one or more zones as the area is large and the range of elevation is large. In the following section, the detail on zoning of the west bank is described.

(3) Gravity Zoning in West Bank

The elevation of the west bank gently slopes down from 540 m at the foothill of Mt. Jebel Körök (Jebel Kujur) to 460 m at the Bahr el-Jebel and the residential area is expanded in the same elevation range. The difference of the elevation is approximately 80 m, which is suitable to form one or two gravity distribution zones.

1) Location of Service Reservoir for Zones

If water is distributed by gravity, location of service reservoir is the most important factors to be studied. If water is supplied through one zone, the elevation of service reservoir should not be lower than 555 m. If water is supplied through two zones; high and low, the boundary of the two zones ideally should be half of the elevation difference, i.e. 500 m, and the elevation of service reservoirs should be at 555 m for high zone and 515 m for low zone.

Site survey of suitable land for service reservoirs was carried out and the location of high zone reservoir was evaluated. Finally, the elevation of high zone reservoir should be at around 540 m in elevation based on the following observations and evaluations.

- It was found that the elevation of around 540 m is the edge of mountain, from which the slope of mountain becomes very steep and the suitable land for location of service reservoir could not be found.

- In addition, the land higher than 530 m in elevation is quite limited at foothill of the mountain. Even in future, large population cannot be accommodated in this small area.

- If reservoir is built at higher land to supply water to small population, energy consumption to pump up large quantity of water that covers whole service area to higher reservoir site is considerable.

To distribute water to the area ranging from 530 m to 540 m in elevation considering optimization of energy efficiency, distribution zone above 530 m is separated from main distribution zone and supplied by independent local system such as small elevated tower.

2) Location of Service Reservoir for Low Zone

Existing service reservoirs will be utilized in the future water supply system wherever possible. Table 2.1 shows the specifications of existing reservoirs including availability of land for expansion. To utilize these reservoirs, the level of those reservoirs should be considered for defining boundary of distribution zones. Out of these sites, the parliament site is located at the center of the Target Service Area and at higher elevation. The site has also been reserved for service reservoir in the MDTF water supply project. The elevation of ground level of the site is about 510 m to 517 m. This is the best site for location of low service reservoir and this site should be one location of the low service reservoir.

Table 2.1 Type and Level of the Existing Service Reservoirs

Location	Type of reservoir	Ground level (m)	Low water level (m)	High water level (m)	Availability of land for expansion
Hospital	Elevated tank	+485m	+491m	+493.5m	No
Kator	Elevated tank	+485m	+496m	+499m	No
Parliament	Elevated tank	+517m	+536m	+540m	Yes

3) Evaluation of Distribution Zoning for West Bank

For water supply area of large distribution zone, two options for distribution zoning are prepared and the land with following elevation ranges are selected according to the topographic conditions, to supply water by gravity from service reservoirs .

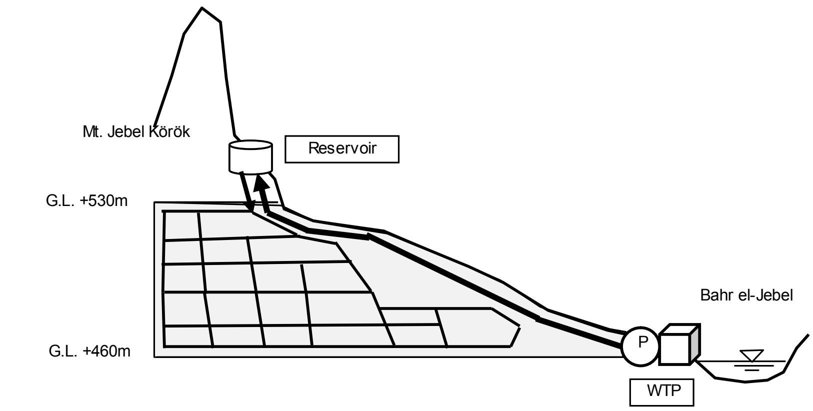
Table 2.2 Options for Large Distribution Zoning

Option	Number of large zone	Approximate elevation range in distribution area	Elevation of service reservoir	Number of service reservoir
A	1	540 m – 460 m (80 m)	540 m	One or more
B	2	540 m – 490 m (50 m)	540 m	One or more
		490 – 460 m (30 m)	510 m	One or more

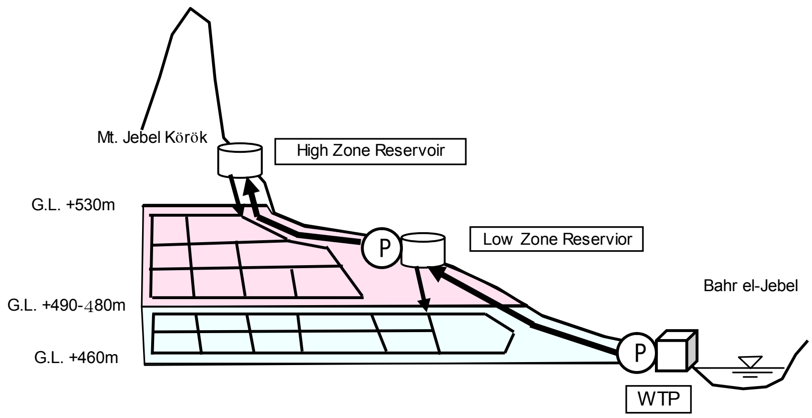
In case of two zones, low and high zones will be separated and the elevation of the boundary between two zones is at around 490 m. For the low zone, one or more reservoirs should be located at the altitude of around 510 m to 515 m to supply water to the low zone by gravity with appropriate pressure, considering the minimum hydraulic pressure and a head loss of approximately 3 m per 1000 m. Likewise, one or more reservoirs for high zone should be located at the altitude of around 540 m. The schematic layouts of these options are shown in Figure 2.1. In two large zones, the boundary of two zones is delineated considering natural conditions such as streams and rivers and manmade conditions such as major streets and administration boundaries, as well as elevation.

The two distribution zone system should be adopted for a large distribution system for the Target Service Area as it has following advantages over the one distribution zone system. The delineation of two large distribution zones is shown in Figure 2.2.

- Energy of pumping to service reservoir is less
- Unnecessary high water distribution pressure is avoidable and thus leakage is reduced
- Phased development of water supply facilities is easier
- Mutual back-up system between two systems can be built
- Affected area of accidental failures is reduced if one zone has problem



(1) One Gravity Zone



(2) Two Gravity Zones

Figure 2.1 Schematic Layout of Distribution Zoning in the West Bank

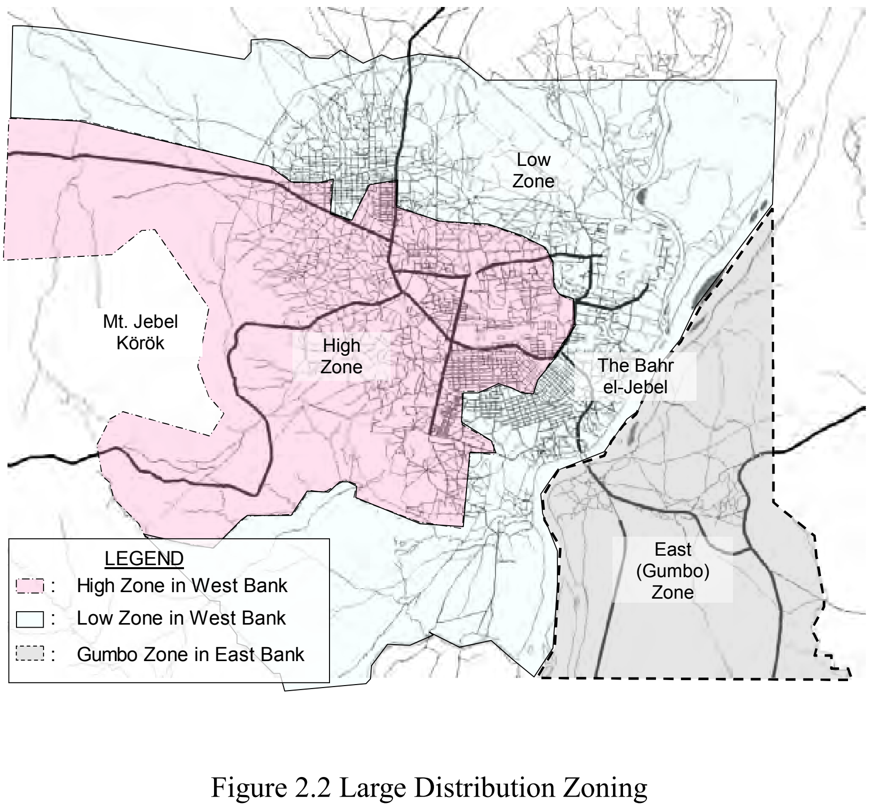


Figure 2.2 Large Distribution Zoning

4) Water Demand by Zone

Water demand by zone is calculated as shown in Table 2.3. The maximum daily water demand in 2025 has been estimated as 236,600 m^3/d including 96,300 m^3/d for the High Zone, 106,500 m^3/d for Low zone in the West Bank, and 33,800 m^3/d for the Gumbo zone in the East Bank.

Table 2.3 Water Demand by Zone

Area	Average Daily Water Demand			Maximum Daily Water Demand		
	2015	2020	2025	2015	2020	2025
West bank						
West High Zone	25,300	46,400	80,300	30,300	55,700	96,300
West Low Zone	26,900	50,700	88,800	32,300	60,800	106,500
Sub-total	52,200	97,100	169,100	62,600	116,500	202,800
East bank						
Gumbo Zone	5,300	14,100	28,200	6,400	16,900	33,800
Total	**57,500**	**111,200**	**197,300**	**69,000**	**133,400**	**236,600**

2.2 Required Capacity of Proposed Major Water Supply Facilities for 2025

The capacity of water intake, treatment and transmission facilities is basically decided so as to meet daily maximum water demand. On the other hand, the capacity of distribution network is designed so as to flow maximum hourly demand. To absorb the gap of the capacity between water transmission and distribution, service reservoir is designed. The required capacity of service reservoir to absorb the capacity gap is varied according to the pattern of hourly demand. In accordance with experiences in cities of similar population scale as Juba, service reservoir requires the capacity equivalent to at least 4 to 6 hour-volume of daily maximum water demand for planning purpose including fire protection use. Reservoir also has a function of storing water for emergency uses such as disruption of water by transmission main or water quality accident in water treatment plant. Therefore, it is recommended that reservoir shall have the capacity equivalent to 8 hours volume of maximum daily water demand.

Based on the estimated maximum daily water demand, the required total capacity of proposed major water supply facilities (water treatment plant and service reservoir) in 2025 is calculated as shown in Table 2.4. The total required capacity of water treatment plant is 237,000 m^3/d composed of 203,000 m^3/d and 34,000 m^3/d for the west bank and the east bank, respectively. The total required capacity of service reservoir is 79,000 m^3 composed of 68,000 m^3 and 11,000 m^3 for the west and east banks, respectively.

Table 2.4 Required Capacity of Proposed Major Water Supply Facilities in 2025

Facility	Unit	West Bank			East Bank	Total
		High Zone	Low Zone	Sub-total	Gumbo Zone	
Water Treatment Plant - To produce the water amount equivalent to maximum daily demand	m^3/d	96,000	107,000	203,000	34,000	237,000
Service Reservoir - To store the water amount equivalent to 8 hours of maximum daily demand	m^3	32,000	36,000	68,000	11,000	79,000

2.3 Site for Surface Water Intake and Water Treatment Plant

As established in Section 1.6 , the project period is divided into three terms.

- Urgent improvement in 2012
- Priority project target in 2015
- Master plan target in 2025

The expansion of the existing water treatment plant can be started shortly and completed without any problem as land acquisition is not required and the expansion capacity is small since the land availability is limited at the existing water treatment complex. Furthermore, it can be developed without construction of large transmission system as it is located in the center of the city, comparing with the construction of a new water supply system in the master plan, which requires land acquisition for water supply facilities and long period and a large amount of investment cost. Therefore, the expansion of existing water treatment plant and rehabilitation of existing distribution network shall be implemented first prior to construction of a new water supply system.

In addition, it is difficult task to meet management system with a quick expansion of large water supply system. From a management aspect, therefore, a gradual expansion of water supply system is feasible.

In the urgent improvement scheme, the existing water supply system including expansion of existing treatment plant will be rehabilitated and improved. Then a new water supply system will be constructed up to 2025. In this plan, therefore, at least 2 water treatment plants will be planned for existing and new water supply systems. In this section, the following water treatment plants are studied.

- Expansion of the existing water treatment plant
- Sites of new water treatment plants for new water supply system

(1) Existing Site of Intake and Water Treatment Plant

In May, 2009, the reconstruction of a water treatment plant with a capacity of 7,200 m^3/d was completed in the existing water treatment plant site and is now in operation. The possible expansion capacity of the existing water treatment plant is studied, considering the available land area at the existing site.

To understand the possibility of expansion of the existing water treatment plant, a site survey was carried out by the Study Team. The survey has identified that the land of approximately length 70 m and width 35 m is available for expansion as shown in Figure 2.3, by demolishing the old nonfunctional existing plant. In this land area, the same capacity of water treatment plant as the newly constructed plants, i.e. 7,200 m^3/d, can be constructed, adopting high rate coagulo-sedimentation method as treatment process, the same treatment process as the newly constructed water treatment plants. Adoption of this method to proposed water treatment expansion keeps consistency of the plant in terms of operation and maintenance and reduces the required land for the plant. Therefore, 7,200 m^3/d (or 7,000 m^3/d) of water treatment plant shall be expanded at the existing water treatment site.

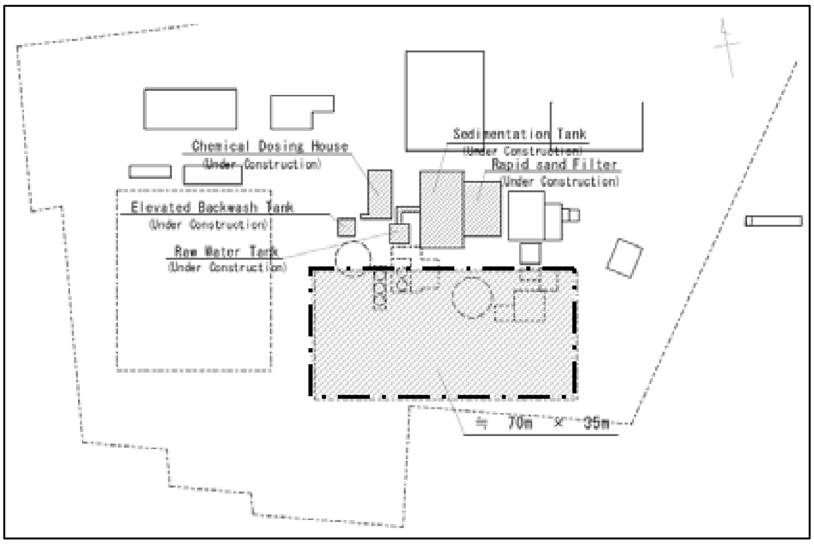


Figure 2.3 Available Land for Expansion in the Existing Treatment Plant Site

(2) Configuration of New Water Treatment Pants for West and East Banks

The Target Service Area is separated into two areas by the river; west and east banks. Taking this into account, following two alternatives can be considered for water transmission system.

- Alternative-1: A water treatment plant is constructed in the west basin that has large water demand and produced water in this plant be conveyed to the east bank through pipe across the river.
- Alternative-2: Two water treatment plants are constructed in the west and east banks separately.

The required water treatment plant capacity for these alternatives is estimated in Table 2.5. In each alternative, the total required capacity of the new water treatment plants is calculated by subtracting 14,000 m^3/d, the proposed total water treatment plant capacity in the existing site, from the total water demand.

The schematic layout of the alternatives and their comparison are shown in Figure 2.4 and Table 2.6.

Table 2.5 Required Water Treatment Capacity (m^3/d) in 2025

Item	Alternative-1	Alternative-2
Maximum Daily Water Demand	237,000	237,000
Existing WTP Site	14,000	14,000
- Existing capacity	7,000	7,000
- Expansion capacity	7,000	7,000
New WTP	223,000	223,000
- West Bank	223,000	189,000
- East Bank	0	34,000

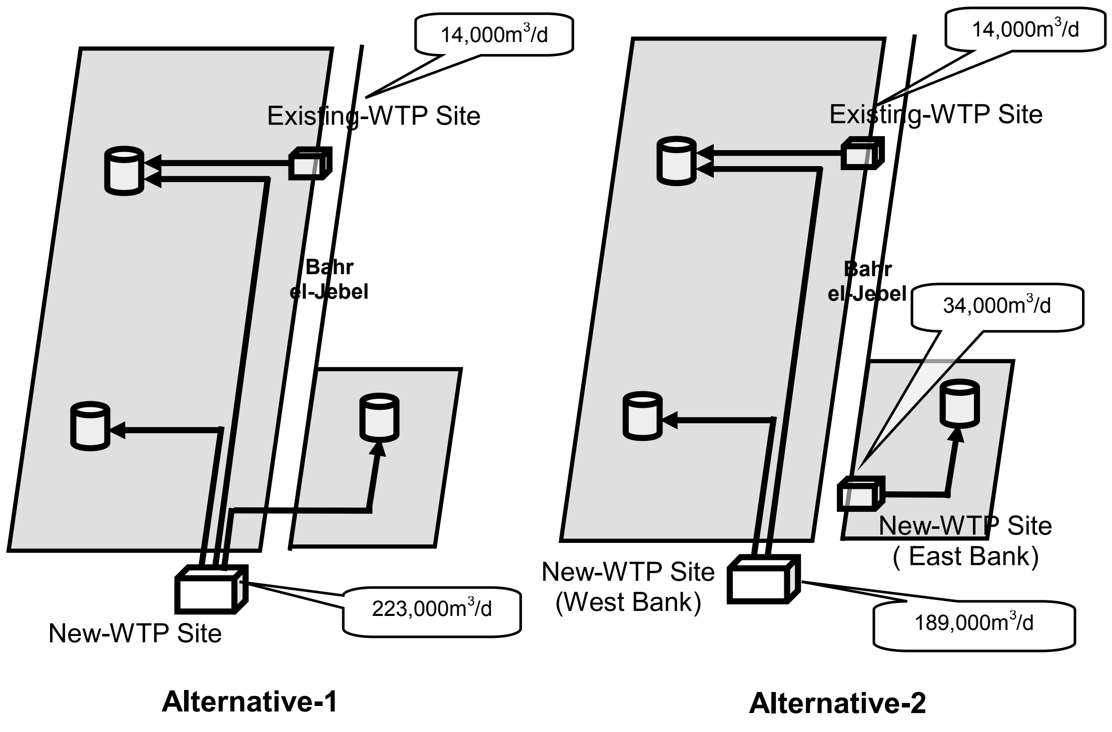


Figure 2.4 Schematic Layout of Alternatives of Configuration of New Water Treatment Plant

Table 2.6 Comparison of Alternatives of New Water Treatment Plants

	United System (One)	Separated System (Two)
Facilities& Required Land	2 WTP Sites Existing Site : 14,000 m^3/d New Site : 223,000m^3/d (265m×150m)	3 WTP Sites Existing Site : 14,000 m^3/d New Sites : (West) 189,000 m^3/d (245m×130m) (East) 34,000 m^3/d (175m×75m)
Important factors to be considered	Road bridge is required for pipe crossing to the east bank.	Road bridge is not required.
Construction schedule	The schedule of pipe crossing work affected by the construction schedule of new bridge.	It may not be possible to construct 2 new WTP at the same time.
Risk	Fatal disruption of water supply in the east bank, when the bridge for pipe crossing falls down.	The risk of one system can be avoided.
Operation and maintenance	Two water treatment plants shall be maintained and operated.	Three water treatment plants shall be maintained and operated. Personal expense is higher than the united system.
Required cost for construction of water treatment plant until 2025	WTP West : 112.1 million USD Additional transmission pipe cross the river: 1.7 million USD 113.8 million USD (100%) (The cost does not include construction of road bridge.)	WTP West : 95.6 million USD WTP East : 31.1 million USD 126.7 million USD (111%)
Cost until 2015	47.7 million USD (100%)	49.3 million USD (104%)
Net Present Value (NPV)	49.8 million USD (100%)	54.4 million USD (109%)
Overall evaluation	・ Operation and maintenance burden is relatively small ・ The construction cost is smaller. ・ The pipe crossing over the river depends on the construction of new bridge.	・ Operation and maintenance burden is relatively large. ・ The construction cost is greater. ・ The pipe crossing over the river does not depend on the construction of new bridge. ・ The risk of one system can be avoided.

Alternative-2 is advantageous in terms of construction costs and less complicated operation and maintenance. However, the construction cost does not include the construction cost of bridge for pipe crossing and the construction depends on the implementation schedule of road bridge construction schedule as the pipe will be placed on the bridge to reduce construction cost of an independent aqueduct over the river. Also the risk of fatal disruption of water supply in the east bank is higher, when the bridge for pipe crossing falls down, although the probability of falling down of bridge by the accident and natural disasters such as flood is very low. Once it falls down, it would take considerable time for recovery. Consequently, by placing greater importance on ensuring reliability of water supply and lowering risk of failures, Alternative -2 is selected for the location of water treatment plants in the west and east banks.

(3) Locations of New Water Intake and Water Treatment Plant in West Bank

1) Initial Screening of Site for New Water Intake and Water Treatment Plant

The result of water quality analysis indicates that the water qualities at the upstream, mid-stream and downstream of the river have very similar characteristics and in general, the qualities of surface water at mid-stream and upstream locations are suitable for water source for conventional water treatment.

For initial screening of location of water intake points, the condition of land availability was checked. At the intake, a pumping station is required and water treatment plant should be located at the nearby site of pumping station. Therefore, enough land should be available for these facilities at the nearby river side.

In the field observation survey along the river side by the Study Team, it was observed that most of the river side in the urbanized area is flood plain during rainy season and has unstable soil or occupied by residence area including IDP camps as shown in Figure 2.5. Therefore, the land in urbanized area is excluded as the candidate for proposed site of new intake and water treatment plant. Although the candidate sites can be found both downstream and upstream of the Juba urbanized area, an intake site shall be selected at the upstream of the urbanized area to avoid any concern of future contamination of the downstream river water by discharged wastewater from the urbanized area.

To find vacant areas for the candidate sites, the Study Team visited the southern area of the confluence of the Khor Ramla River, a seasonal stream that flows into the Bahr el-Jebel in the south of Juba urbanized area. Through the field observation survey in this area along the Bahr el-Jebel, it was observed that most of the area is located in flood plain and the soil is unstable. Such conditions are not suitable as the site for intake structure and water treatment plant. However, following two sites were found stable and suitable as the site of these facilities.

- The area near the confluence of Khor Ramla River (Alternative-1)
- The area near the experimental farm of Juba University (Alternative-2)

These sites for intake and new water treatment plant are compared as shown in Table 2.7.

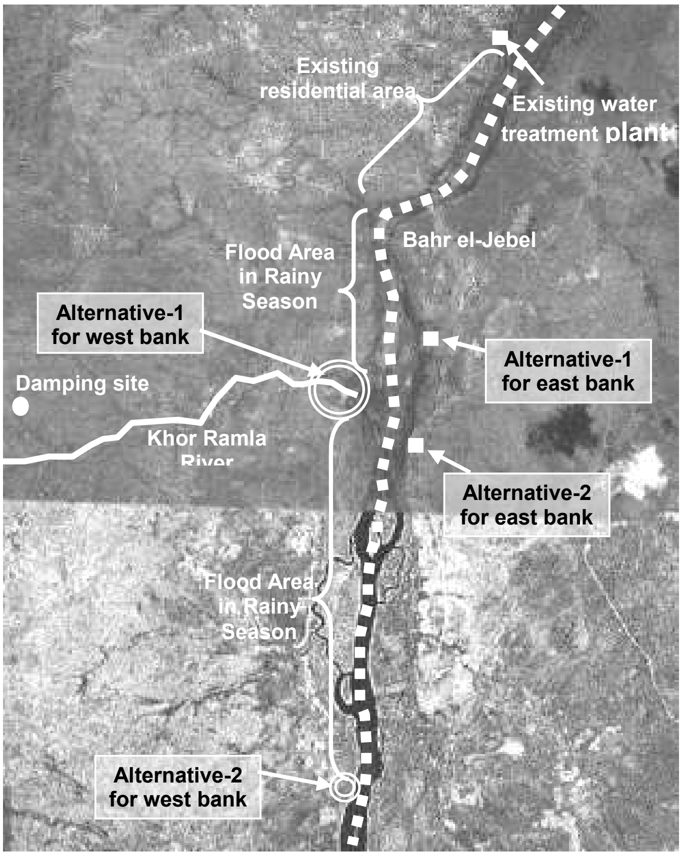


Figure 2.5 Alternatives of Intake Point along the Bahr el-Jebel

Table 2.7 Comparison of Alternatives of Intake Points

Item	Alternative-1	Alternative-2
1. Location	The area near the mouth of Khor Ramla River	The area near the experimental farm of Juba University
2. Water quality	Both areas are located upstream of the Juba urbanized area and there are only a few settlements nearby. The water pollution caused by human activities is negligible. Therefore, the water quality of both intake sites is likely the same and clean.	
3. Land availability	Alternative-2 is located far from the urbanized area and land acquisition is possibly easier than Alternative-1. Land availability shall be checked with the relevant community.	
4. Construction cost	The location of the alternative-2 is about 7 km far from Alternative-1 from Juba urbanized area. Additional construction cost of transmission main and road for alternative-2 is required.	
5. Operation and maintenance cost	Electricity expense of Alternative-2 for pumping is higher as required head of transmission pumps is higher. (The cost of chemicals for treatment is the same as water quality is same.)	
6. Access to facilities	The site access is inconvenient in the Alternative-2 and operators are required to travel longer distance.	
Overall preliminary evaluation	The construction and O&M costs are lower and the site access is easier. (Selected)	

Alternative-1 is selected as the site for water intake and water treatment plant because it has several advantages over Alternative-2 including lower construction and operation & maintenance costs and easier access to the site.

2) Options of Location of Intake and Water Treatment Plant Sites

The river bank and nearby area are low land area and submerged under water in rainy season. When the site for intake pumping station and water treatment plan is selected, such water-logged area should be avoided for the site. The following 3 options are evaluated to select the configuration of intake facilities and water treatment plant considering this aspect. From operation and maintenance aspect, it is recommended that intake facilities including raw water pumps and water treatment plant be located in the same site.

Table 2.8 Options for Location of Intake Facilities and Water Treatment Plant

Option	Location of Facilities	Recommendation
A	Intake facilities are located in the upstream of the mouth of Khor Ramla River and water treatment plant is located in the downstream, if the land for water treatment plant is available in the downstream of the mouth.	
B	Both intake and water treatment are located in the same site in the upstream of the mouth of Khor Ramla River	Recommended option
C	Both intake and water treatment are located in the upstream of the mouth but intake facilities and water treatment plant are located in different site.	

3) Details on Candidate Sites for New Water Intake and Water Treatment Plant for West Bank

The more exact site for intake and water treatment plant should be selected. The Study Team has selected two candidate sites for this purpose; one at the upstream (alternative-1) and the other at downstream (alternative-2) of the Khor Ramla River as shown in Figure 2.6. These sites are compared in Table 2.9 to select a more suitable site for intake and new water treatment plant for the west bank.

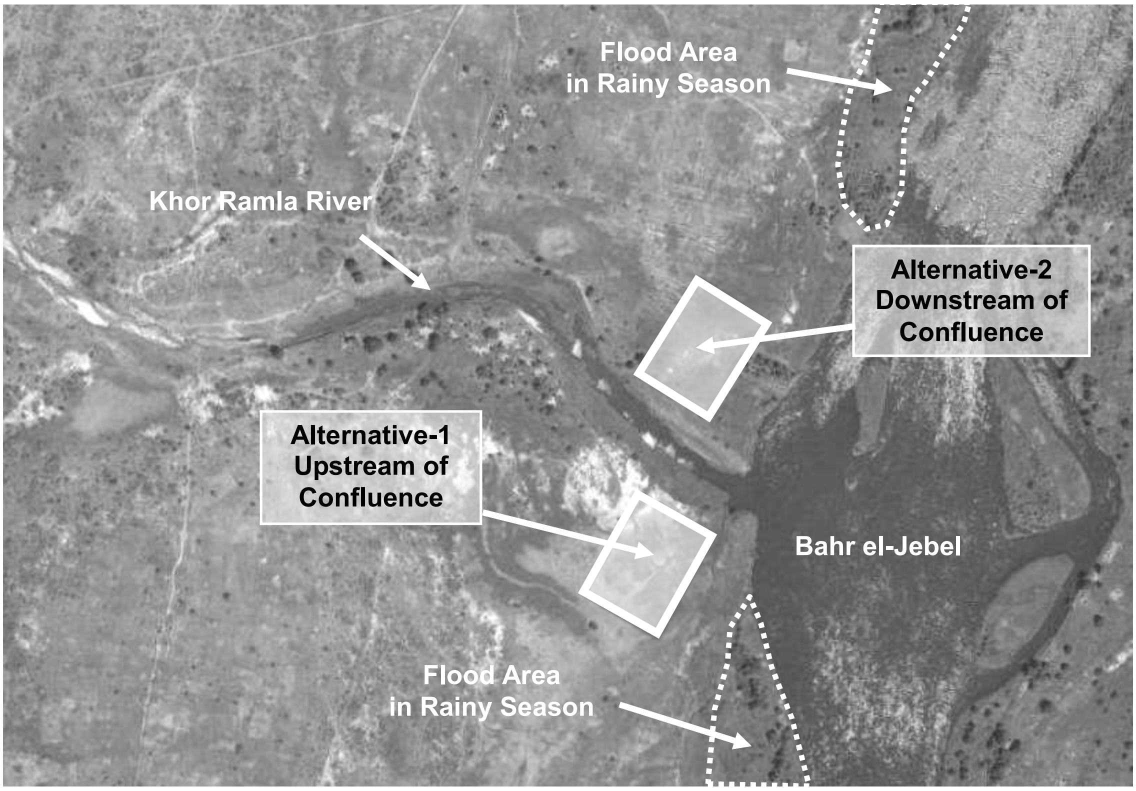


Figure 2.6 Details on Candidate Sites of New Water Intake and Water Treatment Plant for West Bank

Table 2.9 Comparison of Alternatives of Intake and Water Treatment Plant in West Bank

Item	Alternative-1 Upstream of Confluence	Alternative-2 Downstream of Confluence
1. Water quality	The current water quality at both intake sites is suitable for conventional water treatment. However, there is a possibility of contamination from dumping site located in the catchment of Khor Ramla River in future.	
2. Transmission main	Transmission pipe must get across Khor Ramla River and relatively long.	Transmission pipe is not needed to get across Khor Ramla River and relatively short.
		(O)
4. Construction cost until 2025	WTP West : 95.6 million USD Bridge : 1.5 million USD Add Pipe: 1.0 million USD Total: 98.1 million USD (102.8%)	WTP West : 95.6 million USD Total: 95.6 million USD (100.0%)
		Relatively small (O)
5. Land acquisition	More easy because there is vast vacant field	Relatively difficult because residential area is approaching and available land is less than Alternative-1.
Overall preliminary evaluation	The difference of construction costs is not significant, but the upstream site is free from future potential contamination and land acquisition is easier. (Selected)	

Construction cost of alternative-1 is relatively high because of additional cost for bridge crossing over the Khor Ramla River and slightly longer pipe length, but the difference is not significant.

The Study Team had a site survey to confirm whether any potential pollution sources is located in the upstream of the Khor Ramla River and found that the existing damping site of Juba city is located in the upstream of the watershed of the river. To avoid any potential pollution to the source of water supply and considering land acquisition easiness, the Study Team has selected Alternative-1 as the intake site. The further exact site shall be selected in consultation with local communities.

(4) Locations of New Water Intake and Water Treatment Plant in East Bank

Along the east bank of the Bahr el-Jebel, the vast unused land that is not submerged in the rainy season is extending, especially in the upstream of the river. As discussed previously on the location of water treatment plant in the west bank, the location of water treatment plant for the east bank should avoid the downstream of the Khor Ramla River, or upstream of the downstream end of the towhead in the river near the confluence of the Khor Ramla River. If the land is available, the nearest site to the water demand is preferable for water treatment site. As a result of the field survey along the Bahr el-Jebel, the land shown in Figure 2.6 is selected as the site for water treatment plant in the east basin as it is near the Gumbo town and its soil is stable rock base.

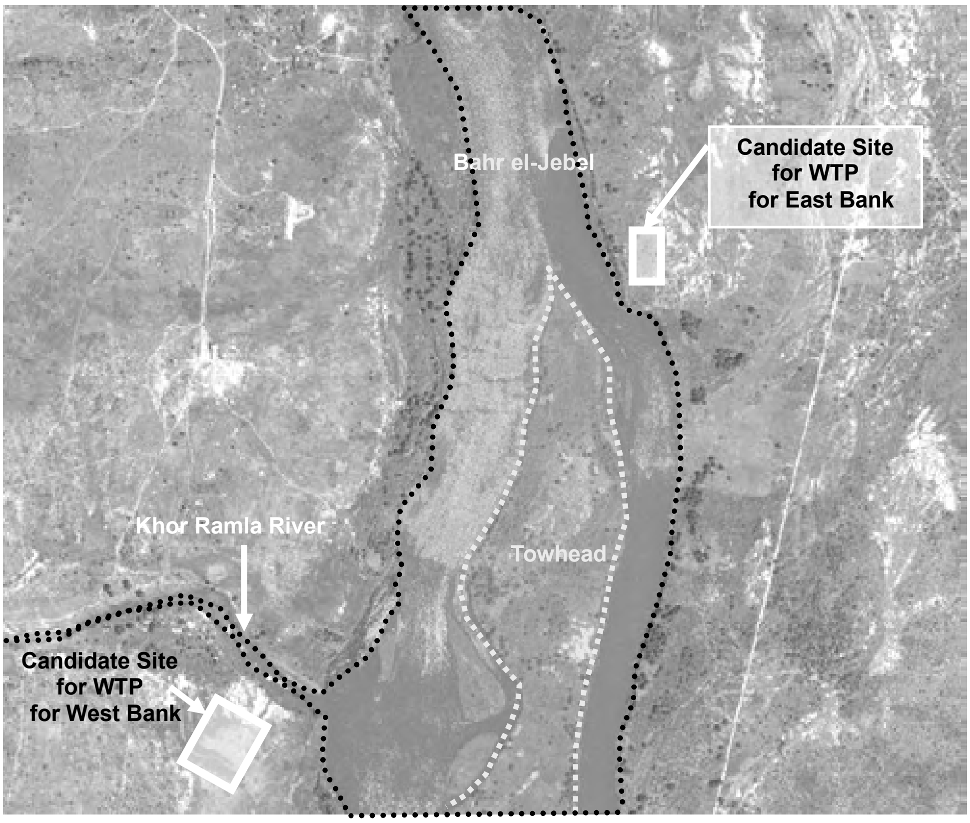


Figure 2.7 Sites for New Water Intake and Water Treatment Plant for East Bank

2.4 Design of Water Treatment Plant

(1) Treatment Process

1) Expansion of Existing Water Treatment Plant

The turbidity of the raw water of the Bahr el-Jebel in existing water treatment plant is as follows. To reduce this turbidity to the draft Southern Sudan guidelines for drinking water quality (DSSGDW), conventional treatment methods, high rate coagulo sedimentation and rapid filtration or horizontal flow sedimentation and rapid filtration can be adopted.

Sampling date	Sampled by	Turbidity
2005/09	GIBB Africa	46 NTU
2008/10/8	the Study Team	17 NTU
2008/11/28	the Study Team	17 NTU
2009/02/17	the Study Team	19 NTU
2009/5/21	the Study Team	49 NTU

The existing water treatment method is high rate coagulo-sedimentation and rapid filtration, which requires comparatively smaller area. The available land in the complex of the existing water treatment plant is limited and about 2,500 m^2 (70 m x 35 m) is available for expansion of facility. Within this land area, a new water treatment plant with the same capacity as the existing water treatment plant can be accommodated, if the same treatment method is adopted for expansion. Considering the limited land and consistency of operation and maintenance of the existing water treatment plant, high rate coagulo-sedimentation and rapid filtration shall be adopted as the treatment method of expansion plant and new water treatment facilities of the same capacity as the existing water treatment plant shall be constructed.

In designing expansion plant, the same design parameters, water levels etc. as in case of the existing facilities shall be adopted to maintain consistency, and existing common use facilities such as chemical injection, back-wash and drainage facilities shall be used for expansion plant to reduce the required land and costs.

2) Proposed New Water Treatment Plant for West and East Banks

The turbidity of the raw water of the Bahr el-Jebel in proposed water treatment plant is as follows. To reduce this turbidity below the guidelines, sedimentation and slow sand filtration, high rate coagulo sedimentation and rapid filtration or horizontal flow sedimentation and rapid filtration can be adoptable. Treatment method adoptable for the turbidity range of raw water is shown in Figure 2.8.

Sampling date	Sampled by	Turbidity
2008/10/8	the Study Team	17 NTU

2008/11/24	the Study Team	14 NTU
2009/02/17	the Study Team	19 NTU
2009/5/21	the Study Team	35 NTU

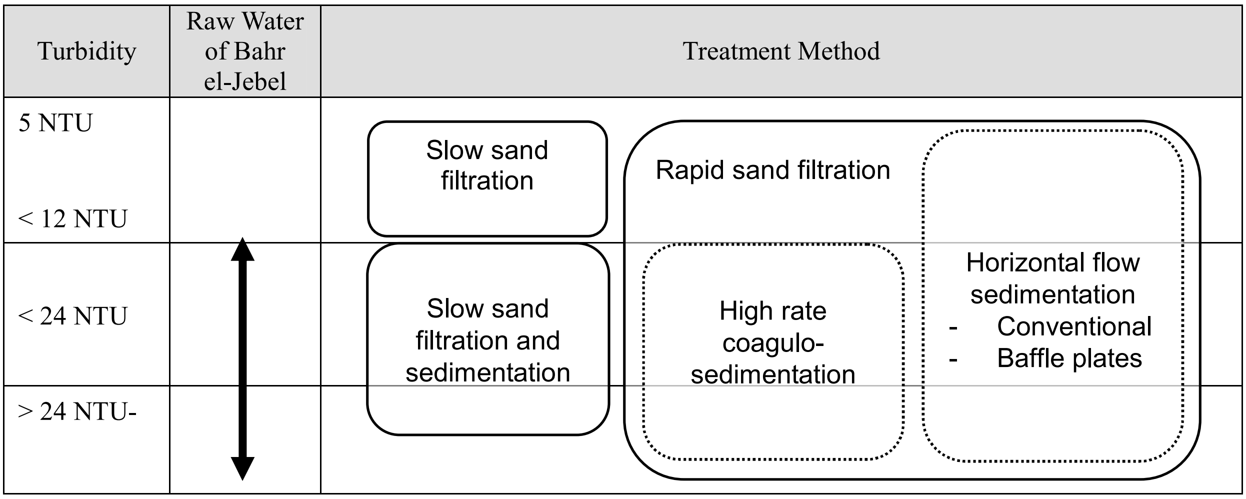


Figure 2.8 Treatment Method Adoptable by Turbidity Range of Raw Water

The following four treatment methods shall be evaluated for adoption of proposed new water treatment plant.

1. Slow sand filtration with sedimentation
2. Rapid sand filtration (along with)
   - 2.1 High rate coagulo-sedimentation basin
   - 2.2 Horizontal flow sedimentation basin
   - 2.3 Horizontal flow sedimentation basin with baffle plate

At first, slow sand filtration with sedimentation basin and rapid sand filtration with horizontal flow sedimentation are compared in Table 2.10. The treatment capacity for comparison is 200,000 m^3/d.

Table 2.10 Comparison of Slow Sand Filtration and Rapid Sand Filtration (Horizontal flow)

Item	Slow Sand Filter	Rapid Sand Filter (Horizontal flow)
Capacity	200,000 m^3/d	200,000 m^3/d
Design criteria	5 m/d	150 m/d
Required area	140,000 m^2 (450 m x 310 m)	40,000 m^2 (265 m x 150 m)
Construction Cost	Relatively low	Relatively high
Land acquisition	Need large land acquisition and cost for land acquisition is large.	Does not need large land and cost for land acquisition is relatively low
O&M Cost	Relatively Low, but need a lot of labor for sand scraper	Relatively High, need higher technology for operation
Operation and maintenance	O&M items are periodical sand scraper, sand washing, and refilling. It requires a great deal of labor. The process does not use complicated mechanical equipment and O&M is simple. But automation is not possible.	Turbidity removable control needs experience and skills. All process can be automated.
Processing treatment ability	The treatment uses biological process. After sand exchange, it requires several weeks to stabilize the ability of treatment. In addition, the ability of treatment depends on raw water quality (temperature, turbidity). The process cannot adapt to a rapid change of raw water quality and high turbidity.	The treatment uses physical process and can adapt to the rapid changes of raw water quality if chemical dozing is done appropriately.
Environmental and social impacts	Large land acquisition is required.	
Overall evaluation	It requires large land and land acquisition costs are high. It cannot adapt to higher turbidity and change of raw water quality. Turbidity may increase temporarily in heavy rain so that treated water quality could be degraded.	Construction cost and O&M costs are higher but adaptability to change of raw water quality is higher and required area is smaller. (Selected)

As a result of evaluation and with following advantages, rapid sand filtration method shall be adopted as water treatment process for proposed new water treatment plant.

- Adaptability to change in raw water quality and higher turbidity is higher.
- The required area is smaller.
- Environmental and social impact of land acquisition is less.
- It is a conventional method and control method is well established.

Three derivatives of rapid sand filtration mentioned above (high rate coagulo-sedimentation; high rate, horizontal flow with baffle plate, and horizontal flow sedimentation basin) are compared in Table 2.11.

As a result of comparison and considering following advantages, horizontal flow sedimentation is selected as the treatment method for proposed new water treatment plant

- Operation and maintenance is moderate and is well established.
- It is adaptable to any turbidity level of raw water.
- It is robust in the large and rapid fluctuation of turbidity.
- It is the most conventional method of rapid sand filtration.

Table 2.11 Comparison of Rapid Sand Filtration Methods

Item	High rate coagulo sedimentation	Horizontal flow sedimentation with baffle plate	Horizontal flow sedimentation
Process	Efficiency of flocculation is improved by flocculating in the presence of existing floc.	Efficiency of sedimentation is improved by installing baffle plate.	Conventional type of sedimentation depending on gravity sedimentation.
Adoptability to turbidity of raw water	Turbidity of raw water should be more than 12 NTU. It is adaptable to higher turbidity. Fluctuation of turbidity and water temperature should be less.	It is adaptable to any turbidity of raw water. It is robust in the fluctuation of turbidity.	
	Less favorable	Good	Good
Required area	Small	Small	Fair
O&M	Machine is required for flocculation and is susceptible to breaks. The O&M is more difficult than horizontal type.	Baffle plates are required to be changed periodically. Storage of sludge is short period and drainage of sludge is required frequently because the capacity of sludge disposal is small.	Period of storage of sludge in sedimentation basin is long and removal of sludge is required less frequently as the capacity is large.
	Less favorable	Less favorable	Good
Overall evaluation		If the enough land is not available, this type will be considered.	Selected

3) Treatment Process for Proposed New Water Treatment Plant for West and East Banks

The selected process for proposed water treatment plant for the west and east banks is outlined in Figure 2.9.

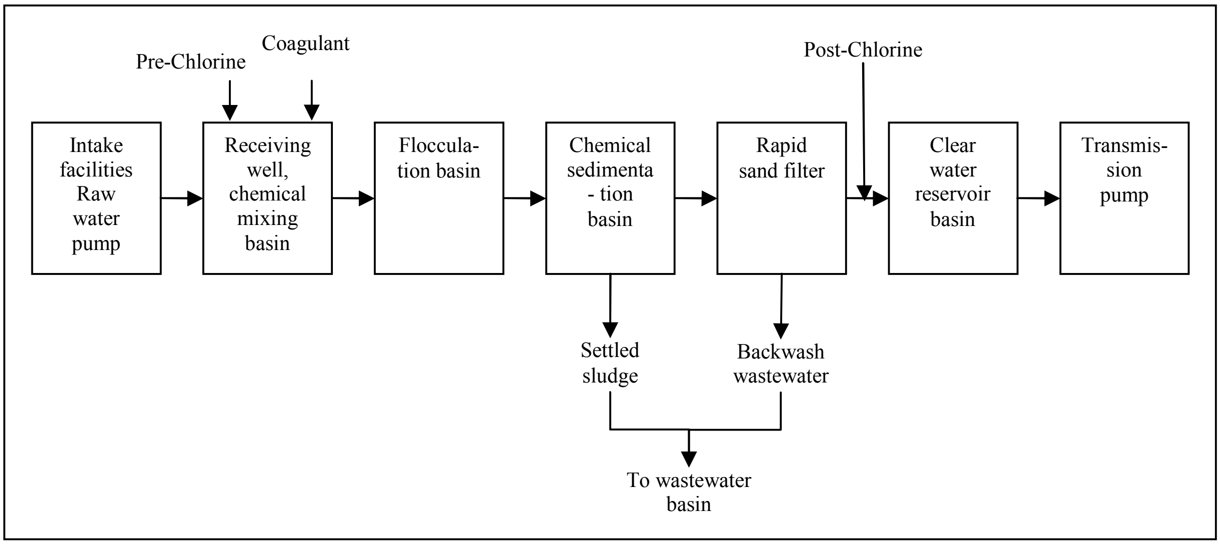


Figure 2.9 Selected Treatment Process

(1) Design Criteria of Proposed New Water Treatment Plant

From experience in Japan and other countries, the following design criteria are adopted for proposed new water treatment plant.

Table 2.12 Design Criteria of Proposed New Water Treatment Plant

Process	Design parameter	Adopted value
Receiving well	Retention time	1.5 min
Mixing basin	Retention time	1 min
Flocculation basin	Retention time	20 min
Sedimentation basin	Surface load	30 mm/min
	Average velocity	0.30 m/min
Rapid filter	Filtration rate	150 m/d (1 basin as reserve)
	Back wash water rate	0.8 $m^3/min \cdot m^2$
	Surface wash water rate	0.15 $m^3/min \cdot m^2$
Clear water reservoir	Retention time	1 hour
Drainage basin	Retention time	For 1 cycle of washing

The capacity of the proposed water treatment plants for west and east banks is summarized in Table 2.13. The water treatment plants for west and east banks are assumed to be constructed in 3 series and 1 series, respectively. The capacity of one series of the water treatment plant for the west bank is 63,000 m^3/d.

Table 2.13 Summary of Proposed Water Treatment Plants for West and East Banks

Item	Proposed water treatment plant	
	West WTP	East WTP
Required capacity	189,000 m^3/d	34,000 m^3/d
Treatment plant series	3	1
Capacity of 1 series	63,000 m^3/d	34,000 m^3/d
Total capacity	189,000 m^3/d	34,000 m^3/d

(2) Components of Proposed New Water Treatment Plant

Based on the design criteria and treatment capacity, component of water treatment plant is planned as shown in Table 2.14 and a preliminary general layout plan is designed and presented in Figure 2.10 for the west bank and Figure 2.11 for the east bank.

Table 2.14 Component of Proposed Water Treatment Plant

No.	Process and building	Specification of proposed water treatment plant	
		West WTP	East WTP
1.	Water intake facility	Two series	Two series
2.	Raw water pump house Raw water pump well Raw water pump	One house Two series 4 sets (one as standby)	One house Two series 2 sets (one as standby)
3.	Receiving well	One well x 3 series	One well x 2 series
4.	Mixing tank	Mechanical type One tank x 3 series	Mechanical type One tank x 2 series
5.	Flocculation basin	Tapered horizontal flow One basin x 3 series	Tapered horizontal flow One basin x 2 series
6.	Chemical sedimentation basin	Horizontal flow with mechanica l sludge collector One basin x 3 series	Horizontal flow with mechanica l sludge collector One basin x 2 series
7.	Rapid sand filter	Gravity flow (back and surface wash) 6 basins x 3 series	Gravity flow (back and surface wash) 6 basins x 2 series
8.	Elevated tank for backwash	One tank	One tank
9.	Clear water reservoir	One basin x 3 series	One basin x 2 series
10.	Transmission pump house Transmission pump	One house 4 sets (including one reserve)	One house 2 sets (including one reserve)
11.	Administration building	1 building Operation room Electrical and generator room Chemical dosing room Water quality laboratory	1 building Operation room Electrical and generator room Chemical dosing room Water quality laboratory

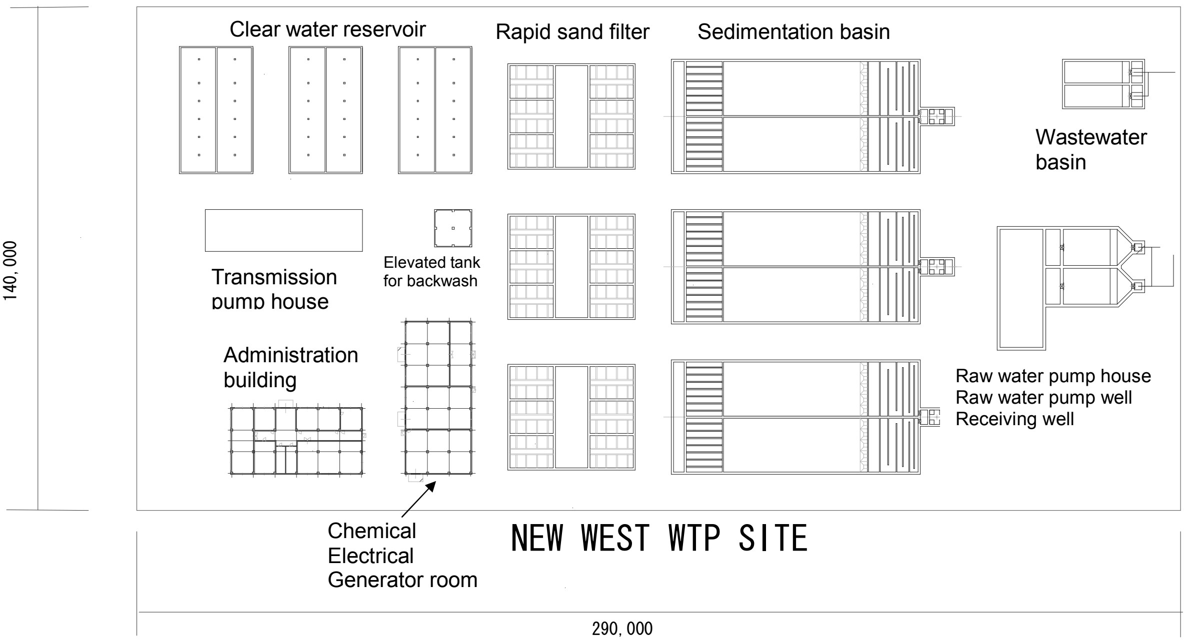


Figure 2.10 General Layout of Water Treatment Plant for the West Bank (West WTP)

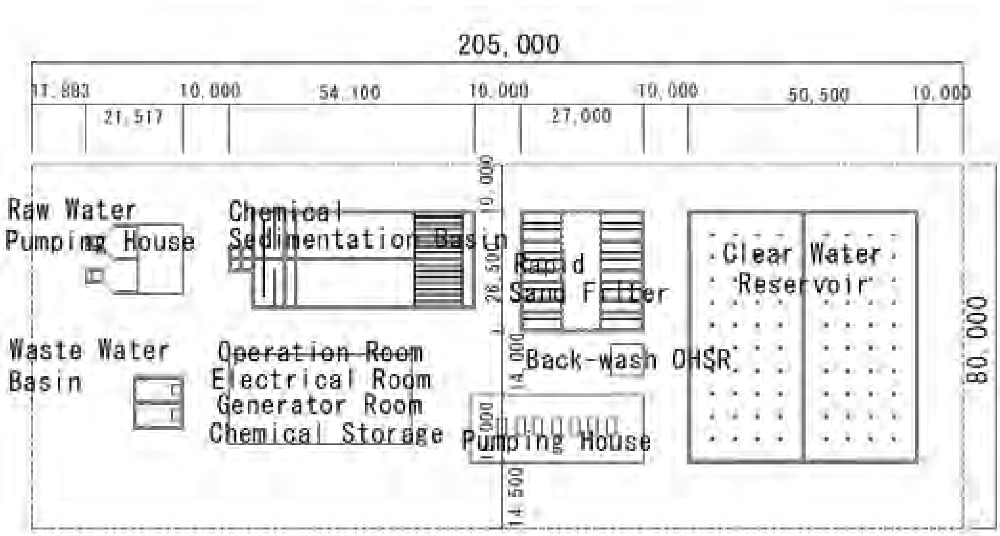


Figure 2.11 General Layout of Water Treatment Plant for the East Bank (East WTP)

2.5 Transmission System and Distribution Main System

(1) Procedure of Selection of Transmission System and Distribution Main System

An optimum transmission system and distribution main system is selected by following procedure. First, the optimum location of service reservoir in each zone is decided. Then, the transmission system to connect water source (water treatment plant) with service reservoir and the distribution main system, the method to distribute water in each zone, is studied and decided.

1. Comparison of location and number of service reservoirs for high and low zones
2. Comparison of routes of transmission pipeline
3. Comparison of distribution main system and sub-zoning system

To select an optimum transmission and distribution main system, alternatives are prepared and compared. The detailed supporting studies are given in Appendix-D and the outline of the studies is shown in the following sections.

(2) Base of Hydraulic Analysis

Design of transmission and distribution main system is carried out based on hydraulic analysis adopting design criteria shown in Table 2.15. Maximum daily demand is calculated by multiplying daily peak factor by average daily demand and maximum hourly demand is calculated by multiplying hourly peak factor by maximum daily demand. Maximum daily demand and maximum hourly demand are adopted for hydraulic analysis of transmission system and distribution network, respectively, considering demand patterns shown in Figure 2.12.

Table 2.15 Design Flow for Hydraulic Analysis in Network Design

	Adopted Design Criteria	Remark
Transmission pipeline	Maximum Daily Demand in 2025	Daily peak factor = 1.2
Distribution pipeline	Maximum Hourly Demand in 2025	Hourly peak factor = 1.65 in 2025 (= 1.73 in 2015)
Minimum hydraulic pressure in distribution network	1.5 kgf/cm^2 in distribution main pipe and 1.0 kgf/cm^2 in service connection.	2 story building can receive water supply by tap directly.
Reservoir capacity	Volume equivalent to 8 hours of maximum daily demand	

Annual fluctuation	Daily fluctuation
Water demand usually increases in hot season. Annual fluctuation tends to be high in the area that has very hot dry season. Source, treatment and transmission facilities are required to meet maximum daily demand. The demand gap between max daily and hourly peak demand is absorbed by service reservoir to meet maximum hourly demand.	Hourly water demand usually is high in the morning and evening when consumption activities increase, and it becomes lowest at night when demand at night is only leakage in normal water service condition. Distribution network is required to meet hourly water demand.

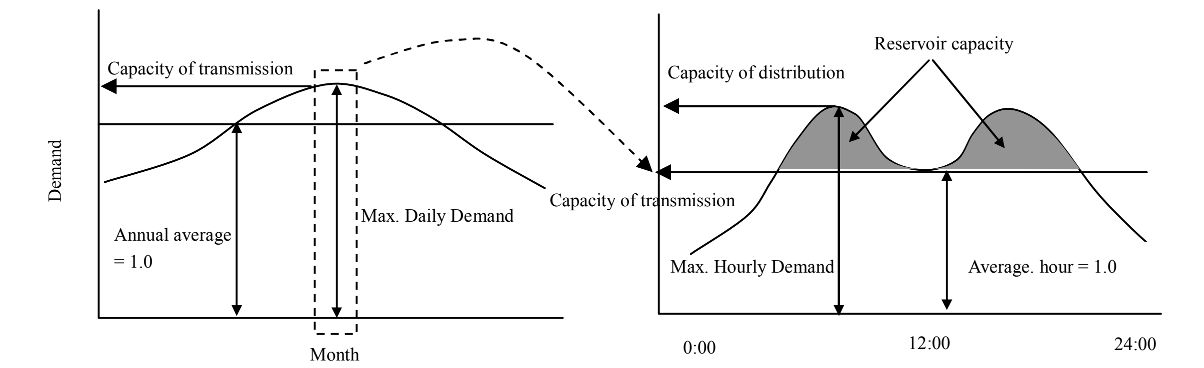


Figure 2.12 Typical Water Demand Fluctuation

The daily peak factor was discussed in the section of water demand estimation. The hourly peak factor is estimated by assuming peak factor of each service level (house connection, public tap and water tanker) as explained below, and percentage of water demand of each service level.

- An hourly peak factor of house connection was set as 1.6 considering the experience of cities, of which the total demand is similar to that of Juba.
- An hourly peak factor of public tap is set as 2.0 assuming 12 hours of usage ratio between 6:00 am and 6:00 pm considering the life pattern of users.
- An hourly peak factor of water tanker is set as 2.4 assuming 10 hours of operation hours between 8:00 am and 6:00 pm considering the current operation hours of water tanker.

The overall hourly peak factors in 2015 and 2025 were calculated as 1.73 and 1.65, respectively. The hourly peak factor in 2015 is higher than that in 2025 as the percentage of service population of public tap or water tanker in 2015 is higher than that in 2025. The hourly peak factor in 2025 is close to 1.6 as the coverage ratio of house connection is higher than that in 2015.

A software, EPANET 2.0 by United Sates Environmental Protection Agency (USEPA), is used for hydraulic analysis, in which Hazen-Williams Formula and 110 are adopted as a friction formula and C-value, respectively.

(3) Service Reservoir System

1) Comparison of Service Reservoir System for High Distribution Zone in West Bank

The optimum ground level of reservoirs for high distribution zone is around 540 m to supply water with appropriate water pressure to the high zone area. The sites with an elevation of around 540 m for service reservoir to serve high zone are limited at the foot of the Mt. Jebel Körök. One reservoir could supply water to entire area of the high zone since distribution area of high zone is approximately within 5 km. However, two reservoirs could be appropriate to supply water to two directions; i.e. north and south, separately considering the expansion of the urban area toward south in future. Therefore, following two alternatives shown in Figure 2.13 are compared. In comparison, the construction cost including transmission pipeline and pump stations to transmit water to those reservoirs, difference in terms of distribution main pipe shown in the Appendix-D.1, and electricity expense have been compared to decide the optimal number of reservoirs. The result of comparison is presented in Table 2.16.

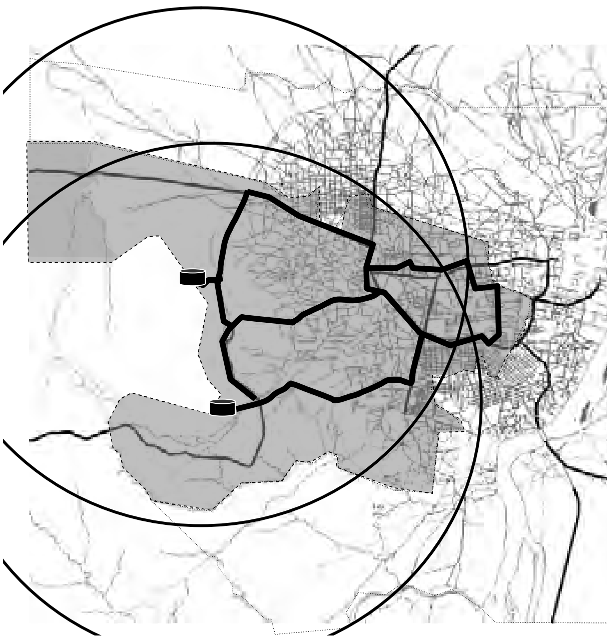
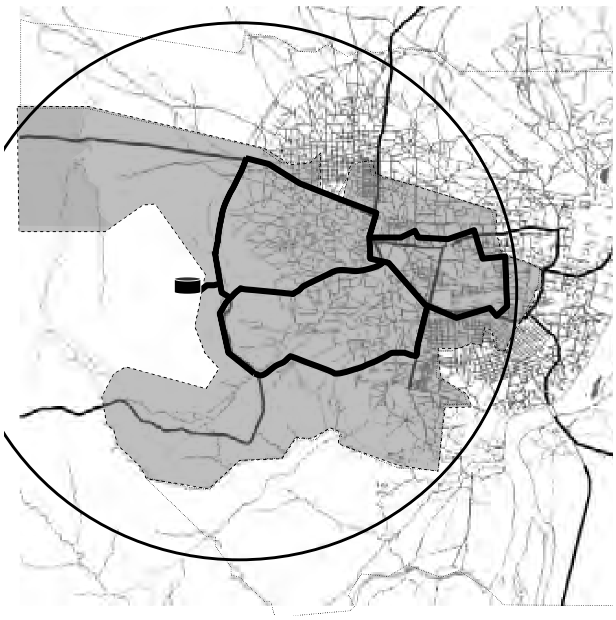
Alternative-1	Alternative-2
	

Figure 2.13 Alternatives of Service Reservoir System for High Zone

Table 2.16 Comparison of Alternatives of Service Reservoir System for High Zone in West Bank

Item	Alternative-1 (Selected)	Alternative-2
System	Mutual backup among two reservoirs functions since distribution main pipeline is connected.	There is no backup for reservoir.
Operation and Maintenance	One additional reservoir is required for operation and maintenance.	-
Construction Cost up to 2015	46.0 million USD (100 %)	55.6 million USD (121 %)
Construction Cost up to 2025	88.7 million USD (100 %)	87.4 million USD (99 %)
Electricity Expense in 2015	1.80 million USD/year (100 %)	1.87 million USD/year (104 %)
Electricity Expense in 2025	6.08 million USD/year (100 %)	6.45 million USD/year (106 %)
Net Present Value	64.8 million USD (100 %)	68.4 million USD (106 %)

Note: Net Present Value (Interest rate = 12 %, Period = 20 years)

Two reservoirs system (Alternative-1) is selected as service reservoir system for high zone for following reasons.

- The construction cost up to 2015 is less as Alternative-2 requires construction of larger diameter of transmission pipeline until 2015.
- Net present value (NPV) is less.
- Mutual backup between two reservoirs is possible in case of accident and during repair work of each service reservoir.

2) Service Reservoir System for Low Distribution Zone in West Bank

The optimum level of service reservoirs for low distribution zone is around 515 m. This level is equivalent to the ground level of the site of the exiting elevated tank near the Parliament. This site is suitable for reservoir to service water supply in low zone considering the elevation and the location of the distribution area. This site is located at the center of the existing urbanized area so that water can be distributed to any direction of the current urbanized area in the low zone. However, considering future expansion of urbanized area, it is highly possible that one reservoir cannot cover the entire area of the low zone due to the distance from service reservoir and tract of the low zone. The following two additional sites were studied as potential sites for additional reservoirs considering the direction of expansion of the urbanized area.

The south of the Target Service Area, a part of the Kator and Rejaf, is in the proximity of the new water treatment plant, from which transmission pipeline will be connected to the new reservoir in

Parliament area. A new service reservoir could be constructed by taking advantage of the area located near the treatment plant. To cater to the growing population in this direction, a new reservoir is necessary in this area in future since south part of zone is relatively large and potential population growth is considerable.

The urbanized area is rapidly expanding to the west, Gudele area. Therefore, possibly a new reservoir is required for this area in future. However, this area is not far from the service reservoir nearb the parliament and Gudele area could be covered by this reservoir. Therefore, following two alternatives shown in Figure 2.14 are prepared and compared. The construction cost including transmission pipeline and pump stations to transmit water to these reservoirs, difference in terms of distribution main pipe shown in the Appendix-D.2, and electricity expenses are compared to decide the optimal number of reservoirs.

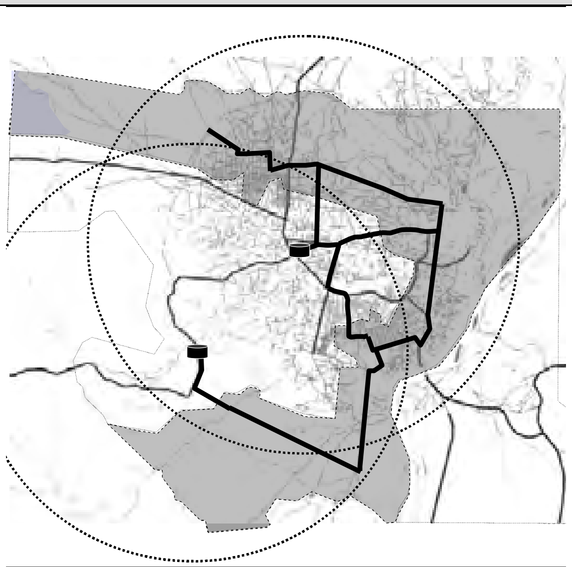
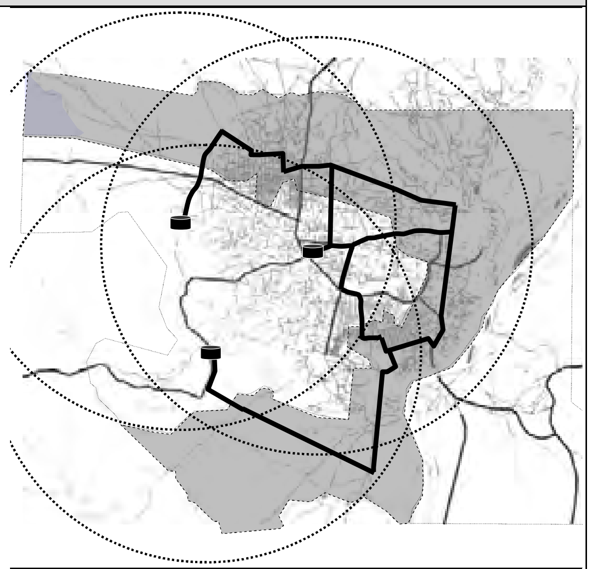
Alternative-1	Alternative-2
	

Figure 2.14 Alternatives of Low Zone

Table 2.17 Comparison of Alternatives of Low Zone

Item	Alternative-1 (Selected)	Alternative-2
System	Mutual backup among two reservoirs functions as distribution main pipeline is connected.	Mutual backup among three reservoirs functions as distribution main pipeline is connected.
Operation and Maintenance	-	One additional reservoir is required for operation and maintenance.
Construction Cost up to 2015	32.3 million USD (100 %)	30.8 million USD (92 %)
Construction Cost up to 2025	65.1 million USD (100 %)	68.8 million USD (106 %)
Electricity Expense in 2015	1.38 million USD/year (100 %)	1.61 million USD/year (117 %)
Electricity Expense in 2025	2.85 million USD/year (100 %)	3.32 million USD/year (117 %)
Net Present Value	43.3 million USD (100 %)	46.0 million USD (106 %)

Note: Net Present Value (Interest rate = 12 %, Period = 20 years)

Two reservoirs system (Alternative-1) is selected as service reservoir system for low zone for following reasons.

- Alternative-1 can supply water with adequate distribution pressure even in Gudele area.
- Electricity expense is lower as additional pump head required to transmit water to Gudele service reservoir from the service reservoir located near the Parliament area results in higher expense in Alternative-2.
- Net present value is less.

3) Service Reservoir System for East Bank (Gumbo area)

The east bank of the river has not been urbanized and organized block has not been observed. However, many plots have started to be demarcated for future residential area in the east bank. The topography of the east zone is shown in Figure 2.15 and the area is relatively flat with an elevation range from around 460 m to 480 m and there is no appropriate location for ground service reservoir from which water can be distributed by gravity. Therefore, a water supply system comprised of an elevated tank and a service reservoir connected by transmission mains are proposed to distribute water in this zone. The location of an elevated tower is planned at the highest point in the zone, which is almost the center of the service area of the east zone. The location of proposed water treatment plant and elevated tank is not far. Therefore, two alternative systems can be compared as follows.

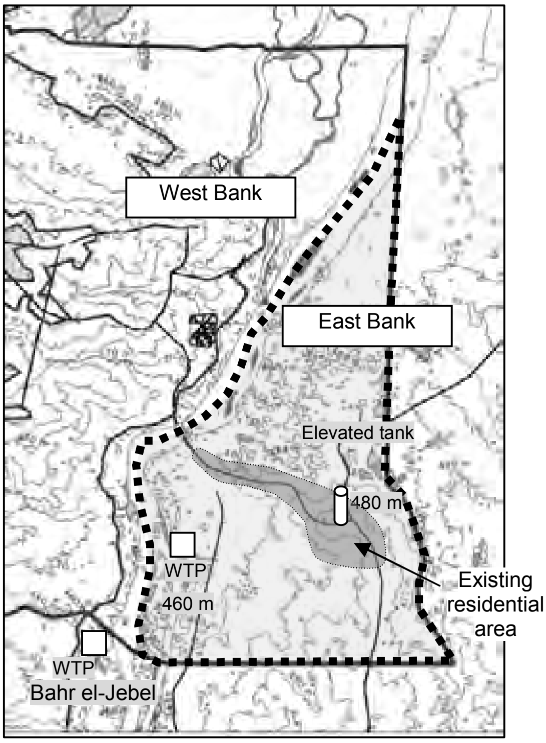
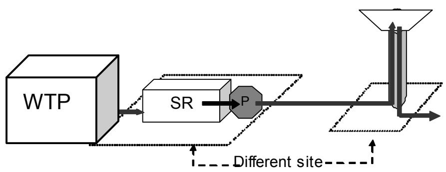
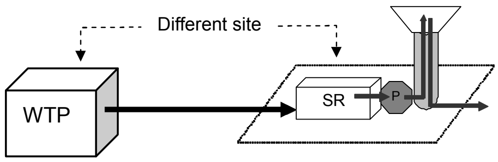


Figure 2.15 Service Reservoir in East Bank

Table 2.18 Comparison of Reservoir System in East Bank

Item	Alternative 1 (Selected)	Alternative 2
Layout		
Location of a service reservoir	A service reservoir is located in the same site as the proposed water treatment plant.	A service reservoir is located in the same site as the elevated tower.
Facilities	Clear water reservoir in water treatment plant site is not required. Pumping from water treatment plant to service reservoir can be saved.	
Operation and maintenance	Pump operation and maintenance can be done only in water treatment site.	Separate operation and maintenance is required in two sites.
Cost	O&M cost is less but construction cost of pipe is a bit higher. Clear water reservoir can be saved. Overall, the cost of this alternative is possibly less.	O&M cost is higher due to 2 operation systems, but construction cost of pipe is a bit lower. Overall, the cost of this alternative is higher.
Land acquisition for service reservoir	The area has large vacant field and it is not difficult to acquire the land.	The area is the center of the city and it is difficult to acquire the land.

As a result of comparison, Alternative-1 (a service reservoir is located in the same site as the proposed water treatment plant) is selected as better reservoir system for service zone in the east bank for following reasons:

- Pump operation and maintenance can be done only in water treatment site; centralized operation.
- Clear water reservoir in the water treatment plant site is not required. Service reservoir is used for this purpose.
- Pumping from water treatment plant to service reservoir can be saved.
- The overall cost including construction and operation and maintenance is lower.

(4) Transmission System

The number and location of service reservoirs for both high and low zones have been discussed in the previous section. In this section, discussion is made on selection of a transmission system from the water treatment plant to these service reservoirs. Two alternatives shown in Figure 2.16 are compared to select an optimal transmission system.

The concept of the alternatives is explained as follows:

Alternative-1: First treated water is transmitted to both low service reservoirs and then the part of water is pumped up to the high zone reservoirs from each low zone reservoir.

Alternative-2: Treated water is transmitted to two high zone service reservoirs and two low zone reservoirs, separately.

The detail of both alternatives are given in the Appendix-D.3 and are compared in Table 2.19.

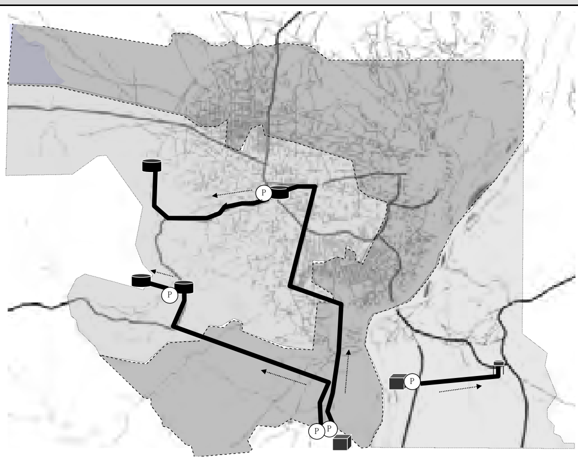
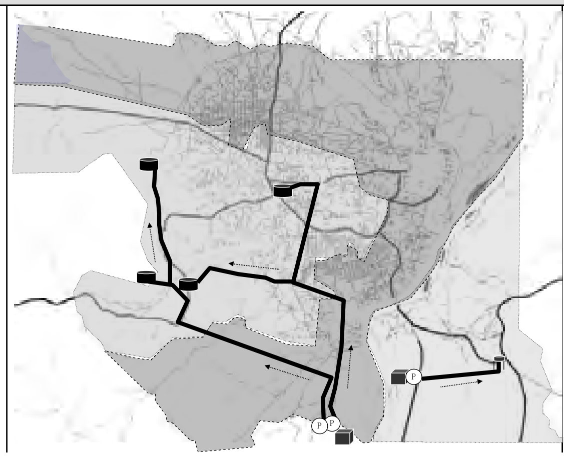
Alternative-1 (Selected)	Alternative-2
	

Figure 2.16 Alternatives for Transmission System

Table 2.19 Comparison of Alternatives for Transmission System

Item	Alternative-1 (Selected)	Alternative-2
Transmission from direction	Treated water is firstly transmitted to low reservoirs separately and then pumped up to high reservoir through two independent low and high zone transmission systems.	Treated water is transmitted to 2 low reservoirs and 2 high reservoirs separately.
Backup/reliability	Each high and low zone transmission system can back up mutually. If one system fails the other system can back up.	High zone system can back up low zone system but there is no back up for high zone system in case of its failure.
Operation and Maintenance	Two additional pump stations are required for operation and maintenance.	-
Construction Cost up to 2015	32.4 million USD (100 %)	40.8 million USD (126 %)
Construction Cost up to 2025	57.6 million USD (100 %)	50.6 million USD (88 %)
Electricity Expense in 2015	1.80 million USD/year (100 %)	1.74 million USD/year (97 %)
Electricity Expense in 2025	6.08 million USD/year (100 %)	6.11 million USD/year (101 %)
Net Present Value	51.0 million USD (100 %)	51.0 million USD (100 %)

Note: Net Present Value (Interest rate = 12 %, Period = 20 years)

Alternative-1 is selected as better transmission system option for following reasons.

- The difference of costs of construction and operation & maintenance is not significant.
- Alternative-1 is advantageous in terms of backup system, although Alternative-1 has disadvantage in O&M of additional pump stations. In Alternative-1, each transmission system can be mutually backed up in case of accident and during repair work of the other system. In case either one of the transmission systems fails so that water is not transmitted to the system, the other transmission system can be used for supplying water to the other system. On the contrary, in Alternative-2, if the transmission system fails in high zone, the system in low zone cannot be used for supplying water to the high zone.
- Initial cost required for the construction until 2015 is lower.

(5) Distribution Main System

1) Type of Distribution Main System

There are two concepts of alignment of distribution main system. One is loop system and the other is arborescent system. The concept of loop system is that water can be distributed in different direction, and that of arborescent system is that water is distributed in a single direction. The quantitative comparison of both systems is explained in Appendix-D.4. Loop system is advantageous in case of accident and during repair work of distribution mains. Therefore, loop system is selected as distribution main systems.

2) Model of Distribution Main Systems

The models of distribution main system are prepared for both 2015 and 2025, in which water tanker feeding stations are planned to distribute treated water to the respective areas. The models of distribution main system in 2025 and 2015 are prepared to cover the Target Service Area of the Master Plan and the targeted areas for house connection and public tap in 2015, in which a part of Kator area is supplied from the existing Kator elevated tank. A part of high zone, of which the elevation is above 530 m at foothill of the mountain, are considered to get supplied water from a proposed new elevated tank, which is planned to be constructed in the same location of South High Service Reservoir in the west bank.

3) Proposed Distribution Main Systems

The result of hydraulic analysis (hydraulic and static pressure of demand nodes, required diameter and length of pipelines) in both 2015 and 2025 is shown in Appendix-D.5. Hydraulic pressure of demand nodes of distribution mains was confirmed to be more than 1.5 kgf/cm^2.

The total length of required distribution mains including sub-mains in 2025 is 169 km, comprising 80 km in high Zone, 75 km in Low Zone and 14 km in East Zone, respectively.

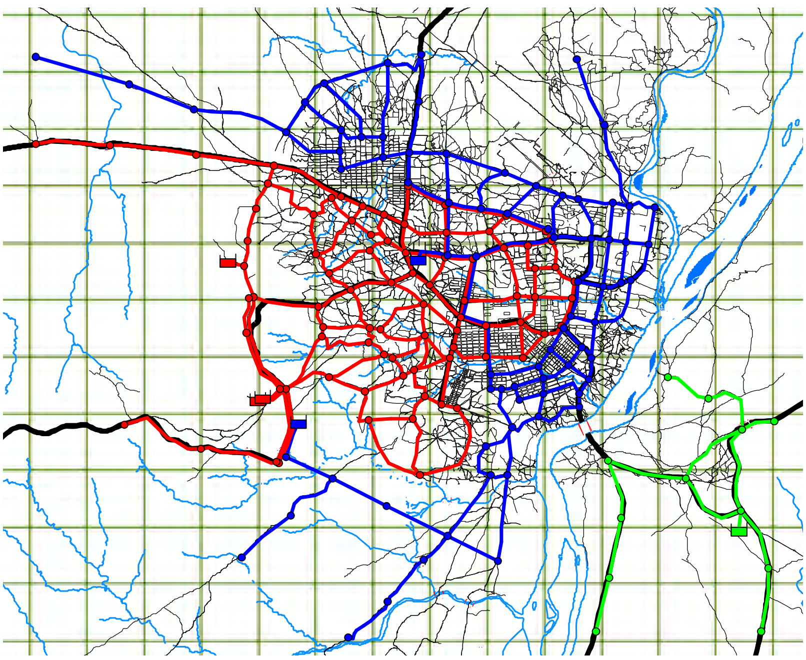


Figure 2.17 Water Distribution Main System in 2025

Table 2.20 Estimated Length of Distribution Main System in 2025 by Diameter

(m)

Diameter (mm)	West High Zone	West Low Zone	East (Gumbo Zone)	Total
1000	0	600	0	600
900	400	0	0	400
800	3,500	3,800	400	7,700
700	2,000	4,600	0	6,600
600	900	3,100	1,600	5,600
500	7,300	2,300	3,900	13,500
400	12,600	21,700	4,100	38,500
300	10,200	13,300	2,700	26,200
200	43,100	25,200	1,400	69,700
Total	80,000	74,600	14,100	168,800

4) Distribution Tertiary Network

Distribution main system is planned adopting the concept of loop system and required length and diameter of pipelines is estimated based on hydraulic network analysis. Distribution tertiary pipelines are designed by adopting the concept of district metered area (DMA). To estimate required diameter of tertiary pipelines, hydraulic network analysis is not required as head loss in DMA is insignificant.

The required length and diameter of tertiary pipelines are estimated by following methodology.

- First, a model area is chosen from a typical area of the existing demarcated residential area. Alignment of tertiary pipelines is designed based on the concept of DMA and pipe density is calculated, which is approximately 27 km per km2.
- Second, the percentage of diameter was set 15 % of 150 mm and 85 % of 100 mm based on the model calibration, and pipe density by diameter in model area is estimated.
- Third, total length of tertiary network is estimated multiplying the area of demarcated residential area by applying pipe density of the model area.

The length of tertiary network by diameter in 2025 is estimated as shown in Table 2.21 and the estimated total length is 1,083 km. In addition the length is estimated for 2015 as shown in Table 2.22 and the total length of the network in 2015 is estimated at 306 km.

Table 2.21 Distribution Tertiary Length and Diameter in 2025

(m)

		Diameter (mm)		Total
		150	100	
High Zone	Rehabilitation Area	11,200	63,200	74,400
	Expansion Area	55,700	315,700	371,400
	Sub-total	66,900	378,900	445,800
Low Zone	Rehabilitation Area	10,100	57,400	67,500
	Expansion Area	65,800	372,700	438,500
	Sub-total	75,900	430,100	506,000
Gumbo Zone	Rehabilitation Area	0	0	0
	Expansion Area	19,700	111,600	131,300
	Sub-total	19,700	111,600	131,300
Total	Rehabilitation Area	21,300	120,600	141,900
	Expansion Area	141,200	800,000	941,200
	Sub-total	162,500	920,600	1,083,100

Table 2.22 Distribution Tertiary Length and Diameter in 2015

(m)

		Diameter (mm)		Total
		150	100	
High Zone	Rehabilitation Area	11,200	63,200	74,400
	Expansion Area	4,200	24,000	28,200
	Sub-total	15,400	87,200	102,600
Low Zone	Rehabilitation Area	10,100	57,400	67,500
	Expansion Area	20,400	115,900	136,300
	Sub-total	30,500	173,300	203,800
Gumbo Zone	Rehabilitation Area	0	0	0
	Expansion Area	0	0	0
	Sub-total	0	0	0
Total	Rehabilitation Area	21,300	120,600	141,900
	Expansion Area	24,600	139,900	164,500
	Sub-total	45,900	260,500	306,400

In addition, the required length of the pipeline to be installed in the existing network area is estimated as 142 km, which is equivalent to approximately 3 times of the total length of existing network (51 km). This difference can be attributed to insufficient pipe density of existing network.

(6) Sub Distribution Zoning

The large gravity distribution zones should be sub-divided for following advantages.

- To ease operation and maintenance of distribution network by sub-unit
- To monitor / manage water distribution flow and controlling of pressure by sub-unit

Considering topography, natural and man-made boundaries including main streets, administrative boundary and alignment of the large distribution zones, sub distribution zones are delineated as shown in Figure 2.18.

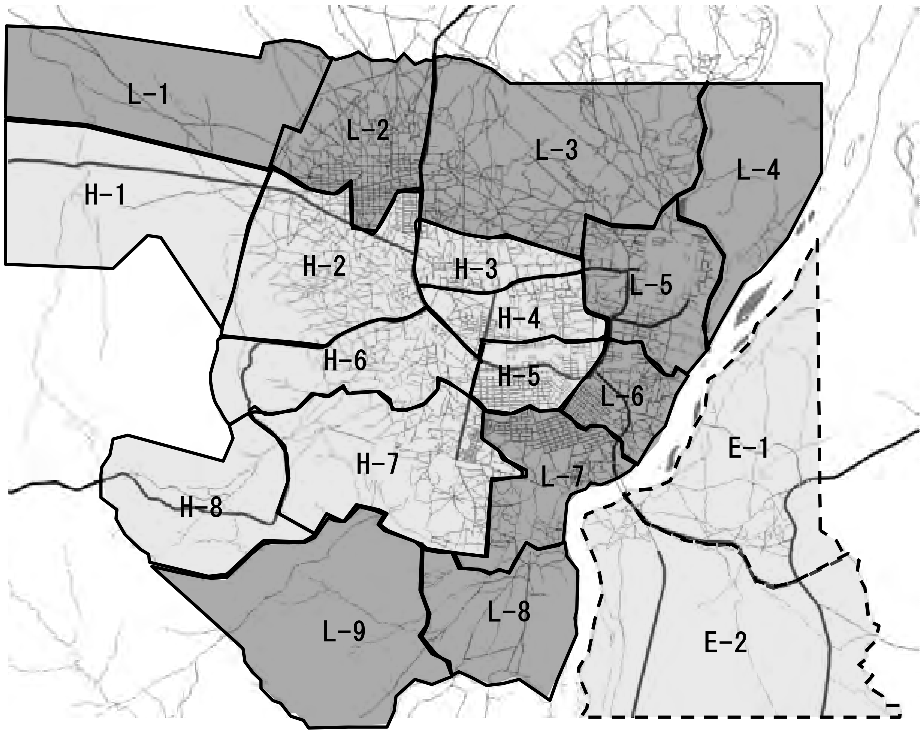


Figure 2.18 Schematic Layout of Sub-Distribution Zone

2.6 Proposed Water Supply System

A general layout of major water supply facilities in 2025 together with the targeted service zones and capacity of major water supply facilities is shown in Figure 2.19 and a diagram of flow and diameter of transmission system in 2025 is presented in Figure 2.20.

A schematic elevation map of the proposed water supply system in 2025 and a schematic diagram of water supply system in 2025 are shown in Figure 2.21 and Figure 2.22, respectively.

The summary of the components and capacity of the Mater Plan is given in Table 2.23. The detailed location and size of proposed major water supply facilities shown in Figure 2.24.

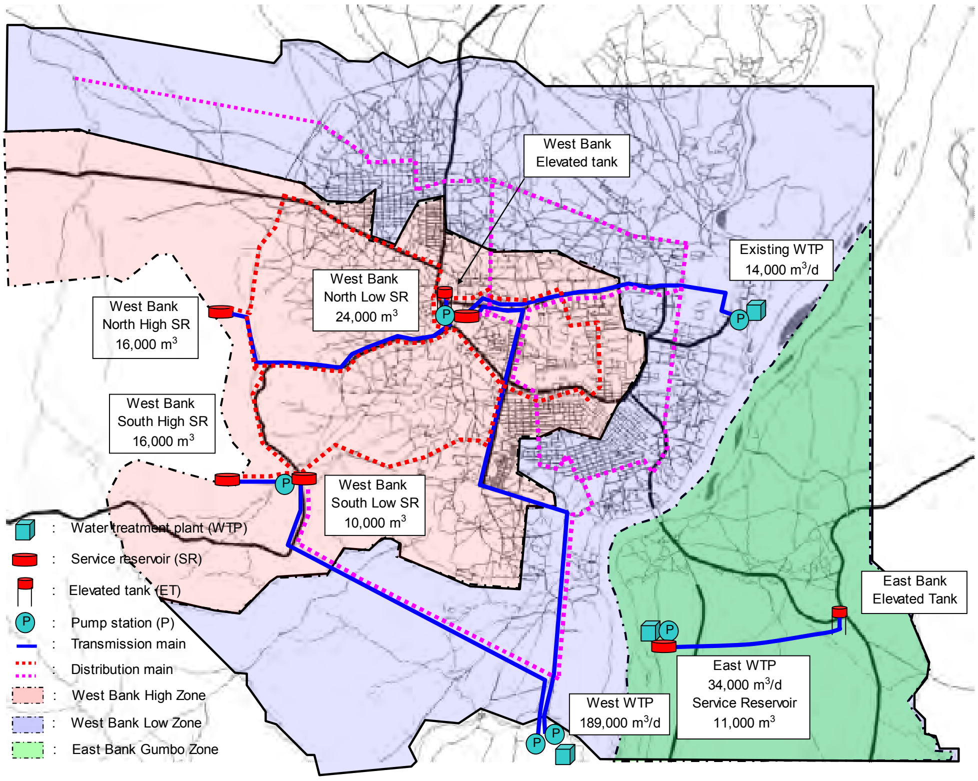


Figure 2.19 General Layout of Water Supply Facilities in 2025 and Capacity of Major Facilities

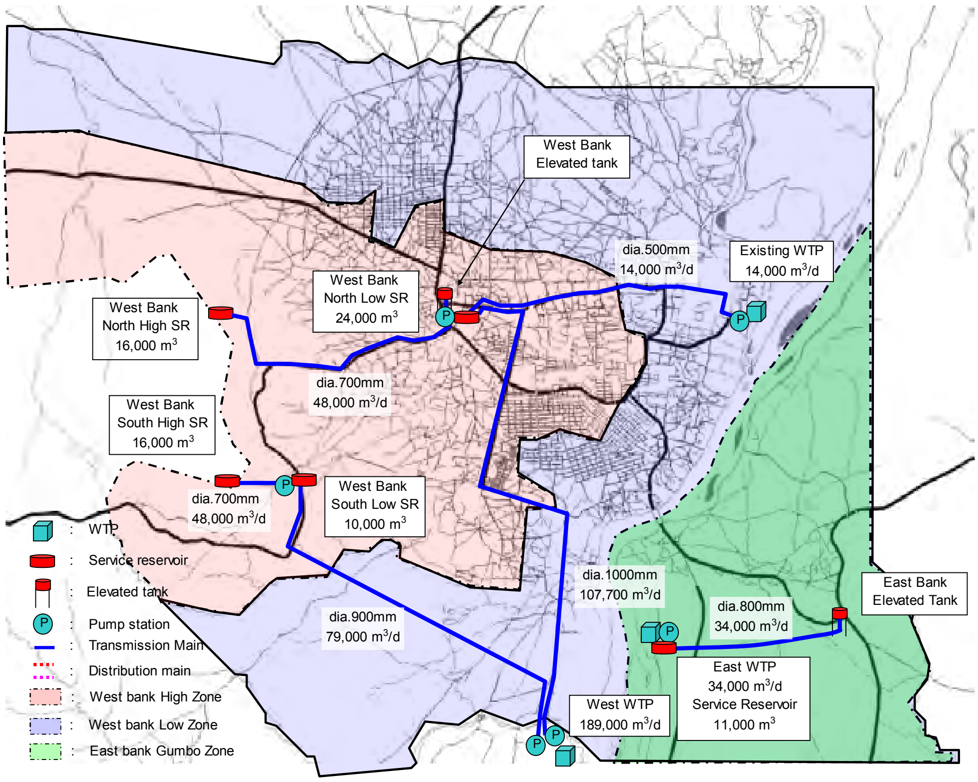


Figure 2.20 Diagram of Flow and Diameter of Transmission System in 2025

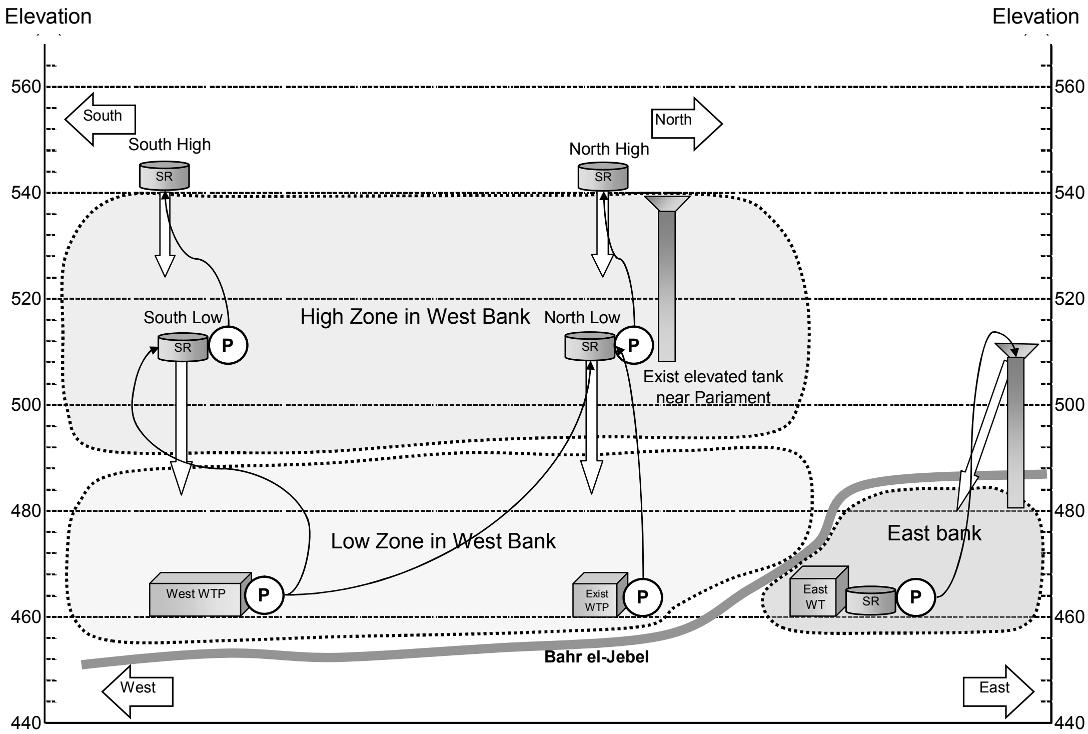


Figure 2.21 Schematic Elevation Map of Water Supply System in 2025

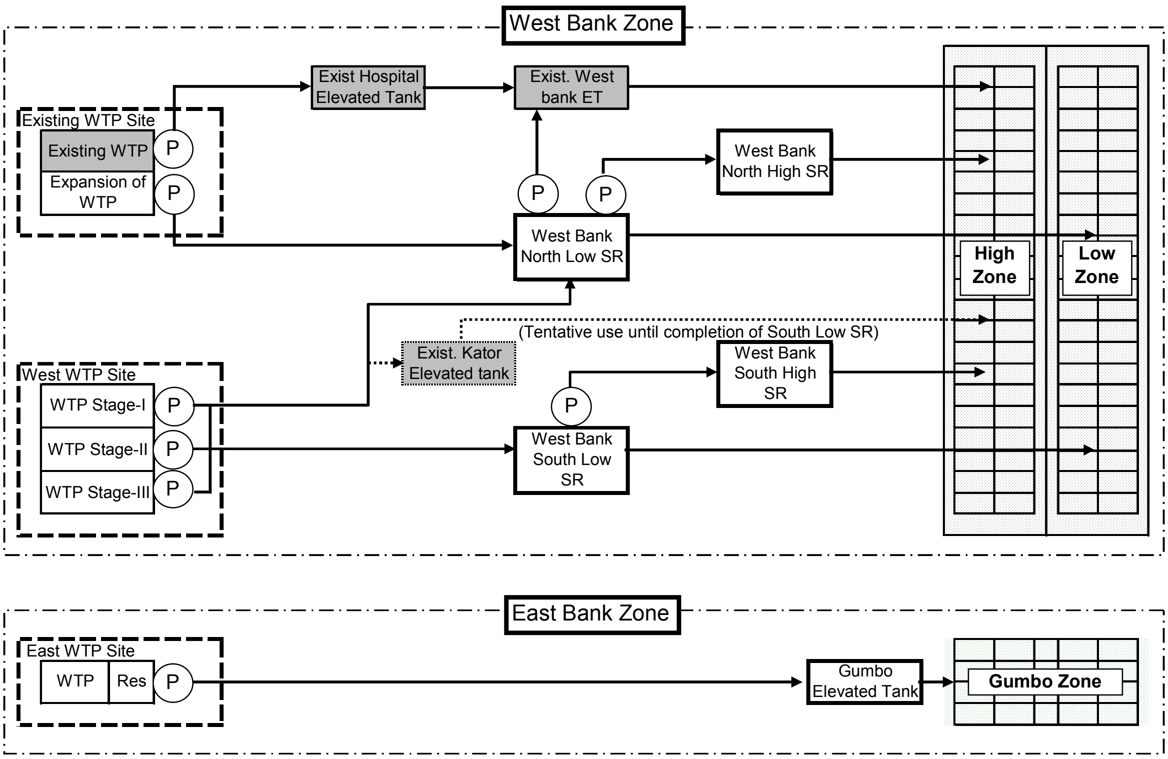


Figure 2.22 Schematic Diagram of Water Supply System in 2025

Table 2.23 Components and Capacity of Mater Plan Project

System component	Facility	Name/Location/Route	Capacity/Specifications
1. Production system	Water Treatment Plants	Expansion of the existing WTP	7,000 m^3/d
		West WTP	189,000 m^3/d
		East WTP	34,000 m^3/d
Total			230,000 m^3/d
2. Transmission System	Transmission pump stations	North Low SR site	48,000 m^3/d x 50 m head
		South Low SR site	48,000 m^3/d x 40 m head
	Transmission pipelines	Existing WTP - North Low SR	Dia. 500 mm x 4.45 km
		West WTP - North Low SR	Dia. 1000 mm x 9.10 km
		North Low SR - North High SR	Dia. 700 mm x 3.75 km
		West WTP - South Low SR	Dia. 900 mm x 5.86 km
		South Low SR - South High SR	Dia. 700 mm x 1.54 km
		New East WTP - Gumbo ET	Dia. 800 mm x 2.55 km
	Total		Dia. 500 -1000 mm, 27.25 km
3. Distribution System	Service reservoirs	North High SR	16,000 m^3
		North Low SR	24,000 m^3
		South High SR	16,000 m^3
		South Low SR	10,000 m^3
		Gumbo SR in East WTP	11,000 m^3
		Gumbo Elevated Tank	1,300 m^3
	Total (except ET)		Capacity = 77,000 m^3
	Distribution Network(High zone)	Distribution main & sub-main	Dia. 900 - 200 mm x 80.0 km
		Distribution tertiary pipelines	Dia. 150 - 100 mm x 445.8 km
	Distribution Network (Low zone)	Distribution main & sub-main	Dia. 1000 - 200 mm x 74.7 km
		Distribution tertiary pipelines	Dia. 150 - 100 mm x 506.0 km
	Distribution Network (Gumbo zone)	Distribution main & sub-main	Dia. 800 - 200 mm x 14.0 km
		Distribution tertiary pipelines	Dia. 150 - 100 mm x 131.3 km
			Dia. 150-1000 mm x 1,251.8 km

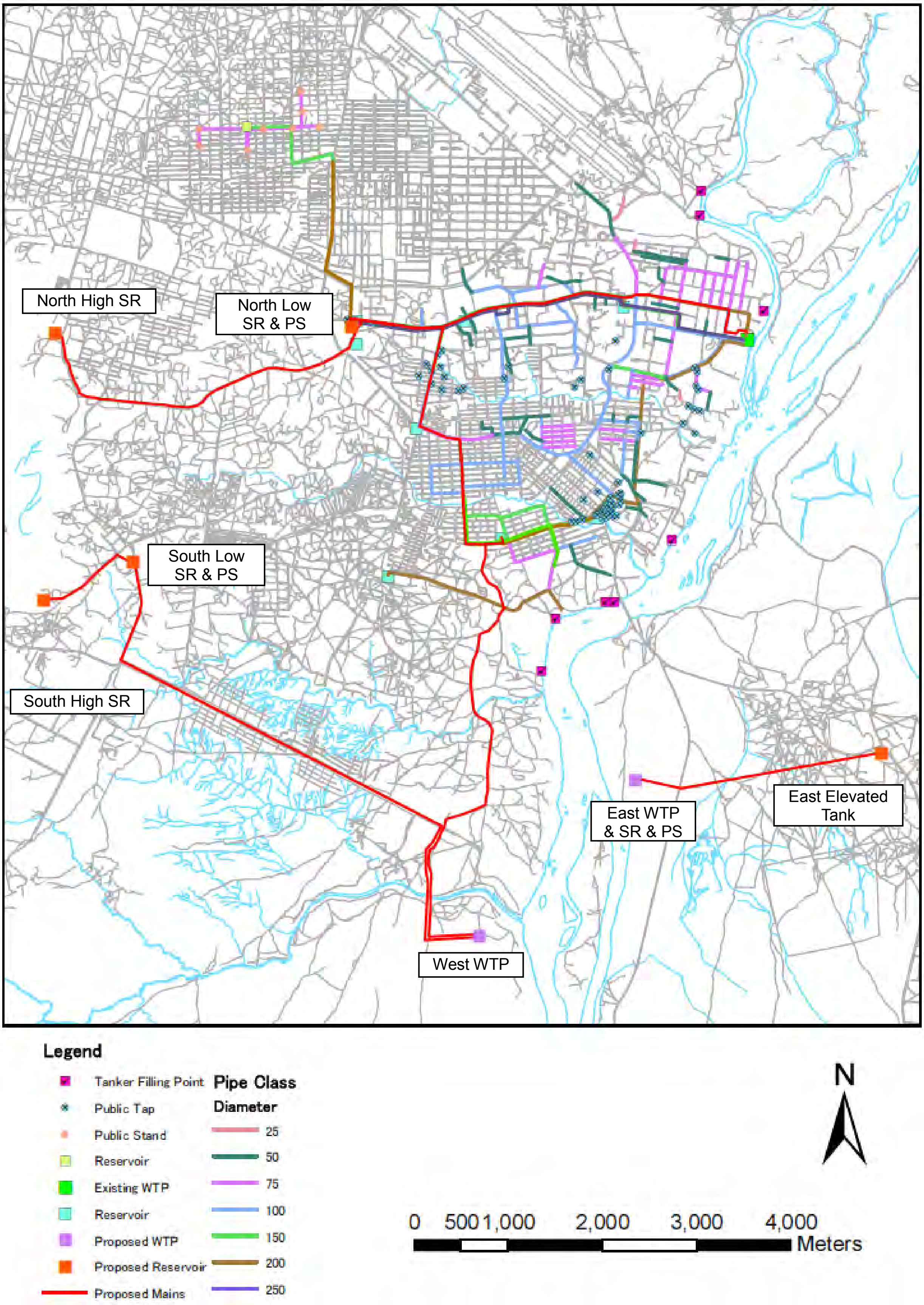


Figure 2.23 Layout of Water Supply Facilities in 2025 and Existing Facilities

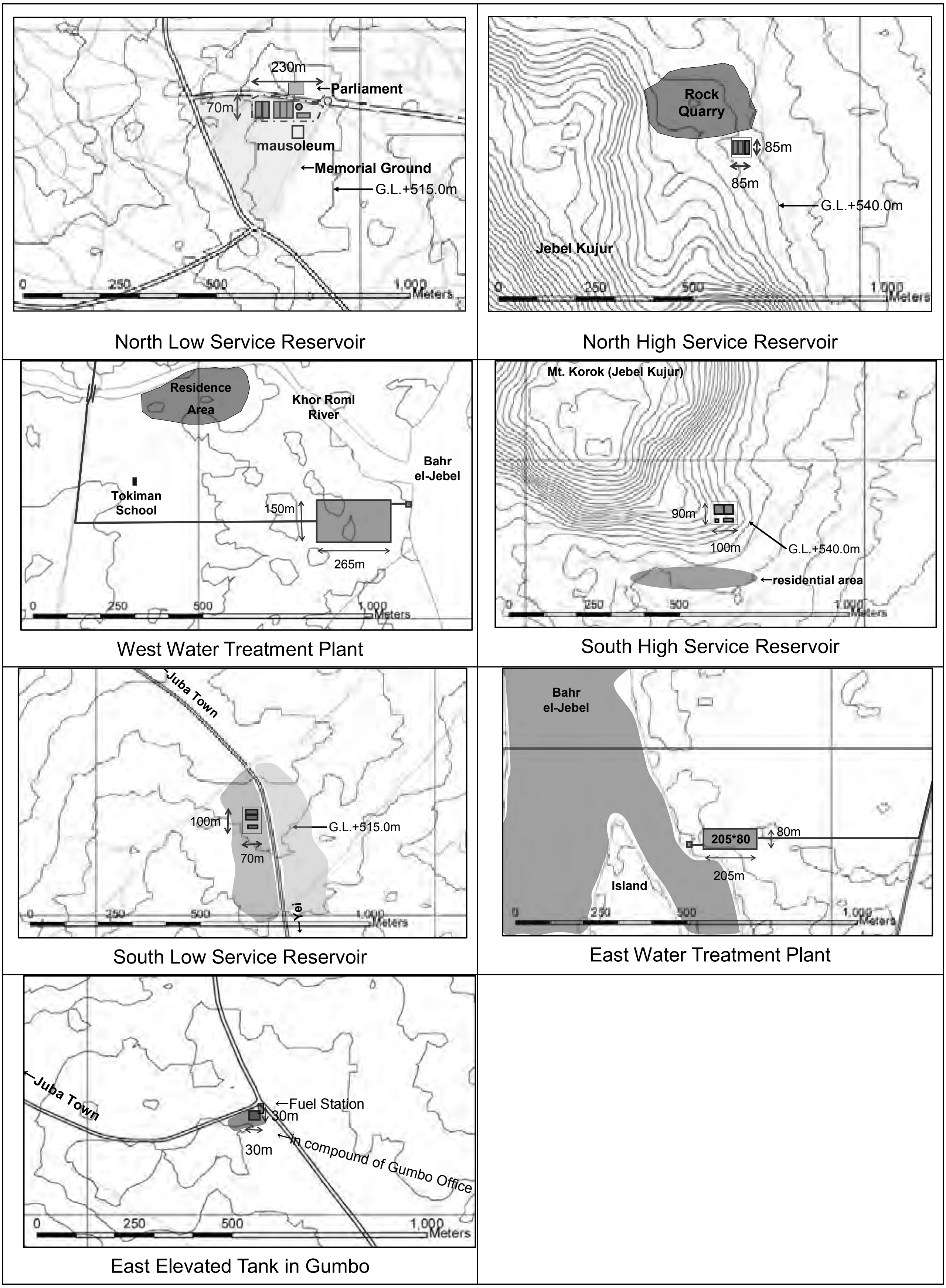


Figure 2.24 Detailed Location and Size of Proposed Major Water Supply Facilities

CHAPTER 3 DEVELOPMENT SCHEDULE OF WATER SUPPLY SYSTEM

3.1 General

The Master Plan requires a large amount of investment and many years to complete. In general, such a large project becomes feasible for implementation if they are implemented through several construction phase with appropriate development steps. Further, the phased development is needed for investment decision by financial or investment institutions.

Water supply system is composed of intake facilities, treatment facilities, transmission facilities, distribution facilities and network. These facilities have different functions and these series of facilities are required to perform as a water supply system to deliver water to users. Therefore, in each development stage, the capacity of facilities has to be coordinated and physically balanced to perform as system in order to make constructed facilities function effectively and efficiently.

3.2 Water Demand and Proposed Water Production Capacity Curve

The proposed water supply system in 2025 is composed of one existing water treatment plant and two planned water treatment plants to produce treated water for supplying to the service area in the west bank and east bank, separately. Therefore, the water demand and proposed water supply curves are prepared separately and these two curves are summed up to generate one combined demand and supply curve.

It is difficult to meet full maximum daily water demand for entire period, especially in the beginning as it requires a great deal of initial investment cost and construction volume. Therefore, in preparing water supply curves to meet the estimated demand, following principles are established.

- As mentioned in the previous section, expansion of the existing water treatment plant will be carried out in the earliest stage and the expansion capacity shall be 7,000 m^3/d.
- Water supply system shall be developed in organized urban areas, where distribution network can be installed along organized streets. Therefore, first development shall be initiated in the existing organized urban area and then the infrastructures should be developed in expected organized urban area in future. Gumbo area in the east zone currently looks like rural village and it is expected that this area will not become organized urban area in near future. Therefore, the development of water supply system in this area will be delayed. Before development of water supply system in this zone, water should be supplied from the water treatment plant in the west zone through water tanker or pipe.
- At least, water supply capacity should meet the average daily water demand in the initial stage of

water supply system development.

- In addition, in the beginning of development, development of distribution network will be slower as the existing network is totally malfunctioned and it has to start from total rehabilitation. Also, the technical capacity of UWC is very limited and it takes long time to be strengthened. Therefore, even if the production capacity is increased, the distribution capacity cannot follow it.

Based on the principle of developing water supply system to meet water demand, water demand and supply curves are prepared as shown in Figure 3.1.

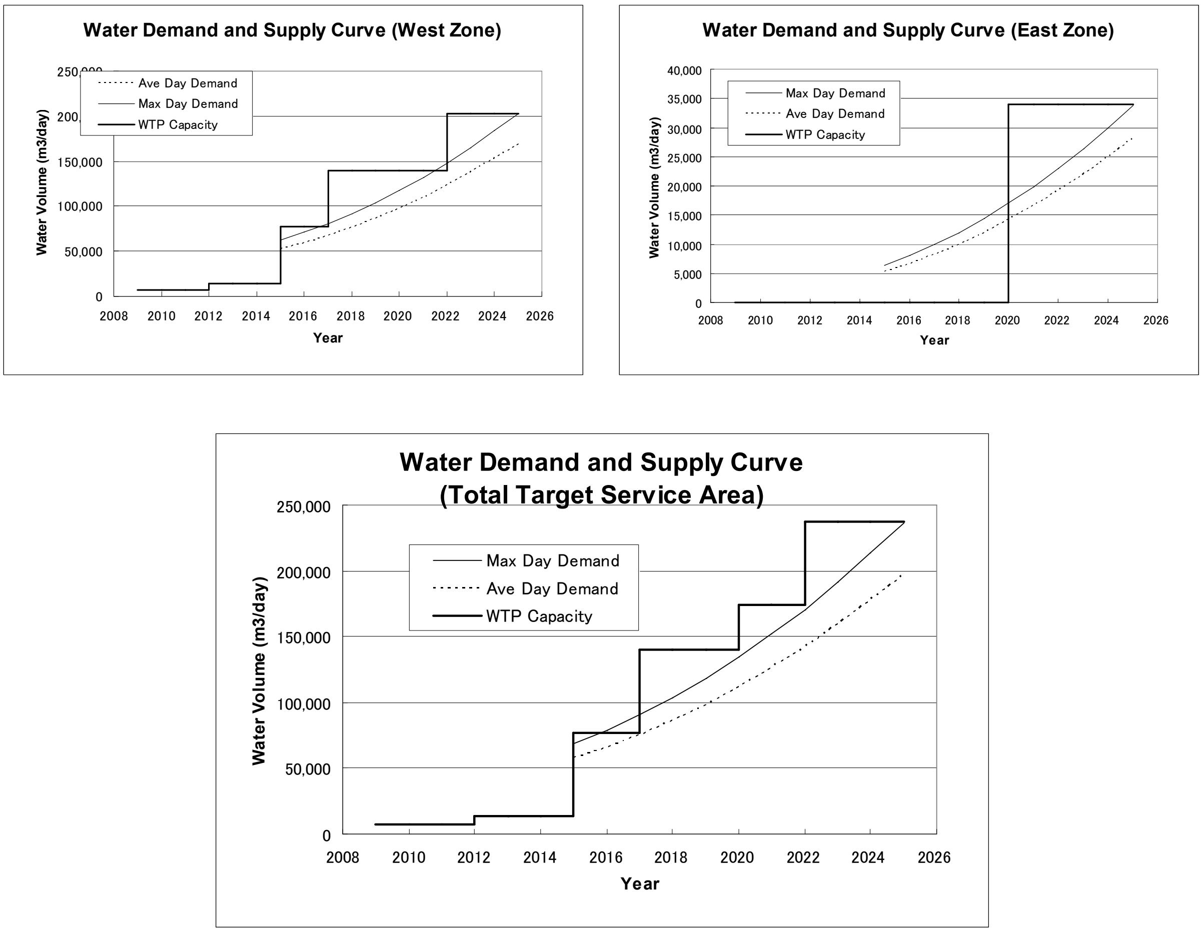


Figure 3.1 Estimated Water Demand and Proposed Expansion of Water Treatment Plant

3.3 Expansion Plan of Water Treatment Capacity

According to this principle, the expansion plan of the water treatment plants through phase-wise construction is prepared and presented in Table 3.1. Furthermore, the detailed construction components of water treatment plant for the west bank to be carried out in phases are summarized in Table 3.2. Regarding the water treatment plant for the east bank, considering its scale of capacity, its construction can be undertaken in one phase, i.e. phase 3 and all components of the facilities will be constructed in this phase.

Table 3.1 Expansion Plan of Water Treatment Capacity by Construction Phase

(m^3/d)

Term	Existing WTP site		West WTP	East WTP	Total capacity
	Existing	Expansion			
Urgent improvement (phase 1) (-2012)	7,000	7,000	-	--	14,000
New system construction (phase 2) (-2015)	-	-	63,000	-	77,000-
New system construction (phase 3) (- 2020)	-	-	63,000	34,000	174,000
New system construction (phase 4) (-2025)	-	-	63,000	-	237,000

Table 3.2 Detailed Components of Water Treatment Plant for West Bank by Construction Phase

No.	Process and building	Specification of proposed water treatment plant	Construction phase		
			Phase 2	Phase 3	Phase 4
1.	Water intake facility	2 series	2 series	-	-
2.	Raw water pump house Raw water pump well Raw water pump	1 house 2 series 4 sets (one as standby)	1 house 2 series 2 sets	1 set	1 set
3.	Receiving well	1 well x 3 series	1 series	1 series	1 series
4.	Mixing tank	Mechanical type 1 tank x 3 series	1 series	1 series	1 series
5.	Flocculation basin	Tapered horizontal flow 1 basin x 3 series	1 series	1 series	1 series
6.	Chemical sedimentation basin	Horizontal flow type with m echanical sludge collector 1 basin x 3 series	1 series	1 series	1 series
7.	Rapid sand filter	Gravity flow type (back and surface wash) 6 basins x 3 series	1 series	1 series	1 series
8.	Elevated tank for backwash	1 tank	1 tank	-	-
9.	Clear water reservoir	1 basin x 3 series	1 series	1 series	1 series
10.	Transmission pump house Transmission pump	1 house 4 sets (including one reserve)	1 house 2 sets	- 1 sets	- 1 sets
11.	Administration building (includ. operation room, electrical and generator, chemical dosing, and water quality laboratory room)	1 building Equipment Electrical and generator Chemical dosing Water quality laboratory	1 building 1/3 1/3 1/3	1/3 1/3 1/3	1/3 1/3 1/3

3.4 Expansion Plan of Transmission System

The expansion plan of transmission system in 2015 is shown in Figure 3.2 and the expansion plan of service reservoir is given in Table 3.3.

Table 3.3 Expansion Plan of Service Reservoir by Construction Phase

(m^3/d)

Term	West Bank				East Bank	Total capacity
	North High	North Low	South High	South Low	Gumbo	
Urgent improvement (phase 1) (-2012)	-	5,000	-	--		5,000
New system construction (phase 2) (2013 -2015)	10,000	5,000	-	-		15,000
New system construction (phase 3 and phase 4) (2016 - 2025)	6,000	14,000	16,000	10,000	11,000	57,000
Total	16,000	24,000	16,000	10,000	11,000	77,000

Note: The capacity of 2,000 m^3/d is covered by the reservoir or clear water tank in West WTP.

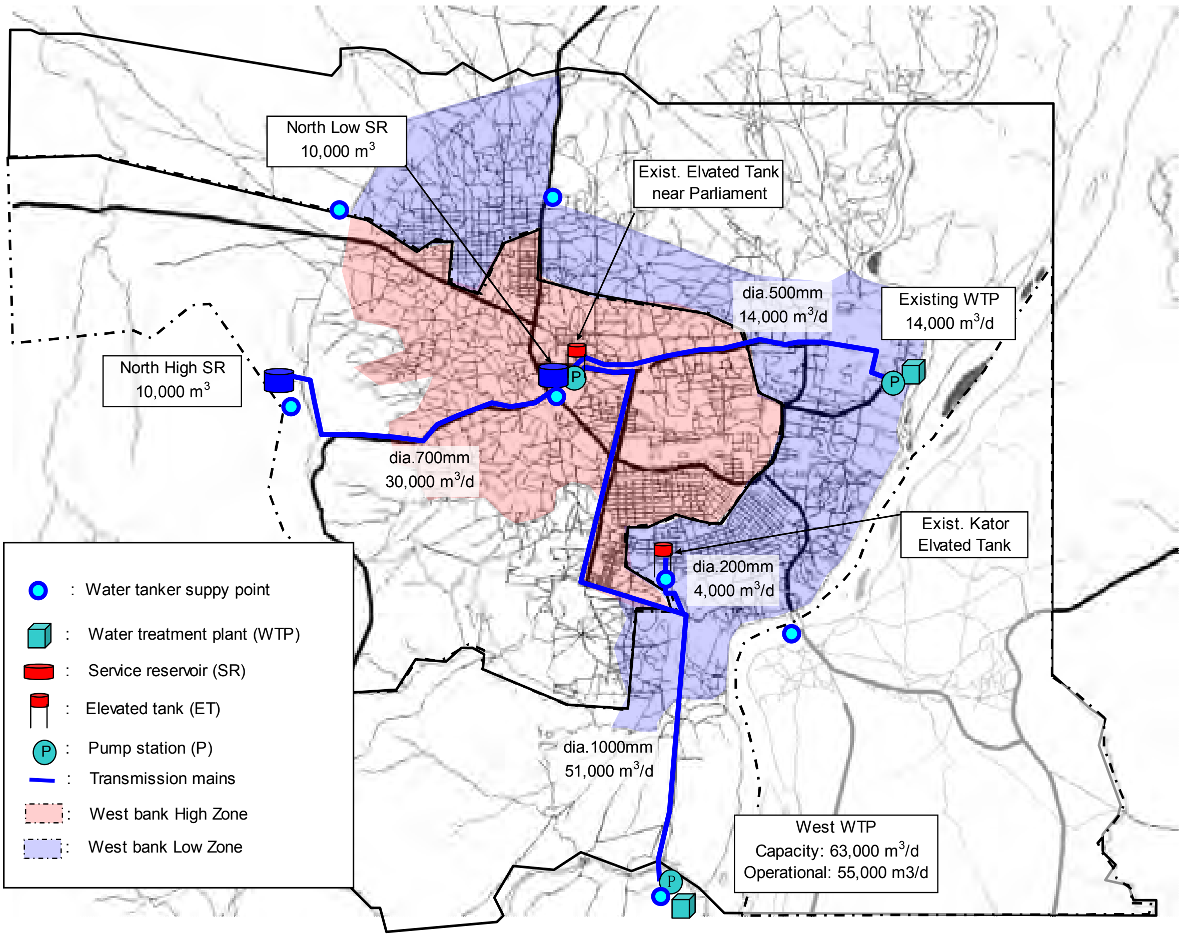


Figure 3.2 Expansion Plan of Transmission Pipeline System in 2015

3.5 Concepts of Phased Implementation

Based on the water demand and production schedule as discussed above, the concept of phased implementation of the proposed project components under the Master Plan is prepared in Table 3.4.

Table 3.4 Concept of Phased implementation of the Master Plan

Phase	Concept	Project components	Total production
Phase-1	This phase is regarded as an emergency improvement phase, in which a small project is implemented to give larger benefits with small investment. The project includes increasing production capacity of the existing WTP and utilization of the existing water supply system. In addition, rehabilitation of the existing network will be carried out to supply the limited water efficiently to the target customers.	• Expansion of the existing WTP • North Low Service Reservoir • Transmission pipeline from the existing WTP to North Low Service Reservoir • Full replacement of the existing network	14,000 m^3/d
Phase-2	This phase is regarded as an initiation of development of the new water supply system of the M/P. The project aims to increase water treatment capacity drastically and mainly supply water to the existing urban area with adequate amount of water.	• Construction of stage 1 of New West WTP • Construction of the first transmission and distribution main system • Expansion of distribution network	77,000 m^3/d
Phase-3	This phase is regarded as intermediate term of development of the new water supply system. The water supply system will be developed in the east bank. The frame of the main water supply system will be formulated.	• Construction of stage-2 of New West WTP • Construction of new East WTP • Second transmission and distribution main system • Expansion of distribution network	174,000 m^3/d
Phase-4	This phase is the final phase of development of new water supply system in the M/P. At the end of this phase, distribution network will be developed in the most of the Target Service Area.	• Construction of stage-3 of New West WTP • Expansion of distribution network.	237,000 m^3/d