CHAPTER 5 URBAN FACILITITIES RESTORATION AND IMPROVEMENT PLAN (WATER SUPPLY SECTOR)

5.1 Strategy for Water Supply Plan

In order to raise water coverage ratio in Greater Monrovia in the restoration of the existing White Plains Water Supply System, LWSC has been carrying out Monrovia Water and Sanitation Program since 2007 which is funded by international donors. Specifically, LWSC focuses on the following goals for future water coverage ratio:

First goal, which is given in Poverty Reduction Strategy (PRS), is to raise water service coverage ratio to 50% by 2011 in the whole of Liberia.

Second goal is based on the sector development plan for 2019 on which LWSC puts its own policy. It is to raise water service coverage ratio to 100% in Greater Monrovia.

In this study, water supply plans shall be formulated for the target years of 2014 and 2019 taking into consideration of these goals.

Current problems on water supply sector in Greater Monrovia and their countermeasures are shown in Table 5.1-1

Table 5.1-1 Current Problems and Countermeasures for Improvement

Current Problems	Countermeasures for Improvement
Much deteriorated water supply facilities	➢ Rehabilitation for rising main and distribution pipelines will be completed by 2011 through the Water and Sanitation Rehabilitation Program (WSRP).
Around 63% of dwellers in Greater Monrovia takes water from unsafe water source such as shallow or dug wells	➢ Capacity of the White Plains Water Supply System will be restored to 16MGD with the rehabilitation of pipelines by 2011. JICA Master Plan (MP) study proposes projects for water supply system improvement for the target year of 2014 and 2019 as follows: 1. Satellite water supply system in Paynesville for the target year of 2014. 2. Expansion of White Plain Water Supply System for the target year of 2019. 3. Expansion of satellite water supply system in Paynesville for the target year of 2019.
Lack of stable water supply	➢ Rising main and distribution pipelines will be separated and one service reservoir will be constructed in each distribution district for stable water supply for the target year of 2019 under the project for Expansion of White Plain Water Supply System.
Low revenue water ratio	➢ Rehabilitation of pipelines will be completed by 2011 through the WSRP. Water tariff system shall be improved by eliminating the flat rate system as well as promotion of leakage reduction through the technical cooperation projects as soon as possible.
Water supply for low income households	➢ Under the JICA MP study, satellite water supply system is proposed to be developed for the target year of 2019.
Lack of water quality parameter and lack of borehole monitoring	➢ Regular monitoring of water quality on water supply system as well as borehole monitoring is expected to be improved through technical cooperation projects as soon as possible.

Source: JICA Study Team

5.2 Basic Frame for Planning

5.2.1 Definition of Water Uses

5.2.1.1 Domestic (Residential) Water

Domestic water is residential water for such as drinking, toilets, laundry, cleaning in daily life. Domestic water consumption increases along with population growth and improved living standards. Service population multiplied by water consumption rates (daily per-capita water consumption) makes domestic water consumption.

5.2.1.2 Institutional and Commercial Water

Institutional and commercial water are defined as water used for civil functions, such as governmental and private offices, hotels, commercial facilities, hospitals and schools. Institutional and commercial water consumptions increase along with urban development and human activities.

5.2.1.3 Industrial Water

Industrial water is used for various purposes of industrial activities, including machinery cooling, treatment of product, washing them, and as a raw material. Industrial water use increases along with socio-economic development. Industrial water demand shall be estimated based on the urban plan which is formulated in this study.

5.2.1.4 Physical Losses

Physical losses occur as overflow from service reservoirs, water leakage on rising main, distribution pipelines, house connections, etc.

5.2.2 Criteria for Water Demand Projection

The criteria for estimating water demand in each water use is as shown in Table 5.2-1.

In terms of domestic use, daily per-capita water consumption is one of the policies of LWSC, which was envisaged in the light of water consumption to be increased due to implementation of the Water and Sanitation Rehabilitation Program (WSRP). Water consumption rate for institutional & commercial use was read from study report, Water Demand and Market Study in Monrovia, Liberia, which was funded by European Commission (EC). It shall be applied for estimating their consumption. Regarding industrial use, industrial areas given in the future land use plan which was formulated in this study multiplied by daily consumption with per-ha per-second make the future industrial water. In general, industrial water consumption rate is 1L per-ha per-sec. in major cities of Africa. In this study, 0.5L per-ha per-sec. was applied for industrial water consumption taking into consideration the restoration and improvement of Greater Monrovia. Physical loss ratio standardized in LWSC in the light of implementation of WSRP, based on the experiences of system operators shall be applied for estimating leakage amount of water.

In order to design the capacity of water supply facilities, daily maximum factor has to be examined in the light of seasonal fluctuation of water use. The daily maximum factor shall be applied based on the past two- year (2006-2007) trends for estimating daily maximum water demand.

Table 5.2-1 Criteria of Water Demand Projection

Water Use			Type of Supplying	Criteria
Administrative Population			For 2014	1,250,000 beneficiaries
			For 2019	1,470,000 beneficiaries
Service Coverage Ratio	House connection		For 2014	15% (Average of all the zones) (See Table 5.3-6)
	Kiosk, Gantry, etc.			56% (Average of all the zones) (See Table 5.3-6)
	House connection		For 2019	22% (Average of all the zones) (See Table 5.3-7)
	Kiosk, Gantry, etc.			78% (Average of all the zones) (See Table 5.3-6)
Domestic Water	[1]	House Connection		16Gal/capita/day (About 60liter/capita/day)
		Kiosk, Gantry, etc		6Gal/capita/day (About 20liter/capita/day)
Institutional & Commercial Water	[2]=[1]x30%			30% of domestic water consumption
Industrial Water	[3]			0.132gal/ha/sec. (About 0.5 liter /ha/sec.)
Physical Losses	[4]=([1]+[2]+[3])x30%		For 2014	30% of daily water consumption
	[5]= ([1]+[2]+[3])x25%		For 2019	25% of daily water consumption
Daily Maximum Water Demand	[6]= ([1]+[2]+[3]+[4])x120%		For 2014	120% of daily average water demand
	[7]= ([1]+[2]+[3]+[5])x120%		For 2019	

Source: JICA Study Team

5.3 Water Supply Development Plan

5.3.1 Groundwater Development Plan

5.3.1.1 Conditions for Groundwater Development

(1) Groundwater Storage and Recharge of Target Aquifer

The groundwater development is important to be carried out within rechargeable amount for sustainable groundwater use.

(a) Shallow Aquifer

The shallow aquifer is the target aquifer of shallow wells. The shallow aquifer consists of Quaternary strata, Tertiary strata, and the weathering zone or crackly zone of Mesozoic or Paleozoic sedimentary formations, intrusive rock such as diabase and Precambrian basement rock such as melanocratic gneiss. The depth of the aquifer is presumed to be several meters to 20m. The geological distribution of the shallow aquifer is shown in Figure 5.3-1 (A).

The amount of groundwater storage of the shallow aquifer is presumed from the aquifer thickness and the effective porosity of every geological division. Moreover, the amount of groundwater storage of the water level fluctuating portion between dry season and rainy season during a year is presumed as the amount of recharge. The groundwater level change between rainy season and dry season of the shallow aquifer is presumed 0.5 to 2.0m from dry-up wells of well inventory investigation. Faillace (1981)[1)] shows 0.5 to 1.0m as the fluctuations of water levels of shallow wells.

The amount of storage is presumed to be 2.34×10^8 m^3, and the amount of recharge is presumed to be 7.16×10^7 m^3. The present water use amount of the shallow aquifer is estimated at 1.11×10^7 m^3 a year when the average water use is assumed to be 30L / day per person, because the present population of the study area is 1,010,575 persons.

The present amount of water use is 16% of the amount of recharge, and it is evaluated to still have enough volume for groundwater development.

(b) Deep Aquifer

The deep aquifer is the target aquifer of deep wells. The deep aquifer mainly consists of the sandstone layers of sedimentary formations such as Tertiary Edina sandstone formation and Ordovician Painesville sandstone formation. The depth of the aquifer is presumed to be 20m to 50m. The deeper portion more than 50m is presumed low possibility as good aquifer because of its shale faces and hard rock condition. The Precambrian basement rock gneiss and the intrusive rock diabase also have a possibility of forming aquifer at crackly parts, but generally it is difficult to find out the crackly part in deep portion. The geological distribution of the deep aquifer is shown in Figure 5.3-1 (B).

The amount of groundwater storage is presumed from the thickness and the effective porosity for every geological division of the deep aquifer. Moreover, the amount of recharge is obtained as storage amount of water level fluctuating portion between rainy season and dry season. The LWSC production well No.1 shows about 2.3m, and well No.2 shows about 0.6m.

The amount of storage is presumed 5.23 x 10^8 m^3, and the amount of recharge is presumed 2.29 x 10^7 m^3.

Deep wells (depth 20m and more) in the study area, existing 4 production wells and about 5 wells in which the hand pump is installed is used, and the amount of groundwater use of deep aquifer is presumed about 2.50 x 10^5 m^3 per year, and it shows to have enough capacity to groundwater development.

(A) Distribution of Strata of Shallow Aquifer **(B) Distribution of Strata of Deep Aquifer**

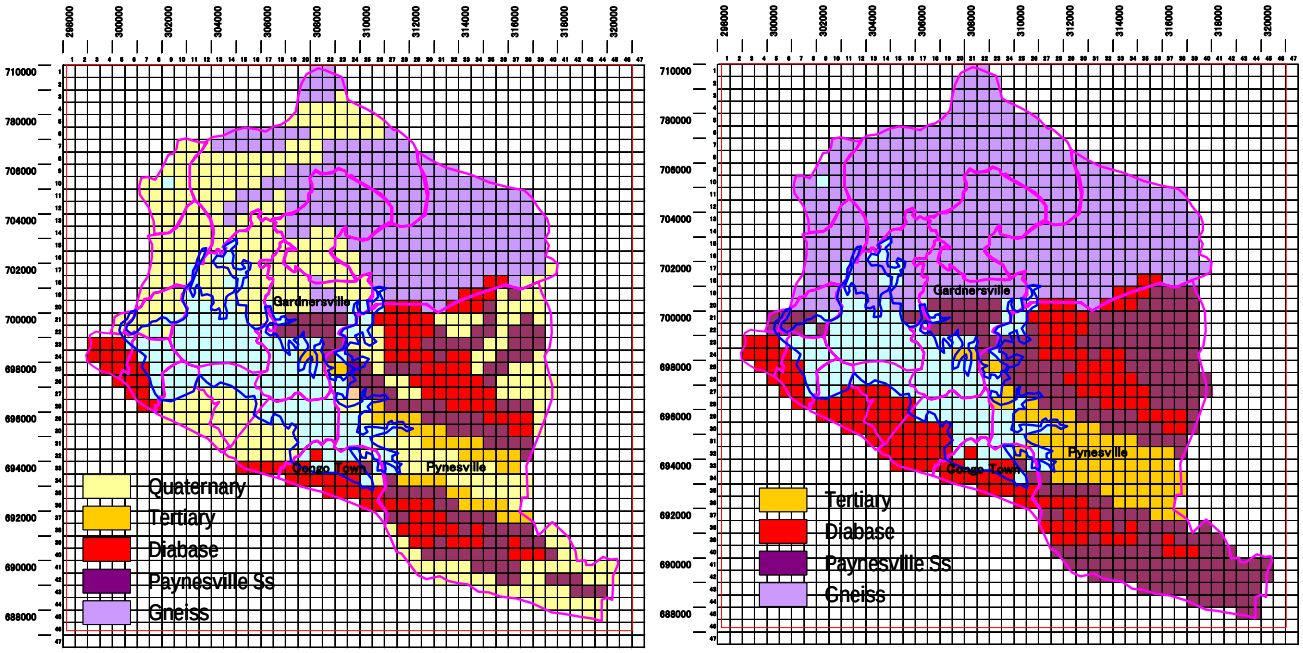


Figure 5.3-1 Geological Distribution of Shallow and Deep Aquifer

(2) Outline Estimation of Water Balance

The water balance is indicted in the following equation.

Precipitation = Evapotranspiration + Surface runoff + Retention of surface soil + Groundwater recharge

Each amount concerning the water balance is presumed as follows:

(a) Precipitation

The rain fall distribution of the study area is shown in Figure 5.3-2. The amount of precipitation of the study area is estimated 9.22 x 108 m^3 per year.

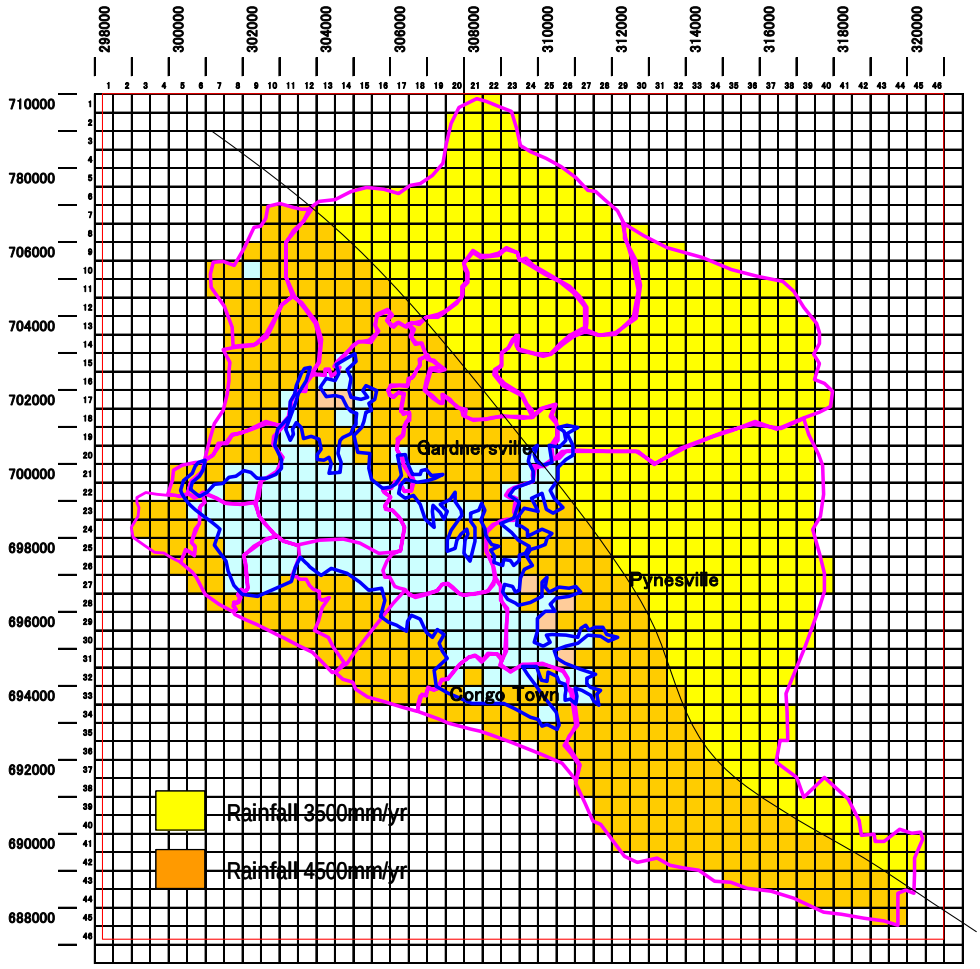


Figure 5.3-2 Distribution of Precipitation

(b) Evapotranspiration

S.H.E.R Ingenieurs-Conseils s. a. (2004)[2)] indicated about 5mm/day on average as the evapotranspiration value of Monrovia by Penman methods (using FAO program). It shows 1825mm/ year and indicates 4.22 x 10^8 m^3 per year, namely 45.8% of the precipitation. (Incidentally the estimation using Thorntewaite method becomes 1559mm/year. That is 3.61 x 10^8 m^3 per year.)

(c) Groundwater Recharge

According to section (1), the groundwater recharge is 9.45 x 10^7 m^3 per year, namely 10.2% of the precipitation. (The recharge of shallow aquifer is 7.16 x 10^7 m^3 and the recharge of deep aquifer is 2.29 x 10^7 m^3).

(d) Surface Runoff and Retention of Surface Soil

The surface runoff and retention of surface soil is 4.06 x 10^8 m^3 per year, namely 44.0% of the precipitation. When the retention of surface soil is presumed 5.20 x 10^7 m^3 per year from assumption of thickness of unsaturated zone and moisture content, the surface runoff is presumed 3.54 x 10^8 m^3 per year.

(3) Groundwater Development Potential

The shallow aquifer already has innumerable shallow wells, and the development with large quantity is difficult. Moreover, it is easy to receive contamination from living environment of watershed.

The deep aquifer is the target of public groundwater development. The main aquifer is the thick part of the sandstone portion of the Edina sandstone formation or the Painesville sandstone formation.

In consideration of the yield condition of exploratory wells of the study and the existing production wells, the distribution of transmissibility is presumed as shown in Figure 5.3-3.

The southeast side of the study area and Du river area including eastward outside the study area have possibility of high groundwater development potential.

Although the highly weathering portion or hardly crackly portion of intrusive rock diabase and melanocratic gneiss has also possibility of groundwater presence, it seems difficult to find out plenty of groundwater bearing portions.

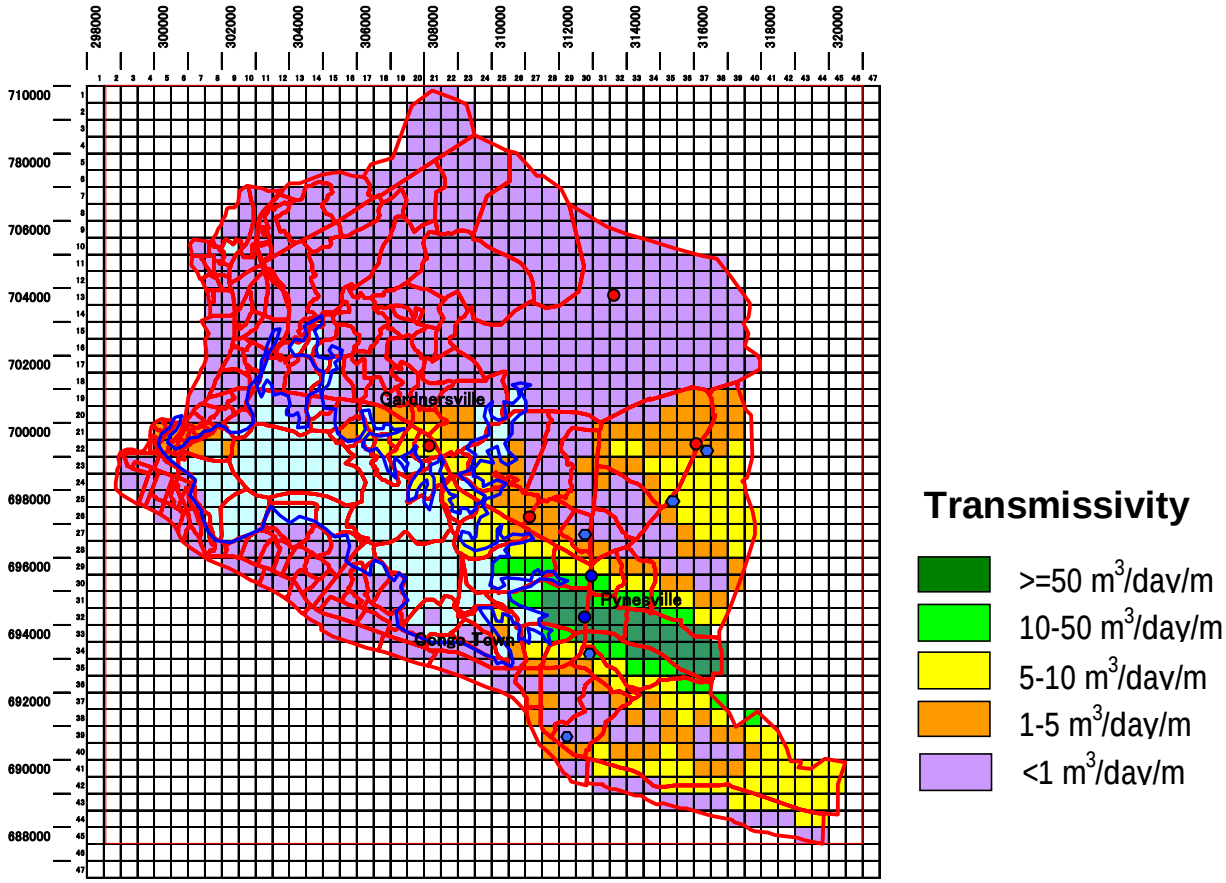


Figure 5.3-3 Distribution of Transmissibility of Deep Aquifer

<< REFERENCE>>

[1)] Faillace (1981); Hydrogeological Characteristics of the Unconsolidated Sediments in Monrovia Area by C.Faillace, Liberian Hydrological Service, December 1981

[2)] S.H.E.R. Ingenieurs-Conseils s.a (2004); To Allow Future Participants in the Market a Detailed and Neutral Overview of the Natural Water Resources in the Area, PROJECT No.8, ACP.LBR_2, Draft Final Report, S.H.E.R. Ingenieurs-Conseils s.a, November 2004

5.3.1.2 Basic Direction of Groundwater Development

The basic direction of groundwater development plan is set up as follows.

1) The thick sandstone portions of the Tertiary Edina sandstone formation and the Paleozoic Paynesville sandstone formation is set as the target aquifer of the groundwater development plan. The crackly portions of the intrusive rock diabase and the basement rock melanocratic gneiss are not set as the target because of difficulty of finding out groundwater bearing parts.

The groundwater development according to the rank shown in Table 5.3-1 is performed.

Table 5.3-1 Rank Classification of Groundwater Development Area

Rank	Category based on Transmissivity	Description
A	>= 50m^3/day/m	Yield comparable as Well No.1, Sand and sandstone of Paynesville formation, Edina formation and Quaternary
B	10-50 m^3/day/m	Yield comparable as Well No.2, Sandstone of Paynesville formation
C	5-10 m^3/day/m	Yield comparable as Well J-1, Sandstone of Paynesville formation

2) The sustainable groundwater development is performed. That is, the withdrawal of groundwater exceeding the amount of groundwater recharge by rainfall every year is not performed.

5.3.1.3 Groundwater Development Area and Required Amount

Five communities which show the groundwater development area according to the short term plan of the water supply development plan in Figure 5.3-4 are the target area. The required withdrawal of groundwater of each community is shown in Table 5.3-2 comparing with the amount of groundwater recharge, which is assumed to be10% of the precipitation. The development amount of groundwater will have turned into 50% or less of the amount of recharge and will be evaluated to be a sustainable amount of groundwater.

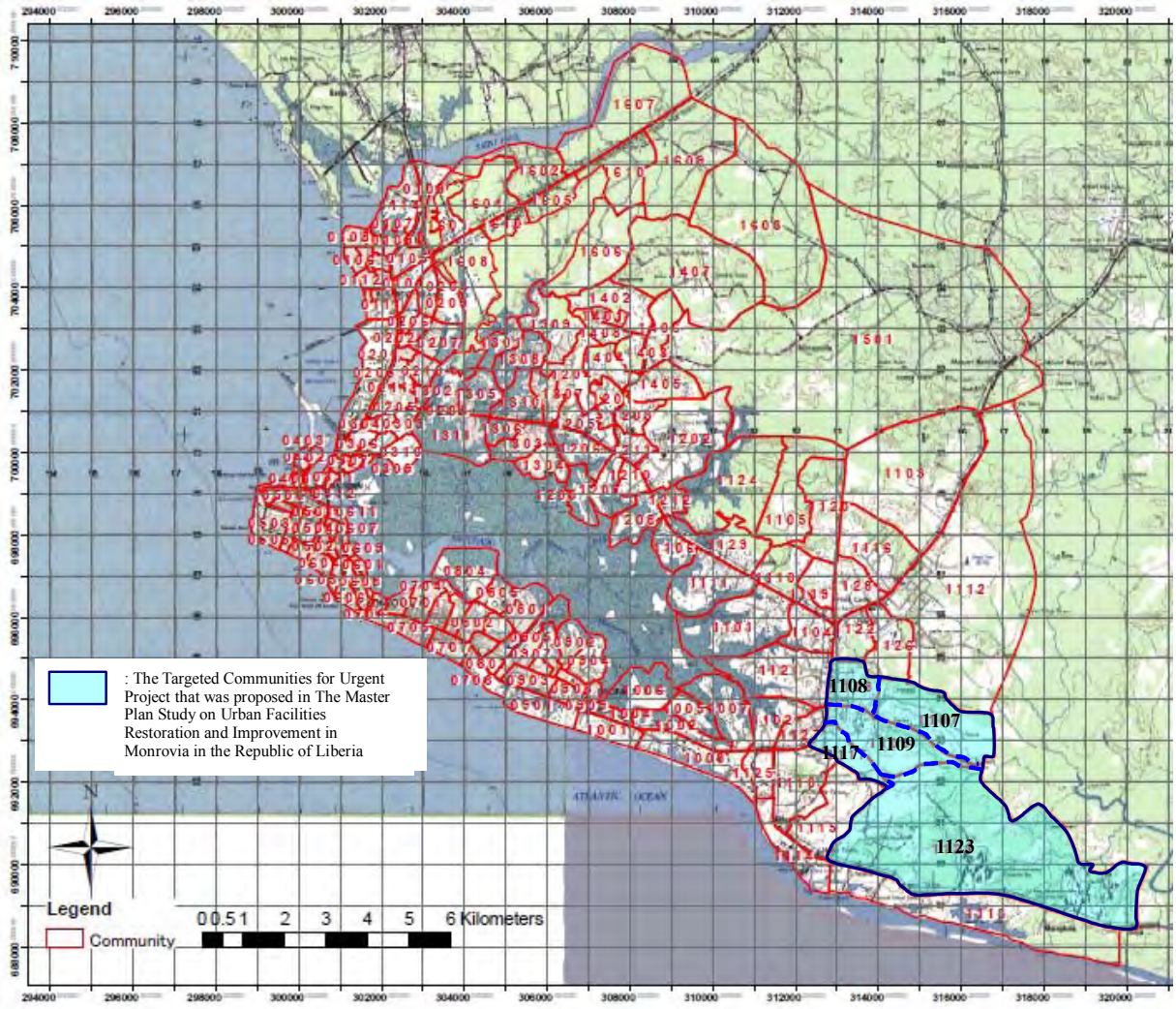


Figure 5.3-4 Target Groundwater Development Area

Table 5.3-2 Required Water Supply Amount of Each Community to Recharge

ID.	Community	Area	Water Supply Amount	Mean Annual Rainfall	Amount of Rainfall	Recharge	Supply Amount/ Recharge
		km^2	m^3/yr	mm	m^3/yr	m^3/yr	%
1107	Duport Road North-East	3.324	414,458	3,500	11,634,000	1,163,400	36
1108	Duport Road North	1.241	207,229	4,300	5,336,300	533,630	39
1109	Duport Road South	2.65	317,751	4,000	10,600,000	1,060,000	30
1117	Paynesville Joe Bar	1.018	221,044	4,500	4,581,000	458,100	48
1123	Rehab / Borbor Town	15.977	442,088	4,085	65,266,045	6,526,605	7

5.3.1.4 Groundwater Development Project

(1) Well Specification and Yield Which Can be Pumped Up

Well standard specification is set up as shown in Figure 5.3-5.

At least the 6" well is required in order to obtain the yield beyond 1.5L/sec using a submersible motor pump. Moreover, although the possible yield can increase 4-5% in case of 8" well, the drilling cost will increase because of the requirement of bigger rotary percussion type rig owing to necessity of drilling of rather hard rock portion. The average total depth and the screen length is set up 50m and 30m respectively , however these dimension are modified according to the hydrogeological condition of the well site.

The possible yield per well on calculation in case of each rank is shown in Table 5.3-3.

Table 5.3-3 Possible Yield and Calculation Condition

Item	Rank A	Rank B	Rank C
Possible yield / well (m^3/day)	**359.4**	**99.1**	**44.5**
<<Condition of calculation>>			
Transmissivity (m^3/day/m)	69.1	17.3	6.91
Permeability coefficient (m/sec)	4.0 x 10-5	1.0 x 10-5	4.0 x 10-6
Storativity	5.0 x 10-2	1.0 x 10-3	2.0 x 10-3
Effective thickness of aquifer (m)	30	30	30
Pumping duration (hr/day)	8	8	8
Drawdown (m)	15	20	20
Condition of calculation	Theirs's non-equilibrium equation, Unconfined aquifer condition	Theirs's non-equilibrium equation, Confined aquifer condition	Theirs's non-equilibrium equation, Confined aquifer condition

5.3.1.5 Required Well Number and Arrangement

The required well number to the required yield of each community is shown in Table 5.3-4.

Based on the groundwater development potential of Figure 5.3-3, it is set up in consideration of the distribution of Rank A, B, and C.

In addition, at present stage, the investigation for the development area is not carried out. Since the condition of Rank A is uncertain, the estimation is carried out divided into the following 2 cases.

1) Case I; In case that well of Rank A can be drilled as same as Figure 5.3-3 illustration

2) Case II; In case that well of Rank A becomes Rank B

In addition, each case was examined as 70% of the strike rate of Rank A, 80% of the strike rate of Rank B, and 90% of the strike rate of Rank C.

A well arrangement plan (Case I and Case II) is shown in Figure 5.3-6.

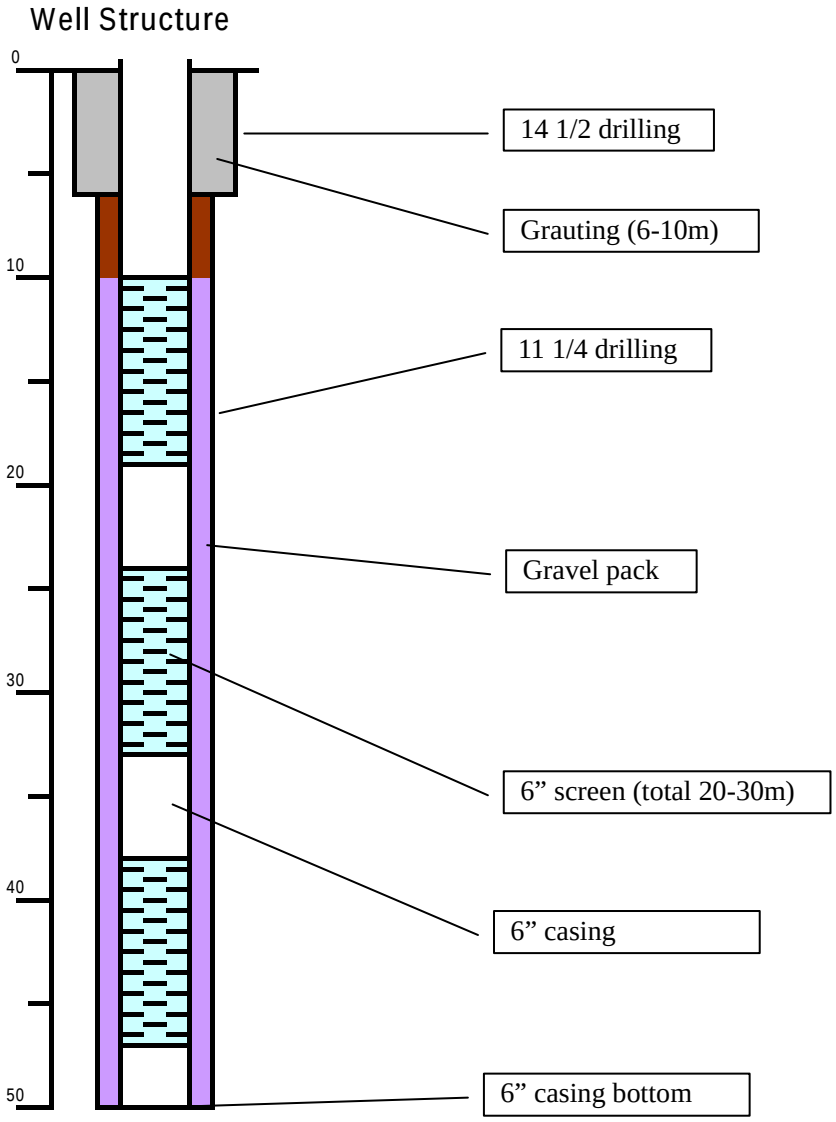


Figure 5.3-5 Standard Structure of Production Well

Table 5.3-4 Required Number of Well in Each Community

ID	Community	Supply amounts of water (m^3/day)	Necessary Well Number					
			Case I			Case II		
			Rank A	Rank B	Rank C	Rank A	Rank B	Rank C
			359.4	99.1	44.5	359.4	99.1	44.5
1107	Duport Road North-East	1,135.5	5	0		0	15	
1108	Duport Road North	567.8	3	0		0	8	
1109	Duport Road South	870.6	3	2		0	11	
1117	Paynesville Joe Bar	605.6		1	12		1	12
1123	Rehab - Borbor Town	1,211.2		8	6		8	6
Total		4,390.6	40			61		

In addition, in consideration of the sphere of influence, the interval of Rank A wells are set 500m and more, Rank B wells 200m and more and C rank wells 100m and more.

Moreover, since the well arrangement becomes very tight in Joe Bar Community (Code 1117) because

of narrow area and predominant Rank B and C distribution, the water supply from other areas is required.

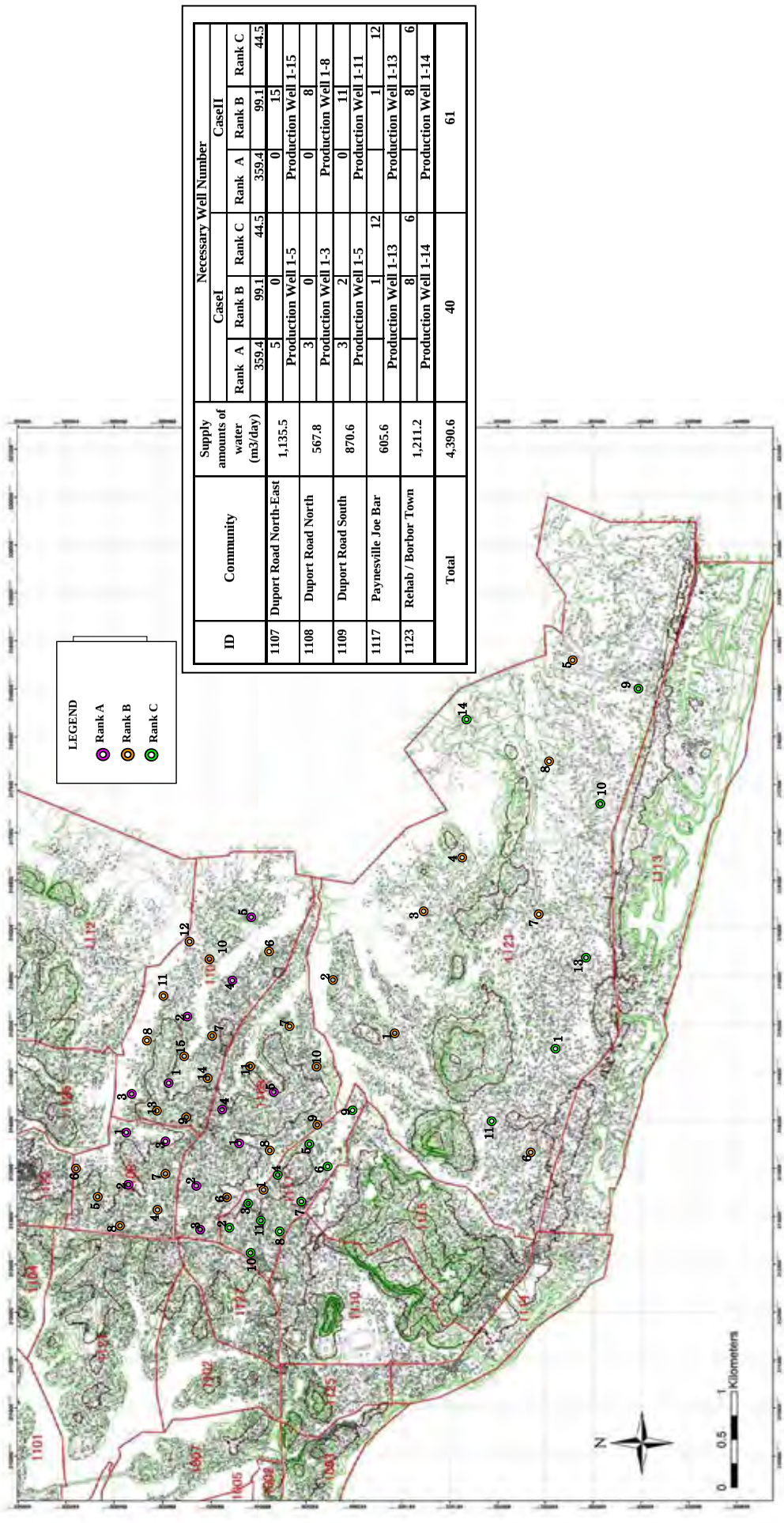
Anyway, the conductance of electric sounding and exploratory well drilling investigation in the target area is necessary, and the adjustment of the project plan is required before starting the project.

5.3.1.6 Water Supply to the Oil Contaminated Area in Gardnerville Zone

The results of well inventory investigation on oil contamination in Gardnerville zone are shown in Section 2.5-7 of CHAPTER 2. According to the results of the investigation, oil contamination was found in some areas around LPRC's old oil refinery.

In terms of water supply service in Gardnerville zone, capacity of the White Plains water supply system will be restored to 16MGD by 2011 so that some areas of Gardnerville zone will also be covered by this system. The entire Gardnerville zone is proposed to be covered by the White Plains water supply system and to be expanded in the target year of 2019. Therefore, groundwater development in the areas around LPRC's old oil refinery is not required in the future.

However, in case of need to develop small scale groundwater development for urgent purpose, the oil contaminated area as shown in Figure 2.5-41 shall be avoided and carefully examined even in their surrounding areas prior to drilling works of groundwater development, and drilling sites should be decided.



ID	Community	Supply amounts of water (m3/day)	Necessary Well Number					
			Case I			Case II		
			Rank A	Rank B	Rank C	Rank A	Rank B	Rank C
			359.4	99.1	44.5	359.4	99.1	44.5
1107	Duport Road North-East	1,135.5	5	0		0	15	
			Production Well 1-5			Production Well 1-15		
1108	Duport Road North	567.8	3	0		0	8	
			Production Well 1-3			Production Well 1-8		
1109	Duport Road South	870.6	3	2		0	11	
			Production Well 1-5			Production Well 1-11		
1117	Paynesville Joe Bar	605.6		1	12		1	12
			Production Well 1-13			Production Well 1-13		
1123	Rehab / Borbor Town	1,211.2		8	6		8	6
			Production Well 1-14			Production Well 1-14		
	Total	4,390.6	40			61		

Figure 5.3-6 Arrangement of Production Wells for Groundwater Development Project

5.3.2 Water Supply Development Plan

5.3.2.1 Water Demand Projection

Based on the design criteria mentioned in Table 5.2-1, future water demand in Greater Monrovia was estimated to be 18.8mln Gal/day (about 71,000m^3/day) in 2014 and 30.3mln Gal/day (about 114,000m^3/day) in 2019 shown in Table 5.3-5. Figure 5.3-7 also shows the trends of water demand for 2008, 2014 and 2019 by zone. Water demand of Paynesville Zone is highest in 16 zones, accounting at least 5MGD and 10MGD in 2014 and 2019 respectively, this is because Paynesville zone will urbanize according to the urban development plan which was formulated in this study. Table 5.3-6 and Table 5.3-7 show a breakdown of water demand estimates in 2014 and 2019.

Table 5.3-5 Service Population and Water Demand in Greater Monrovia

Items		2008	2014	2019
Administrative Population		1,009,912	1,250,000	1,470,000
Service Population		372,436	888,800	1,470,000
Service Coverage Ratio	%	37	71	100
Water Demand	Gal/day	4,300,000	18,883,947	30,250,000
	m^3/day	16,276	71,476	114,496

Source: JICA Study Team

Table 5.3-6 Water Demand by Zone in 2014

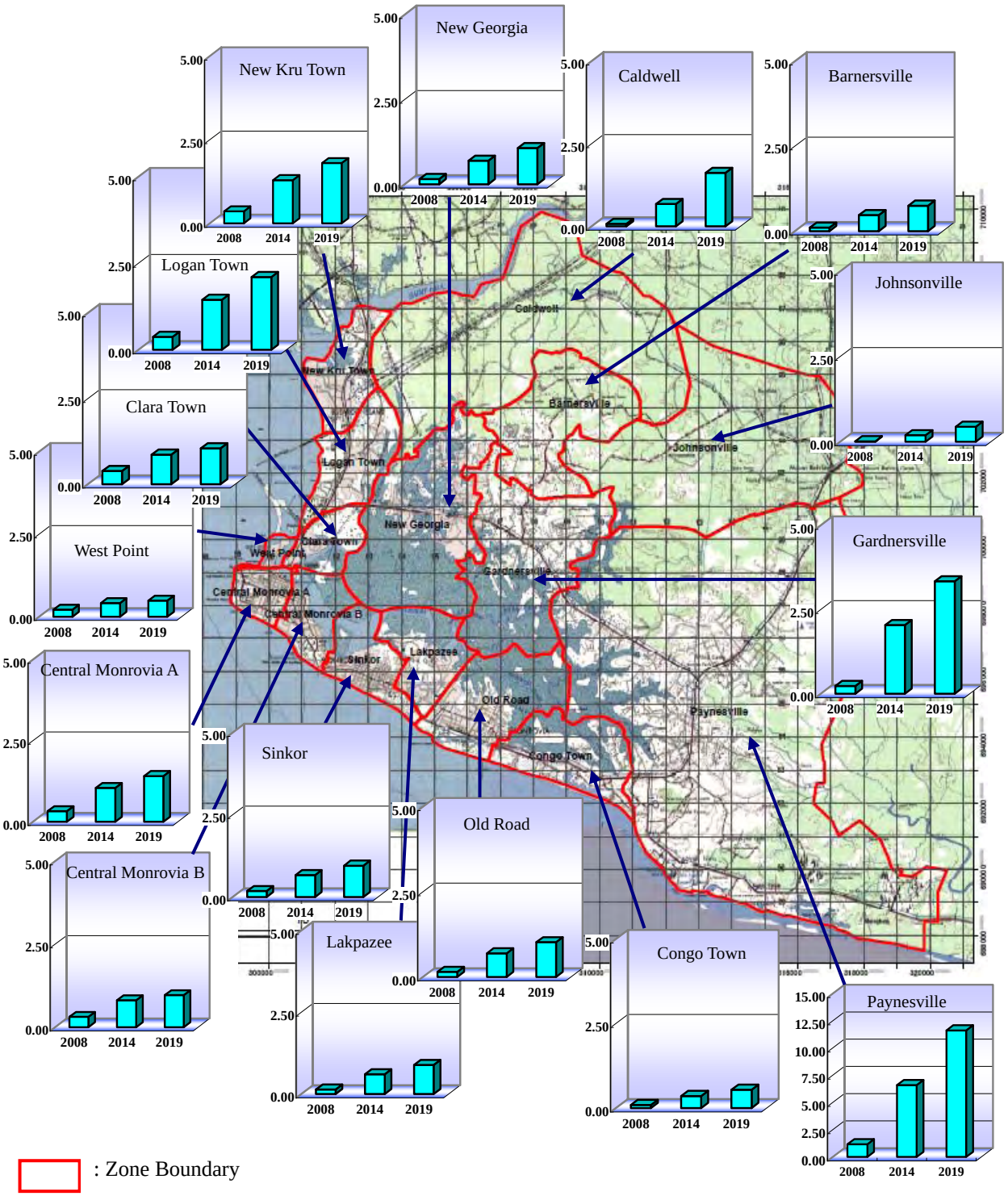
No.	Zone Name	Pop. in 2008	Pop. in 2014	Coverage Ratio in 2014 (%)		Service Pop. in 2014			Water Consumption (Gal/d)			Institutional & Commercial (Gal/d)	Ind. Area (ha)	[3] Large Consumption (Gal/d)	Total Water Consumption (Gal/d)	Daily Max. Water Demand (Gal/d)
				House Connection	Kiosk	House Connection	Kiosk	Total	House Connection	Kiosk	Total [1]	[1]x30%=[2]			[1]+[2]+[3]=[4]	([4] x 1.2)/0.7
1	New Kru Town	73,379	75,670	7	67	5,297	50,699	55,996	84,752	304,194	388,946	116,684	36	251,739	757,369	1,298,347
2	Logan Town	58,168	63,201	14	66	8,848	41,713	50,561	141,568	250,278	391,846	117,554	53	335,954	845,354	1,449,178
3	Clara Town	55,462	57,815	16	66	9,250	38,158	47,408	148,000	228,948	376,948	113,084	2	12,442	502,474	861,384
4	West Point	29,516	29,175	14	69	4,085	20,131	24,216	65,360	120,786	186,146	55,844			241,990	414,840
5	Central Monrovia A	42,139	55,580	33	52	18,341	28,902	47,243	293,456	173,412	466,868	140,060			606,928	1,040,448
6	Central Monrovia B	40,688	46,216	28	57	12,940	26,343	39,283	207,040	158,058	365,098	109,529			474,627	813,646
7	Sinkor	43,780	47,210	21	50	9,914	23,605	33,519	158,624	141,630	300,254	90,076			390,330	669,137
8	Lakpazee	42,045	44,595	20	48	8,919	21,406	30,325	142,704	128,436	271,140	81,342			352,482	604,255
9	Old Road	48,274	51,328	20	48	10,266	24,637	34,903	164,256	147,822	312,078	93,623			405,701	695,487
10	Congo Town	25,217	29,065	14	55	4,069	15,986	20,055	65,104	95,916	161,020	48,306			209,326	358,845
11	Paynesville	350,335	509,871	13	55	66,283	280,429	346,712	1,060,528	1,682,574	2,743,102	822,931	44	289,107	3,855,140	6,608,811
12	Gardnersville	80,397	90,327	13	53	11,743	47,873	59,616	187,888	287,238	475,126	142,538	92	572,314	1,189,978	2,039,962
13	New Georgia	54,188	59,041	13	53	7,675	31,292	38,967	122,800	187,752	310,552	93,166			403,718	692,088
14	Barnersville	35,224	40,195	13	53	5,225	21,303	26,528	83,600	127,818	211,418	63,425			274,843	471,159
15	Johnsonville	4,514	16,437	13	53	2,137	8,712	10,849	34,192	52,272	86,464	25,939			112,403	192,691
16	Caldwell	26,586	34,272	13	53	4,455	18,164	22,619	71,280	108,984	180,264	54,079	51	158,630	392,973	673,668
Total		**1,009,912**	**1,250,000**			**189,447**	**699,353**	**888,800**	**3,031,152**	**4,196,118**	**7,227,270**	**2,168,180**	**278**	**1,620,186**	**11,015,636**	**18,883,946**

Source: JICA Study Team

Table 5.3-7 Water Demand by Zone in 2019

No.	Zone Name	Pop. in 2008	Pop. in 2019	Coverage Ratio in 2019 (%)		Service Pop. in 2019			Water Consumption (Gal/d)			Institutional & Commercial (Gal/d)	Ind. Area (ha)	[3] Industrial (Gal/d) (x 0.132gal/ha/s)	Total Water Consumption (Gal/d)	Daily Max. Water Demand (Gal/d)
				House Connection	Kiosk	House Connection	Kiosk	Total	House Connection	Kiosk	Total [1]	[1]x30%=[4]			[1]+[2]+[3]=[4]	([4] x 1.2)/0.75
1	New Kru Town	73,379	78,818	10	90	7,882	70,936	78,818	126,112	425,616	551,728	165,518	36	410,573	1,127,819	1,804,510
2	Logan Town	58,168	68,431	20	80	13,686	54,745	68,431	218,976	328,470	547,446	164,234	53	604,454	1,316,134	2,105,814
3	Clara Town	55,462	60,724	20	80	12,145	48,579	60,724	194,320	291,474	485,794	145,738	2	22,810	654,342	1,046,947
4	West Point	29,516	29,370	20	80	5,874	23,496	29,370	93,984	140,976	234,960	70,488			305,448	488,717
5	Central Monrovia A	42,139	67,692	40	60	27,077	40,615	67,692	433,232	243,690	676,922	203,077			879,999	1,407,998
6	Central Monrovia B	40,688	51,579	30	70	15,474	36,106	51,580	247,584	216,636	464,220	139,266			603,486	965,578
7	Sinkor	43,780	50,842	30	70	15,253	35,589	50,842	244,048	213,534	457,582	137,275			594,857	951,771
8	Lakpazee	42,045	47,451	30	70	14,235	33,216	47,451	227,760	199,296	427,056	128,117			555,173	888,277
9	Old Road	48,274	54,715	30	70	16,414	38,300	54,714	262,624	229,800	492,424	147,727			640,151	1,024,242
10	Congo Town	25,217	32,748	20	80	6,550	26,198	32,748	104,800	157,188	261,988	78,596			340,584	544,934
11	Paynesville	350,335	650,620	20	80	130,124	520,496	650,620	2,081,984	3,122,976	5,204,960	1,561,488	44	501,811	7,268,259	11,629,214
12	Gardnersville	80,397	100,081	20	80	20,016	80,065	100,081	320,256	480,390	800,646	240,194	92	1,049,242	2,090,082	3,344,131
13	New Georgia	54,188	64,053	20	80	12,811	51,242	64,053	204,976	307,452	512,428	153,728			666,156	1,065,850
14	Barnersville	35,224	44,995	20	80	8,999	35,996	44,995	143,984	215,976	359,960	107,988			467,948	748,717
15	Johnsonville	4,514	26,643	20	80	5,329	21,314	26,643	85,264	127,884	213,148	63,944			277,092	443,347
16	Caldwell	26,586	41,239	20	80	8,248	32,991	41,239	131,968	197,946	329,914	98,974	51	581,645	1,010,533	1,616,853
Total		**1,009,912**	**1,470,000**			**320,117**	**1,149,884**	**1,470,001**	**5,121,872**	**6,899,304**	**12,021,176**	**3,606,352**	**278**	**3,170,535**	**18,798,063**	**30,076,901**

Source: JICA Study Team



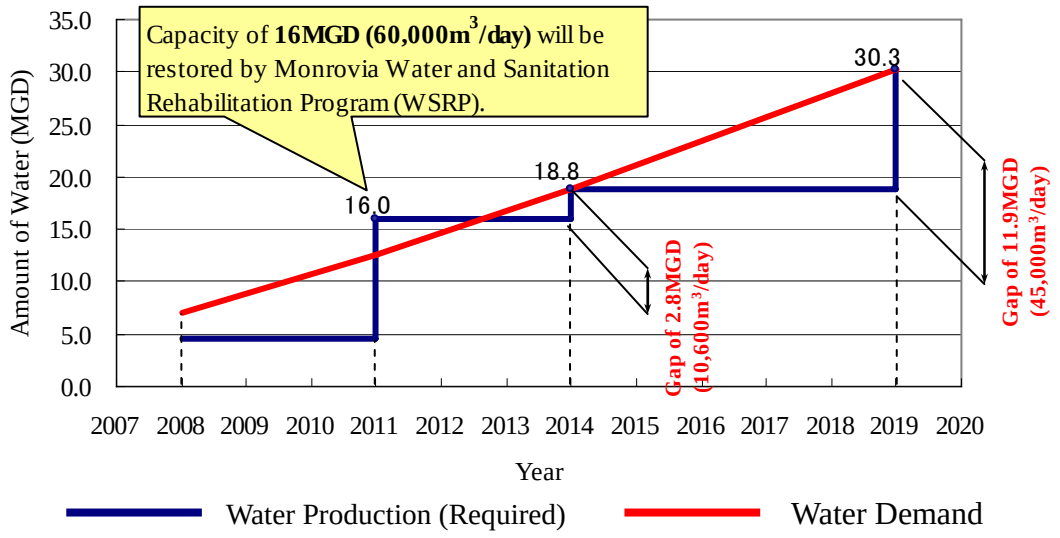
Source: JICA Study Team

Figure 5.3-7 Water Demand by Zone

5.3.2.2 Water Balance

Figure 5.3-8 shows water production and water demand for the future. The capacity of the existing White Plains water supply system is to be restored to 16MGD in 2011 through the Water and Sanitation Rehabilitation Program (WSRP). Hence, water production will exceed the water demand

up to the year 2013. However, water production will be short by about 3MGD (about 10,000m^3/day) in Greater Monrovia by 2014, unless water supply system is developed after 2011. Even though water production of 3MGD is developed for the demand in 2014, the Greater Monrovia will face water shortage of about 12MGD (about 40,000m^3/day) in 2019.



Source: JICA Study Team

Figure 5.3-8 Trend of Water Production and Water Demand

5.3.2.3 Short Term Plan of Water Supply Development

At present, the White Plains water supply system is being rehabilitated by the assistance of multiple funds of international donors, etc., so that the water supply system will be restored to its design capacity of 16MGD (about 60,000m^3/day) for dwellers of 0.75mln.. However, Greater Monrovia will face water shortage of about 3MGD (about 10,000m^3/day) in 2014. Out of 3MGD, water of about 2.5MGD (Population: about 0.13mln) will be short in Paynesville zone, with the largest population in Greater Monrovia.

Paynesville zone is predicted to be developed for residential area as the results of this Master Plan Study. However, distribution network has not been developed in Paynesville zone with the exception of the pipelines along trunk road. Development of water distribution network is urgent issues for supplying water. As mentioned above, even if the White Plains water supply system is restored, the total required water for Greater Monrovia will not be secured by it.

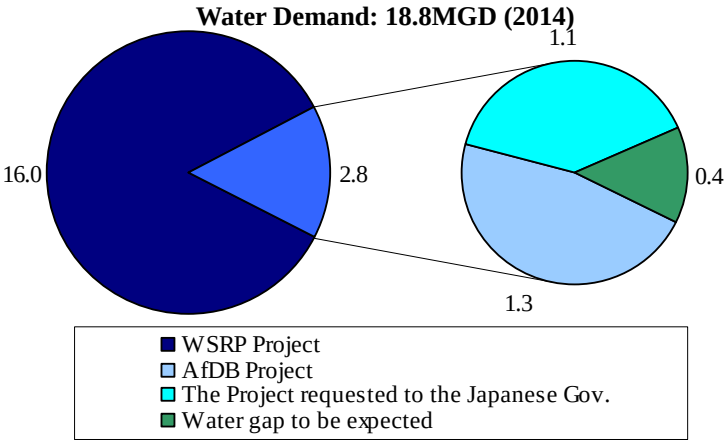
Therefore, as Paynesville zone has the highest groundwater potential in Greater Monrovia, development of independent water supply system, called as satellite water supply system using groundwater is the countermeasure for urgent water supply development for the target year of 2014.

As an immediate action, project implementation of the satellite water supply system is expected to eliminate water shortage, realize stable water supply with safe quality water and contribute to raise water coverage ratio.

From the aspect of above circumstances, LWSC focuses on development of water supply system for covering water shortage in Paynesville zone as well as the restoration of White Plains water supply system. Therefore, LWSC has commenced preliminary study for the northern part of Paynesville as Monrovia Expansion and Rehabilitation of Three County Capitals (ERTC), which is funded by AfDB. The beneficiaries are estimated to be about 70,000 persons. On the other hand, LWSC also made a request of Project for Emergency Development of Water Supply System at Paynesville in Greater Monrovia (hereafter PEDW) as Japanese grant aid, which focuses on southern part of Paynesville.

Figure 5.3-9 shows the expected water production by projects for the target year of 2014, such as WSRP, the project which was requested to Japanese government and AfDB project. Total water demand in 2014 is 18.8MGD (about 70,000m^3/day), while water production of 16MGD (about

60,000m^3/day) is secured by WSRP. It is expected that the rest of some amounts of 2.8MGD (about 10,000m^3/day) shall be covered by the satellite water supply system.



Source: JICA Study Team

Figure 5.3-9 Water Production by Projects for 2014

When three (3) projects are carried out as expected, service coverage areas will be as shown in Figure 5.3-11. Target areas of PEDW are composed of five (5) communities of Duport Road North-East, Duport Road North, Duport Road South, Paynesville Joe Bar and Rehab-Borbor Town communities. Their service population is about 60,000, accounting for about 70% of the administrative population. Total water demand for the beneficiaries is about 1.1MGD (about 4,400m^3/day) (see Table 5.3-8). Figure 5.3-10 shows typical satellite water supply system using groundwater that was constructed as a pilot project in this study and proposed as water supply system for the short term project.

Table 5.3-8 Information on the Project Areas by Community

ID.	Community	2014		
		Administrative Population(A)	Service Population	Water Demand (mln Gal/day)
1107	Duport Road North-East	22,986	15,630	0.30
1108	Duport Road North	11,205	7,619	0.15
1109	Duport Road South	17,625	11,985	0.23
1117	Paynesville Joe Bar	12,189	8,289	0.16
1123	Rehab - Borbor Town	24,266	16,501	0.32
Total		**88,271**	**60,024** (About 68% of (A))	**1.16** (4,400m3/day)

Source: JICA Study Team

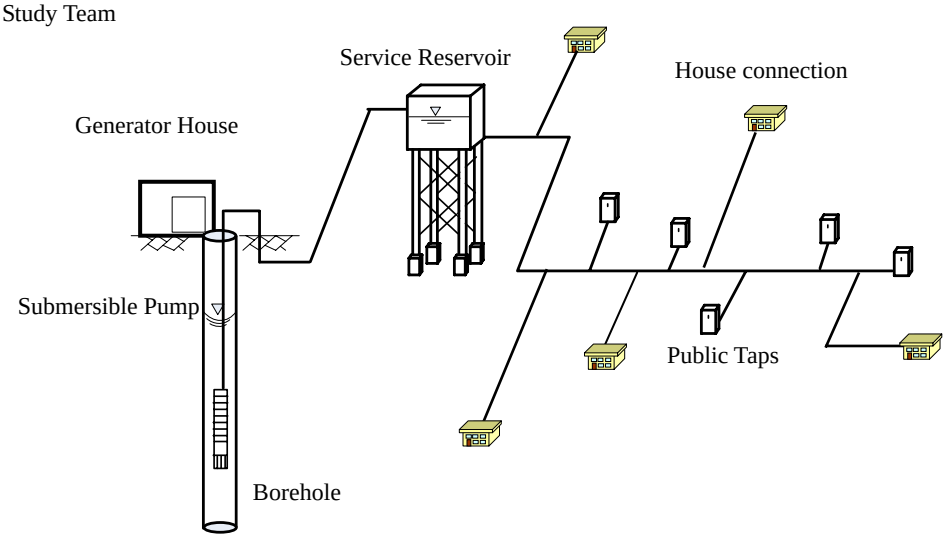


Figure 5.3-10 Conceptual Satellite Water Supply System

: Existing Rising Main		DIP	: Ductile Cast Iron Pipes
: Change Point of Pipe Diameter		CIP	: Cast Iron Pipes
: White Plains Treatment Plant to be restored		OCN	: Concrete Pipes
: Booster Pump Station			: Service Area in 2008
: High Lift Pump Station			: Project Area Monrovia Water & Sanitation Rehabilitation Program
: Existing Service Reservoir			: Project Area requested to the Japanese
(G)	: Ground Service Reservoir.		: Project Area under study by AfDB

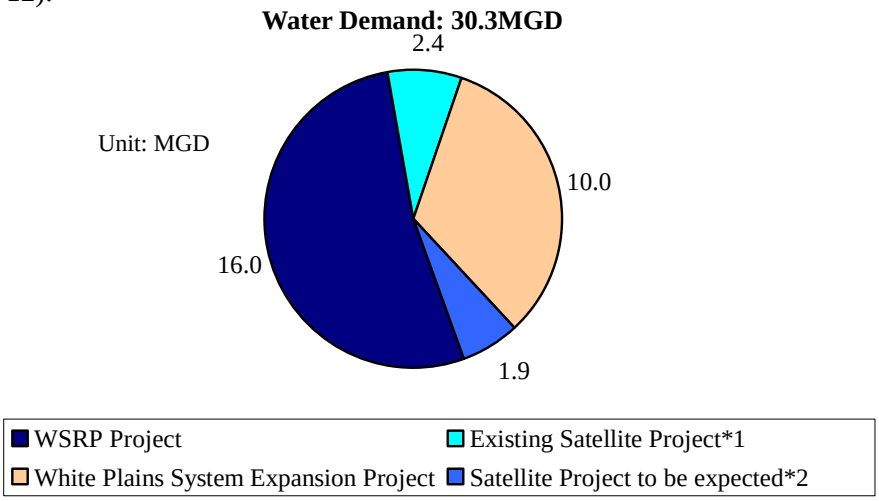
Source: JICA Study Team

Figure 5.3-11 Service Area and Conceptual Water Supply System in 2014

5.3.2.4 Mid-Term Plan of Water Supply Development

(1) Water Production by Project

Unless the White Plains water supply system is expanded after 2014, water production will be about 12MGD short in Greater Monrovia in 2019. Thus, an expansion of water supply system is one of the major issues. In some parts of Paynesville zone as shown in Figure 5.3-11, dwellers who would not been covered by either the satellite water supply projects or WSRP by 2014, will be supplied from the additional satellite water supply system as Phase II project from 2014 as well as before that. This is because rich groundwater potential must effectively be put to good use in the areas where there is no distribution network system. Water production in the additional satellite water supply system shall be expected to be about 1.9MGD (about 7,000m^3/day) by 2019, while water production of about 10MGD (38,000m^3/day) shall be covered by the White Plains water supply system to be expanded (see Figure 5.3-12).



Source: JICA Study Team
'*1' shows two projects: one is the project for the year 2014 requested to the Japanese side and the other is the project to be carried out by AfDB for the target year of 2019.
'*2' shows the project which is mentioned hereinafter as the Project for Emergency Development of Water Supply System at Paynesville in Greater Monrovia (Phase II)

Figure 5.3-12 Water Production by Project in 2019

(2) Expansion Project of White Plains Water Supply System (EPWS)

In order to supply safe and stable water of 26MGD to dwellers of 1.1mln in Greater Monrovia, the existing White Plains water supply system is required to be expanded and improved drastically for the future. Table 5.3-9 shows future vision by facility in 2014 and 2019.

Table 5.3-9 Future Vision of the White Plains Water Supply System

Water Supply Facility	Current Situation in 2009	Restoration Plan for 2014	Improvement Plan for 2019
Water Sources	Water of about 4.5 MGD is lifted from the Saint Paul River in addition to small production capacity of 0.1 MGD in Air field and Paynesville	Since the Water and Sanitation Rehabilitation Program (WSRP) complete by 2011, raw water which is taken from the Saint Paul River shall be increased to at least 16MGD.	Raw water of another 10MGD which is taken from the Saint Paul River shall additionally be increased.
Treatment Plant	The treated water of about 4.3MGD, making up 26% of the conventional capacity, is produced at the treatment plant.	The treatment plant is going to be rehabilitated to be restored to 16MGD by 2011.	Total capacity of treatment plant shall be increased into 32MGD (Max. capacity)
High Lift Pumps	Total capacity of high lift	High lift pumps restored	Total pump capacity will be

Water Supply Facility	Current Situation in 2009	Restoration Plan for 2014	Improvement Plan for 2019
	pump is about 7MGD.	through the WSRP will transfer the treated water of 16MGD.	increased to about 26MGD (It depends on rising main system).
Rising Pipelines	Water of about 4.5MGD with the rising main pipelines which are laid from 1950s to 2001 is transferred to the center of Monrovia. The rising pipelines are directly used for distribution so the treated water could not reached service reservoirs.	The rising pipelines will be rehabilitated by 2011 through the WSRP so that leakage amount of water on the pipelines will be reduced.	In order to provide stable water to service areas, the rising mains and distribution pipelines shall be separated and the rising mains shall also be expanded to transfer water of 26MGD.
Service Reservoirs	There are only service reservoirs of 1.6MGD. However, treated water has not reached the service reservoirs because of mainly lack of high lift pump capacity.	Since total capacity of high lift pump is increased by the WSRP, some amount of the treated water will be able to reach to the service reservoirs.	In order to supply the stable water, capacity of service reservoirs shall be increased to 15MG and service area shall be divided into some service districts with each service reservoir.
Distribution Pipelines	There are distribution pipelines of only about 200kms in Greater Monrovia. Water points are so limited that water is mainly supplied by trucks.	About 75% of the distribution pipelines will be rehabilitated by 2011 through the WSRP so that leakage amount of water on the pipelines will be reduced.	Distribution pipelines shall be expanded to increase water supplying points such as kiosks, house connections, etc.

Source: JICA Study Team

(a) Expansion Plan of Intake and Water Treatment Plant

Flow sheet of White Plain water treatment plants for restoration plan for 2014 and improvement plan for 2019 are shown in Figure 5.3-13. Layout of White Plain water treatment plant for 2019 is shown in Figure 5.3-14.

In 2014, the projects are mainly composed of the rehabilitation of damaged mechanical and electrical facilities: the maximum capacity will be expanded up to 24MGD for intake facility, 16MGD for water treatment facility by completion of WSRP.

For the target year of 2019, four (4) more lines, which consist of 8MGD for intake facilities, 16MGD for water treatment facilities, will be constructed to meet the water demand additionally in 2019. As the result of expansion, the total maximum capacity will be 32MGD for intake facilities, water treatment facilities.

For the process of water treatment facilities for 2014 and 2019, almost the same process as current facilities, which consist of mixing, flocculation, sedimentation, rapid sand filtration, will be applied. For disposing of sludge generated from water treatment plant, drying bed will be applied, for the environmental consideration and for the surrounding areas.

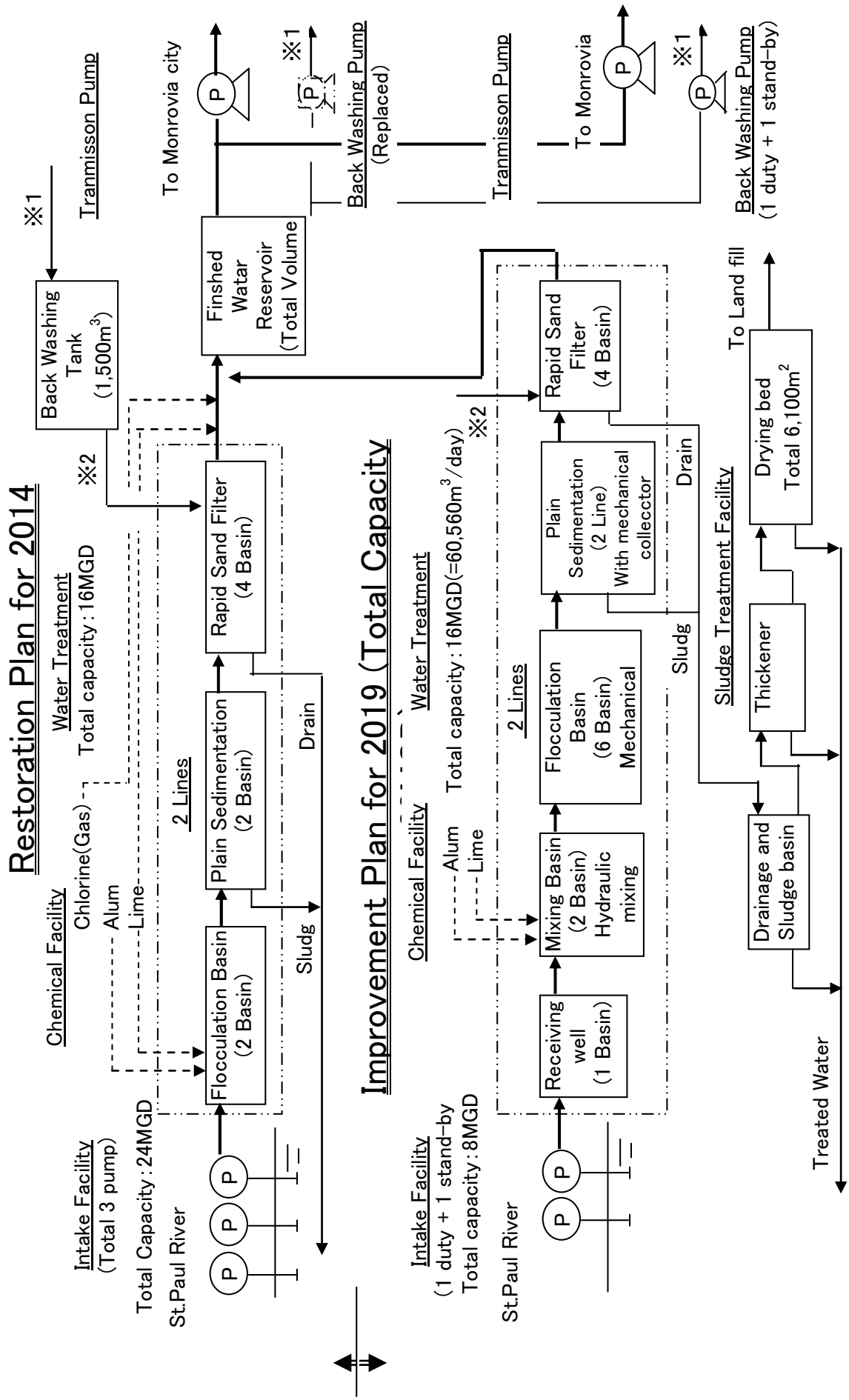


Figure 5.3-13 Flowsheet of White Plain Water Treatment Plants for Vision in 2014 and in 2019

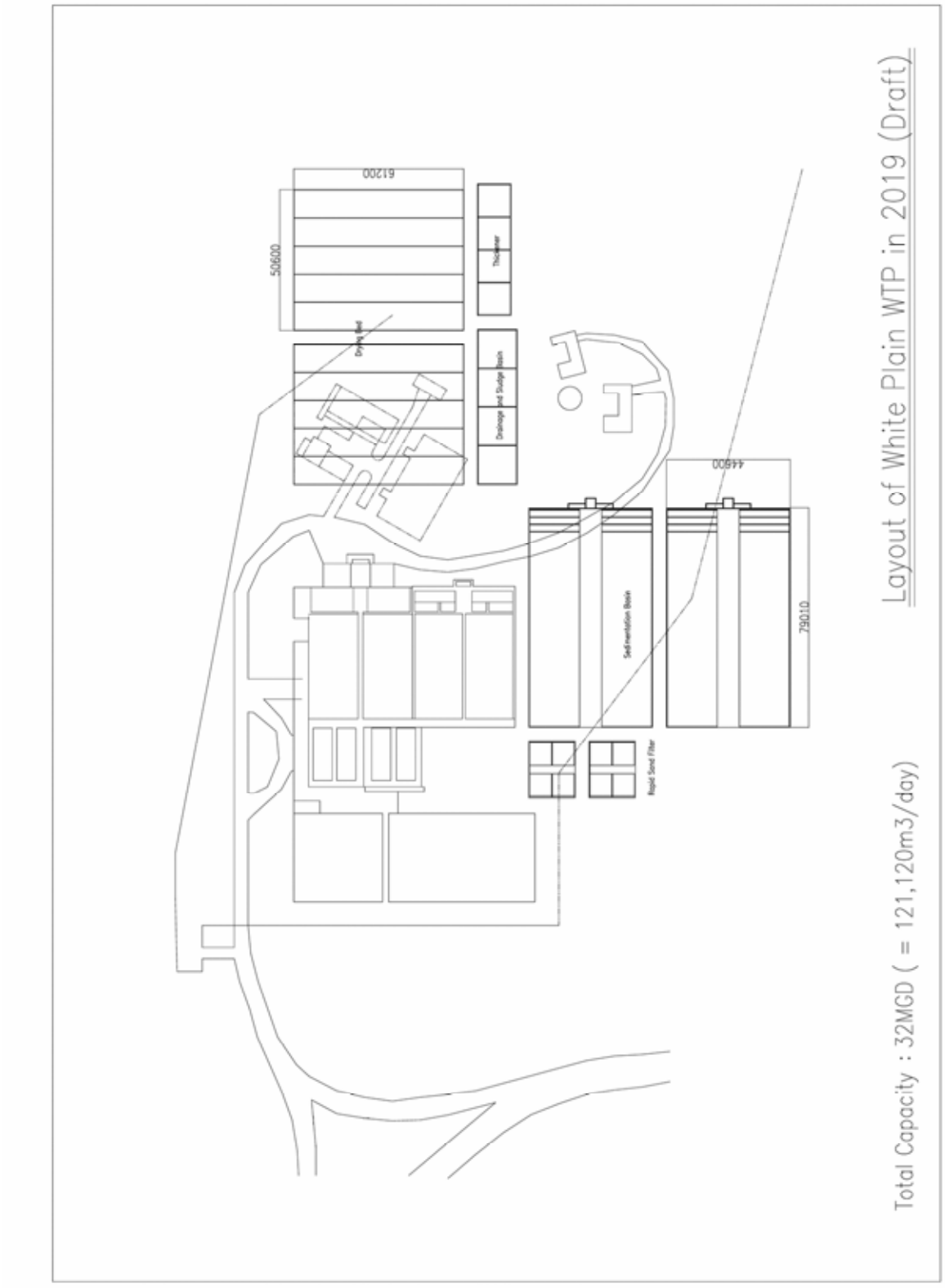


Figure 5.3-14 Layout of White Plain Water Treatment Plant in 2019

(b) Expansion Plan of Transmission and Distribution Facilities

Conventionally, the rising pipelines have not been separated from distribution pipelines and have been used not only for transferring water but also for supplying water. As water demand has increased year by year, the treated water could not been reachable to the two (2) existing service reservoirs. Furthermore, there are two existing service reservoirs with capacity of 1.6MG (about 6,000m^3). This is insufficient capacity for service population of 0.37mln in 2008.

In this study, in order to supply stable water, the following schemes are proposed.

- The rising main shall be utilized for transferring the treated water to service reservoirs.
- Service reservoirs with appropriate capacity shall be developed in Greater Monrovia.
- One service area as shown in Figure 5.3-11 shall be isolated.

On proposing expansion plans of White Plains water supply system, three (3) scenarios shall be examined as shown in Table 5.3-10. Figure 5.3-15 - Figure 5.3-17 shows service area, conceptual rising main system and service reservoirs by scenario. Finally the best scenario shall be selected taking into account of technical and financial aspects, etc.

Table 5.3-10 Outlines of Expansion Plans by Scenario

Scenario	Sub-Scenario	Outlines of Plans
Scenario 1.	**Scenario 1-1.**	• It is proposed that treatment plant of 16MGD (60,000m^3/day) shall be expanded and total maximum capacity of the treatment plan counts 32MGD (120,000m^3/day). • Service area is isolated into six (6) with six (6) additional service reservoirs, and the two (2) existing service reservoirs located in Mamba Point. All of them are the ground reservoirs. • The existing rising mains of 16" (400mm) at west side and 36" (900mm) at east side shall also be utilized as rising main pipelines. In addition to that, it is proposed that two (2) major rising mains of 20" (500mm) and 28" (700mm) shall be laid along the existing rising main of 16" and 36" respectively. Additional distance of rising mains count about 40km. Rising mains shall be composed of four (4) systems. • The existing rising mains of 16" laid along Somalia Drive Road, and that of 12" (300mm) & 24" (600mm) laid along Tubman Boulevard Road shall be utilized as distribution pipelines.
	Scenario 1-2.	• Numbers of service areas in this scenario is the same as that in Scenario 1-1. • The differences between Scenario 1-1 and 1-2 are the rising main system. The rising mains are composed of three (3) systems in this scenario. While two (2) existing rising mains of 16" at west side and 36" at east side with the exception of that 16" lines laid along Somalia Drive Road shall be utilized effectively, additional rising main of 36" with the distance of about 14km is required.
Scenario 2.		• It is proposed that service area is isolated into 10 areas with additional 10 service reservoirs, and the two (2) existing service reservoirs located in Mamba Point. Since there are no hills in the most parts of areas, the elevated storage tanks are proposed for supplying treated water to Caldwell, Barnersville and New Georgia zone. • The existing rising mains of 16" at west side and 36" at east side shall be effectively be utilized, however, as its pipe diameter of 16" is too small to transfer the required water, it is proposed that additional rising mains of 20" (500mm) - 32" (800mm) shall be expanded along its 16" lines. • The existing rising mains of 16" laid along Somalia Drive Road, and that of 12" (300mm) & 24" (600mm) laid along Tubman Boulevard Road shall be utilized as distribution pipelines as well as Scenario 1-2.

Source: JICA Study Team

Source: JICA Study Team

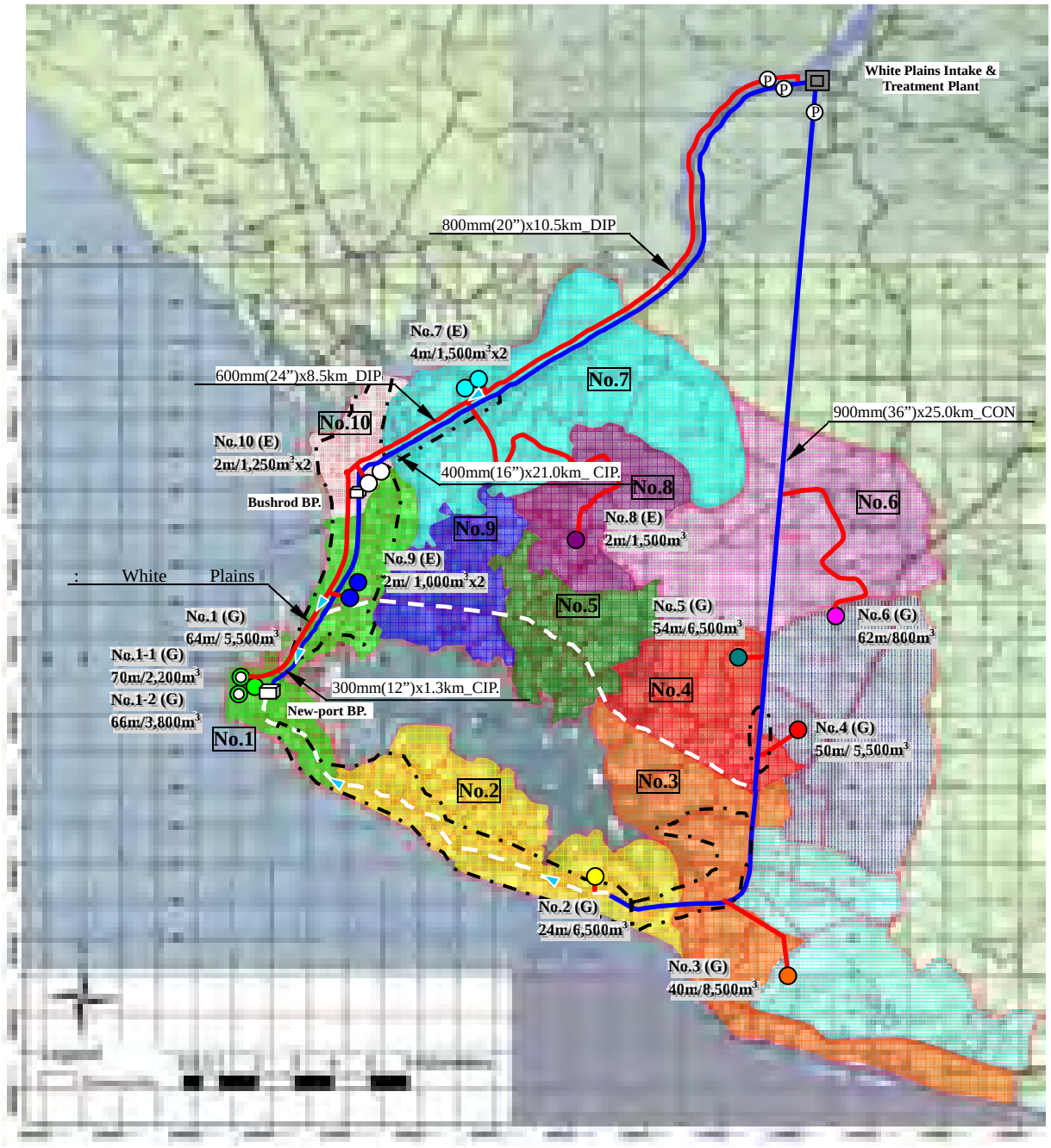
	: Existing Rising Main		: Existing Service Reservoir
	: Expanded Rising Main	40/8,000m^3	: Ground Level/Capacity of SR
	: Existing Rising Main to be used for Distribution Lines	(G), (E)	: Ground SR., Elevated SR
	: Change Point of Pipe Diameter	DIP	: Ductile Cast Iron Pipe
	: White Plains Treatment Plant to be expanded	CIP	: Cast Iron Pipe
		OCN	: Concrete Pipe
	: Booster Pump Station		: Service Area in 2008
P	: High Lift Pump Station		: Project Area requested to Japanese side
	: Proposed Service Reservoir		: Project Area under study by AfDB

Figure 5.3-15 Service Area and Conceptual Water Supply System in 2019 (Scenario 1-1)

Source: JICA Study Team

	: Existing Rising Main		: Existing Service Reservoir
	: Expanded Rising Main	40/8,000m^3	: Ground Level/Capacity of SR.
	: Existing Rising Main to be used for Distribution Lines	(G), (E)	: Ground SR., Elevated SR.
	: Change Point of Pipe Diameter	DIP	: Ductile Cast Iron Pipe
	: White Plains Treatment Plant to be expanded 500mm(20")x3.5km_DIP	CIP	: Cast Iron Pipe
		OCN	: Concrete Pipe
	: White Plains Treatment Plant to be expanded		: Service Area in 2008
P	: High Lift Pump Station		: Project Area requested to Japanese side
	: Proposed Service Reservoirs		: Project Area under study by AfDB

Figure 5.3-16 Service Area and Conceptual Water Supply System in 2019 (Scenario 1-2)



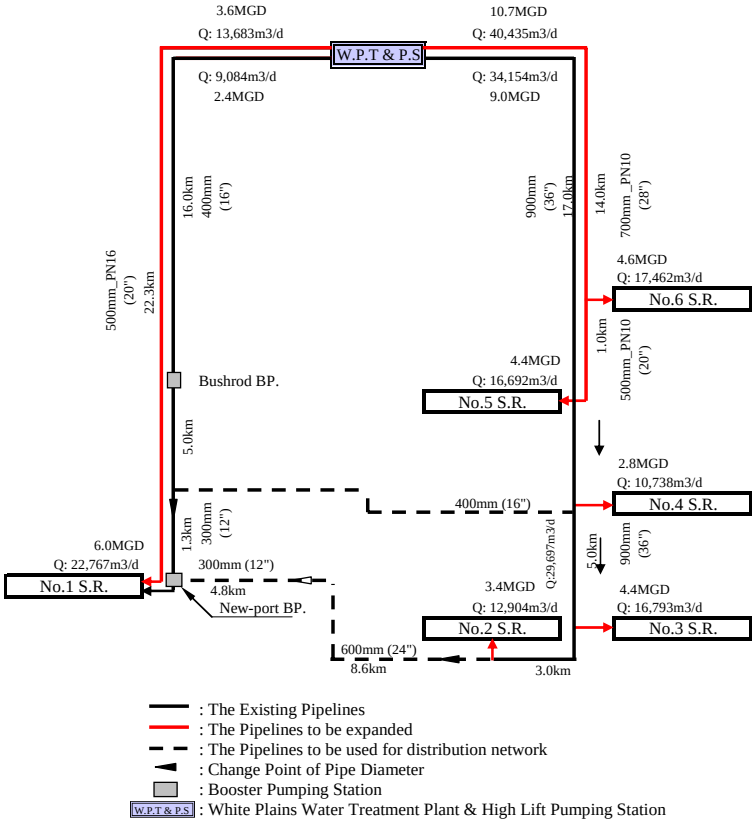
Source: JICA Study Team

: Existing Rising Main		: Existing Service Reservoirs	
: Expanded Rising Main		40/8,000m^3	: Ground Level/Capacity of SR.
: Existing Rising Main to be used for Distribution Lines		(G), (E)	: Ground SR., Elevated SR.
: Change Point of Pipe Diameter		DIP	: Ductile Cast Iron Pipe
: White Plains Treatment Plant to be expanded 500mm(20")x3.5km_DIP		CIP	: Cast Iron Pipe
		OCN	: Concrete Pipe
: White Plains Treatment Plant to be expanded			: Service Area in 2008
: High Lift Pump Station			: Project Area requested to Japanese side
: Proposed Service Reservoirs			: Project Area under study by AfDB

Figure 5.3-17 Service Area and Conceptual Water Supply System in 2019 (Scenario 2)

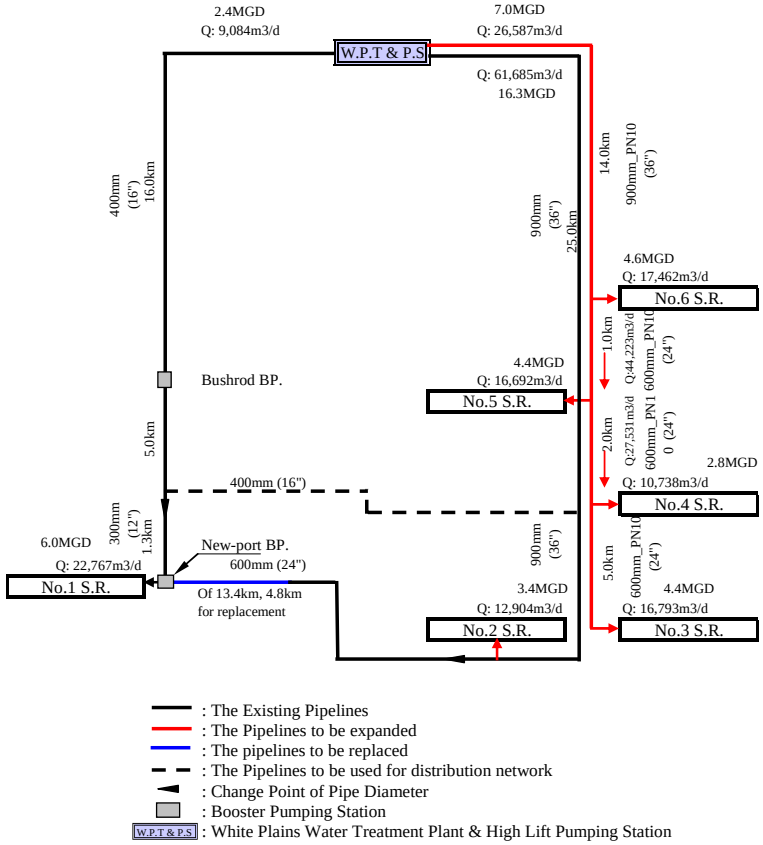
1) Rising Main Pipelines

It is proposed that the existing rising main pipelines to be restored by WSRP shall effectively be utilized for the expansion plan in three (3) scenarios. In Scenario 1-1, additional rising main pipelines shall be expanded along both the existing rising pipelines of 16" at western part and 36" at eastern part of Greater Monrovia respectively (see Figure 5.3-187). In terms of Scenario 1-2 and Scenario 2, additional rising main pipelines shall be expanded along the existing rising pipelines of 36" at eastern part in Scenario 1-2 (see Figure 5.3-19), while along the existing rising pipelines of 16" at western part in Scenario 2 (see Figure 5.3-20). Table 5.3-11 to Table 5.3-13 shows information such as material, pipe length, pipe diameter, nominal pressure on the rising main pipelines.



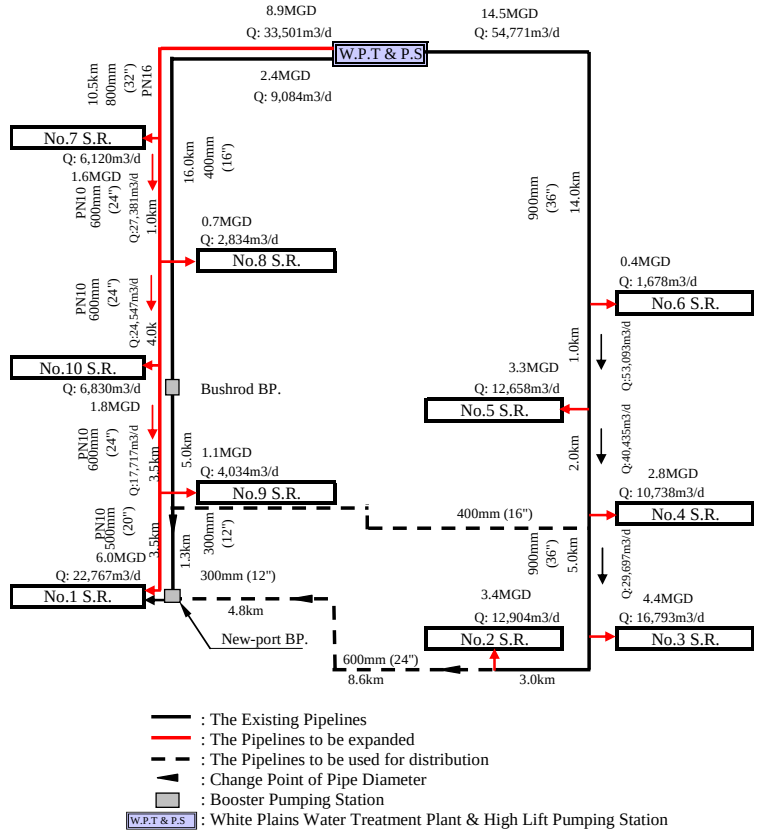
Source: JICA Study Team

Figure 5.3-18 Rising Main System (Scenario 1-1)



Source: JICA Study Team

Figure 5.3-19 Rising Main System (Scenario 1-2)



Source: JICA Study Team

Figure 5.3-20 Rising Main System (Scenario 2)

Table 5.3-11 List of Rising Main Pipelines (Scenario 1-1)

Item	Materials	PN	Diameters (mm)	Distance (m)
Rising Main Pipelines	DIP	16	500	22,300
	DIP	10	700	14,000
	DIP	10	600	5,000
	DIP	10	500	5,000
	DIP	10	400	2,000
Total				**48,300**

Source: JICA Study Team

Table 5.3-12 List of Rising Main Pipelines (Scenario 1-2)

Item	Materials	PN	Diameters (mm)	Distance (m)
Rising Main Pipelines	DIP	10	900	14,000
	DIP	10	600	17,800
	DIP	10	500	4,000
	DIP	10	400	2,000
Total				**37,800**

Source: JICA Study Team

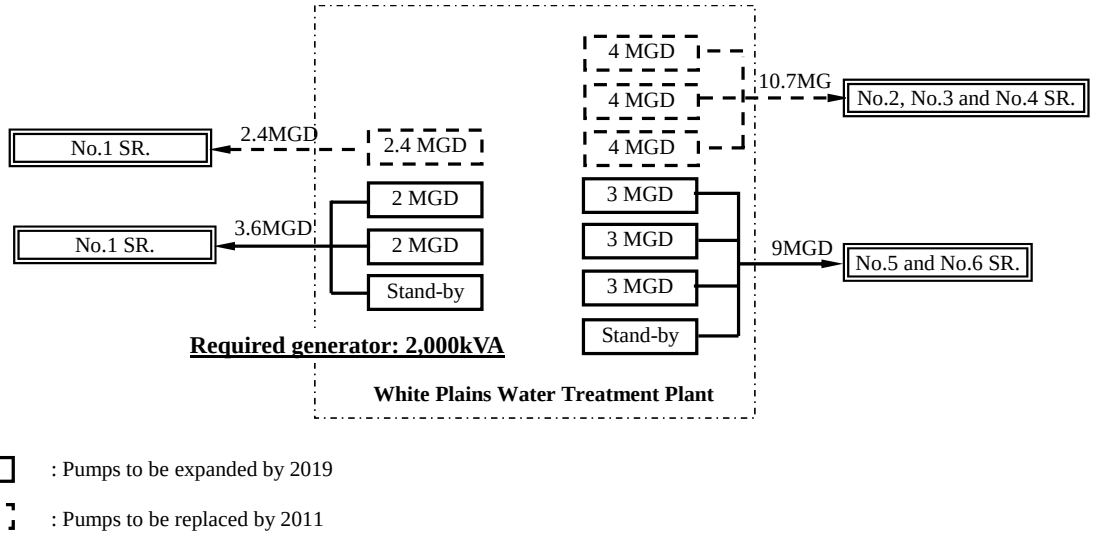
Table 5.3-13 List of Rising Main Pipelines (Scenario 2)

Item	Materials	PN	Diameters (mm)	Distance (m)
Rising Main Pipelines	DIP	16	800	10,500
	DIP	16	500	500
	DIP	10	600	8,500
	DIP	10	500	7,500
	DIP	10	400	2,000
	DIP	10	300	9,500
	DIP	10	250	5,500
Total				**44,000**

Source: JICA Study Team

2) High Lift Pump System

High lift pumps shall also be expanded with the demand increase in 2019. The pumps to be replaced by 2011 and expanded by 2019 are shown in Figure 5.3-21- Figure 5.3-23 by three (3) scenarios of the rising main system. Total maximum capacity counts about 27MGD. Pump specifications of each scenario are shown in Table 5.3-14- Table 5.3-16.



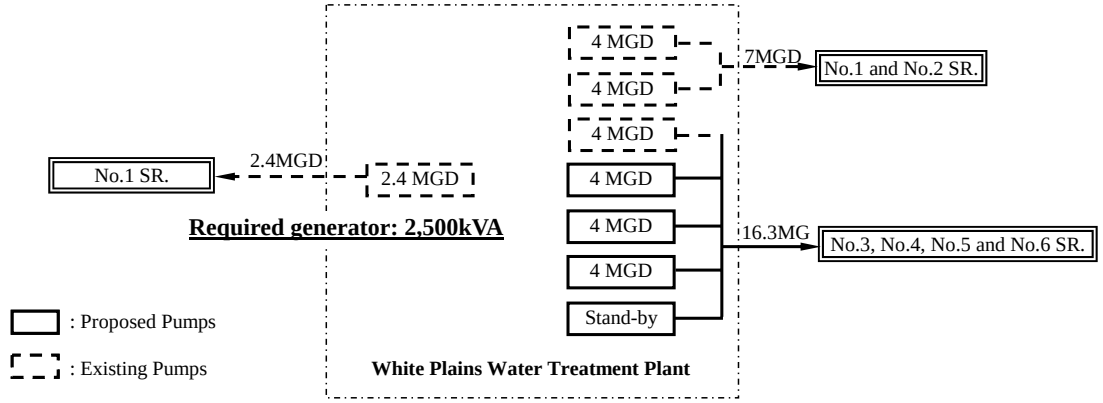
Source: JICA Study Team

Figure 5.3-21 High Lift Pump System (Scenario 1-1)

Table 5.3-14 Pump Specification and Numbers of Pumps (Scenario 1-1)

Items	Flow Capacity		Total Head (m)	Quantity (Pecs.)
	(MGD)	(m^3/h)		
Centrifugal Surface Pump	2.0	320	110	3
Centrifugal Surface Pump	3.0	480	100	4

Source: JICA Study Team



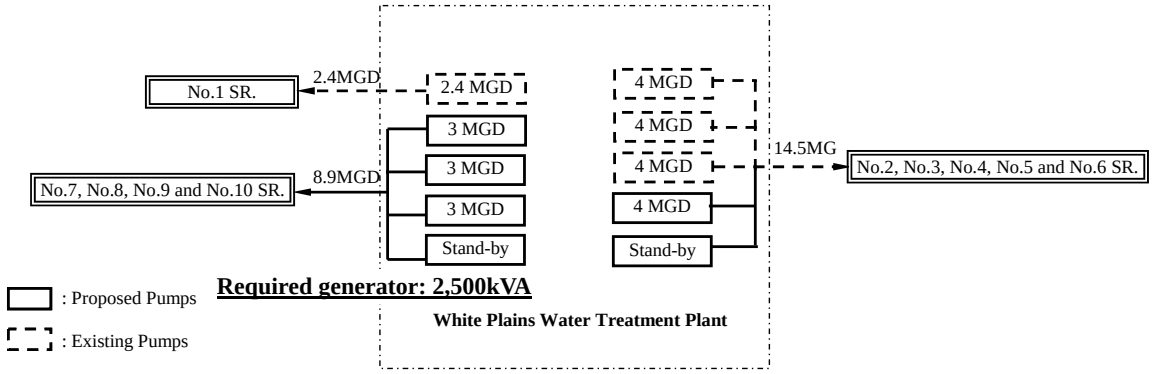
Source: JICA Study Team

Figure 5.3-22 High Lift Pump System (Scenario 1-2)

Table 5.3-15 Pump Specification and Numbers of Pumps (Scenario 1-2)

Items	Flow Capacity		Total Head (m)	Quantity (Pecs.)
	(MGD)	(m^3/h)		
Centrifugal Surface Pump	4.0	640	100	4

Source: JICA Study Team



Source: JICA Study Team

Figure 5.3-23 High Lift Pump System (Scenario 2)

Table 5.3-16 Pump Specification and Numbers of Pumps (Scenario 2)

Items	Flow Capacity		Total Head (m)	Quantity (Pecs.)
	(MGD)	(m^3/h)		
Centrifugal Surface Pump	3.0	480	110	4
Centrifugal Surface Pump	4.0	640	100	2

Source: JICA Study Team

3) Service Reservoirs

There are only two (2) service reservoirs with total capacity of 1.6MG (about 6,000m^3) in Greater Monrovia. However, these reservoirs have not been utilized because treated water is not reachable to

the service reservoirs. In addition, even if the treated water is transferred to the service reservoirs, the capacity of service reservoirs is too small to store enough treated water. The existing service reservoirs only have capacity that can store water of six (6) hour-volume of daily maximum demand.

According to the increased water demand in the future, expansion of service reservoirs will be noticeable issue. Therefore, the service reservoirs are proposed to be expanded to control the following functions:

- Absorb the hourly peak demand in the water service area.
- Divert water from service area in case of emergency to other service area.
- Supply fire fighting.
- Control water pressure on the distribution pipelines.

Generally, capacity of service reservoir is estimated as volume to be stored for 10-12 hours of daily maximum demand in the urban area. In this study, typical value of 12 hours for it shall be applied for designing the capacity of the service reservoir in light of Monrovia being the capital city.

The proposed numbers of service areas is divided into two (2) type categories. Each category is composed of six (6) service areas with six (6) service reservoirs as scenario 1-1 & 1-2 and 10 service reservoirs with 13 service reservoirs as scenario 2 respectively.

Table 5.3-17 shows capacity of service reservoirs in case of six (6) service areas and Table 5.3-18 shows that in case of 10 service areas. All the service reservoirs are the ground type in the scenario shown in Table 5.3-17, because service reservoirs can be located on the hill. However, other scenario (see Table 5.3-18) as shown in Figure 5.3-17 is composed of service reservoirs of on-ground and elevated types. This is because there is no hill at all in the western part of Greater Monrovia.

Table 5.3-17 Capacity of Service Reservoirs (Scenario 1-1 &1-2)

Service Area No.	Service Area	Nos of Zones	Type of Reservoirs	Max. Water Demand		Required Capacity (m^3)	Existing Capacity (m^3)	Required Capacity for Expansion (m^3)	Proposed Capacity for Expansion (m^3)	Nos of Service Reservoir
				MGD	m^3/day					
				-	[1]	[2]=[1]x12/24	[3]	[4]=[2]-[3]		
1	Logan Town, Clara Town, West Point, Central Monrovia A, Central Monrovia B	5	Ground	6.0	22,767	11,384	6,056	5,328	5,500	1
2	Sinkor, Lakpazee, Old Road, Congo Town	4	Ground	3.4	12,904	6,452	0	6,452	6,500	1
3	Parts of Paynesville	1	Ground	4.4	16,793	8,397	0	8,397	8,500	1
4	Parts of Paynesville		Ground	2.8	10,738	5,369	0	5,369	5,500	1
5	Gardnersville, New Georgia	2	Ground	4.4	16,692	8,346	0	8,346	8,500	1
6	New Kru Town, Barnersville, Johnsonville, Caldwell	4	Ground	4.6	17,462	8,731	0	8,731	9,000	1
Total		**16**		**25.6**	**97,356**	**48,679**	**6,056**	**42,623**	**43,500**	**6**

Source: JICA Study Team

Table 5.3-18 Capacity of Service Reservoirs (Scenario 2)

Service Area No.	Service Area	Nos of Zones	Type of Reservoirs	Max. Water Demand		Required Capacity (m3)	Existing Capacity (m3)	Required Capacity for Expansion (m3)	Proposed Capacity for Expansion (m3)	Nos of Service Reservoir
				MGD	m3/day					
				-	[1]	[2]=[1]x12/24	[3]	[4]=[2]-[3]		
1	Logan Town, Clara Town, West Point, Central Monrovia A, Central Monrovia B	5	Ground	6.0	22,767	11,384	6,056	5,328	5,500	1
2	Sinkor, Lakpazee, Old Road, Congo Town	4	Ground	3.4	12,904	6,452	0	6,452	6,500	1
3	Parts of Paynesville	1	Ground	4.4	16,793	8,397	0	8,397	8,500	1
4	Parts of Paynesville		Ground	2.8	10,738	5,369	0	5,369	5,500	1
5	Gardnersville	1	Ground	3.3	12,658	6,329	0	6,329	6,500	1
6	Johnsonville	1	Ground	0.4	1,678	839	0	839	800	1
7	Caldwell	1	Elevated	1.6	6,120	3,060	0	3,060	3,000	2
8	Barnersville	1	Elevated	0.7	2,834	1,417	0	1,417	1,500	1
9	New Georgia	1	Elevated	1.1	4,034	2,017	0	2,017	2,000	2
10	New Kru Town	1	Elevated	1.8	6,830	3,415	0	3,415	3,500	2
Total		**16**		**25.5**	**97,356**	**48,679**	**6,056**	**42,623**	**43,300**	**13**

Source: JICA Study Team

4) Distribution Main Pipelines

In order to design the distribution main pipelines to be expanded, the following design criteria shall be applied for setting up diameters of the pipelines.

Peak hourly factor of 1.5 is applied for estimating maximum hourly flow. Diameters of pipelines are designed considering minimum residual water pressure of 0.05MPa in principle.

Table 5.3-19 and Table 5.3-20 shows specification of the pipelines to be expanded by 2019.

Table 5.3-19 List of Distribution Main Pipelines (Scenario 1-1 & 1-2)

Item	Materials	PN	Diameters (mm)	Distance (m)
Distribution Main Lines	DIP	10	700	6,900
	DIP	10	600	16,700
	DIP	10	500	5,300
	DIP	10	400	11,200
	DIP	10	350	900
	DIP	10	300	26,600
	DIP	10	250	10,900
	PVC	10	200	32,200
	PVC	10	150	1,600
	PVC	10	40-200	101,000
Total				**213,300**

Source: JICA Study Team

Table 5.3-20 List of Distribution Main Pipelines (Scenario 2)

Item	Materials	PN	Diameters (mm)	Distance (m)
Distribution Main Lines	DIP	10	600	11,000
	DIP	10	500	8,500
	DIP	10	400	10,100
	DIP	10	350	1,100
	DIP	10	300	22,200
	DIP	10	250	14,600
	PVC	10	200	29,400
	PVC	10	150	17,700
	PVC	10	40-200	100,200
Total				**214,800**

Source: JICA Study Team

(3) Project for Expansion of Water Supply System at Paynesville in Greater Monrovia (PEWS) _Phase II

In order to raise water service coverage ratio to 100% in Paynesville zone for the target year of 2019, PEDW shall be followed by Project for Expansion of Water Supply System at Paynesville in Greater Monrovia (Phase II) so that water of 1.9MGD (about 7,000m^3/day) can be produced and supplied for dwellers of 0.1mln. Type of the satellite water supply system is as shown in Figure 5.3-10 as well as that of PEDW.

(4) Technical Cooperation Project of Groundwater Management (TCPGM)

Shallow wells including dug wells and boreholes have not methodically been developed in Greater Monrovia. Especially, after and/or during the civil conflict, the groundwater has remarkably been developed for residential purpose as an emergency measure by NGO, etc. However, as there is no registration system in Ministry of Land, Mines and Energy or LWSC, water quality, water level condition of most of the wells, the numbers of wells are not clarified in these governmental offices. Therefore, in order to supply safe and stable water to citizen using water source of deep groundwater, groundwater management system is required to be established.

Groundwater management system which shall be trained in the project is composed of the following works:

- Training on the regular monitoring of static water level of boreholes and its evaluation measurements.
- Training on a regular analysis of water quality such as pH, Total E-Coli, Turbidity, Color, EC, and its evaluation measurements.

- Training on an establishment of rules and regulations on registration required for developing groundwater.

Groundwater management shall be focused on only boreholes of at least 20m in depth.

(5) Technical Cooperation Project of Non-Revenue Water Reduction (TCPNR)

LWSC has faced serious problems on much non-revenue water. Leakage on the pipelines, defection on water tariff system, faulty meters etc, cause non-revenue water.

First of all, in term of leakage issue, the existing rising main and distribution pipelines of the White Plains water supply system in Greater Monrovia were constructed in long time ago as 1950s to 1970s. Such deteriorated pipelines may cause the much non-revenue water from the aspects of current revenue water as shown in Table 2.5-10. Thus, the White Plains water supply system has partially being rehabilitated in Monrovia Water Supply and Sanitation Rehabilitation Program since 2008. This is also one of the measures for eliminating non-revenue water. In addition, after completion of the rehabilitation program, it is very important accurately to verify amount of non-revenue water effectively to utilize the White Plains water supply system through regular monitoring. However, there is no inventory data of pipelines and accurate non-revenue of the water supply system.

Secondary, LWSC has its own water tariff system of a metered rate, but as the most customers have no water meter and/or faulty water meter, LWSC has being forced to charge the customers at flat rate. Gap between water consumption at flat rate and actual water consumption causes to accelerate an increase of non-revenue water. Accordingly, water tariff system should comprehensively and appropriately be improved to increase revenue water.

Accordingly, in order to eliminate non-revenue water, it is proposed that the following contents of capacity buildings shall be carried out.

(Analysis of Current Situation)

- Study water production and distribution water.
- Study non-revenue water excluding leakage.
- Study leakage.
- Verify location of the existing network pipelines through site reconnaissance.

(Action Plan)

- Select pilot project.
- Digitize network pipelines in pilot project area using GIS software.
- Site reconnaissance for checking network pipelines.
- Check installation condition of the existing water meters in pilot project area.
- Check the minimum water flow at night in pilot project area.
- Carry out leakage detection in pilot project area
- Repair leakage points in pilot project area.
- Check minimum water flow at night in pilot project area after repair of leakage points.
- Improve water tariff system
- Workshop and seminar

5.4 Recommendation on Institutional Measures

After civil conflict, LWSC has been coordinating various projects due to the international cooperation for restoring and improving water supply and sanitation systems. However, there is no division or staff that can exclusively coordinate the projects in LWSC, so that project progress, budgetary allocation and detail scope including terms of reference of the projects have not quantitatively been comprehended. In addition, present conditions of the existing water supply system and water supply service have not specifically been clarified by LWSC. In order to improve the water supply service, it is very important for LWSC quantitatively to comprehend current situation and some issues on water supply service.

Accordingly, in order to achieve goals of water supply service, which is focused on 2019, since it is envisaged that projects for restoring and improving water supply system furthermore increase, exclusive division shall be required to be established in LWSC. The division will not only be able to coordinate the projects appropriately, but also to make water supply strategy plans, which might be assisted by international organization.

On the other hand, development including improvement of water supply services proceeded for long time during civil conflict. At the same time, water supply inventory, design manual, water law have not been developed. In order to manage, implement water supply project systematically, and standardize water supply system, they should be developed urgently by LWSC, MoLME and MoPW.

5.5 Project Implementation Plan

5.5.1 Cost Estimate

5.5.1.1 Short Term Plan of Water Supply Development

(1) Monrovia Water and Sanitation Rehabilitation Program (WSRP)

As mentioned in Table 2.5-3 of CHAPTER 2, the capital cost of WSRP is summarized as shown in Table 5.5-1.

Table 5.5-1 Capital Cost of WSRP

Item	Cost (mln USD)
Rehabilitation for intake pump, White Plains purification plant, booster pumping station, rising mains, distribution pipelines and service reservoirs	**38.50**
Procurement of generators	
Design/supervision and contingency	

Source: LWSC

(2) Monrovia Expansion and Rehabilitation of Three County Capitals (ERTC)

Since the project is under study, the capital cost has not been estimated by AfDB yet. Therefore, Table 5.5-2 shows approximate project cost which was estimated based on the measures of estimates for PEDW by JICA study team.

Table 5.5-2 Capital Cost of ERTC

Item	Cost (mln USD)
Water Source (85 Boreholes)	0.80
Service reservoirs (35 pls, Cap. 70m^3, Elevated tanks)	3.90
Submersible pump (10m^3/hr x 50m x 60 sets)	1.20
Generators and its houses (20-30kVA x 60 sets)	1.40
Pipelines (PVC and/or GS, 100-200mm x 120km)	7.20
Public taps (6 faucets x 230pls)	0.30
Sub-total	**14.80**
Engineering, Supervision & Contingency (30% of Sub-total)	4.44
Total	**19.24**

Source: JICA Study Team

(3) Project for Emergency Development of Water Supply System at Paynesville in Greater Monrovia (PEDW)

The capital cost of Project for Emergency Development of Water Supply System at Paynesville in Greater Monrovia (PEDW) is summarized as shown in Table5.5-3. The cost of soft (Non-physical) components, which are very important for enhancing O&M, is also included in this Table.

Table 5.5-3 Capital Cost of PEDW

Item		Cost (mln USD)
Facilities	73 Boreholes (Depth: About 50m)	0.73
	26 Service reservoirs (Concrete, Cap. 70m^3, Elevated tanks)	2.33
	2 Service reservoirs (Concrete, Cap. 350m^3, Ground tanks.)	
	Submersible pump (10m^3/hr x 50m)	1.53
	Generators and its houses, 20-30kVA	1.83
	Pipelines (PVC and/or GS, 100-200mm x 100km)	6.00
	Public taps (6 faucets) x 200pls.	0.28
	Sub-total	**12.70**
Soft (Non-physical) components	O&M of submersible pumps and generators, and Water flow control	0.10
	Monitoring of water level and water quality of boreholes	
	Management of water tariff collection	
	Sub-total	**0.10**
Design/Supervision		**1.30**
Total (Cost requested to Japanese Government)		**14.10**
Contingency	**20% of Facility Sub-total**	**2.50**
Grand Total		**16.60**

Source: JICA Study Team

5.5.1.2 Mid Term Plan of Water Supply Development

(1) Expansion Project of White Plains Water Supply System (EPWS)

Table 5.5-4 shows the capital cost of Scenario 1-1, 1-2 and Scenario 2 on Expansion Project of White Plains Water Supply System (EPWS). Cost of Scenario 2 that the additional rising main pipelines are expanded along the 16" existing rising main pipelines at west side and the one existing service area is isolated into 10 service areas, is the cheapest water supply system at USD about 129mln among three (3) scenarios.

Table 5.5-4 Capital Cost of EPWS

Facility	Specification	Cost (mln USD)		
		Scenario 1-1	Scenario 1-2	Scenario 2
Intake & Water Treatment Plant	The expanded capacity of water treatment plant: 16MGD Including intake pump, receiving wells (x1), mixing tank (x2), flocculation basin (x6), sedimentation basin(x2), rapid sand filter (x4), thickener, drying bed, drainage & sludge basin	30.2	30.2	30.2
High Lift Pumping Station	See Figure 5.3-20-22	3.77	3.46	3.66
Generators	See Figure 5.3-20-22	2.84	3.60	3.60
Rising Main Pipelines	See Table 5.3-12-14	22.29	24.56	18.83
Service Reservoirs	See Table 5.3-18, 19	10.48	10.48	11.50
Distribution Pipelines	See Table 5.3-20, 21	36.81	36.81	31.15
Sub-total		**106.39**	**109.11**	**98.94**
Engineering, Supervision & Contingency	30% of sub-total	31.92	32.73	29.68
Total		**138.31**	**141.84**	**128.62**

Source: JICA Study Team

(2) Project for Expansion of Water Supply System at Paynesville in Greater Monrovia (PEWS) _Phase II

The capital cost of PEWS as Phase II is shown in Table 5.5-5. This is the project for developing water supply system in the remained areas with the exception of the areas covered by the White Plains water supply system in Paynesville zone after implementation of the Monrovia Expansion and

Rehabilitation of Three County Capitals (committed by AfDB), and the Project for Emergency Development of Water Supply System at Paynesville in Greater Monrovia (requested to Japanese side in 2009).

Table 5.5-5 Capital Cost of PESW _Phase II

Item	Cost (mln USD)
Water Source (120 Boreholes)	1.20
Service reservoirs (50 pls, Concrete, Cap. 70m^3, Elevated tanks)	5.60
Submersible pump (10m^3/hr x 50m x 84 sets)	1.70
Generators and its houses (20-30kVA x 84 sets)	2.10
Pipelines (PVC and/or GS, 100-200mm x 170km)	10.20
Public taps (6 faucets x 350pls)	0.40
Sub-total	**21.20**
Engineering, Supervision & Contingency (30% of Sub-total)	6.36
Total	**27.56**

Source: JICA Study Team

(3) Technical Cooperation Project of Groundwater Management (TCPGM)

The cost of technical cooperation project of groundwater management as non-physical project is shown in Table 5.5-6.

Table 5.5-6 Project Cost of TCPGM

Items	Specification	Cost (mln USD)
Groundwater management	8M/M	0.20
Water quality control		
Lodging expenses		0.05
Equipments	Water quality analysis equipments	0.02
Operating expenses	Consumable items, local personnel, miscellaneous	0.05
Total		**0.32**

Source: JICA Study Team

(4) Technical Cooperation Project of Non-Revenue Water Reduction (TCPNR)

The cost of technical cooperation project of non-revenue water reduction as non-physical project is shown in Table 5.5-7.

Table 5.5-7 Project Cost of TCPNR

Items	Specification	Cost (mln USD)
Non-revenue reduction program	24 M/M	0.60
Leakage detection		
Management of water production and distribution water		
Network analysis		
Lodging expenses		0.14
Equipments	Ultrasonic flow meter, ground detector, leakage detector, network analysis software, PC, GIS software, etc.	0.55
Operating expenses	Consumable items, local personnel, miscellaneous	0.21
Total		**1.50**

Source: JICA Study Team

5.5.1.3 Project Evaluation of EPWS

Technical and financial evaluation of the EPWS project of Scenario 1-1, 1-2 and 2 are summarized as shown in Table 5.5-8. As the results of evaluation, Scenario 2 scored the lowest 12 points in the three (3) scenarios. In this study, schedule of the Scenario 2 shall be proposed in the implementation plan.

Table 5.5-8 Technical and Financial Evaluation

	Scenario 1-1	Scenario 1-2	Scenario 2	Remarks
1. Construction Period	Long (3)	Short (1)	Medium (2)	
2. Ease of Water Supply Management	Medium (2)	Disadvantage (3)	Advantage (1)	In case of emergency, it is advantage as many service reservoirs as possible
3. Necessity of Land Acquisition	Medium (2)	Low (1)	High (3)	Land acquisition for service reservoirs
4. Project Capital Cost	Medium (2)	High (3)	Low (1)	
5. Rate of Dependence Risk to the Existing Rising Main Pipelines	Low (1)	High (3)	Low (1)	Most of the existing pipelines were laid in 1950s to 1970s
6. Viability of Implementation by 2019	Medium (2)	High (3)	Low (1)	Viability depends on project capital cost
7. Operation Cost (Fuel for Generators)	High (3)	High (3)	High (3)	Operation cost for generators, which are utilized for rising main pumps, etc.
Evaluation (Total Score)	15	17	12	

Source: JICA Study Team
Note:
1. Long: 3, Medium: 2, Short: 1
2. Disadvantage: 3, Medium: 2, Advantage: 1
3. High: 3. Medium: 2, Low: 1
4. High: 3, Medium: 2, Low: 1
5. High: 3, Medium: 2, Low: 1
6. Low: 3, Medium: 2, High: 1
7. High: 3, Medium: 2, Low: 1

5.5.2 Implementation Schedule

It is very difficult to prioritize the infrastructure development projects (for No.3-No.5) targeting year of 2019, because, purpose of all the projects is to improve service coverage to be 100% in 2019 in Greater Monrovia. However, since the investment cost of EPWS is enormous, it is proposed that EPWS is commenced by 2013 at the latest and carried out by package such as treatment plant Phase I&II, rising main pipelines, distribution main pipelines and service reservoirs. In terms of PEWS, since PEWS is targeted in Paynesville zone, it will be followed by ERTC and PEDW, which are also targeted in Paynesville zone. Table 5.5-9 shows implementation schedule of infrastructure and technical cooperation projects. In order to supply safe and stable water to all the population in Greater Monrovia by 2019, since 2012, investment cost of about USD30mln at the most is required for implementing the infrastructure development projects with the exception of WSRP and ERTC, which were already committed by donors such as W.B., AfDB, etc. To judge from the aspect of the historical trends of investment fund on water supply sector, this amount of investment cost is viable to implement the infrastructure development projects.

Table 5.5-9 Project Implementation Schedule

(Unit: mln USD)

No.	Project		Investment Cost (Source of Fund)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Infrastructure Development Projects														
1	WSRP		38.50 (WB, AfDB, EC, DIFID)	4.75	9.75	24.00								
2	ERTC		19.24 (AfDB)	3.00	8.12	8.12								
3	PEDW		16.60 (Japan)*1		2.50	7.10	7.00							
4	EPWS	Expansion of Treatment Plant Phase I	128.62 (None) 15.93					5.30	5.30	5.33				
		Expansion of Treatment Plant Phase II	23.34								7.78	7.78	7.78	
		Expansion of Rising Main Line	33.96					6.79	6.79	6.79	6.79	6.80		
		Expansion of Distribution Main line	40.44							8.09	8.09	8.09	8.09	8.08
		Service Reservoir Installation	14.96					5.00	5.00	4.96				
5	PEWS (Phase II)		27.56 (None)				2.5	8.14	5.64	5.64	5.64			
Total			**230.52**	**7.75**	**20.37**	**39.22**	**9.50**	**25.23**	**22.73**	**30.81**	**28.30**	**22.67**	**15.87**	**8.08**
Technical Cooperation Projects														
6	TCPGM		0.32 (None)				0.10	0.11	0.11					
7	TCPNR		1.50 (None)				0.50	0.50	0.50					
Total			**1.82**				**0.60**	**0.61**	**0.61**					

Source: JICA Study Team

1. WSRP: Monrovia Water and Sanitation Rehabilitation Program
2. ERTC: Monrovia Expansion and Rehabilitation of Three County Capitals
3. PEDW: Project for Emergency Development of Water Supply System at Paynesville in Greater Monrovia
4. EPWS: Expansion Project of White Plains Water Supply System
5. PEWS: Project for Expansion of Water Supply System at Paynesville in Greater Monrovia
6. TCPGM: Technical Cooperation Project of Groundwater Management
7. TCPNR: Technical Cooperation Project of Non-Revenue Water

Note:

*1: USD 14.1million with the exception of contingency out of USD 16.6million for PEDW (Phase I) was requested to Japanese side but Japanese side has not committed yet.

5.6 Public Tap and Hand Pump Installation in Pilot Project

5.6.1 Work Objectives

In order to improve O&M capacity of community on water supply management through, satellite water supply system utilizing groundwater and hand pump were installed in three (3) sites in this study as a pilot project.

O&M monitoring concerning the communities and its water committees shall be conducted in the supplemental survey, which will begin in cooperation with JICA study team from the end of September 2009.

5.6.2 Selection Criteria of Water Supply System

In case of beneficiaries targeting 1,000 for the satellite water supply system and 300 for the hand pump, viability of installation and types of water supply system were determined based on the following criteria:

- Satellite Water Supply System
  - Water Yield: at least 1.5L/s as the results of pumping test
  - Water Quality: Drinking Water Standard on WHO Guideline
- Hand pump
  - Water Yield: More than 0.3L/s and less than 1.5L/s as the results of pumping test

- Water Quality: Drinking Water Standard on WHO Guideline

5.6.3 Construction Site

As the results of the pumping test of exploratory wells and water quality analysis, construction for each site is summarized in Table 5.6-1.

Table 5.6-1 Summary of Construction Sites

Items		J-1	J-2	J-3
Name of Zone		Gardnersville	Paynesville	Paynesville
Name of Community		Monrovia Transport Authority (MTA)	Neezoe	Barnard Farm
Administrative Population (2008)		4,146	11,899	9,962
Beneficiaries		1,000	300	300
Service Coverage Ratio (%)		24.1	2.5	3.0
Types of Water System		Satellite Water Supply System	Hand Pump	Hand Pump
Well Depth (m)		73	60	63
Optimum Water Yield of Well	L/min	96	19	29
	Gal/min	25	5	8

Source: JICA Study Team

5.6.4 Design Criteria and Specification of Water Supply System

Table 5.6-2 and Table 5.6-3 show design criteria and specification of the satellite water supply system, and that of hand pump system respectively. In addition, Figure 5.6-1 shows a plan layout and conceptual system drawings.

Table 5.6-2 Design Criteria and Specification of the Satellite Water Supply System (J-1)

Items	Contents	Specification
1. Demand Projection		
Service Population		1,000
Water Consumption Rate	Gal per Capita per Day	8 GCD
	Liter per Capita per Day	30 LCD
Non-Revenue Water	Leakage	15% of total water consumption
Water Demand	Average	$35m^3$/day
	Maximum	$41m^3$/day
2. Operation		
Daily Pump Operation Time		8 hours
Daily Kiosk Operation Time		6 hours
3. Facility Specification		
Well	Depth	73 (m)
	Diameter	6” (150mm)
	Number of Well	1
Lifting Pipe	Material	Polyethylene
	Length	50 (m)
Submersible Pump	Specification	$0.09m^3$/min x 55m x 2.2kW
	Pump Position	45m below from ground elevation
Generator	Capacity	12.5kVA
Generator House	Material	Concrete block
	Size	$4,200mm^W$ x $4,200mm^L$ x $3,100mm^H$
Rising Pipelines	Material	u-PVC for buried pipelines and GS for the exposed pipelines
	Diameter x Length	40 mm x 50 m
Storage Water Tank	Tank Material	Dura Plast
	Total Capacity	500gal x 4 sets =2,000gal ($7.5m^3$)
	Stand Material & Height	Steel and 12.8 m (From ground level to the stage)
Distribution Pipelines	Material	u-PVC for buried pipelines and GS for the exposed pipelines
	Diameter x Length	50 mm x 430 m
	Diameter x Length	40 mm x 470 m

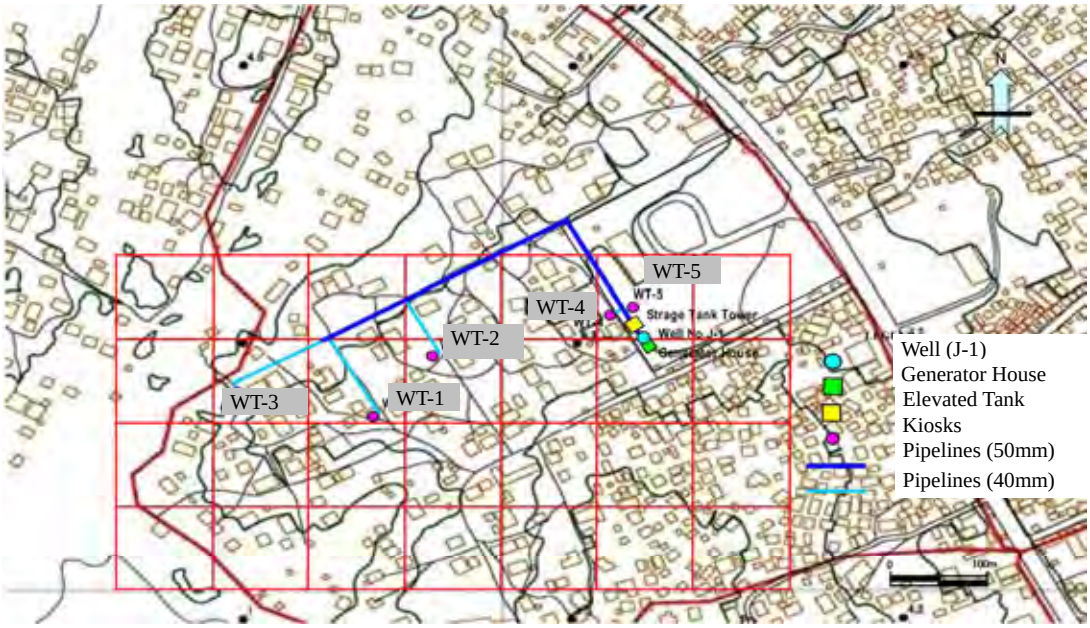
Items	Contents	Specification
Kiosks	Material	Concrete
	Number of Kiosks	5 (WT-1 to WT-5)
	Number of Faucets per Kiosk	6 (2 for WT-5)

Source: JICA Study Team

Table 5.6-3 Design Criteria and Specification of Hand Pump System

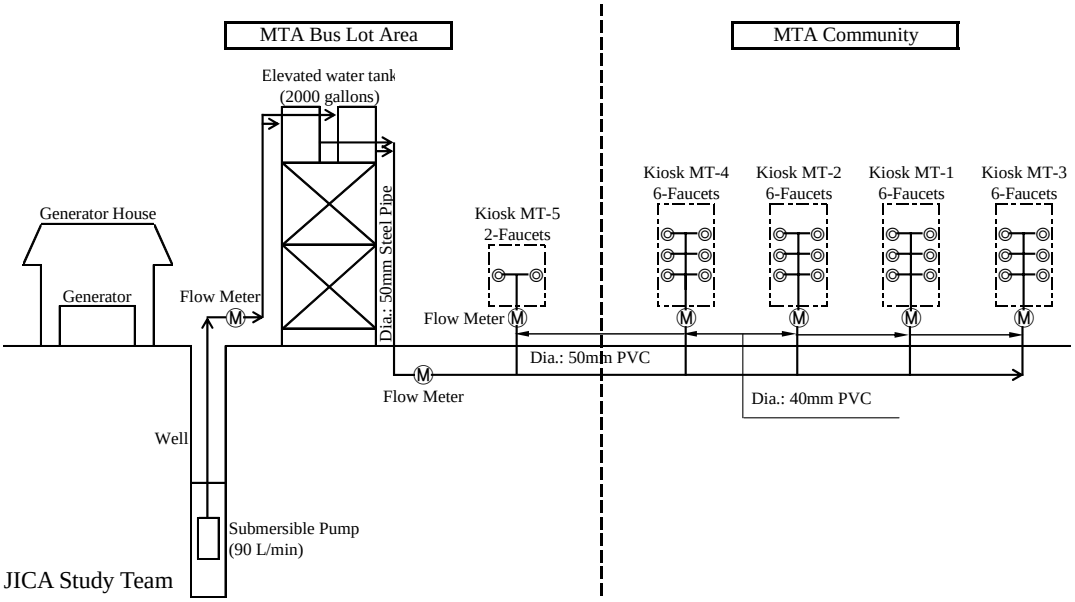
Items	J-2	J-3
Well Depth	60 m	63 m
Well Diameter	6" (150mm)	6" (150mm)
Hand Pump Material	Afridev	Afridev
Position of Hand Pump Strainer	40m	47m

Source: JICA Study Team



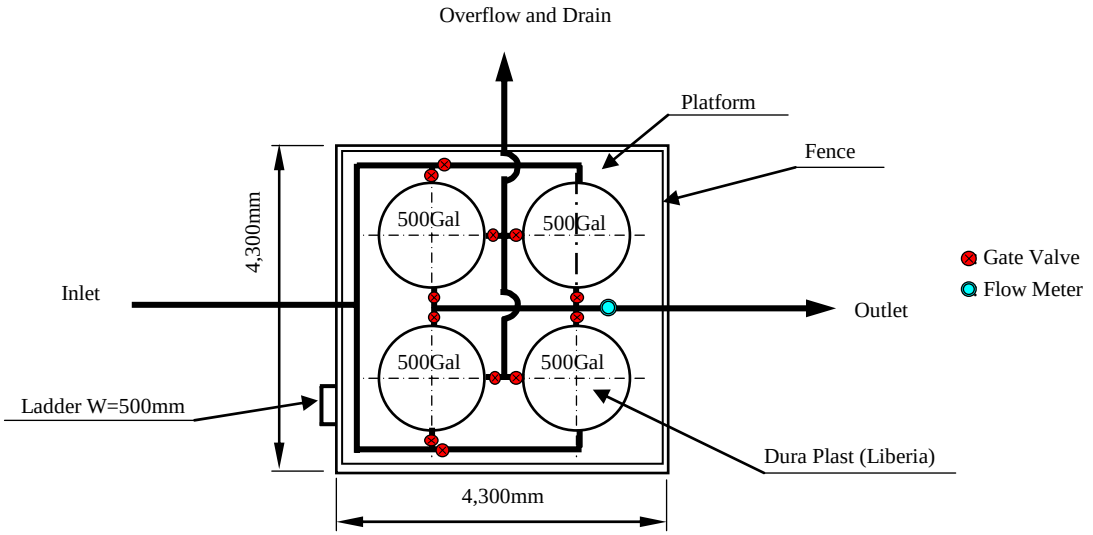
Source: JICA Study Team

Figure 5.6-1(1) Plan Layout And Conceptual System Drawings of J-1 (1)



Source: JICA Study Team

Figure 5.6-1(2) System Elevation Drawing of J-1 (2)



Source: JICA Study Team

Figure 5.6-1(3) Pipelines around Storage Water Tank of J-1 (3)

5.6.5 Lessons through the Pilot project

5.6.5.1 Local Contractors

As far as the study team studied, there are four (4) to five (5) local contractors who have capabilities for drilling wells. However, most of local contractors have experiences for drilling shallow wells of 100m or less in depth. In addition, there is Australian drilling company that specializes in mining sector and was registered in Liberia as a local contractor. The Australian drilling company enables to drill wells of 250m or less in depth.

It is the first experience for Liberia to develop the satellite water supply system which was constructed through the pilot project in this study. However, the structure of the satellite water supply system is not complicated so that the general local contractors such as Chico (Chinese Company) which engages in World Bank's project and Bezaleel + Turnkey (Liberian Company) which had experiences through the pilot project in this study enable to construct the satellite water supply system.

Local contractors have capabilities of construction but deficiencies in their time schedule management cause delayed construction. Therefore, sufficient support of Japanese contractors is very important for establishing construction management system and time schedule management.

5.6.5.2 Procurement of Construction Machinery

Regarding well-drilling rigs, there are few drilling rigs with the capacity of at least 100m in depth except that of some companies. Well drilling rigs with the capacity of at least 250m are mainly under the terms of the lease of Nigeria.

In addition, pieces of general construction machinery such as crane trucks, excavators can be provided in Liberia relatively.

Considering current status of procurement in Liberia, procurement plan should be examined and proper plans of time schedule management are required through the contractor's direction of Japanese or other third countries.

5.6.5.3 Procurement of Construction Materials

Construction materials with the exception of cement, gravel, sand, reinforcement, small-sized L-beam and some small-sized water supply materials cannot be provided in Liberia so that these materials are supplied from neighboring countries of Nigeria, etc. The numbers of days for material procurement count about two (2) weeks after their order. Procurement places of the main construction materials used for the pilot project in this study are as follows:

Table 5.6-4 Procurement Places of Main Construction Materials

Liberia	Nigeria
• Aggregate • Cement • Reinforcement bar • L-beam (small size only) • I-beam (200mm x 100mm, small size only) • Galvanized pipes (small size (50mm) or less only) • u-PVC pipes (small size (50mm) or less only) • Poly-storage tank (500Gal) • Flow meter (25mm or less) • Gate valve (40mm or less) • Faucets	• Casing and slit pipes (u-PVC) • Submersible pump • Generator • Flow meter (at least 50mm) • Gate valve (at least 50mm)

Source: JICA Study Team

Considering situation of construction material procurement in Liberia, procurement plan should be examined and proper plans of time schedule management are required through the contractor's direction of Japanese or other third countries.

5.6.5.4 Land Acquisition

Land acquisition on any sector is of the role of the Ministry of Land Mine and Energy regardless of governmental and private land. In terms of land acquisition on water supply facilities, governmental land such as national, zonal and communal land will be given in first priority for constructing wells, generator houses, service reservoirs, kiosks, etc. If private land is required to be acquired for constructing water supply facilities as unavoidable case, the Ministry of Land Mine and Energy will be involved in negotiation with landowners and will secure the land. Location of the kiosks will be selected considering convenience in water use and the requests of water from communal users. There is governmental land considerably in Monrovia and it does not cause land acquisition concerns for implementation of the projects.

5.6.5.5 Relations between Pilot Project and Communal Dwellers

Communal dwellers entirely accepted establishment of the water committee proposed by JICA study team and LWSC; selection of pump operators and kiosk caretakers; land acquisition, role of daily O&M in community level, and they expressed cooperation to LWSC and communal society. Most of the dwellers have experience for establishing their social organization on management of the conventional shallow wells so that they could understand what management system of public infrastructural facilities should be.

In addition, dwellers accepted water tariff proposed by JICA study team in this study. This is because the dwellers desire to leave utilizing shallow and dug wells which may be concerned with water contamination, and to use deep wells from which safe and stable water can be lifted. Judging from the results of public awareness survey carried out in this study, the proposed water tariff (less than USD10-15 per household per month) is payable for the dwellers.

For implementing the project of development of satellite water supply system, the system to establish water committee was already prepared. Accordingly, it is very essential that water supply management by water committee is ensured not only through workshop for instructing water tariff system but also through the practical training on operation of water supply system under supervision of LWSC prior to operational commencement of the system.

5.6.5.6 Burglary Protection

Local contractors seriously paid attention to burglary protection of construction materials during construction for the pilot project. Presence of security persons is necessary for reducing material burglary in construction sites during construction period.

CHAPTER 6 URBAN FACILITIES RESTORATION PLAN (SANITATION SECTOR)

6.1 Strategy for Sanitation Improvement Plan

6.1.1 National High Level Plan

The National Poverty Reduction Strategy (PRS) finalized in April 2008 shows overall vision and main strategies of the Liberian Government. This PRS includes implementation of the projects in sanitation sector from 2008 to 2011 as well as those in water supply sector.

In terms of sanitation sector, the access ratio to appropriate sanitation was 27% in 1990. However, it is decreased to 7% in 2003. After civil war, the access ratio is achieved to 15% in 2004 owing to rehabilitation. From the aspects of circumstances, the National PRS is targeting on the access ratio of 40% in 2011.

The following targets show main countermeasures to achieve goals on sanitation sector:

- 100% Rehabilitation of Monrovia Sewerage System;
- Rehabilitation of 3,000 public toilets (school, hospital, clinic) in Liberia;
- Establishment of 50,000 private toilets in local communities;
- Establishment of 10,000 public toilets (school, health center, public facilities) in Liberia;
- Establishment of processing center of toilet construction material and its production; and
- Scale expansion of national hygiene promotion activities.

In order to raise sanitary service coverage ratio in Greater Monrovia, LWSC has been carrying out Monrovia Water and Sanitation Program since 2007 which was funded by international donors. Specifically, LWSC focuses on the following goals of future sanitary service coverage ratio:

First goal, which was given in Poverty Reduction Strategy (PRS) is to raise sanitary service coverage ratio to 40% by 2011 in overall Liberia.

Second goal is based on the sector development plan for 2019 on which LWSC puts its own policy. It is to raise sanitary service coverage ratio to about 80% in Greater Monrovia.

In this study, sewerage facility plan is to be formulated for the targeted years of 2014 and 2019 taking into account these goals.

6.1.2 Relation with MDG

As one of the Millennium Development Goals (MDGs), the following goals are set for the sanitation sector in Target 7c:

- Reduce by half the proportion of people without sustainable access to safe drinking water and basic sanitation

And especially for the sanitation sector, following target is set:

- Proportion of population using improved sanitation facility

Regarding the improved sanitation facility, WHO and UNICEF Joint Monitoring Programme defined that

the use of public or any improved facilities are considered as "unimproved sanitation facilities" and not counted it as the achievement for MDGs.

Although public toilets are defined so, in view of current situation of sanitation facilities in Monrovia, installation of public toilets as an emergency measure is proposed in this study.

6.1.3 Current Issues and Countermeasures

Present conditions of sanitation in Greater Monrovia are described in section 2.6 and current issues in sanitation sector in Greater Monrovia and their countermeasures are shown in Table 6.1-1.

Table 6.1-1 Current Issues and Countermeasures (Sanitation Sector)

Item	Issues	Countermeasures
Sanitation Conditions in general	Access ratio to appropriate sanitation: 15% for Liberia and around 50% for Monrovia in 2004 Sewage treatment: no adequate treatment is being done	Restoration of sanitation facilities for the target years of 2014 and 2019 such as: ➢ Restoration of sewerage system [2019] ➢ Installation of community sanitation system [2014 & 2019] ➢ Installation of on-site facilities (i.e. public toilets, etc) [2014 & 2019]
Off-site sanitation (sewerage of separate system)	Sewer pipes are clogged with sludge and debris.	➢ Procurement of maintenance equipment including vacuum trucks and jet cleaning machines
	Mechanical and electrical equipment of sewerage facilities such as pumps in Sewage Pump Stations are stolen or damaged.	➢ Rehabilitation of Sewage Pump Stations including installation of mechanical and electrical equipment
	Sewage Treatment Plant has not been repaired and inoperative.	➢ Reconstruction of Fiama Sewage Treatment Plant
Off-site sanitation	Toilet type: mainly pour-flush latrine, sewage overflowing to the residential area Sludge generated from public toilet, etc. : no adequate disposal area	➢ Immediate rehabilitation of lagoon system in Fiama Sewage Treatment Plant site

Source: Emergency Rehabilitation Program Report, WB

6.2 Sanitation Restoration Plan

6.2.1 Issues to be Solved Urgently and Rehabilitation Required

The following rehabilitations are required to solve the issues for sanitation urgently:

1) Construction of sludge (night soil) treatment plant
   Sludge clogged in the sewer shall be withdrawn immediately and disposed appropriately.

2) Rehabilitation of sewerage system and sewer network
   In the area where sewer was installed before war and is destroyed at present, such as New Kru Town, Logan Town, Clara Town, Central Monrovia A, Central Monrovia B, Sinkor, Lakpazee, Old Road, replacement of sewer and pump station shall be conducted.

3) Construction of sewage treatment plant
   Sewage treatment plant shall be constructed to treat sewage appropriately discharged from the area where the sewer is installed.

4) Construction of community sanitation system and public toilet

In the area where it is difficult to have private toilet, public toilets shall mostly be installed and also community sanitation system shall be provided in the community where private toilets have already been provided. Night soil generated from public toilets and community sanitation system shall be transferred to sludge treatment plant by vacuum trucks.

6.2.2 Overall Rehabilitation Plan

Several studies for the rehabilitation of the existing sanitation system have been done by foreign aid organizations such as the World Bank (WB) and European Community (EC), which have assisted the Liberian Government to establish new sanitation system.

According to the result of the detailed survey conducted in several areas in Greater Monrovia, the following three types of sanitation system are found appropriate and proposed as the sanitation system for Greater Monrovia.

(1) Off-site sewerage system in the areas where sewerage facilities were installed before war.

(2) Community sanitation system in the areas where private toilets are provided in community.

(3) On-site sanitation system in the area where it is difficult to own private toilets.

The conceptual scheme explaining these systems is shown in Figure 6.2-1 and the areas to be covered by them are shown in Figure 6.2-2.

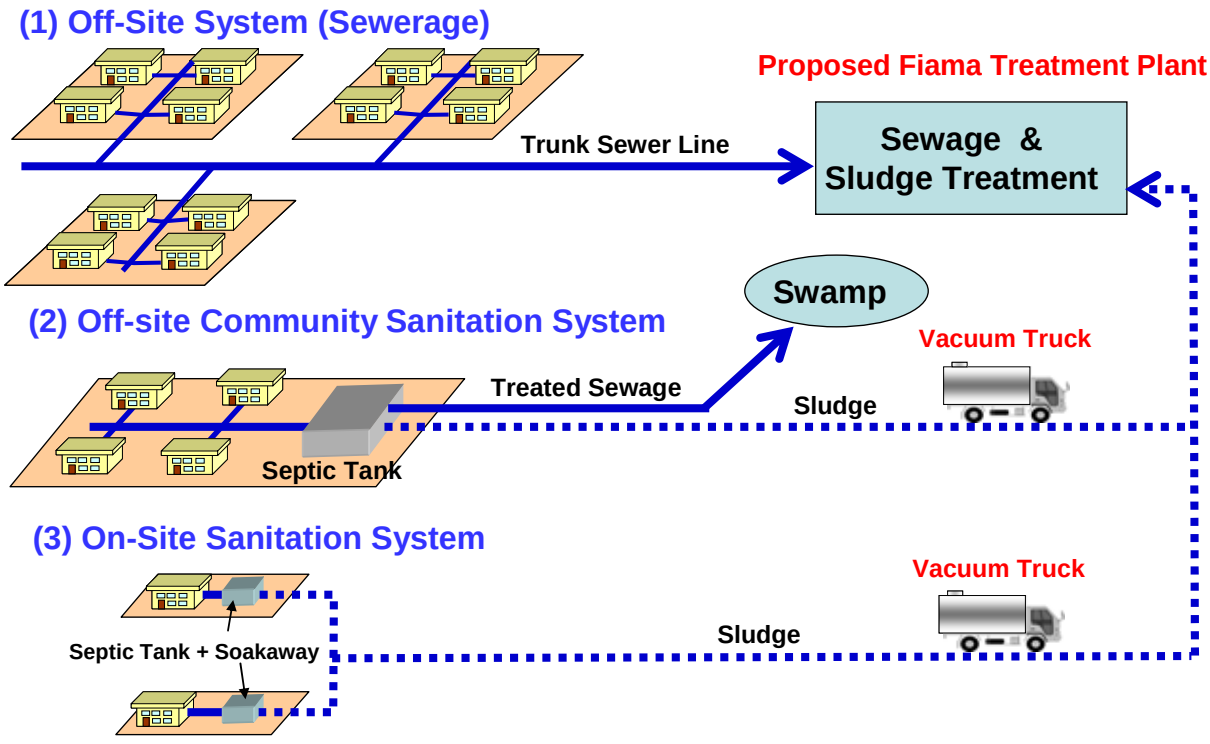


Figure 6.2-1 Type of Proposed Sanitation System in Greater Monrovia

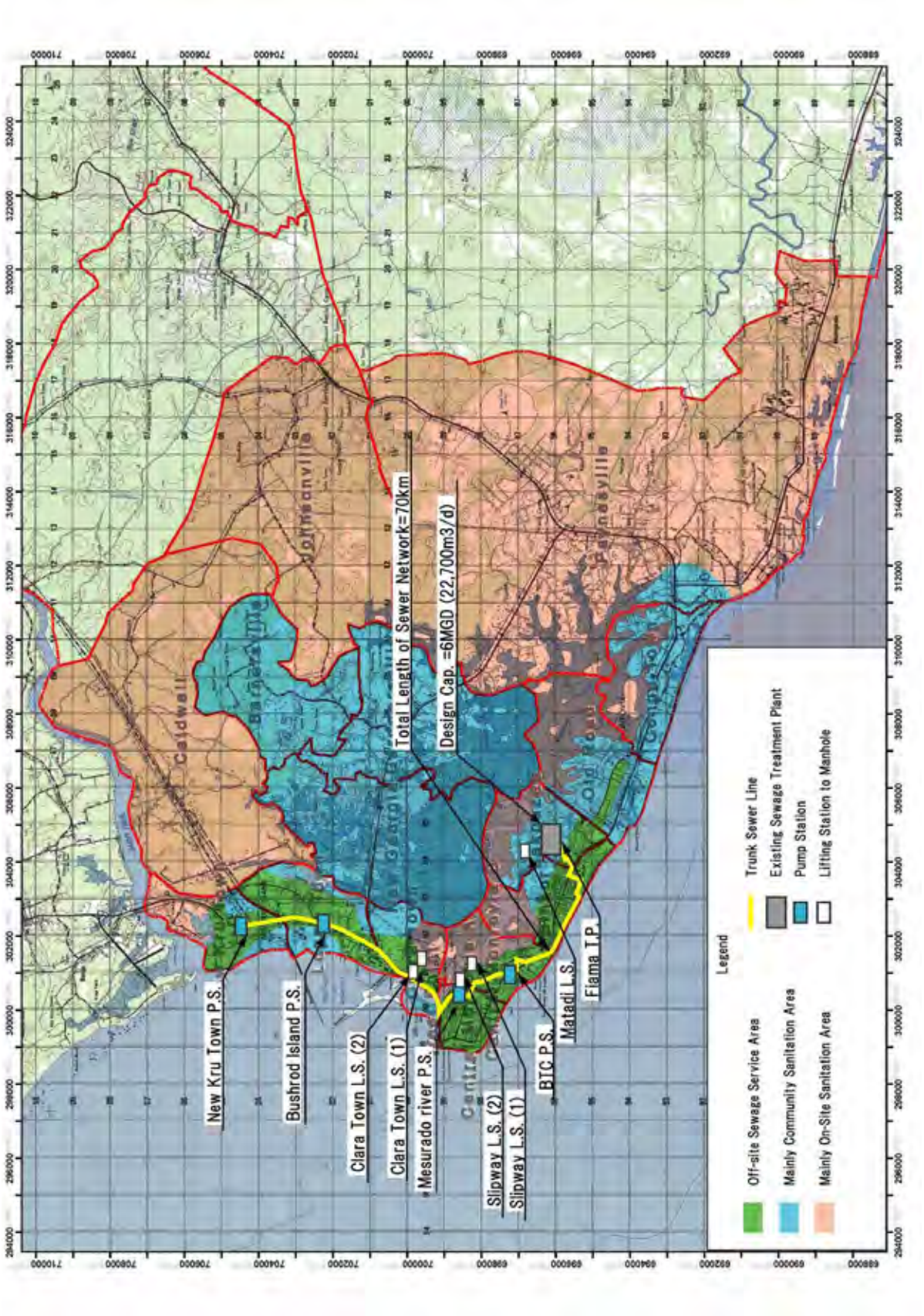


Figure 6.2-2 Areas to be Covered by Proposed Sanitation Systems in Greater Monrovia

According to the quantitative analysis of water usage, population density and current sanitation conditions in Greater Monrovia, the restoration plan as shown in Table 6.2.-1 are on going and proposed:

Table 6.2-1 Restoration Plan for Sanitation Sector

Projects	Types of Projects	Progress Status (Source of Funds)	Target Year
1. Monrovia Water and Sanitation Rehabilitation Program	Immediate Rehabilitation of the Sewage Treatment Plant (Restoration on Stabilization Pond, Construction of 11 public Toilets and Procurement of one Vacuum Track)	On-going (AfDB)	2011
2. Urban Infrastructure Construction and Rehabilitation of Monrovia Sewage network Pumping Stations	De-sludge and Cleaning the blocked sewer pipelines in Central Monrovia to Sinkor area Rehabilitation of Pumping Stations (4 Nos.) and Lifting Stations (5 Nos.) in off-site Sewage pipelines for Central Monrovia	On-going (WB)	2011
3. Community Sanitation System and Public Toilet Installation & Vacuum Truck Procurement Plan	Installation and procurement: 1) 66 community sanitation systems and 225 public toilets 2) 8 vacuum trucks	Proposed in JICA M/P study	2014 (approx.50% of population with sanitation in Greater Monrovia)
4. The Project for Reconstruction of Sewage Treatment & Sludge Treatment Plant	1) Reconstruction of the sewage treatment plant of 6MG/day (22,700m^3/day) 2) Construction of sludge treatment plant of 230 m^3/day	Proposed in JICA M/P study	2019 (approx.80% of population with sanitation in Greater Monrovia)
5. Community Sanitation System and Public Toilet Installation & Vacuum Truck Procurement Plan	Installation and procurement: 1) 93 community sanitation systems and 86 public toilets 2) 7 vacuum trucks	Proposed in JICA M/P study	

6.2.3 Restoration Plan on Sanitation Sector

The following restoration shall be necessary in order to solve the current issues:

1) Restoration plan for the target year of 2014
   - Community Sanitation System and Public Toilet Installation & Vacuum Truck Procurement Plan for the target year of 2014

2) Restoration plan for the target year of 2019
   - Community Sanitation System and Public Toilet Installation & Vacuum Truck Procurement Plan for the target year of 2019
   - The Plan for Reconstruction of Sewage Treatment & Sludge Treatment Plant

6.2.3.1 Restoration Plan for the Target Year of 2014

Public Toilet and Vacuum Trucks will be provided for Community Sanitation System and Public Toilet for the target year of 2014.

(1) Required Number of Public Toilet

Number of user for one toilet seats in Public Toilet: 60 persons/seat/day

Toilet seats per one Public Toilet: 8 seats

Total numbers of Public Toilet by 2010: 111

Required number of Public Toilet for 2014 is 225 (refer to Table 6.2-2).

Table 6.2-2 Required Number of Public Toilet for 2014

No	Zone Name	Population in 2014	Coverage Ratio in 2014 (%)	Public Toilet Service Population in 2014				Number of Public Toilet user (pop.)[2]	Toilet Seat per Public Toilet [3]	Total Number of Toilet [1]/([2] *[3])	Number of Existing Public Toilet	Required Number of Public Toilet
				Connected to Off-site System (Fiama STP)	Connected to Community Sanitation System	On-site (Public & Private Toilet)	Total [1]					
1	New Kru Town	75,670	55	0	0	26,485						
2	Logan Town	63,201	65	0	0	22,120						
3	Clara Town	57,815	70	0	0	23,126						
4	West Point	29,175	65	0	8,753	8,753						
5	Central Monrovia A	55,580	70	19,453	0	0						
6	Central Monrovia B	46,216	70	16,176	0	0						
7	Sinkor	47,210	70	0	0	2,361						
8	Lakpazee	44,595	65	0	0	2,230	161,504	60	8	336	111	**225**
9	Old Road	51,328	55	0	0	2,566						
10	Congo Town	29,065	50	0	0	1,453						
11	Paynesville	509,871	45	0	0	25,494						
12	Gardnersville	90,327	45	0	0	0						
13	New Georgia	59,041	45	0	0	0						
14	Barnersville	40,195	45	0	0	0						
15	Johnsonville	16,437	45	0	0	822						
16	Caldwell	34,272	45	0	0	1,714						
Total		1,250,000		35,629	8,753	117,122						

(2) Required Community Sanitation system

Total number of population for community sanitation system in 2014 is 198,079 (for detailed calculation, refer to Appendix A1)

Population of one community sanitation system: 3,000

Required number of community sanitation system: 198,079/3,000 = 66 places

(3) Required Number of Vacuum Trucks

1) Number of vacuum trucks possessed by LWSC
   1 vehicle to be procured by DFID and AfDB project

2) Number of required vacuum trucks
   Capacity of a vacuum truck: 7 m^3
   Carrying frequency: 2 times/day
   Volume of sludge generated a day is 125 m^3/day (refer to Table 6.2-3)
   Number of required trucks: 125/ (2 x 7) – 1 = 8 vehicles

Table 6.2-3 Required Volume to be Collected by Vacuum Trucks for 2014

No	Zone Name	Population in 2014	Coverage Ratio in 2014 (%)	Service Population in 2014			Sludge Generation per Capita per Day (m^3/cap.day) [2]	Total Sludge Generation from Septic Tank (m^3/day) [3]=[1]*[2]	% of Total sludge Volume Treated to Treatment Plant[4]	Volume of sludge (m^3/day) [3]*[4]
				Total Pop. for Off-site Community Sanitation System	Total Pop. On-site	Total [1]				
1	New Kru Town	75,670	55	3,784	30,268					
2	Logan Town	63,201	65	0	25,280					
3	Clara Town	57,815	70	2,891	26,017					
4	West Point	29,175	65	8,753	10,211					
5	Central Monrovia A	55,580	70	0	0					
6	Central Monrovia B	46,216	70	0	0					
7	Sinkor	47,210	70	0	9,442					
8	Lakpazee	44,595	65	8,919	11,149	499,075	0.001	499	25%	**125**
9	Old Road	51,328	55	2,566	7,699					
10	Congo Town	29,065	50	8,720	5,813					
11	Paynesville	509,871	45	76,481	152,961					
12	Gardnersville	90,327	45	36,131	4,516					
13	New Georgia	59,041	45	23,616	2,952					
14	Barnersville	40,195	45	16,078	2,010					
15	Johnsonville	16,437	45	3,287	4,109					
16	Caldwell	34,272	45	6,854	8,568					
Total		1,250,000		198,079	300,996					

6.2.3.2 Restoration Plan for the Target Year of 2019

(1) Community Sanitation System and PublicToilet

1) Required Number of Public Toilet

Required number of public Toilet is 86 as shown in Table 6.2-4.

Table 6.2-4 Required Number of Public Toilet for 2019

No	Zone Name	Population in 2019	Coverage Ratio in 2019 (%)	Public Toilet Service Population in 2019				Number of Public Toilet Users (pop.) [2]	Toilet Seat per Public Toilet [3]	Total Number of Toilets [1]/([2]*[3])	Number of Public Toilets Provided by 2014	Required Number of Public Toilets
				Connected to Off-site System (Fiama STP)	Connected to Community Sanitation System	On-site (Public & Private Toilet)	Total [1]					
1	New Kru Town	78,818	75	0	0	27,586						
2	Logan Town	68,431	95	0	0	23,951						
3	Clara Town	60,724	95	0	0	24,290						
4	West Point	29,370	100	0	19,090	8,811						
5	Central Monrovia A	67,692	100	23,692	0	0						
6	Central Monrovia B	51,579	100	18,053	0	0						
7	Sinkor	50,842	100	0	0	2,542						
8	Lakpazee	47,451	100	0	0	2,373	202,779	60	8	422	336	**86**
9	Old Road	54,715	85	0	0	2,736						
10	Congo Town	32,748	80	0	1,637	1,637						
11	Paynesville	650,620	75	0	0	32,531						
12	Gardnersville	100,081	75	0	0	5,004						
13	New Georgia	64,053	75	0	0	3,203						
14	Barnersville	44,995	75	0	0	2,250						
15	Johnsonville	26,643	75	0	0	1,332						
16	Caldwell	41,239	75	0	0	2,062						
Total		1,470,000		41,745	20,728	140,307						

2) Required Community Sanitation system

Total number of population for community sanitation system for 2019 is 474,290 (for detailed calculation, refer to Appendix A2)

Population of one community sanitation system: 3,000

Required number of community sanitation system: 474,290/3,000 = 159 places

Number of community sanitation system to be provided in 2014: 66 places

Therefore, number of community sanitation system required in 2019: 159-66 = 93 places

3) Required Number of Vacuum Trucks

Number of required vacuum trucks

Capacity of a vacuum truck: 7 m^3

Carrying frequency: 2 times/day

Volume of sludge generated a day is 230 m^3/day (refer to Table 6.2-5)

Number of required trucks: 230/ (2 x 7) = 16 vehicles

Number of vacuum trucks to be provided for 2014: 9 vehicles

Therefore, number of vacuum trucks required for 2019: 16-9 = 7 vehicles

Table 6.2-5 Sludge Volume to be Collected by Vacuum Trucks for 2019

No	Zone Name	Population in 2019	Coverage Ratio in 2019 (%)	Service Population in 2019			Sludge Generation per Capita per Day (m^3/cap.day) [2]	Total Sludge Generation from Septic Tank (m^3/day) [3]=[1]*[2]	% of Total sludge Volume Treated to Treatment Plant[4]	Required Capacity for sludge Treatment (m^3/day) [3]*[4]
				Total Pop. For Community Sanitation System	Total Pop. On-site	Total [1]				
1	New Kru Town	78,818	75	11,823	31,527					
2	Logan Town	68,431	95	3,422	27,372					
3	Clara Town	60,724	95	6,072	27,326					
4	West Point	29,370	100	19,090	10,279					
5	Central Monrovia A	67,692	100	0	0					
6	Central Monrovia B	51,579	100	0	0					
7	Sinkor	50,842	100	0	10,168					
8	Lakpazee	47,451	100	21,353	11,863	915,896	0.001	916	25%	**230**
9	Old Road	54,715	85	5,471	8,207					
10	Congo Town	32,748	80	19,649	6,550					
11	Paynesville	650,620	75	227,717	260,248					
12	Gardnersville	100,081	75	65,053	10,008					
13	New Georgia	64,053	75	41,634	6,405					
14	Barnersville	44,995	75	29,247	4,500					
15	Johnsonville	26,643	75	9,325	10,657					
16	Caldwell	41,239	75	14,433	16,495					
Total		1,470,000		474,290	441,606					

(2) Plan for Reconstruction of Sewage Treatment & Sludge Treatment Plant

1) Treatment Process for night soil and sewage

Treatment process and features for sewage treatment and sludge treatment system are shown in Figure 6.2-3.

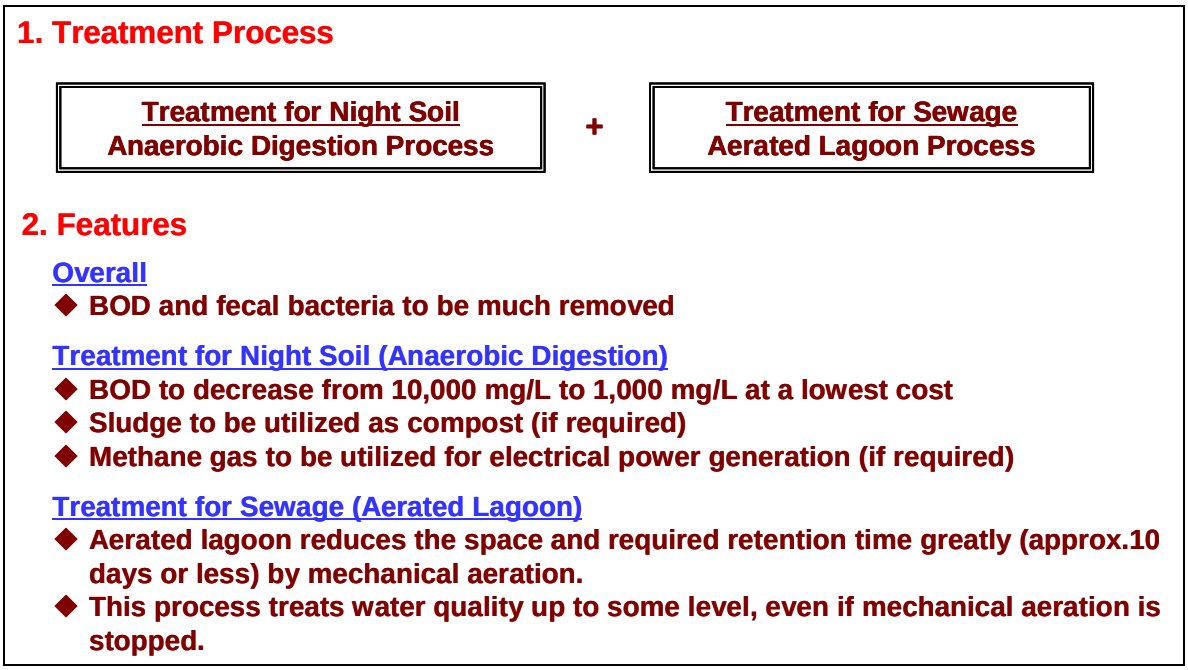


Figure 6.2-3 Proposed Night Soil and Sewage Treatment Process

2) Reconstruction of the Existing Sewage Treatment Plant

- Capacity of 6MG/day (22,700m^3/day) shall be planned to recover the condition of pre-war level taking into the consideration that the existing sound underground pipelines will be left as it is without increasing pipe size after rehabilitation, de- sludge and cleaning.
- The Sewage Treatment Plant will be constructed in the existing Fiama Sewage Treatment Plant area after dismantling the existing facilities (refer to Figure 6.2-4).
- New low-cost and easy-maintenance aerated lagoon system will be provided (refer to Figure 6.2-5).
- Summary of facilities is shown in Table 6.2-6.

Table 6.2-6 Summery of Facilities for New Sewage Treatment Plant for 2019

No.	Items	Specification	Remarks
1	Capacity of Sewage Treatment Plant	22,700(m^3/day)	Restoration of the existing treatment plant with a treatment capacity of 6MG (27,000m^3)
2	Grid Basin	2mW x 3.5mL x 2mH x 2basins Screen, Screw pumps etc.	
3	Preliminary Sedimentation Basin	4mW x 50mL x 4.5mH x 4basins Collector etc	Volume:3,200m^3
4	Aerated Lagoon	95mW x 95mL x 4.5mH x 4basins Aerator etc	Volume:144,400m^3
5	Maturation pond	95mW x 190mL x 2mH x 2basins	Volume:54,150m^3

3) Construction of New Sludge Treatment Plant

- Capacity of 230m^3/day Sludge Treatment Plant shall be planned to treat the sludge generated from the Community Sanitary System and the Public Toilet (refer to Figure 6.2-5)
- New Sludge Treatment Plant will be constructed in the existing Fiama Sewage Treatment Plant area (refer to Figure 6.2-4)
- Summary of facilities is shown in Table 6.2-7

Table 6.2-7 Summery of Facilities for New Sludge Treatment Plant for 2019

No.	Items	Specification
	Capacity of Sludge Treatment Plant	230 (m^3/day)
1	Receiving Facility	5mW x 5mL x 4mH x 2basins 10mW x 10mL x 4mH x 2basins Screen, Sand Separation Facility ,Comminuting Facility, Debris Separation Facility, Conveyance Pump etc
2	Digestion Tank	<For Sewage> First ϕ 19m x 5mH x 4basins, Second ϕ 19m x 5mH x 2basins <For Night Soil> First ϕ 17m x 5mH x 4basins, Second ϕ 17m x 5mH x 2basins
3	Power Generation Facility	<For Sewage> Generator 300kw <For Night Soil> Generator 200kw, Gas Holder, Desulphurization Facility, Flare Stack. etc
4	Thickener	ϕ 6.5m x 4mH x 2basins, Collector, Conveyance Pump etc
5	Drying Bed	<For Sewage> 10m x 120mL x 1mH x 4basins <For Night Soil> 10m x 120mL x 1mH x 3basins

4) Selection of Construction Site for New Sewage and Sludge Treatment Plant

Three candidate sites shown in Figure 6.2-6 were surveyed in this study and evaluated according to the characteristics of each site described in Table 6.2-8. After examination of the sites, it is concluded that the existing Fiama T.P site is proposed as a Sewage and Sludge Treatment Plant (STP) site in view of the distance from Central Monrovia and also of the construction cost.

Table 6.2-8 Characteristics of Alternative Sites for New Sewage Treatment Plant

Candidate Site	Characteristics	Result
Existing Fiama STP Site	This is the area inside the existing sewage treatment plant and also the nearest to Central Monrovia. Therefore, this is considered as the most advantageous in terms of the cost. However, the following issues are found according to the site survey. ➢ Since the site is the area covered by Ramsar Convention, the adequate procedure to use the land will be required.	**Adequate**
Site (1)	This site is nearer than Site-2 from Central Monrovia. However, the following issues are found according to the site survey: ➢ The area is not enough for construction of new STP. ➢ The area is Missionary area having hospital, several schools, radio station, farm and also residential area, therefore this site is not adequate for new STP.	**Not adequate**
Site (2)	The space is enough for new STP and dwellers are few. However, the following issues are found according to the site survey: ➢ Since the site is far from Central Monrovia and the distance from Fiama SPT is about 25km, new several pump stations will be necessary in order to transfer sewage. ➢ Since there are many shrubs and palms in the site, much work for site clearance will be necessary. ➢ Since there are many swamps in the site, huge reclamation work will be necessary.	**Not adequate**

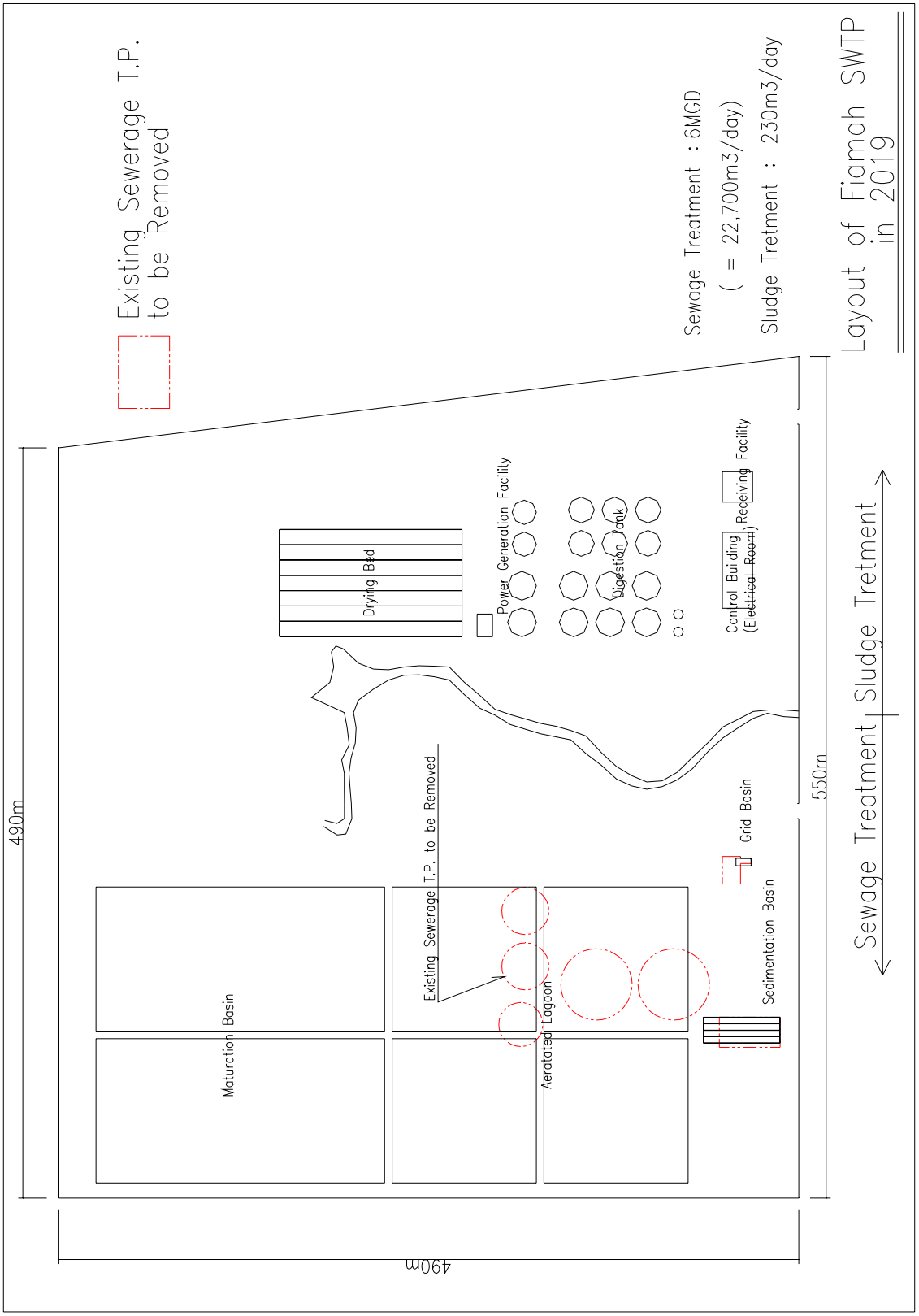


Figure 6.2-4 Layout of New Sewage and Sludge Treatment Plant

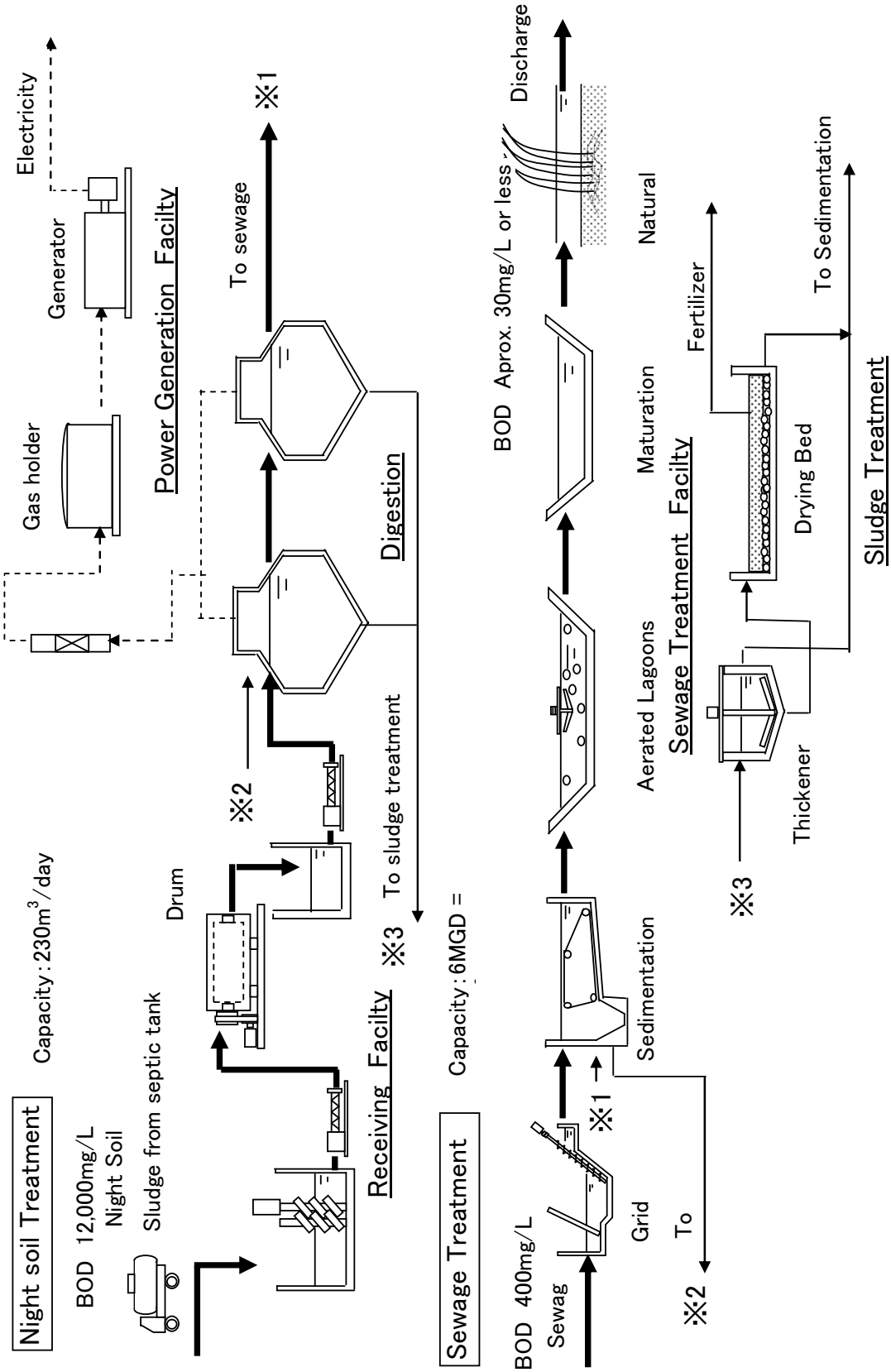


Figure 6.2-5 Flow Diagram of New Sewage and Sludge Treatment Plant

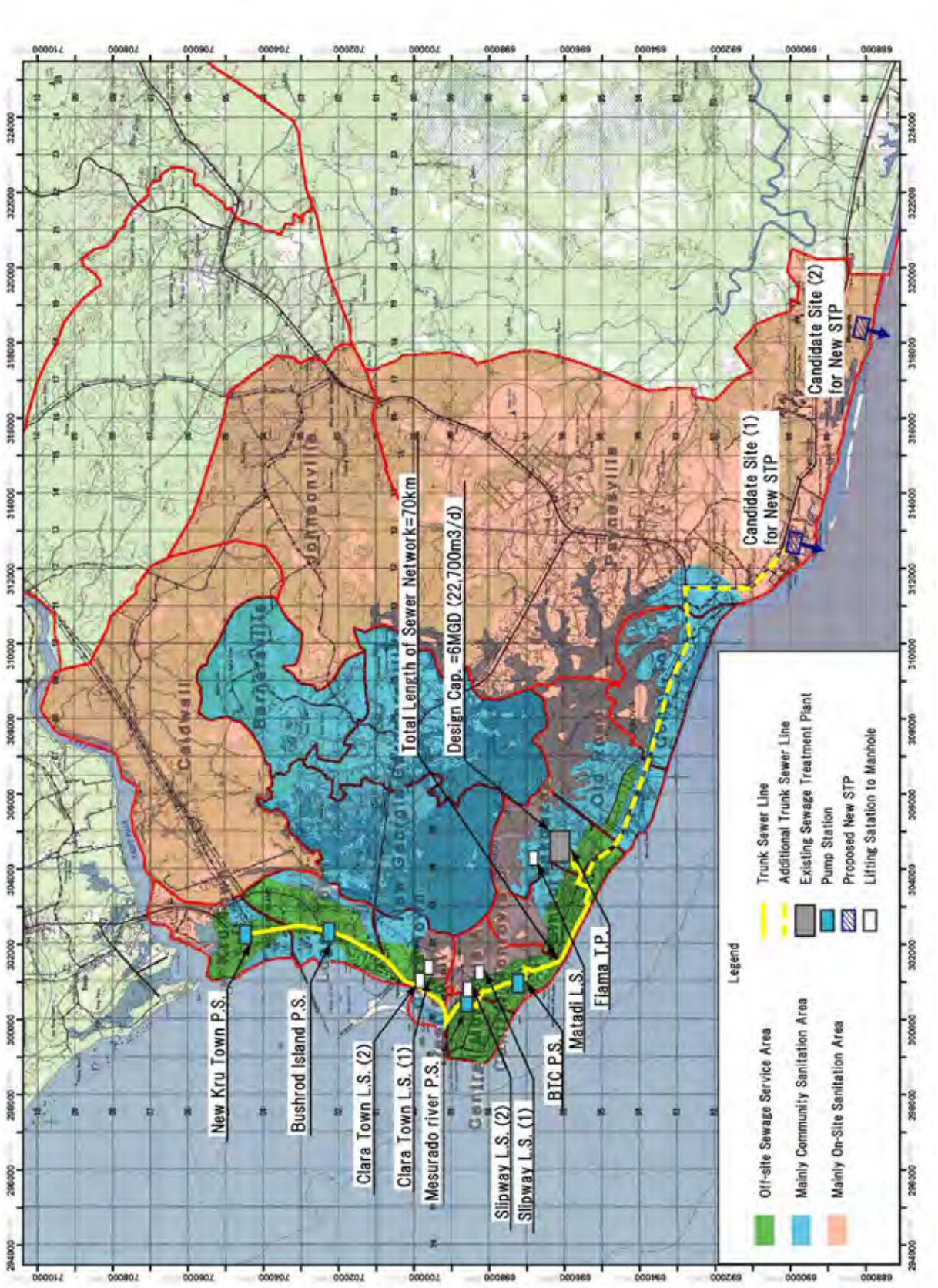


Figure 6.2-6 Candidate Sites for New Sewage and Sludge Treatment Plant

6.3 Project Implementation Plan

6.3.1 Cost Estimate

6.3.1.1 Monrovia Water and Sanitation Rehabilitation Program (WSRP)(SN-1)

The capital cost for Sanitation in WSRP is summarized as shown in Table 6.3-1.

Table 6.3-1 Capital Cost of Project SN-1

Item	Cost (mln USD)
Rehabilitation for 20-30 Public Toilets and Procurement of one Jet Cleaning Equipment	**2.9**
Immediate Rehabilitation of the Sewage Treatment Plant (Restoration on Stabilization Pond, Construction of 11 public Toilets and Procurement of one Vacuum Track)	
Design/supervision and contingency	

Source: LWSC

6.3.1.2 Urban Infrastructure Construction and Rehabilitation of Monrovia Sewage Network Pumping Stations (SN-2)

Since the project is under study, the capital cost has not been estimated by WB yet. Therefore, Table 6.3-2 shows approximate project cost which was estimated by JICA study team.

Table 6.3-2 Capital Cost of Project SN-2

Item	Cost (mln USD)
De-sludge, Cleaning and rehabilitation of the blocked sewer pipelines in Central Monrovia to Sinkor area	**4.8**
Rehabilitation of Pumping Stations (4 Nos.) and Lifting Stations (5 Nos.) in off-site sewage pipelines for Central Monrovia	
Design/supervision and contingency	

Source: POYRY for WB

6.3.1.3 Community Sanitary System and Public Toilet Installation & Vacuum Truck Procurement Plan for 2014 (SN-3)

The capital cost of Project for Community Sanitary System and Public Toilet Installation & Vacuum Truck Procurement Plan in 2014 is summarized as shown in Table 6.3-3.

Table 6.3-3 Capital Cost of Project SN-3

Item	Cost (mln USD)
66 Community Sanitary system	14.52
225 Public toilets	2.25
8 Vacuum Trucks	1.28
Sub-total	**18.1**
Design/supervision and contingency	**3.3**
Total	**21.4**

Source: JICA Study Team

6.3.1.4 The Project for Reconstruction of Sewage Treatment Plant & Sludge Treatment Plant (SN-4)

The capital cost of the Project for Reconstruction of Sewage Treatment Plant & Sludge Treatment Plant is summarized as shown in Table 6.3-4.

Table 6.3-4 Capital Cost of Project SN-4

Item	Cost (mln USD)
Reconstruction of Sewage Treatment Plant (6MG/day)	31.3
Construction of Sludge Treatment Plant of 230 m^3/day	31.6
Sub-total	**62.9**
Design/supervision and contingency	**11.3**
Total	**74.2**

Source: JICA Study Team

6.3.1.5 Community Sanitary System and Public Toilet Installation & Vacuum Truck Procurement Plan for 2019 (SN-5)

The capital cost of Project for Community Sanitary System and Public Toilet Installation & Vacuum Truck Procurement Plan in 2019 is summarized as shown in Table 6.3-5.

Table 6.3-5 Capital Cost of Project SN-5

Item	Cost (mln USD)
93 Community Sanitary system	20.46
86 Public toilets	0.86
7 Vacuum Trucks	1.22
Sub-total	**22.5**
Design/supervision and contingency	**4.1**
Total	**26.6**

Source: JICA Study Team

6.3.2 Implementation Schedule

Table 6.3-6 Project Implementation Schedule

(Unit: mln USD)

No.	Project	Investment Cost	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1	SN-1	2.9	0.96	0.96	0.98								
2	SN-2	4.8	0.80	2.00	2.00								
3	SN-3	21.4			5.35	5.35	5.35	5.35					
4	SN-4	74.2							14..84	14..84	14..84	14..84	14..84
5	SN-5	26.6							5.32	5.32	5.32	5.32	5.32
Total			**1.76**	**2.96**	**8.33**	**5.35**	**5.35**	**5.35**	**20.16**	**20.16**	**20.16**	**20.16**	**20.16**

Source: JICA Study Team

Note:

Project numbers in the above table mean the following project:

SN-1: Monrovia Water and Sanitation Rehabilitation Program (WSRP)
SN-2: Urban Infrastructure Construction and Rehabilitation of Monrovia Sewage Network Pumping Stations
SN-3: Community Sanitation System and Public Toilet Installation & Vacuum Truck Procurement Plan for 2014
SN-4: The Project for Reconstruction of Sewage Treatment & Sludge Treatment Plant
SN-5: Community Sanitation System and Public Toilet Installation & Vacuum Truck Procurement Plan for 2019

6.4 Recommendation on Institutional Measures

(1) Project Coordination

After civil conflict, LWSC has been coordinating various projects by the international cooperation for restoring and improving water supply and sanitation systems. However, there is no division or staff that exclusively coordinates the projects in LWSC, so that project progress, budgetary allocation and detail scope including terms of reference of the projects have not quantitatively been comprehended. In addition, present conditions of the existing sanitation system and service have not specifically been clarified by LWSC. In order to improve the sanitation service, it is very important for LWSC quantitatively to comprehend current situation and some issues on sanitation service.

Accordingly, in order to achieve the goals of sanitation service, which is focused on the target year of 2019, since it is expected that projects for restoring and improving sanitation system be increased, exclusive division shall be required to be established in LWSC. The division shall be able to not only to coordinate the projects appropriately, but also to make sanitation strategy plans, to which assisted by international organization will be needed.

(2) Development of Sewer and Sanitation Management

On the other hand, development including improvement of sanitation services has not been conducted for long time during civil conflict. At the same time, sewerage facility inventory, design manual, sanitation law have not been developed. In order to manage, implement sanitation project systematically, conduct O&M efficiently and standardize sanitation system, they should be developed urgently by LWSC, MLME and MPW.

(3) Re-use of Sludge and Methane Gas

Re-use of sludge and methane gas discharged from sewerage treatment plant can be applied for organic fertilizer and the biomass fuel for generating electric power. For the development of their facilities, land acquisition; sustainability of the facilities; investment funding; transportation of the product; O&M management system, etc. shall be examined comprehensively.

(4) Relation between Plan of Waste Disposal and That of Sanitation

Dump and the scatter of waste to the public storm water drainage or the combined sewer system seriously cause the clogging in the channel of the drainage, the sewer pipes and floods in the concerned areas. Regarding the separate sewer system, the scatter of waste is not related to the clogging in the separate sewer system directly. However, in order to dispose the waste in the Greater Monrovia properly and to protect natural condition from contaminated water passing through the waste, the formulation of waste disposal plan is required. Based on the future vision or the plan of waste disposal, Master Plan of the sanitation sector can be adjusted for the future, if necessary.

6.5 Access Population and Ratio to Sanitary Facilities

After implementation of on-going sanitation projects (Project SN-1 and SN-2) and proposed projects in this study (Project SN-3 to SN-5), the access population and ratio to the sanitary facilities will be developed as shown in Table 6.5-1 and Figure 6.5-1 with the following two cases:

Case-1: Access population and ratio to all the sanitary facilities in Greater Monrovia

Case-2: Access population and ratio to the sanitary facilities in Greater Monrovia excluding public toilets which are defined as "unimproved sanitation facilities" and not counted as the achievement of MDGs

Table 6.5-1 Projection of Access Population and Ratio to Sanitation Facilities from 2008 to 2019

Case	Type of Sanitation	2008	2014	2019
Case-1	Off-site system (sewerage)	20,000	157,000	281,000
	Off-site community sanitation system	0	198,000	474,000
	On-site sanitation (public toilet and private toilets)	495,000	301,000	442,000
	Total Access Population	515,000	656,000	1,197,000
	(Access Ratio: %)	**51**	**53**	**81**
Case-2	Off-site system (sewerage)	20,000	157,000	281,000
	Off-site community sanitation system	0	198,000	474,000
	On-site sanitation (private toilets)	338,000	139,000	239,000
	Total Access Population	358,000	494,000	994,000
	(Access Ratio: %)	**35**	**40**	**68**

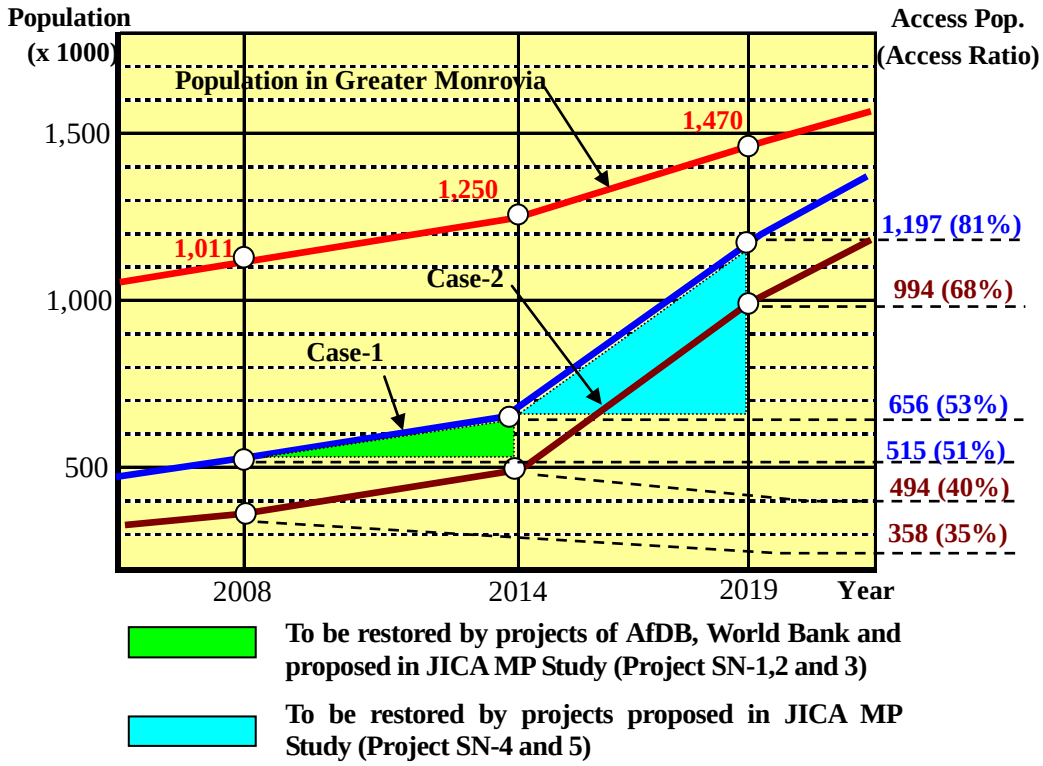


Figure 6.5-1 Trend of Access Population and Ratio to Sanitation Facilities for Greater Monrovia

CHAPTER 7 URBAN FACILITIES RESTORATION PLAN (STORM WATER DRAINAGE SECTOR)

7.1 Strategy for Storm Water Drainage Plan

For storm water drainage sector, the scope of the development plan is defined in the restoration plan of the planning horizon 2014. Based on the constraints and key issues described in the chapter 2.7.3, the vision, strategy, and goal for the restoration plan in this sector are set up as follows:

Vision :

- To develop capital function for economic performance without storm water drainage friction through the year
- To establish storm water drainage system in the core area of Monrovia

Strategy :

- To minimize frequent inundated area by the drainage system improvement
- To improve the drainage system in collaboration with the road sector development
- To demolish the sludge, debris and floating material in the drainage system

Goal :

- To strengthen the capacity of operation and maintenance by the supply of cleaning vehicle of underground drainage and the preparation of operation and maintenance manual
- To strengthen the drainage capacity by drainage channel construction
- To recover the drainage structures damaged by the civil conflict

7.2 Storm Water Drainage Plan

7.2.1 Priority Area

For the restoration plan of the storm water drainage, the recovery of fundamental function of drainage system is primary. The priority areas of the restoration plan are to select the old districts of Central Monrovia, Bushrod Island and Sinkor damaged by the civil friction. These areas are highly densely populated and there are many commercial buildings, government offices and accommodation facilities. The local houses have been built close to each other and there are number of drainages that have been blocked due to the solid waste deposit and the mud siltation in the drainage channels. In addition, the underground drainage pipes are blocked or broken, forcing the storm water onto the surface in the rainy season. Through the discussion in the Mini Work Shop held in July, it is reported that the zones of Lakpazee and Old Road have the serious inundation. For this Study, Lakpazee and Old Road are added to the priority area. The priority area is shown in Figure 7.2-1

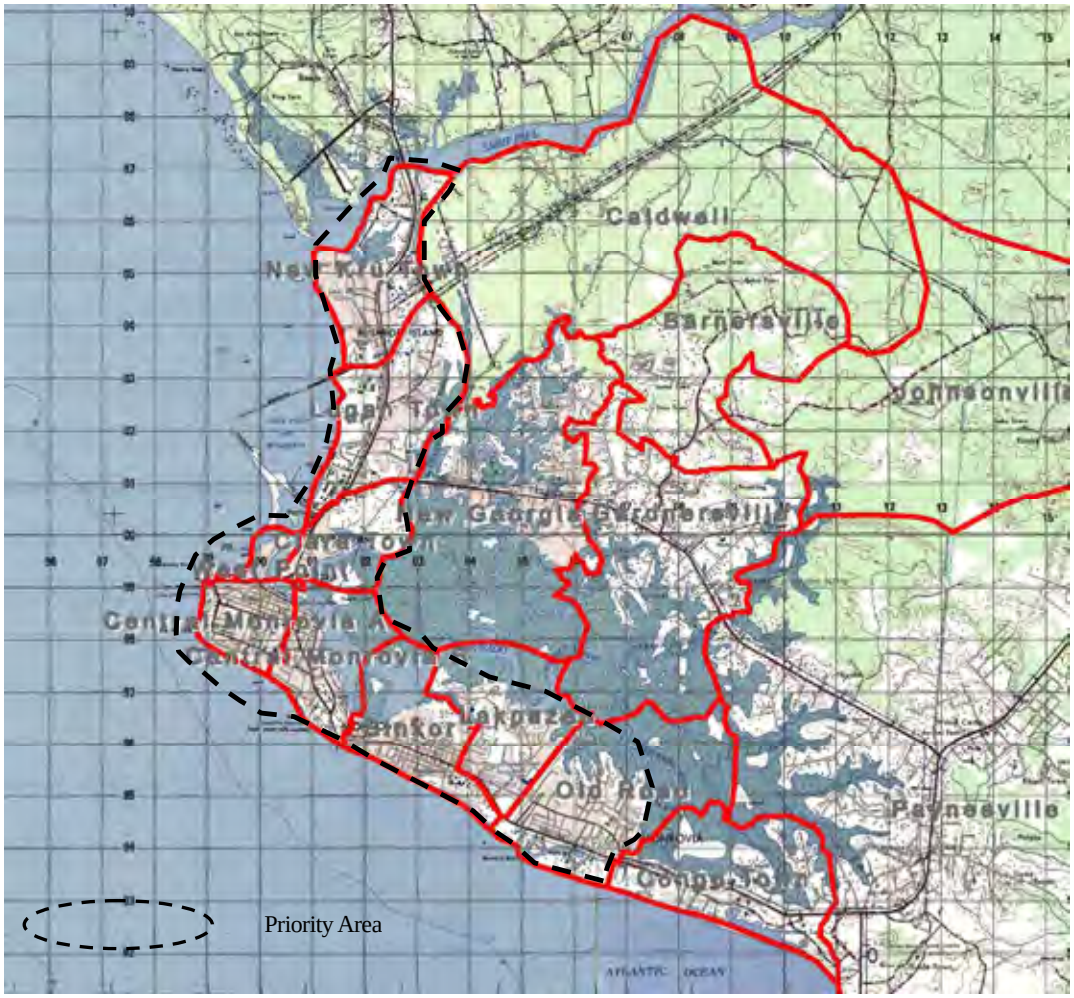


Figure 7.2-1 Priority Area for Restoration Plan

7.2.2 Proposed Plan Component

Based on the urgent issues described in 2.7.3.1, the following countermeasures shall be required for the functionary recovery of the storm water drainage;

- Cleaning and repair of surface channels, manholes and all inlets by works
- Furnishing of locally made inlet gutters from reinforcing bars
- Replacement of broken or missing concrete manhole covers
- Cleaning and repair of drainage pipes and underground channels
- Establishment of new secondary concrete drainage channels in densely populated areas
- Layout drawing of existing drainage system
- Preparation of the inventory of the existing drainage structure
- Procurement of vacuum truck with pressure pump and jetting equipment and tools for maintenance
- Capacity Development of MPW staffs for planning and designing of drainage
- Development of organization for operation and maintenance

Within these required countermeasures, the Liberia Urban Infrastructure Rehabilitation Programme (LIRP) and Urban Rehabilitation and Sanitation Project (URSP) described in 2.7.1.4 have been implementing the works of the cleaning and construction of open drainages, and new box culverts installation. In addition, MPW has implemented the drainage cleaning and box culverts installation in Monrovia using its own

budget of USD 0.4 mln in the year 2008/2009. During the Study, the site reconnaissance on the box culverts was carried out and the installation has been still implemented by MPW in collaboration with the road improvement. Figure 7.2-2 (1) shows the location and the site pictures of the culverts. Based on the premise that MPW has implemented the culverts installation for some time in the future, the restoration plan will exclude the new installation of the culverts. On the contrary, the channel improvement work of Soniwein drainage is still ongoing in the year of 2009.

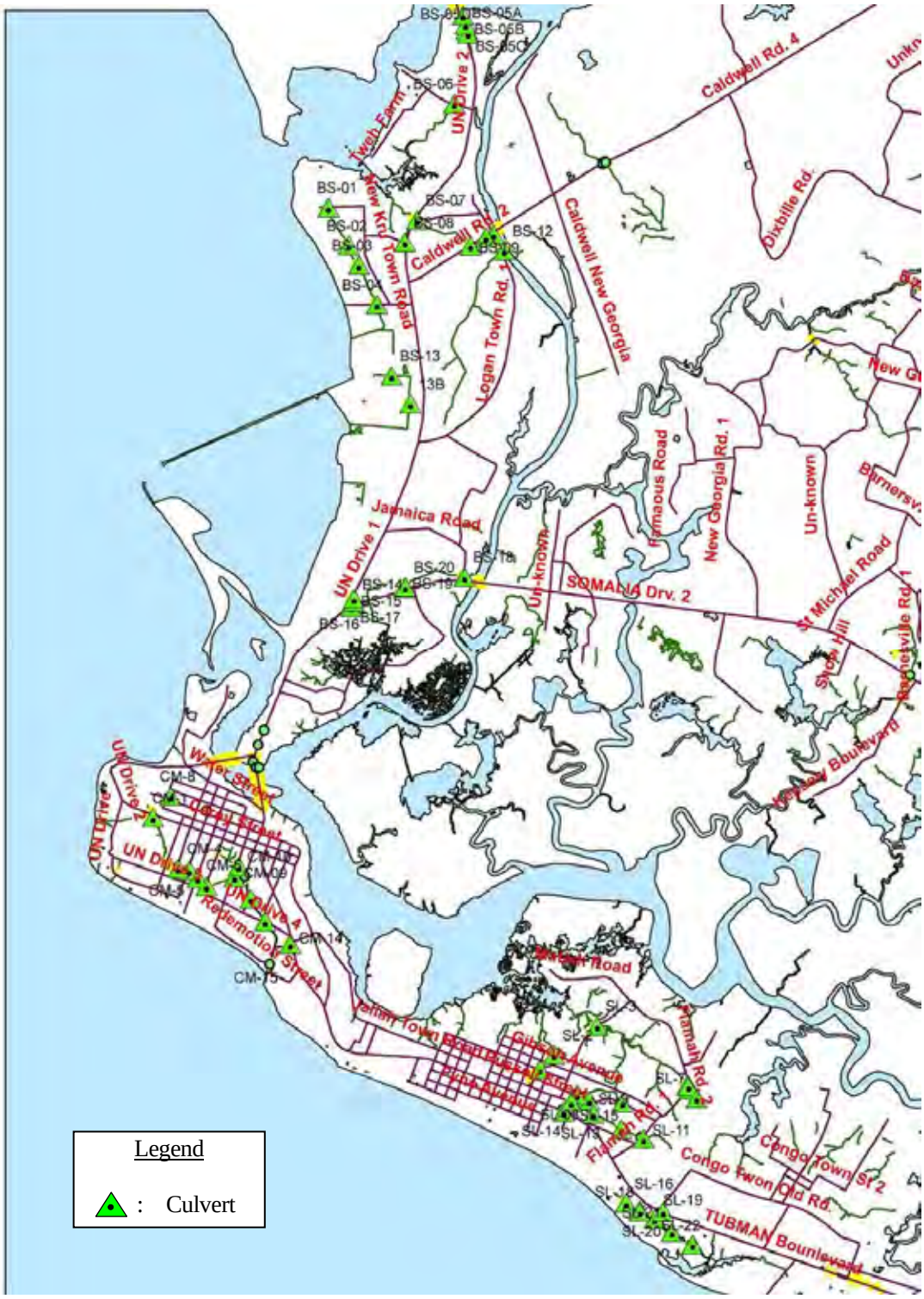


Figure 7.2-2 (1) Location of Culverts in the Priority Area

BS-01-Lagoon west Road –Down Stream
New Kru Town Community

BS-02-New Kru Town -Fundaye road
New Kru Town Community

BS-03-D-Tweh Road
New Kru Town Community

BS-04-Popo Beach road –Down Stream
New Kru Town Community

BS-05-St. Paul Bridge Road
St. Paul Bridge Community

BS-06-Island Clinic Road Culvert
Island Clinic Community

BS-07-Karnga building-Duala
Duala Community

BS-08-Duala market-New kru town road
Duala Community

Figure 7.2-2 (2) Site Picture of Culverts, Bushrod Island

Through the discussion with MPW staff and URSP Team, and based on the information obtained from previous Emergency Rehabilitation Programme under World Bank, the project component for the

Restoration Plan to the planning horizon of 2014 is proposed as below.

- Improvement of underground drainage structure
- Improvement of open drainage channels
- Equipment Supply of underground drainage pipes cleaning
- Establishment of operation and maintenance management system

(1) Improvement of Underground Drainage Structures

After the result of LIRP, the cleaning of the open channel has been implemented, but the cleaning and repair of the underground pipes is not yet implemented as of June 2009. At Bushrod Island, Central Monrovia and Sinkor areas, underground drainage system shall be improved integral with inlet and manhole for the Restoration Plan.

This improvement works are composed of the followings;

- Cleaning and replacement /repair of drainage pipes,
- Furnishing of locally-made inlet grating,
- Cleaning and repair of manholes, and
- Replacement of broken or missing concrete manhole covers

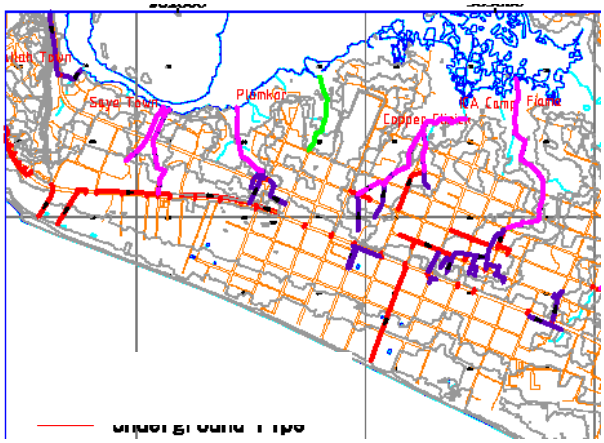
The total length of the underground pipes in Monrovia is 27,374 m and the length of pipes is 18,920 m for Central Monrovia, 3,180 m for Bushrod Island and 5,274 m for Sinkor. The length for replacement/repair of the pipes and the number of pieces for furnishing inlet grating, manholes, repair/construction manhole inlet and new manhole covers is 550 m, 970 pc, 950 pc, 380 pc 370 pc respectively. In the previous Study, the detail and these inventory were non-distinctive. Meanwhile, structure quantities except underground pipe for each area are assumed on the rate of the underground pipe length. The location of underground pipes is shown in Figure 7.2-3. The location is tentatively incorporated in GIS Map prepared by JICA Study Team for Mapping.

The quantities of drainage pipes, manhole, and inlet grating are summarized below.

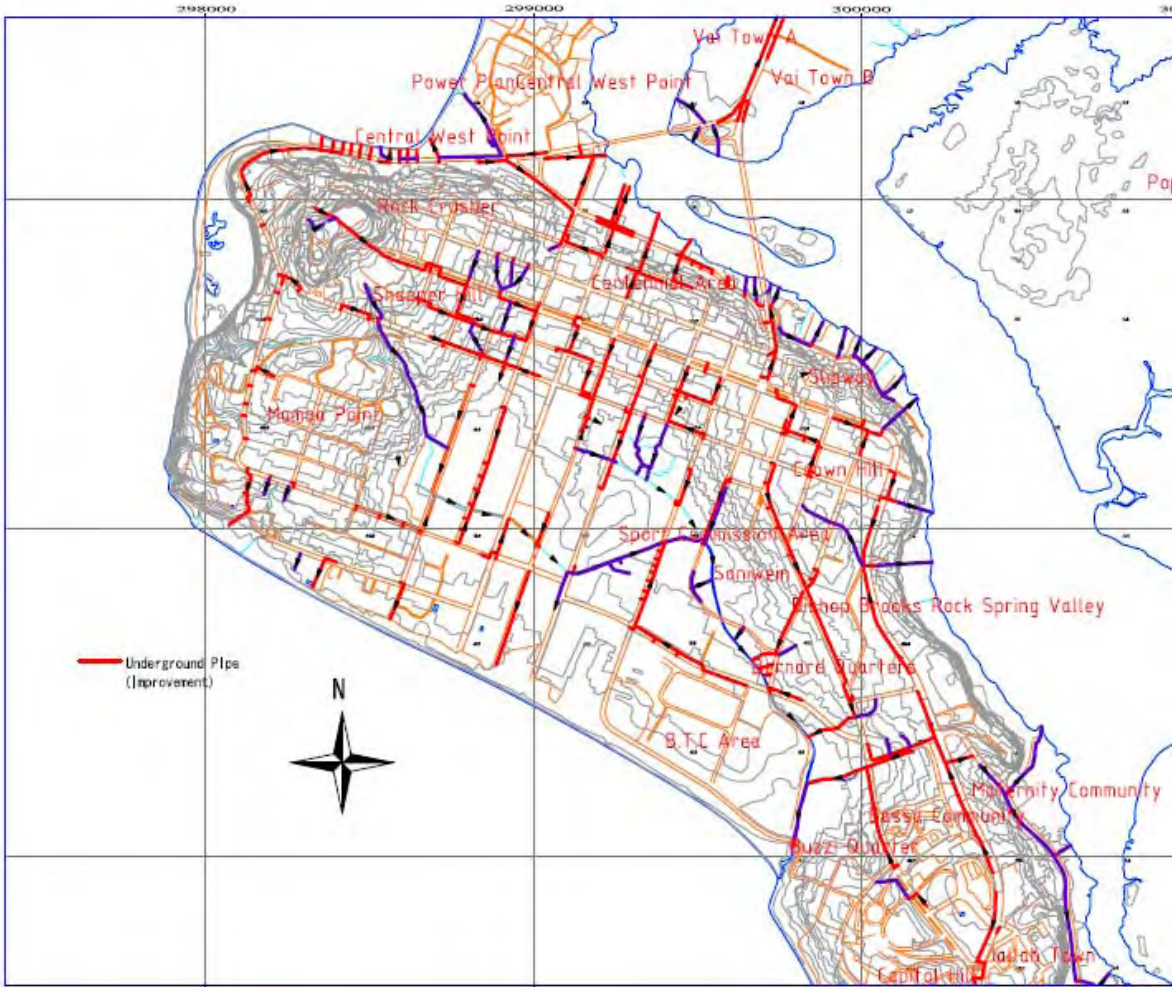
Table 7.2-1 Structure Summary of Improvement Underground Drainage Structures

Drainage Structure	Unit	Total	Bushrod Island	Central Monrovia	Sinkor
Underground Drainage Pipes	m	27,374	3,180	18,920	5,274
Replace & Repair Pipes	m	550	64	380	106
Cleaning Pipes	m	26,824	3,116	18,540	5,168
Furnishing Inlet, Grating	pc	970	116	669	185
Cleaning Manholes	pc	950	114	656	180
Repair & Construct Manhole	pc	380	46	262	72
New Manhole Covers	pc	370	44	255	71

Clara Town Zone in Bushrod Island



Sinkor Zone



Central Monrovia Zone A, B

Figure 7.2-3 Location of Underground Drainage Pipes

(2) Improvement of Open Drainage Channels

During or after LIRP, some drainage channels in Bush Island of the Freeport/Somalia Drive area, and the section of the Soniwein drainage channel in Central Monrovia, have been upgraded to concrete lining channel (Figure 7.2-4). Therefore, additional channels on Bushrod Island and in Sinkor including Lakpazee and Old Road shall require concrete lining or new concrete channels for the Restoration Plan. The new channels shall follow natural drainage system. These channels will increase drainage flow capacity than the earth channel condition.

Condition in April 2007 Upgraded in February 2008

Randall Section, Soniwein Drainage in Central Monrovia

(Picture Source: EIP Consultants Team)

Figure 7.2-4 Upgrading of Drainage Channel after LIRP

In the density areas like Westpoint, Clara Town, or Logan Town, some small drainage structures as new concrete channel (channel top width 2 m) between the local houses shall be required as additional. These locations will be defined within detail design stage. At the master plan stage, the length of 1,500 m will be proposed for Bushrod, Central Monrovia and Sinkor.

The improvement plan of open drainage channel of the priority area for the Restoration Plan is summarized as follows.

(a) Bushrod Island

New concrete channel (with 1.5m/3.0m base in channel section) shall be constructed in the communities of Duala, Bong Mines Bridge, King Peter, Stockton Creek and Jamaica Road. These areas are in low lying area and commonly inundated in the rainy season. But the business activities in these areas are still high. The small drainage structure of only new concrete channel (channel top width 2 m) will be constructed in the highly densely local houses.

(b) Central Monrovia

Soniwein drainage is the biggest drainage in Central Monrovia. Upgrading of the channel is implemented but some sections of underground and outlet to the Atlantic Ocean will be implemented soon. The small drainage structure of only new concrete channel (channel top width 2 m) will be constructed in the highly densely local houses.

(c) Sinkor(Lakpazee, Old Road)

Upgrading by concrete lining will be planned along the drainage of the communities; Saye, Plumkor, Copper Clinic, Camp Fiama, and Wroto. The total lining length is approximately 5,300 m. New concrete channel will be planned to mainly go to Lakpazee and Old Road divisions, with total length 2,500 m. The small drainage structure of only new concrete channel (channel top width 2 m) will be constructed in the highly densely local houses.

Table 7.2-2 summarizes the quantities for the improvement open drainage channel and the location of the improvement is shown in Figure 7.2-5.

Table 7.2-2 Improvement of Open Drainage Channel

Drainage Channel	Unit	Total	Bushrod Island	Central Monrovia	Sinkor
Concrete Channel (2.0 m top)	m	4,500	1,500	1,500	1,500
Concrete Lining (1.5 m base)	m	4,200	0	0	4,200
Concrete Lining (3.0 m base)	m	1,100	0	0	1,100
Concrete Channel (1.5 m base)	m	5,900	3,800	0	2,100
Concrete Channel (3.0 m base)	m	1,800	1,400	0	400

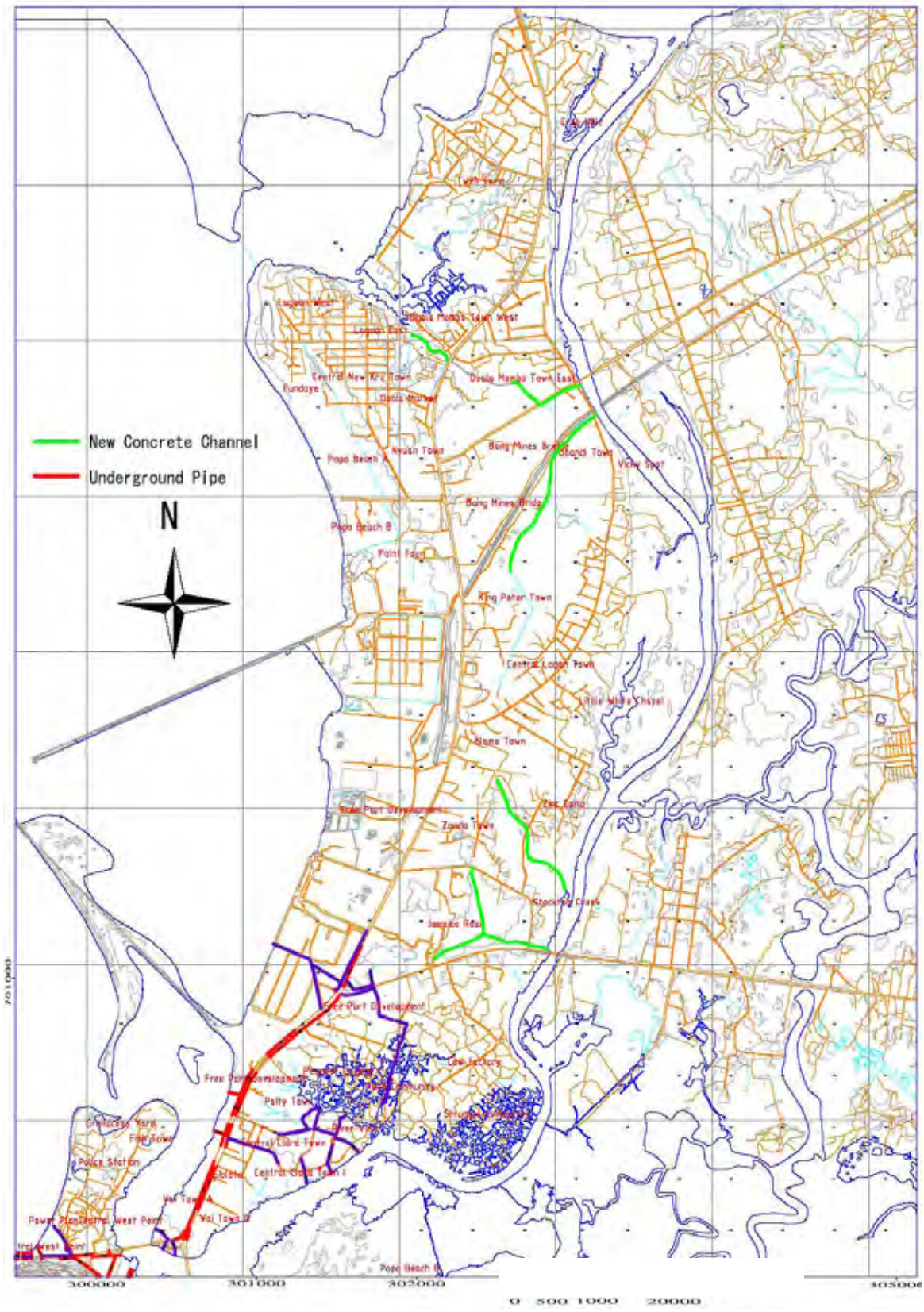


Figure 7.2-5 (1) Drainage Improvement Location in Bushrod Island

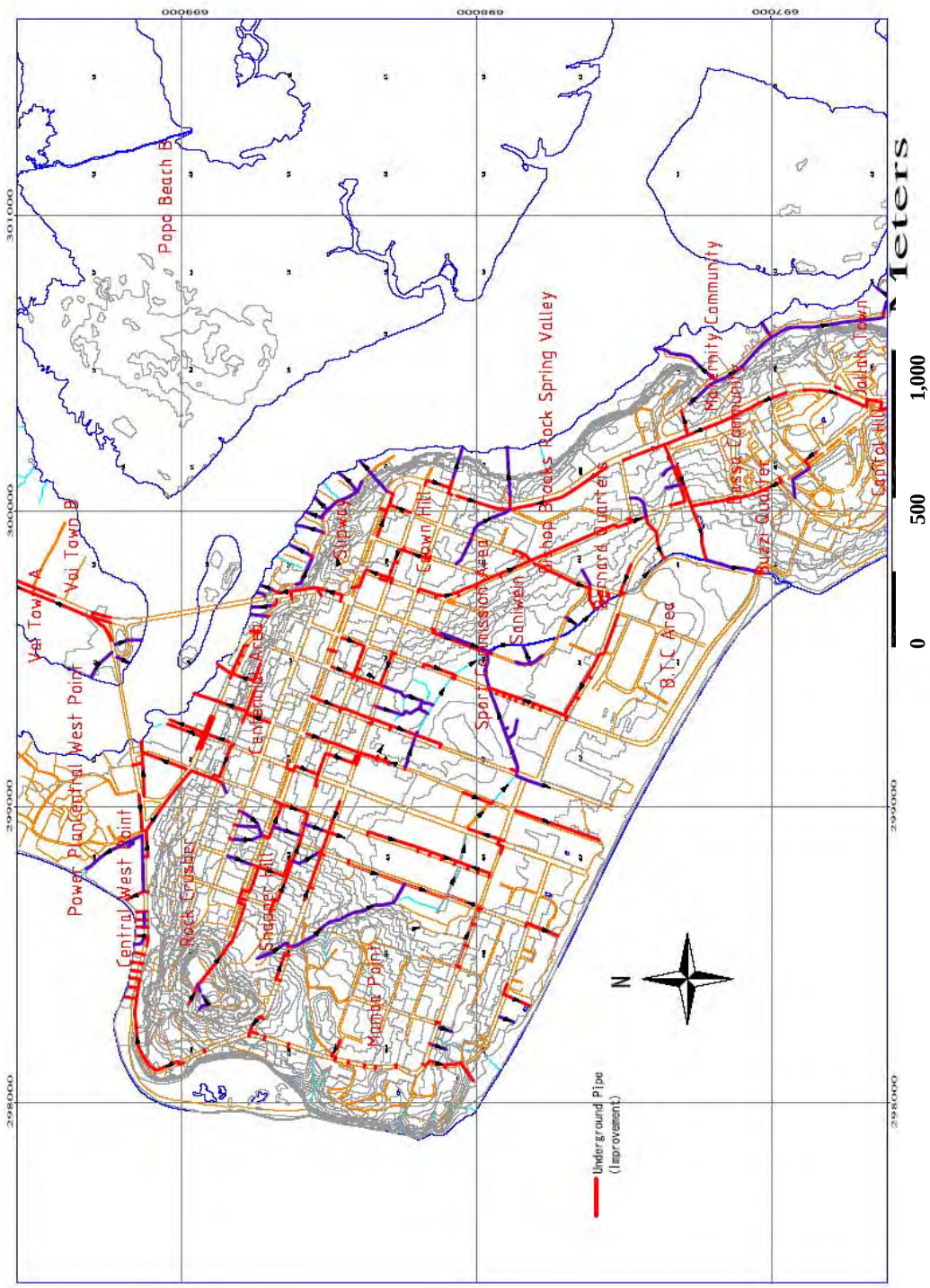


Figure 7.2-5 (2) Drainage Improvement Location in Central Monrovia

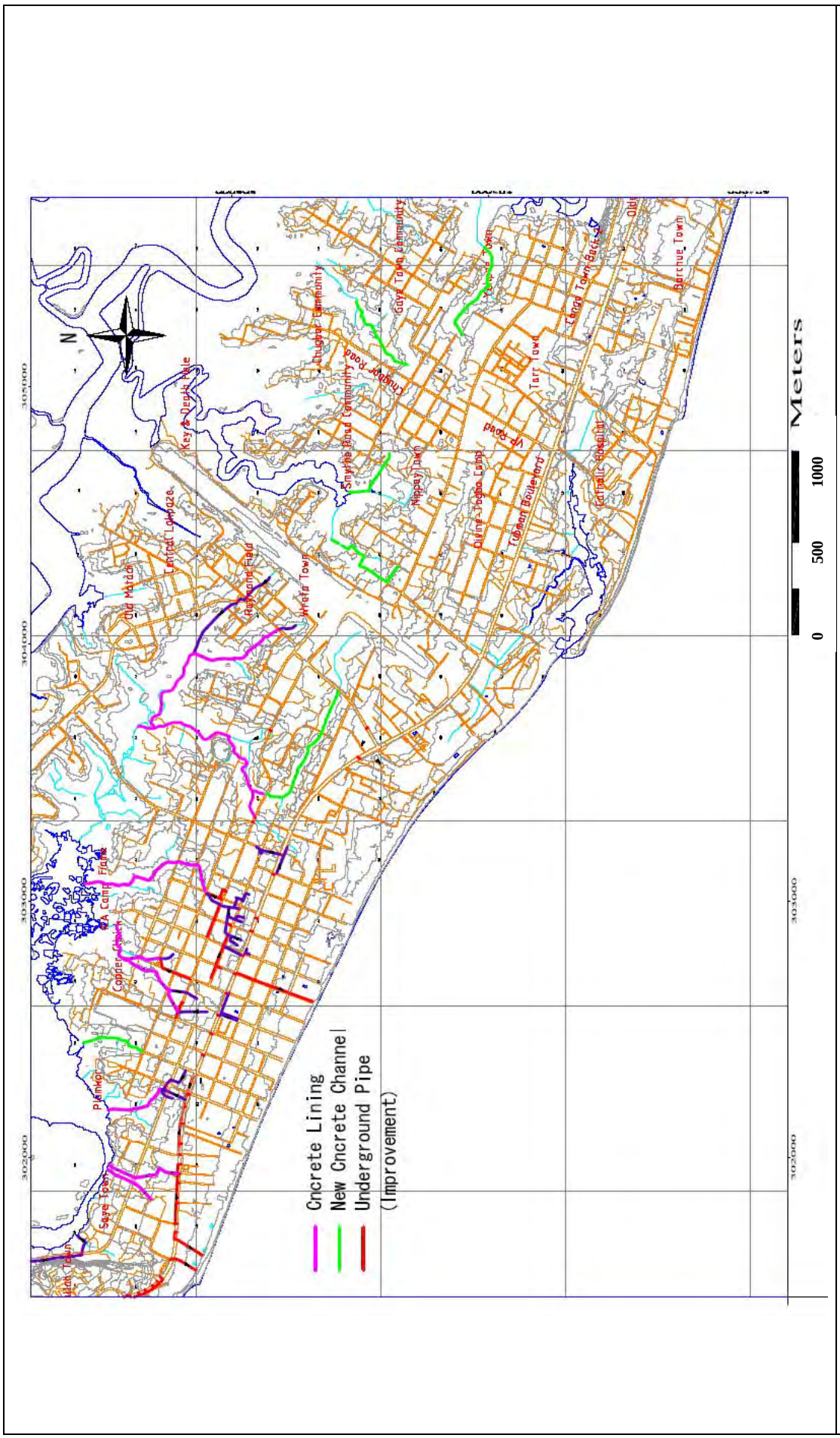


Figure 7.2-5 (3) Drainage Improvement Location of Sinkor, Lakpazee and Old Road Zones

The rainfall intensity of short duration is developed for the drainage planning. At Monrovia, there exists only 2 years meteorological data on the frequency of short duration rainfall in the year of 1954 and 1955 listed in Table 7.2-3. The average of the values in the duration of 1954 and 1955 is applied for the calculation.

Table 7.2-3 Point Rainfall Intensity (mm/hr) for Monrovia

Year	Duration (minutes)					
	5	10	15	30	60	120
1954	227	196	170	122	66	44
1955	125	107	92	81	69	59

These average values in the duration are higher than the values of 5 years return period at Accra in Ghana listed in Table 7.2-4. At this stage, the average values in the duration of Monrovia are acceptable for the drainage planning. The probable rainfall intensity analysis at Accra is based on the Gumbel Method. The similar analysis should be done at Monrovia Meteorological Station in future. It is expected that the automatic rain gage will be installed and the recorded data is stored.

Table 7.2-4 Probable Rainfall Intensity (mm/hr) for Accra

Return Period	Duration (minutes)				
	12	24	42	60	120
5	127	99	74	62	38
10	141	117	86	72	44

(Data: Accra Meteorological Station)

(3) Equipment Supply of Underground Drainage Pipes Cleaning

There are approximately 27 km underground pipes with diameter 600 – 1,200 mm in the priority area. After the civil conflict, the maintenance work of the pipes has not been sustained. As a result, there are many blockages in the pipes. The drainage water flow on the road surface by the blockages of the drainage pipes causes the following;

- Degradation of living environment for the inhabitants
- Breaching of pavement of the city road
- Induction of traffic accidents by vehicle sliding due to flowing on the road surface during the raining

For keeping original function of the piped drainage, the supply of water jet and vacuum cleaning equipment shall be discussed.

As the detail condition of length and sediment percentage of the equivalent diameter (600, 900, 1200 mm) are not provided, the necessary unit numbers are developed on the assumption of each total length of 9,000 m, the sediment rate of 60 % and total working day of 260 days.

As a result, the necessary equipment units are summarized in Table 7.2-5 and the equipment image is illustrated in Figure 7.2-6.

Table 7.2-5 Equipment Summary of Underground Pipes Cleanings

No.	Equipment name	Specification	Q'ty	
1)	4tons water jet cleaner	219L/min x 19.6MPa	1	unit
2)	4tons vacuum cleaner (lift type)	$21m^3$/mi n x -97KPa	1	unit
3)	4tons water tank	$4.5m^3$	2	units
4)	4tons sludge hauling dump truck		2	units
5)	4tons truck for equipment transport	with 3tonnes crane	1	units
6)	Submersible pump	50mm dia.	2	sets
7)	Diesel generator	20kVA	2	sets

Water Jet Cleaner

Vacuum Cleaner

Figure 7.2-6 Equipment Image of Drainage Pipes Cleaning

(4) Establishment of Operation and Maintenance Management System

Primary function of the drainage is to flow the storm water in the rainy season. However, some blocking and drained water stagnation in the channel by the sludge and debris often can be seen in Soniwein River and it makes poor hygiene for living environment of the inhabitants. The cleanings of the channel or demolishment of the solid waste shall be required before the rainy season starts.

Generally, operation and maintenance work on a routine basis shall be done to achieve the objectives of drainage system through fulfilling of functions of drainage facilities such as drainage channel, underground drainage pipes, manholes and culverts. Operation and maintenance manual includes general affairs related to drainage, budget execution, and asset management, etc.; guidance for drainage connections; monitoring and guidance on storm water drainage, operation and maintenance of drainage including culverts, inventory management, recording, environmental conservation, emergency measures, and public relations activities.

There is still no manual or guideline on operation and maintenance in MPW. Therefore, the establishment of operation and maintenance management system shall be required all together with the equipment supply for underground drainage pipes cleanings.

7.2.3 Recommendation on Other Flood Risk Area

Through the site survey, the inundation areas are identified based on the information interviewed from local residents and the GIS maps, as follows:

- Congo Town (Peace Island) near the building of ex Ministry of Defence.
- SKD Boulevard Street – wetland near the left branch river of Mesurado River
- Pipeline 1 Street – branch road of Red Light district
- Kakata Highway – paved branch road of Red Light district
- Jacob Peace Island Road – branch road from Somalia Drive road