Chapter 7 Present Sewage Volume in the Three Areas and Projection of Sewage Generation Volume for the Project Area

7.1 Present and Planned Sewage Generation Volume by Area

7.1.1 Per Capita Sewage Generation Volume

As mentioned in section 6.3.3, unit water consumption rate for domestic use is planned at 150 lpcd, i.e. water quantity reaching the consumer tap. As per Section 3.5 "Per Capita Sewage Flows" of the CPHEEO Manual on Sewage and Sewage Treatment, ideally all consumed water should reach the collection system. However, the observed dry weather quantity is less than per capita consumption, since some water is lost due to evaporation, seepage into ground, leakage etc. In Dry and Arid regions, the mean sewage flow can be as little as 40% of the water consumption, whereas in fully developed areas, the flow may be as high as 90%. A conservative value of 80% is adopted for Bengaluru as used in Sewerage DPR for 110 Villages.

As per Section 3.6 of CPHEEO Manual on Sewage and Sewage Treatment, the design infiltration value is suggested at 10% of design sewage flow. Thus, per capita sewage volume is calculated at 132 lpcd {= 150 lpcd (per capita water consumption) x 80% (sewage generation ratio) + 10% of domestic sewage generation volume (groundwater infiltration)}.

7.1.2 Sewage Generation in Core Area

For the calculation of sewage volume by target year, projected population for Core area is used as shown in Table 7.1.1. Table 7.1.2 shows sewage volume to be generated by target year in the Core area. The calculated volume of 745 MLD in 2016 is larger than the total sewage treatment capacity of existing STPs (721 MLD).

Table 7.1.1 Projected Population for Core Area

Zone	Population (persons)				
	2016	2019	2024	2034	2049
East	1,928,782	1,974,268	2,052,473	2,218,306	2,492,509
West	1,461,314	1,495,776	1,555,028	1,680,667	1,888,413
South	2,246,722	2,299,706	2,390,805	2,583,971	2,903,374
Total	5,636,817	5,769,750	5,998,306	6,482,944	7,284,296

Source: JICA Survey Team

Table 7.1.2 Sewage Generation Volume in Core Area

Zone	Sewage Generation in MLD				
	2016	2019	2024	2034	2049
East	255	261	271	293	329
West	193	197	205	222	249
South	297	304	316	341	383
Total	745	762	792	856	961

Source: JICA Survey Team

7.1.3 Sewage Generation in ULB Area

Table 7.1.3 shows projected population in eight zones of ULB area. Sewage volume to be generated by target year in the ULB area is calculated at 323 MLD in 2016 as shown in Table 7.1.4.

Table 7.1.3 Population projections for ULB Areas

Unit: person

ULB Name	2016	2019	2024	2034	2049
Bytrayanapura	359,282	408,589	497,148	708,064	1,122,021
Yelahanka	179,597	204,245	248,513	353,946	560,874
K.R. Puram	354,891	403,596	491,072	699,410	1,108,308
Mahadevpura	293,928	334,266	406,716	579,266	917,924
Bommanahalli	428,781	487,626	593,316	845,032	1,339,064
R.R. Nagar	183,697	208,907	254,186	362,025	573,676
Kengeri	80,913	92,018	111,962	159,462	252,689
Dasarahalli	559,102	635,833	773,645	1,101,865	1,746,050
Total	2,440,189	2,775,079	3,376,559	4,809,072	7,620,605

Source: JICA Survey Team

Table 7.1.4 Sewage Generation in ULBs

ULB Name	Sewage Generation in MLD				
	2016	2019	2024	2034	2049
Bytrayanapura	47	54	66	93	148
Yelahanka	24	27	33	47	74
K.R. Puram	47	53	65	92	146
Mahadevpura	39	44	54	76	121
Bommanahalli	57	64	78	112	177
R.R. Nagar	24	28	34	48	76
Kengeri	11	12	15	21	33
Dasarahalli	74	84	102	145	230
Total	323	366	447	634	1,005

Source: JICA Survey Team

As shown in Table 7.2.3, next section, ten units of STPs are under construction through BWSSP Phase 2, which will be commissioned by 2019 with combined planned capacity of about 336 MLD. Hence most of sewage to be generated in ULBs area would be treated (about 92 % in 2019). These STPs are planned to provide services for ULB and part of 110 Villages.

7.1.4 Sewage Generation in 110 Villages Area

Table 7.1.5 presents projected population for the calculation of sewage volume in the 110 Villages. Currently certain areas in 110 Villages are served by some sewerage systems for ULB areas with reference to watershed. Excepting for such areas, there is no sewerage system in the 110 Villages.

Table 7.1.5 Projected Population for Five Zones by Target Year

Unit: person

Name of Zone	2016	2019	2024	2034	2049
Bytrayanapura	303,641	339,849	413,004	588,921	933,196
Mahadevpura	281,489	315,053	382,874	545,957	865,116
Bommanahalli	356,028	398,482	484,259	690,523	1,094,195
R.R. Nagar	257,218	310,618	375,453	524,910	817,245
Dasarahalli	241,769	270,606	328,847	468,914	743,037
Total	1,440,145	1,634,608	1,984,437	2,819,225	4,452,789

Source: JICA Survey Team

Due to absence of CWSS water supply system in the village area, they are served by either public / private wells or water supplied by BWSSB / private contractors via water tankers. As a result, the current per capita sewage generation volume may be much lower than 132 lpcd. The generated sewage is either discharged into nearby channels/drainage or into septic tanks and in some cases private STPs built by large residential complexes. However, for design purposes the per capita sewage generation volume is assumed at 132lpcd. Total sewage volume generated in the 110 Villages area in 2016 arrived at 190 MLD as shown in Table 7.1.6.

Table 7.1.6 Sewage Generation in 110 Villages

Unit: MLD

Name of Zone	2016	2019	2024	2034	2049
Bytrayanapura	40	45	55	78	123
Mahadevpura	37	42	51	72	114
Bommanahalli	47	53	64	91	144
R.R. Nagar	34	41	50	69	108
Dasarahalli	32	36	43	62	98
Total	190	217	263	372	587

Source: JICA Survey Team

7.1.5 Overall Sewage Generation Volume

The total sewerage generation volume in BBMP area is summarized in Table 7.1.7. The total sewage volume generated in 2016 arrived at about 1,258 MLD. The sewage volume for the three areas is also shown by target year in Table 7.1.7.

Table 7.1.7 Sewage Generation in Bengaluru in the Planning Years

Unit: MLD

Area	2016	2019	2024	2034	2049
Core	745	762	792	856	961
ULBs	323	366	447	634	1,005
110 Villages	190	217	263	372	587
Total	1,258	1,345	1,502	1,862	2,553

Source: JICA Survey Team

7.2 Comparison between Projected Sewage Volume and Capacity of Sewerage Systems

7.2.1 Capacity of STPs

As shown in Chapter 4, existing STPs (up to secondary treatment) are located at 14 sites, and the total treatment capacity is 721 MLD, main treatment target is from the Core area and ULB area (see Table 7.2.1).

Table 7.2.1 Existing STPs in Bengaluru (up to secondary treatment)

No.	Name of the STP	Capacity (MLD)	
		2016	2034
1	Cubbon Park STP	1.5	Same capacity as existing
2	Hebbal Valley STP	60.0	
3	ITI Colony STP (Kempabudhi)	1.0	
4	Jakur STP	10.0	
5	Kadabeesanahalli STP	50.0	
6	K&C valley STP	248.0	
7	Krishnaraja (K.R.) Purum STP	20.0	
8	Lalbaugh STP	1.5	
9	Madiwala STP	4.0	
10	Mailasandra STP	75.0	
11	Nagasandra STP	20.0	
12	Raja Canal STP	40.0	
13	Vrishabhavathi (V.) Valley STP	180.0	
14	Yellahanka	10.0	
	Sub-Total	721.0	

Note: A renewal program for STPs commissioned by 2019 to be undertaken in 2034 including review of capacities
Source: JICA Survey Team

7.2.2 Reuse of Treated Sewage from BWSSB Tertiary Treatment Plants

An advanced treatment method is adopted for some of the existing STPs, and treated sewage is utilized by some users as shown in Table 7.2.2. It can be seen that the data indicates about 6 MLD to 8 MLD is sold to various consumers.

Table 7.2.2 Current Reuse of Treated Sewage in Bengaluru

Name of the User	Jan-16	Feb-16	Mar-16	Apr-16	May-16
Arvind Mills	14.941	17.495	13.626	18.908	16.515
Bhagyalakshmi Farms	1.847	1.692	4.767	4.848	4.472
Chinnaswamy Stadium	-	-	-	-	744
Horticulture Dy. Director	71.158	72.189	78.960	81.020	84.865
Karnataka Golf Course	26.037	16.171	18.618	19.484	13.467
NECE	0.600	0.600	0.600	0.600	0.600
Paranjape Schemes Bangalore	0.019	0.135	0.098	0.132	-
Project Manager L & T	0.040	0.077	0.013	0.021	0.042
STW	0.630	1.057	-	1.259	1.176
Tangline Development Ltd	1.078	1.277	1.538	14.752	13.049
TTW	72.935	76.286	74.292	90.438	81.291
Wonder Blues	0.600	0.600	0.600	1.200	0.600
Grand Total in ML/Month	**189.885**	**187.579**	**193.112**	**232.662**	**216.820**
Grand Total in MLD	**6.33**	**6.25**	**6.44**	**7.76**	**7.23**

Source: BWSSB

Note: Monthly reuse amount (ML/Month) by consumer is presented from Jan, 2016 to May 2016, while daily amount (MLD) consumed/sold out is also shown at last line in the table.

7.2.3 STPs under Construction and Proposed by Existing DPR

STPs which currently under construction or proposed are shown in Table 7.2.3. In 2034, 721 MLD will be treated by exiting STPs and 1,094 MLD by under construction and proposed STPs. Thus, 1,815 MLD will be treated by public STPs. Among these, 16 STPs (equivalent to 133 MLD) were proposed in DPR prepared by BWSSB. In this JICA Survey, numbers of STPs are revised as 14 STPs (equivalent to 114 MLD, refer to Chapter 10).

Table 7.2.3 Under Construction and Proposed STPs in Bengaluru

No.	Name of the STP	STPs existing / proposed under specific projects	Capacity (MLD), 2034
1 Existing STPs		As per Table 7.2.1	**721**
2 Under Construction and Proposed			
(1) BWSSP - Phase 2 (JICA funded)			
1	Bellandur Amanikere STP	Under construction. Would be commissioned by 2019.	90
2	Chikkabanavara STP		5
3	Chodenapura STP / Doddabelle STP		20
4	Horamavu STP		20
5	K&C valley STP		60
6	Kadugodi STP		6
7	Kengeri STP		60
8	Nagasandra STP		20
9	Raja Canal STP		40
10	Yellamallappa Chetty STP		15
		Sub-total	**336**
(2) Funded by other sources			
1	Anjanapura STP	BDA funded	20
2	Puttenahalli STP	Additional transition phase	10

No.	Name of the STP	STPs existing / proposed under specific projects	Capacity (MLD), 2034
3	Varthur Kodi STP	(KMRP)	15
4	Doddabelle Tertiary STP (140MLD tertiary only – primary and secondary treatment considered in other plants)	Megacity Project	-
5	Jakkur STP upgrade - from 10MLD to 15MLD	BWSSB funding	5
		Sub-Total	**50**
(3) Already tendered or being by BWSSB from GOI / GOK schemes			
1	Sarakki	AMRUT	5
2	Hulimavu		10
3	Chikkabegur		5
4	Agaram STP		35
5	K R Puram		20
6	V Valley	Megacity	150
7	Doddabele		40
8	K & C Valley		150
9	Hebbal Valley STP		100
10	Bangalore University		60
		Sub-total	**575**
(4) 110 Villages (Scheme under consideration) **			
1	Billishivale STP	110 Villages Proposed in DPR	18
2	Chikkabanavara STP		5
3	Doddabettahalli STP		8
4	Doddabidarakallu STP		4
5	Hagadur STP		17
6	Hemmigepura-1 STP		13
7	Hemmigepura-2 STP		11
8	Herohalli STP		7
9	Hosahalli STP / Kachohalli STP		7
10	Kariovbanahalli STP		10
11	Kattigenahalli STP		7
12	Naganathapura STP		5
13	Pillaganahalli STP		3
14	Somapura STP		8
15	Thalaghattapura STP		5
16	Yelahankakere STP		5
		Sub-total	**133**
	Total ((1) +(2) +(3) +(4))		**1,094**

Note: A renewal program for STPs commissioned by 2019 to be undertaken in 2034 including review of capacities
**Number and Treatment capacity of STPs in the DPR are revised in Chapter 10.
Source: JICA Survey Team

7.2.4 Comparison between Sewage Generation Volume and Integrated STP Capacity

From the above study, sewage generation volume and integrated STP capacity in 2016 and 2034 are shown in Table 7.2.4. About 57% of generated sewage was treated by public STPs in 2016, but it is expected that almost all sewage generated in 2034 will be treated. However, thereafter expansion of STPs will be required to meet the increase of population.

Table 7.2.4 Sewage Generation in Bengaluru in the Planning Years

Item	2016			2034		
	Core & ULB	110 Villages	Total	Core & ULB	110 Villages	Total
Population (Thousand person)	8,077	1,429	9,506	11,292	2,843	14,135
Sewage Generation (MLD)	1,068	190	1,258	1,490	372	1,862
STP Capacity (MLD)	721	-	721	-	-	1,815

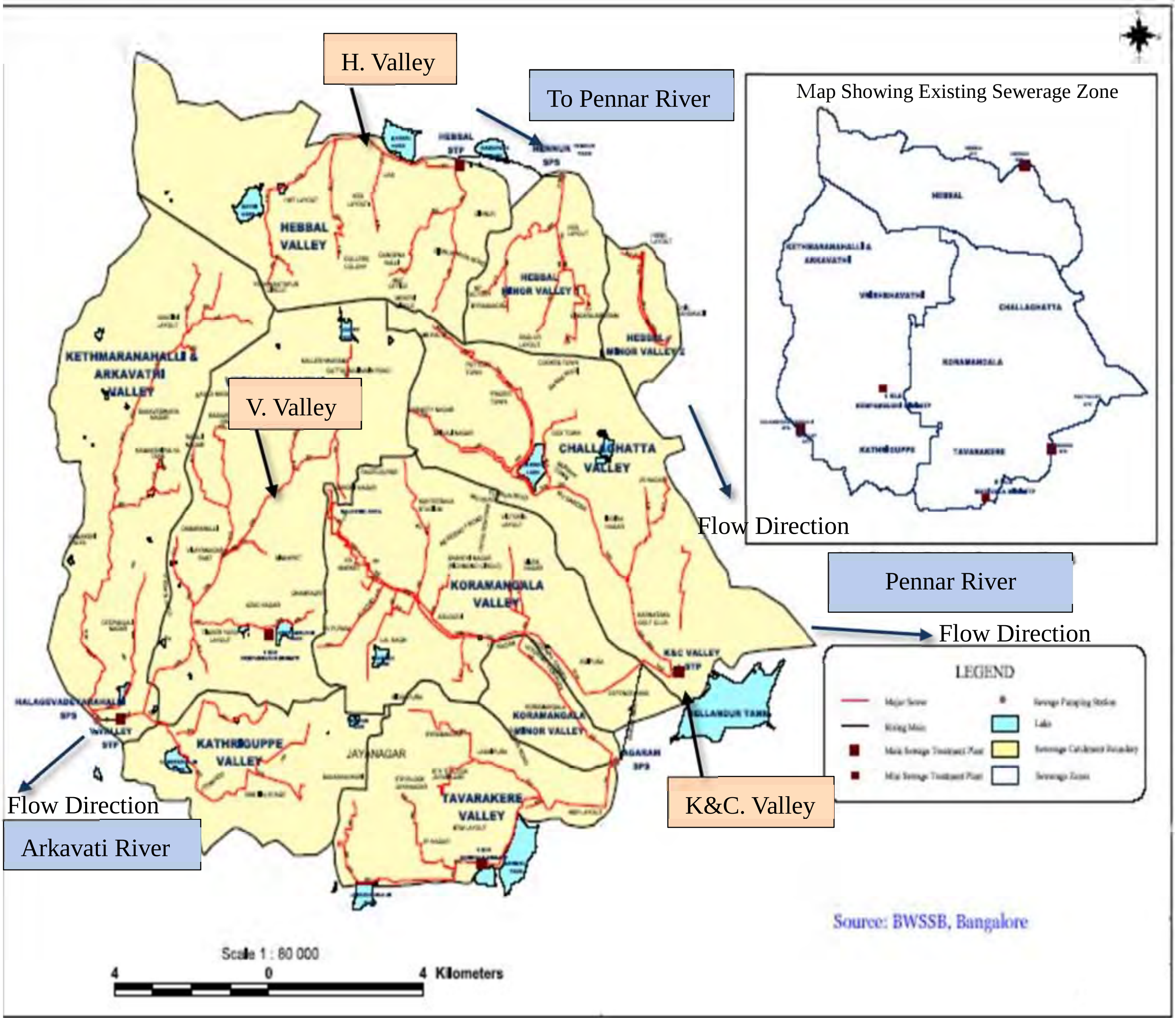
Source: JICA Survey Team

Chapter 8 Water Pollution Status in Public Water Bodies

8.1 Drainage Basins in BBMP

Bengaluru is located in the watershed of two (2) principal river basins, Arkavati to the west and Pennar to the east. The local topography is characterized by a series of well defined major and minor valleys which radiate from the ridge of high ground to the north of the city and fall gradually in a wide belt of flat land extending beyond the limits of the metropolitan area in the south. Figure 8.1.1 shows valleys in Bengaluru.

There are three major drainage basins namely Hebbal (H) Valley, Vrishabavathi (V) Valley [including minor two valleys namely Arkavati Valley and Katriguppe Valley] and Koramangala & Challaghatta (K & C) Valley [including a minor valley namely Tavarekere Valley].



Source: BWSSB

Figure 8.1.1 Drainage Area in BBMP Area

Due to topographical conditions, the drainage comprises the storm water drains, streams, valleys interspersed with lakes, naturally forming lake series. There are 2,789 lakes in Bengaluru Metropolitan Region and 596 lakes listed in Bengaluru Development Authority area limits.

The prominent lake series in Bengaluru in the major valleys are listed below.

1) Hebbal valley (H. Valley)
   ⇒ Madavara Lake Series
   ⇒ Yellamailappa Chetty Lake Series
2) Vrishanavathi Valley (V. Valley)
   ⇒ Puttenahalli Lake Series
   ⇒ Byramangala Lake Series
3) Koramangala and Challaghatta Valley (K&C valley)
   ⇒ Varthur Lake Series
   ⇒ Hullimavu Lake Series

The two major valleys namely V Valley and K & C Valley run generally north to south. H Valley (Yellamalappa Chetty Lake Series) forms the drainage zone north of the ridge and runs in the north easterly direction and joins Pinakini River. The Madhavara lake series of Hebbal starts with Chikkabanawara on the North West and ends in Madavara Lake South West of Bengaluru and flows into Kumadavathi, a tributary of Arkavati. The Byramangala Lake series flows into Vrishabavathi, a tributary of Arkavathi. Both these rivers enter the Cauvery basin. The number of the lakes in BBMP area have reduced in overall numbers as well as size over the years due to development pressures and siltation.

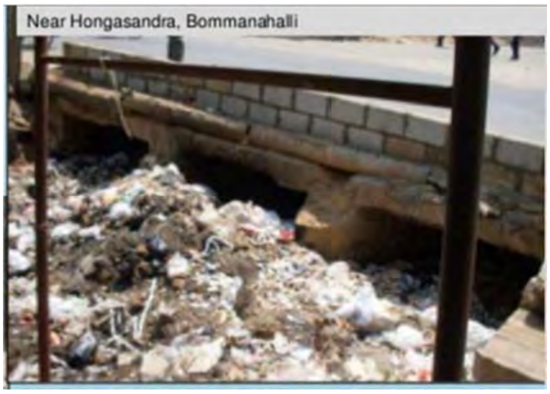
8.2 Annual and Seasonal Fluctuations in Water Quality

8.2.1 Outline of Master Plan for the Improvement of Storm Water Drainage

A Master Plan for the Storm Water Drains (SWD) was prepared by Bengaluru Development Authority (BDA) covering an area of 710 km^2 (225 km^2 for Core area and 485 km^2 for peripheral area) in Bengaluru in 2013. The total water shed area is 1016 km^2 with total length of 840 km. Out of this about 240 km is in the Core area and remaining 600 km in peripheral areas. Figure 8.2.1 shows the study area for the master plan for the SWD. Some of the photos taken during the preparation of the Master Plan are presented in Photo 8.2.1.

Source: Master Plan for the SWD

Figure 8.2.1 The Study Area of Master Plan for SWD

	
Status of SWD in Bengaluru	Status of SWD in Bengaluru
	
Status of SWD in Bengaluru	Status of lakes in Bengaluru

Source: Masterplan Report on remodeling of Storm Water Drains (SWD) in BBMP

Photo 8.2.1 Status of SWD and Lakes in Bengaluru

In addition to flood protection, one of the objectives of the Master Plan is also to improve the health and environmental sanitation conditions in the surrounding vicinity of the SWD and water bodies as well as to protect the existing waterways and water bodies from environmental degradation. Data on water quality at SWD is not available.

The Master Plan also aims to improve the ground water levels by holding rainwater in the water bodies and provide an alternative water source in case of emergency. The cost of the Master Plan is given adjoining graphic. BBMP has taken up implementation of SWD works in piecemeal fashion depending upon the availability of funds from different sources. Table 8.2.1 shows required cost for the improvement of SWD in the Master Plan for the SWD.

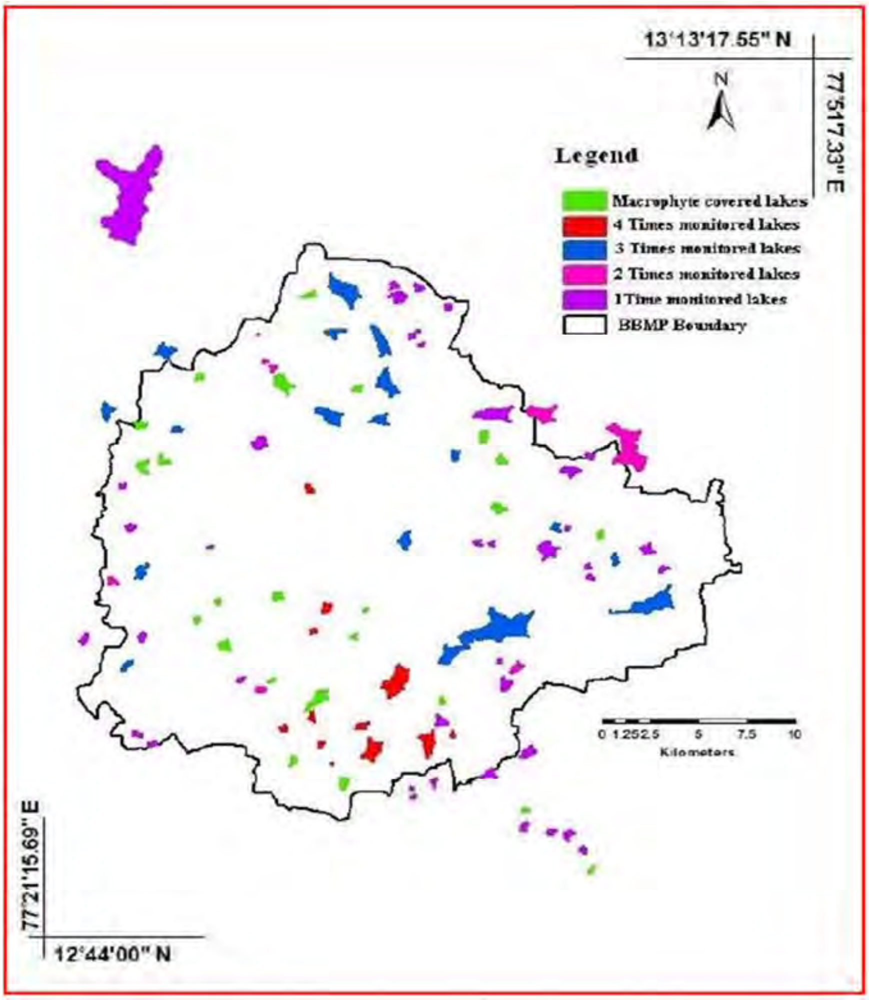
Table 8.2.1 Cost required for Improvement of SWD in 2010

Sl. No.	Name of the Zone	Amount (INR in Crores)
1	East	654.22
2	West	
3	South	
4	Bommanahalli	665.14
5	Yelahanka	655.26
6	Dasarahalli	508.99
7	Mahadevpura	914.91
8	Rajrarajeshwarinagara	759.73
	Total Estimated Cost	4,158.25
	Say	**4,160.00**

Source: Master Plan for the SWD

8.2.2 Water Quality in Lakes

Studies have been conducted by various agencies regarding the water quality status of lakes in BBMP area. Studies and papers are available for some lakes in the city, namely Belandur Lake, Shoolkere Lake, Madivala Lake, Ulsoor Lake, Jakkar Lake, Mallathalli Lake etc. A technical report entitled “Wetlands, Treasure of Bengaluru published by Environmental Information System (ENVIS) in Jan 2016” studied 105 lakes in Bengaluru as shown in Figure 8.2.2. Out of these 25 lakes were completely covered with Macrophytes and hence not considered by the study. A physico-chemical monitoring of 80 lakes was carried out in 2013 for a period of 24 months. The highlight of the report states that 98% of the lakes are encroached and 90% of the lakes are polluted.

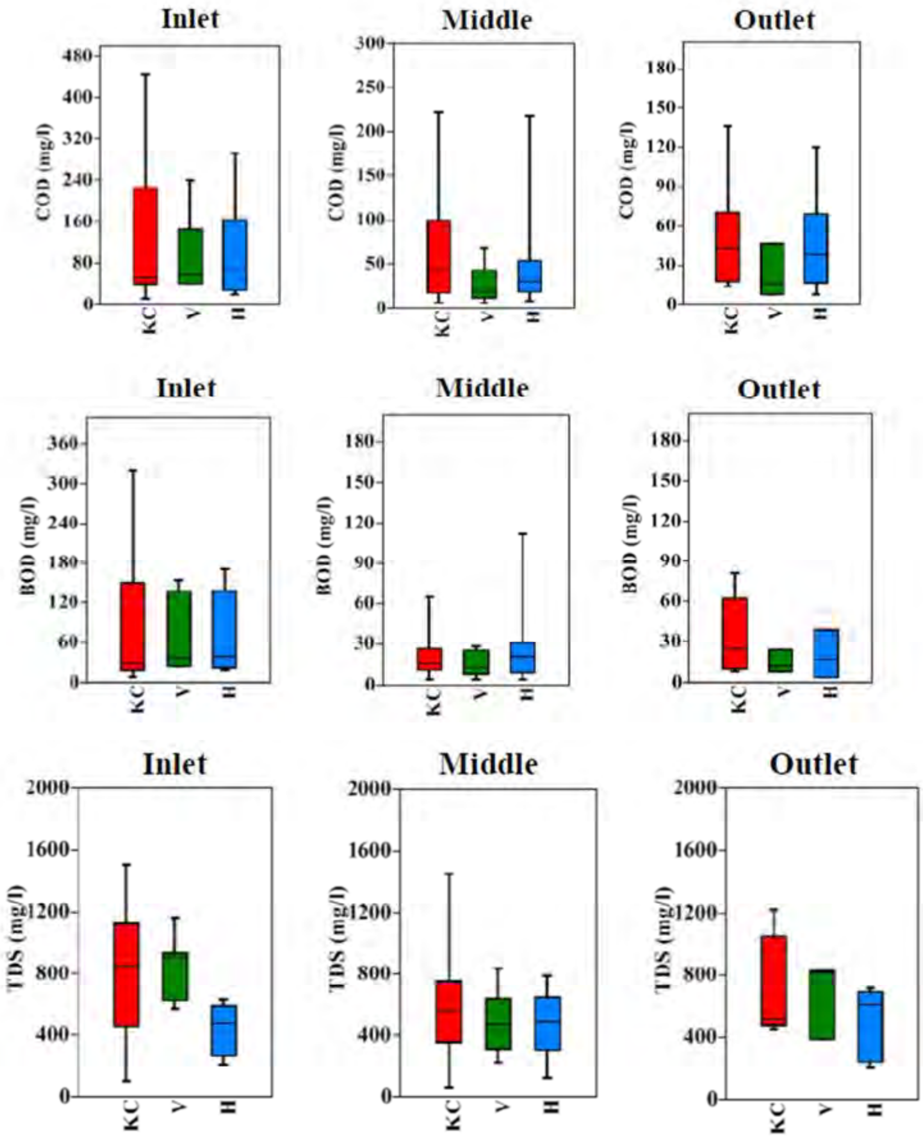


Source: Wetlands, Treasure of Bengaluru

Figure 8.2.2 Sampling Frequency in Lakes

The physico-chemical analysis falling under V. Valley, K&C Valley and H. Valley were undertaken. The parameters included water temperature, pH, total dissolved solids, electrical conductivity, turbidity, dissolved oxygen, COD, BOD, total alkalinity, chloride, total hardness, calcium hardness, magnesium hardness, nitrate, orthophosphate, sodium and potassium. Some lakes were sampled more than once.

Figure 8.2.3 presents the range of water quality for major parameters (COD, BOD and TSD) at inlet, Middle and Outlet of the lakes by Valley. The study results concluded that lakes in K & C Valley are more polluted than V. Valley and H. Valley as well as receiving larger flow. The data also reveal that inlet parameters are higher values comparing with outlet parameters, because of sustained inflow of untreated sewage.



Source: Wetlands, Treasure of Bengaluru

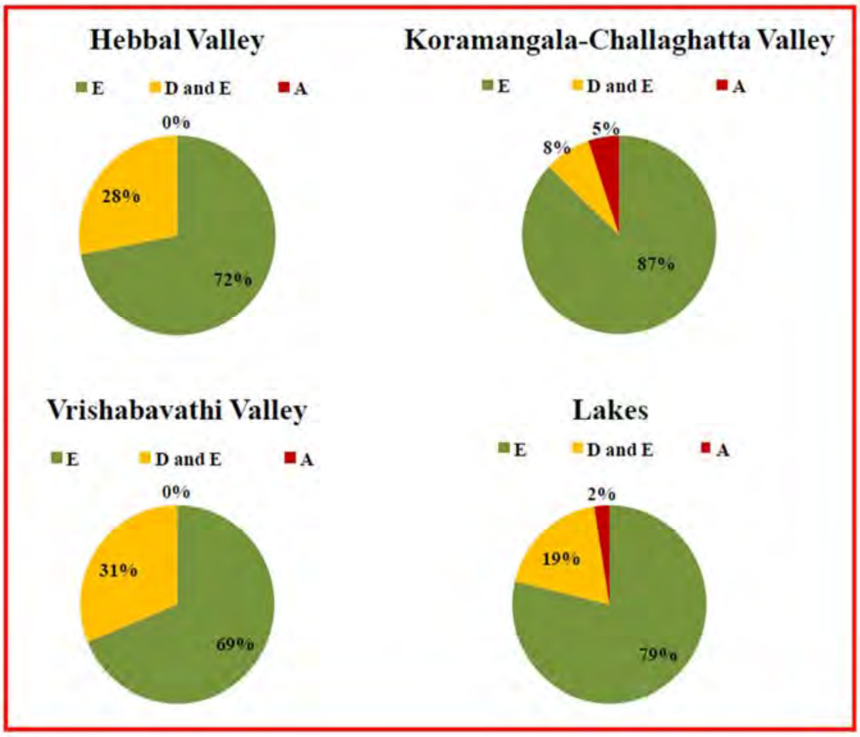
Figure 8.2.3 Lake Water Quality in Major Valleys

The Central Pollution Control Board (CPCB), in collaboration with the concerned State Pollution Control Boards, has classified all the water bodies including coastal waters in the country according to their "designated best use" as shown in Table 2.2.6, Chapter 2. This classification helps the water quality managers and planners to set water quality targets and identify needs and priority for water quality restoration programs for various water bodies in the country.

It can be seen in that about 79% of Bengaluru lakes are classified as E category (Irrigation, industrial cooling and controlled waste disposal, see Figure 8.2.4).

It can therefore be concluded that a high percentage of the sewage generated in Bengaluru finds its way into the lakes.

The lakes like Sankey, Dasarahalli, Ulsoor, Anchepalya, Bomsandra, Kamsandra I and II have growth of Algae indicating continuous sewage inflow and high nutrients.



Source: Wetland, Treasure of Bangalore

Figure 8.2.4 Lake Classification as per CPCB Criteria

The Lake Development Authority (LDA) is a main body to coordinate the rejuvenation and maintenance of lakes and wetlands. It aims at communication with various government bodies, civic agencies, media, and people (including public awareness). Examples of lakes rejuvenated by LDA are

1) Vengaianakere Lake
2) Nagavara Lake
3) Sankey Lake
4) Hebbal Lake (See in Photo 8.2.2)

Photo 8.2.2 Hebbal Lake after Rejuvenation

8.2.3 Water Quality in the Existing Drainages

During the course of preparatory survey water quality examination was conducted for the water in the drainages to get information on the status of water pollution. Water samples {two (2) times each: 1st time 11/19-11/21, 2016 and 2nd time 12/18-12/29, 2016} were collected from 21 points; two (2) points in Core area, two (2) points in ULB area and remaining 17 points in 110 Villages. Table 8.2.2 shows examination results at a total of 21 points. Figure 8.2.5 presents the locations of sampling points and Figure 8.2.6 shows the results for BOD concentration at sampling points (SWD and Lakes). The BOD in the drainage at some points shows almost same quality of raw sewage. On the other hand, the quality in the lake seems to be diluted during the course of flowing (about 1/10 of raw sewage quality).

Inflow and effluent quality at the existing STPs was examined having obtained common quality in BOD and TSS (Total Suspended Solid) except for the one examination results at Raja Canal STP. In the absence of sewerage system at present in 110 villages, the sewage samples were collected from channels/drainages near planned STP sites. Since water sampling for two times was made during the dry season and groundwater level is low, the water quality seems to represent discharged sewage.

Table 8.2.2 Water Examination Results at 21 Points at Existing Drainages

No	Planned STP No	Sample Particulars	pH	Turbidity, NTU	TSS mg/l	COD mg/l	BOD mg/l	Amm-N mg/l	Total P mg/l	DO mg/l	Total N mg/l	Nitrate N mg/l	Coliform Group/100ml	Remarks
1	STP No.5	Mouth of Belandur Lake	7.47	18	14	89.9	27.6	33.7	2.7	<1.0	45.2	<0.1	9.2×10^{6}	
			7.43	7.4	17	53.6	20	38.3	1.4	2.8	65.9	18	2.4×10^{5}	
2	STP No.6	Channel near Naganathapura Bus Stop	7.21	104.5	44	376.1	210	54.2	5.6	<1.0	78.9	15.1	2.2×10^{7}	
			7.65	162.5	388	65.9	9.3	44.9	11.5	5.6	59.5	7.9	1.7×10^{7}	
3	STP No.7	Drainage near Pillaganahalli STP	7.53	166.5	78	599.6	290	102.3	7.8	<1.0	140.9	<0.1	2.8×10^{7}	
			7.82	30.2	140	238.9	117	76.5	5.3	<1.0	89.9	7.9	5.4×10^{7}	
4	K&C Valley STP	Inflow sewage to existing STP K&C Valley STP	7.19	125	132	474.2	240	42.7	2.6	<1.0	84.2	31.3	1.7×10^{6}	Existing STP: 30 MLD in Core area
			7.49	84.1	390	527	255	45	6	3.3	100.7	6.7	5.4×10^{7}	
5	K&C Valley STP	Effluent from existing STP K&C Valley STP	7.70	0.6	2	9.1	2.4	1.2	1.3	5	1.9	<0.1	5.4×10^{4}	in Core area
			7.75	1	<1.0	12	3	3.3	0.06	8.7	22.8	13.4	1.6×10^{4}	
6	Raja Canal STP	Inflow to existing STP	7.41	131.5	80	370	195	53	10	<1.0	78.3	19.3	5.4×10^{7}	Existing STP:40 MLD in ULB area
			7.45	141.5	120	5603※	1000※	109.4	8.2	<1.0	178.1	52.3	2.4×10^{7}	
7	Raja Canal STP	Effluent from Raja Canel STP	7.78	1.7	6.0	14.0	3.3	5.7	0.73	6.8	9.81	2.7	9.2×10^{4}	in ULB area
			7.62	1.7	6.0	4.8	1.5	7.5	0.15	4.7	22.9	13.5	1.6×10^{5}	
8	STP No.4	Channel near the Bileshivale Lake	7.35	40.8	34	189.2	105	42.7	2.8	<1.0	66.2	13.8	3.5×10^{7}	
			7.29	25.6	82	197.8	98	53.9	4.9	<1.0	63.5	6.6	2.2×10^{7}	
9	STP No.1	Channel near Kogilu Lake	7.49	40.8	26	156.3	98	34.9	2.9	<1.0	48.7	7.8	1.6×10^{8}	
			7.33	19.5	41	131.8	67.5	50.9	1.8	<1.0	59.9	5.4	2.4×10^{7}	

No	Planned STP No	Sample Particulars	pH	Turbidity, NTU	TSS mg/l	COD mg/l	BOD mg/l	Amm-N mg/l	Total P mg/l	DO mg/l	Total N mg/l	Nitrate N mg/l	Coliform Group/100ml	Remarks
10	STP No.2	Channel near the Lake, Kenchanahalli, Road	8.3	279	220	419.4	67.5	58.4	0.79	4.4	95.2	30.1	2.4×10^6	
			8.53	46.3	72	94.8	9	47.9	<0.05	7	56.3	4.8	5.4×10^3	
11	STP No.2	Channel near Yelahanka Lake,	8.82	194	80	275	34.3	6.6	0.64	8.7	51.2	28.3	1.7×10^5	
			8.2	47	74	103	16.8	53.9	0.44	6.7	66.6	3.6	1.6×10^5	
12	STP No.8	Drainage near the lake	8.39	153.8	140	452.3	270	54.7	4.7	<1.0	75.6	1.5	1.7×10^7	
			7.81	10.5	80	148.3	60	63.2	3.3	1.2	82	7.3	1.7×10^7	
13	STP No.9	Channel near Sompura Lake,	8.38	21	18	25.3	6	<0.5	0.05	5.6	15.9	11.8	5.4×10^3	
			7.85	46.5	14	28.8	9.9	1.2	0.13	4.1	8.5	5.5	5.4×10^4	
14	STP No.10	Channel near Varhasandra Lake, Varhasandra Main Road	8.21	20	20	78.1	39.6	17.1	1.5	<0.1	25	1.5	1.6×10^6	
			7.74	6	8	82.4	29	13.9	1.2	2.3	26.7	8.5	2.4×10^7	
15	STP No.11	Channel near the lake, Hemmigepura Main Road	8.36	62.5	80	238.5	96	29.9	3.1	<1.0	47.4	0.9	3.5×10^9	
			7.55	81.5	292	420.2	210	42.5	3.2	<1.0	66.2	7.3	1.7×10^7	
16	STP No.14	Drainage near planned STP	8.38	140	120	476.9	260	24.7	3.4	<1.0	50.3	1.5	1.7×10^5	
			7.6	141	320	469.7	246	32.8	3	<1.0	48	5.5	9.2×10^6	
17	STP No.15	Drainage near planned STP	8.3	237.5	472	756.6	300	57.6	5.9	<1.0	93.8	1.5	5.4×10^6	
			7.71	68	112	354.3	168.7	42.5	4.3	<1.0	67.4	10.9	5.4×10^6	
18	STP No.13	Channel near planned STP	8.45	232.5	960	589.4	230	56.4	6.1	<1.0	58.5	1.5	2.4×10^7	
			7.81	1024	2520	4944※	2300※	86.3	5.1	<1.0	120.3	14.6	2.4×10^5	
19	STP No.12	Channel near planned STP	8.41	80.5	40	176.8	84	43.5	2.6	<1.0	83.8	1.5	2.4×10^7	
			7.69	40.3	148	140.1	45	42.5	1.8	2.9	59.5	6.7	2.4×10^7	

No	Planned STP No	Sample Particulars	pH	Turbidity, NTU	TSS mg/l	COD mg/l	BOD mg/l	Amm-N mg/l	Total P mg/l	DO mg/l	Total N mg/l	Nitrate N mg/l	Coliform Group/100ml	Remarks
20	STP No.16	Channel near Chikkabanavara Lake	8.55	231.3	532	123.4	30	47	3.5	4	57.3	0.9	2.4×10^7	
			7.64	81.5	74	115.4	28.5	34.8	1.1	<1.0	56.9	4.2	2.4×10^7	
21	STP No.3	Channel near Yelahanka Lake	8.35	34.5	20	86.4	42	32.3	2.3	4.4	37.3	0.3	9.2×10^5	
			7.34	82.5	213	395.5	150	35.4	2.9	<1.0	60.5	6.6	2.4×10^7	

Note: Two (2) times of water quality examination results are tabulated. ※The results of BOD and COD at No 6 and No 18 are quite different. The larger values seem to be caused by examination failure in view of common experience on the water quality of sewage or inflow of industrial wastewater. Two times examination; upper line from 11/19 to 11/21, 2016 and lower line from 12/18, 2016 to 12/29, 2016.

Source: JICA Survey Team

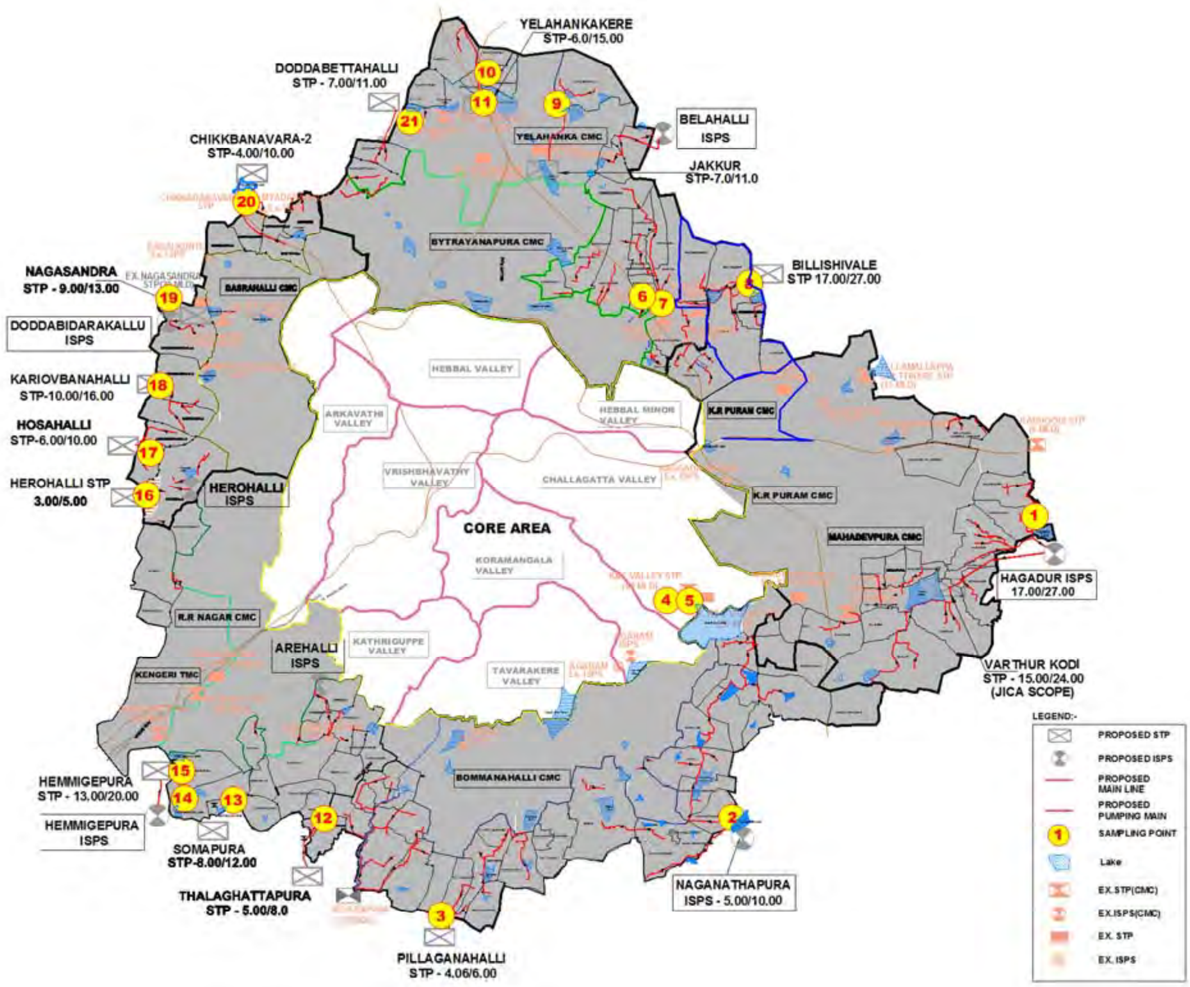


Figure 8.2.5 Locations of Water Sampling Points

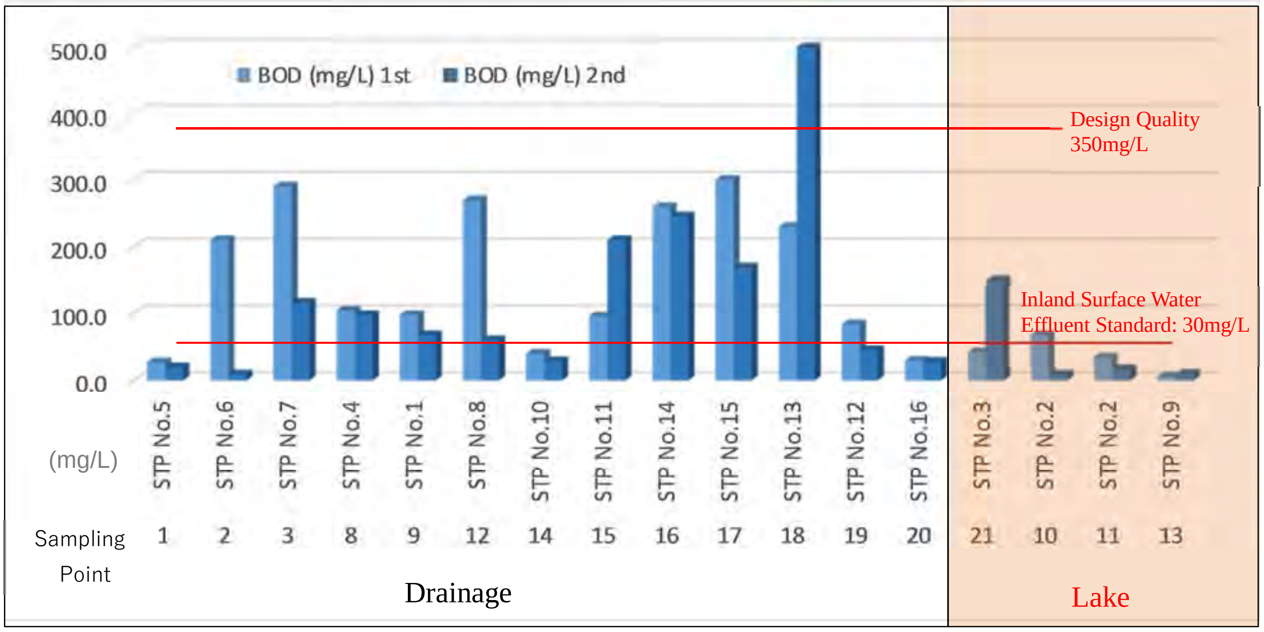


Figure 8.2.6 Results for BOD Concentration at Sampling Points

8.3 Water Pollution Status and the Need of Sewerage Systems

8.3.1 Existing Sewerage Services

Geographically, Bengaluru consists of three areas; Core area, ULB area and 110 Villages. The population of Core area in 2011 were about 5.4 Million. The population in the Core area have been almost saturated with a very low annual growth rate projected over the next thirty years. Most of the Core area is covered by sewerage systems with 14 STPs (total treatment capacity of 721 MLD).

While, the population of ULBs (incorporated into BBMP in 2007) in 2011 were about 1.97 Million. Main sewer lines and household connections have been constructed using KMRP fund. The construction of STPs has been under way using the fund for BWSSP Phase 2 and is likely to be completed by 2018. ULB area is expected to be sewered under the BWSSP Phase 2 project including 10 STPs with a total capacity of 336 MLD.

The 2011 population for 110 Villages is about 1.1 Million. Currently the water supply in the area is mainly from deep wells and tanker water. There is lack of municipal sewerage system in the area. A limited number of large housing societies have constructed and maintain private STPs to reuse water for flushing and gardening purposes. The sewage in most cases finds its way to the local storm water drains and channels and finally flowing into the lakes.

8.3.2 Analysis on Present Water Pollution and Sewerage Services

Presently sewage collection and treatment have been provided in the Core area (100% coverage) and part of five (5) ULBs (R.R. Nagar, Mahadevpura, Dasarahalli, K.R Purum and Yelahanka; overall average is 50%). Table 8.3.1 shows served population in the concerned ULBs in 2011.

Table 8.3.1 Present Served Population by Concerned ULB

No.	ULBs Name	Location	STPs Name	ULB population in 2011, (person)	Served Population, (person)	Average Flow in 2011, (MLD)	Served (%)
1	Yelahanka	Yelahanka	Yelahanka (Allasandra)	144,948	28,452	3.84	20
			Jakkur		116,496	15.73	80
2	R.R. Nagar	R.R. Nagar	Mailasandra	148,257	31,826	4.30	21
3	Mahadevpura	Mahadevpura	Kadabeesanahalli	237,222	23,463	3.17	10
4	KR Puram	K R Puram	K R Puram	286,423	92,884	12.54	32
		Mahadevpura	Kadabeesanahalli		105,914	14.30	37
5	Dasarahalli	Dasarahalli	Nagasandra-1	451,237	95497	12.89	21
		R.R. Nagar	Mailasandra		144120	19.46	32
Total				1,268,087	638,652	86.23	50%

Source: JICA Survey Team

A trial calculation on generated sewage volume in 2011 was made for the sewerage service area covering entire Core area and part of ULBs, referring to the report prepared by the Expert Committee for identification of sources for suitable water supply to BBMP and BWSSB study on available water sources. Table 8.3.2 summarized generated sewage volumes in the served area.

Table 8.3.2 Generated Sewage Volume at Present and Overall Treatment Capacity of the Existing STPs in Core and ULB Area

Item	Calculation
Water supply to Core & ULB areas (consumed)	Cauvery water 759 MLD, groundwater 400 MLD (total 1,159 MLD)
Population in Core & eight (8) ULB areas	5.4 Million + 1.97 Million =7.37 Million
Average per capita water consumption	157 lpcd (1,159 MLD/7.37 Million)
Sewage generated volume in Core and ULB area	Core area: 157 lpcd x 5.4 Million x 0.8 x 1.1 =746 MLD Part of ULBs: 157 lpcd x 638 thousand x 0.8 x 1.1 = 88 MLD Total sewage volume generated: 834 MLD (sewage is assumed at 80 % of water consumption and 10% infiltration of groundwater into sewers)
The total sewage treatment capacity in Core area and eight (8) ULBs	721 MLD (536 MLD in Core + 185 MLD in part of 8 ULBs) in average flow
Comparison between present generated sewage volume and treatment capacity	834 MLD/721 MLD=1.16 (116%)

In assumption of service coverage in the Core and ULB areas (100% in Core area and about 50% in 5 ULBs), generated sewage volume is equivalent to about 116 % of the total treatment capacity at present. On the other hand, in the on-going Water Supply and Sewerage M/P, inflow sewage volume is referred to at about 70% of the treatment capacity of the existing STPs (According to daily average sewage flow records in the last two years from September 2013 to August 2015, inflow volume is reported at about 70% of the total capacity of the 14 existing STPs {actual sewage inflow volume (509 MLD) / design capacity of STPs (721 MLD) =70%}.

Although above mentioned generated sewage volume is based on some assumptions, it seems that about 40% {325 MLD (834-509)/834 MLD} of sewage are not collected in the service area, even if a long time has passed since completion of sewerage systems and partial sewage collection from drainages has been practiced using interceptors. In this regard, there seems to be a limitation on the installation of house connections. As a result of the study on sewerage service coverage, a considered coverage may be 60% in the existing sewerage service area. Figure 8.3.1shows present sewage treatment status in the existing sewerage service area.

In the 110 Villages, presently, channels/drainages are playing a role as sewers, but are polluted with a high BOD and SS concentrations of organic substances, as confirmed by the water quality examination results. It was revealed that BOD concentration of the inflow to the STP is more than 200 mg/l and water quality in the public channels is 20-40 mg/l as a result of dilution effects with lake water, groundwater infiltration, natural purification, etc.

Based on the above studies, further augmentation/improvement of sewerage systems in Core/ULB areas are required, especially with reference to the installation of house connections as well as expansion of the STPs.

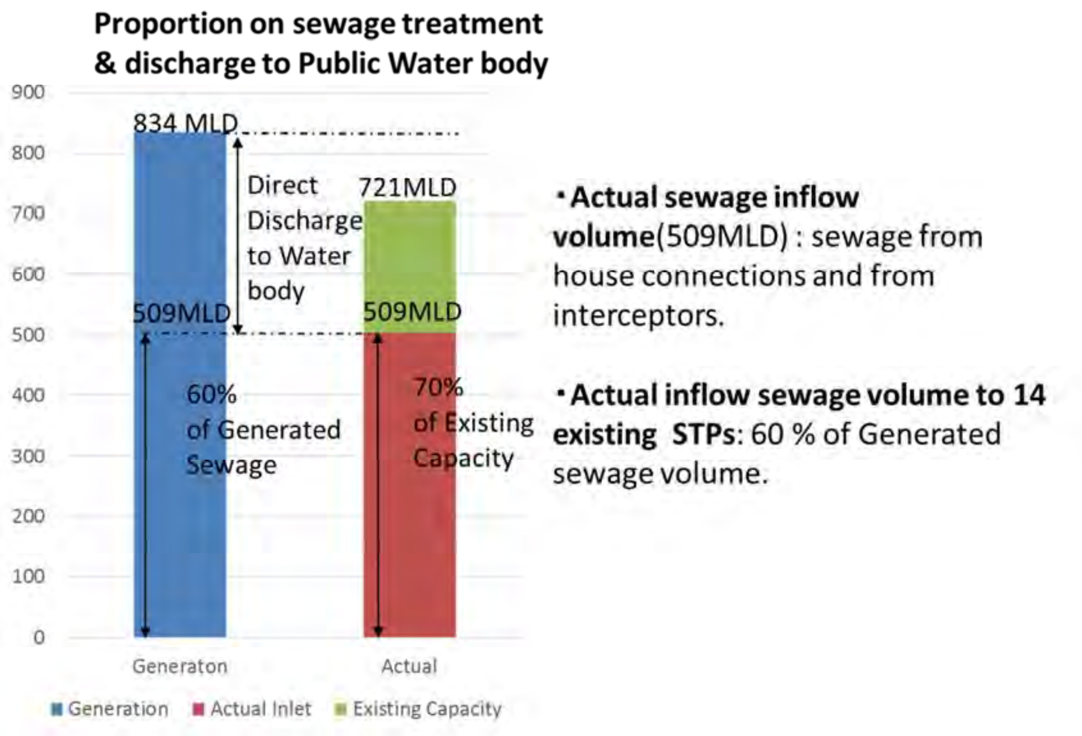


Figure 8.3.1 Present Sewage Treatment Percentage in the Existing Sewerage Service Area

Based on the above studies, further augmentation/improvement of sewerage systems in Core/ULB areas are required, especially with reference to the installation of house connections as well as expansion of the STPs and the construction of sewerage systems is also urgent for 110 Villages. The following are concrete requirements in provision of sewerage systems in the entire BBMP area.

1) Reduce the sewage from entering the storm water drains, reducing interceptors/increasing house connections
2) To improve the ecology and environment of the lakes
3) Aid in increasing the ground water table especially in selected lakes where STPs are constructed
4) Facilitate reuse of treated sewage
5) Provide better hygienic conditions

Chapter 9 Project Needs and Implementation Arrangements for Proposed Projects

9.1 Project Needs and Expected Benefits

Bengaluru city has expanded rapidly with establishment of job generating industries. Recently, there has been a drastic change in the city growth trend in various sectors. This is mainly caused by migration of people from neighboring states. The changes in land use to meet the increasing housing demand, industrial infrastructures and commercial establishments have resulted in the increase of water demand and need of sanitation improvement such as sewerage services.

Currently, water supply for the BBMP area is provided using surface water from Cauvery River and groundwater. The survey results of "Groundwater Hydrology and Ground Water quality in and around Bengaluru City" assisted by World Bank in March/2011 revealed that over exploitation of groundwater has resulted in fast depletion of groundwater table and deterioration in quality in the BBMP area. In this regard, limited withdrawal of groundwater and effective use of it have become important day by day requiring the increase of the water supply from the Cauvery River.

A lot of foreign companies have been investing in the Karnataka State. Among them, there are a total of 451 Japanese establishments in the State as of October/2016 (information from JETRO India), which is about three (3) times of that in 2010. There are nineteen industrial areas in the Bengaluru Metropolitan Region as shown in Figure 9.1.1.

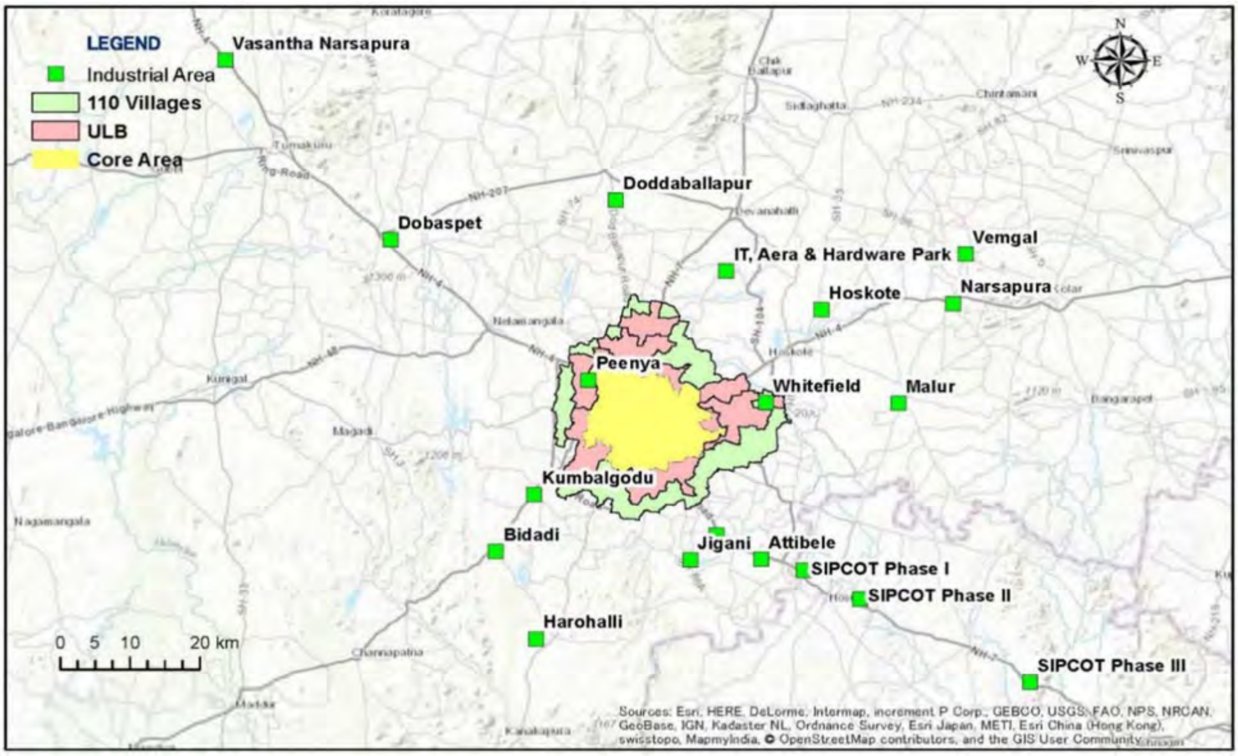


Figure 9.1.1 Location of Industrial Estates in Bengaluru Metropolitan Region

As mentioned before, Bengaluru city has been expanded from the Core area to ULBs, then to 110 Villages. The surrounding area of the 110 Villages is expected to be further developed as discussed in the population projection in Chapter 5 (Bengaluru and Hyderabad Urban Agglomerations are expected to grow continuously through the future.). Under this land development in the current BBMP area, the industrial areas operated by foreign companies are no more developed in the Core and ULB areas, located out of 110 Villages.

The water supply in the 110 Villages from where the employees commute to the industrial areas and their surrounding areas where many enterprises are located, is presently provided by individual groundwater sources. Additional water supply through Stage V Project to the BBMP area, especially for 110 Villages will allow for the use of the limited groundwater available in the industrial area until piped water supply would be provided, since the available groundwater is taken from the same aquifer in the BBMP area. The sewerage services in the areas are also quite limited. The improvement of water supply and sanitation sector in the above mentioned areas are urgently required against the contamination of the groundwater sources and water pollution caused by direct discharge of sewage to public land or drainages.

Aside from the above mentioned general project needs, specific needs and benefits of 110 Villages Project in water and sewerage sector to improve living standards are summarized below.

- Uniform water supply services can be provided for entire BBMP area upon completion of 110 Villages Water Supply Project together with CWSS Stage V Project.
- As confirmed in the water balance study, water demand for the BBMP area can be satisfied at least up to 2034 in provision of water supply by CWSS Stage V Project. As a result, 24/7 water supply will be practiced through the cooperation by all concerned stakeholders (at least technical feasibility for the achievement of the normal services was confirmed through water balance study).
- Development in the 110 Villages can be accelerated and migration from Core area is expected resulted in the alleviation of population density in the Core area.
- Profile of the city with environmental soundness can be enhanced including hygienic environment. Investment in BBMP area both by domestic and foreign companies will be promoted, resulted in the creation of pathway for new economic growth in the BBMP.

9.2 Implementation Arrangements for Proposed Projects

(1) Project Component Connected to 110 Villages Water Supply Project

All projects proposed by BWSSB are to be implemented at the same time to meet the above needs. However, due to their cost requirements, huge areas to be covered and large range of scope of work, priority and/or arrangements for the implementation were studied as included in Chapter 9, Supporting Report. The study included the following:

- Baseline plan for the implementation of proposed projects
- Study on alternative arrangements for the implementation of proposed projects
- Rough cost estimate for alternative options using cost base in the existing DPRs

(2) Additional Project Components to Complete Proposed Projects

During Preliminary Survey, additional two (2) project components were identified to complete proposed projects by BWSSB. These are connected to Stage V Project and 110 Villages Water Supply Project as enumerated below.

1) Project Component Connected to Stage V Project (Branch Feeding Pipes)

Because of the water shortage in Core/ULB areas in the medium term period, the total water allotted for 110 Villages (775 MLD) was planned to share to Core/ULB areas in the medium term period without staged increase of intake amount in Stage V to meet required demand in 110 Villages through the future (DPR planned to adopt staged development to meet demand from 2034 to 2049).

2) Project Component Connected to 110 Villages Water Supply (Feeder Pipes between GLRs and OHTs, OHTs and Pumping facilities)

BWSSB commenced water supply project for 110 Villages to expedite services in 2016, as a temporary water supply systems using water to be saved in the Core area and some sharing water transmitted by Stage IV Phase 2 Project. This project covers feeder pipes between existing five GLRs (Stage IV Phase 2) and connection point to main distribution pipes at each village, and pumping facilities. Upon completion of Stage V Project, the following facilities shall be replaced/constructed to establish permanent water supply systems for 110 Villages.

- Feeder pipes should be replaced to connect between planned 13 GLRs and planned OHTs for 110 Villages
- Construction of OHTs
- Construction of booster pump, water sump and pump house

(3) Grouping of All Component Projects

The proposed projects were sorted into two groups; one for those to prepare preliminary design of facilities by JICA Survey and another to be undertaken by Indian side utilizing local funds, as shown below.

1) Projects for preparation of preliminary design of the facilities: (1) Stage V Project excluding Branch Feeder Pipes and (2) major sewerage facilities for 110 Villages Sewerage Project
2) Projects to be implemented by Indian side: (1) 110 Villages Water Supply Project including those to be required to connect between planned GLRs and OHTs, OHTs and pumping facilities as well as distribution pipe networks, (2) Branch Feeder Pipes to share water to Core/ULBs, (3) upstream sewage collection facilities (lateral sewers) for 110 Villages Sewerage Project and (4) UFW Reduction Project

Table 9.2.1 summarizes the reasons of the sorting proposed projects into two groups (identifying priority projects for foreign assistance). This arrangement was proposed in consideration of major three factors; (1) urgency of the component project to catch up the needs affected by rapid population increase in the 110 Villages, (2) availability of local funds for the development of relevant sector in BBMP area and (3) currently practiced financial assistance from Greater Bengaluru Water Supply Project (GBWASP) / Karnataka Municipal Reforms Project (KMRP) (assistance to ULBs is under way). BWSSB has initiated financial arrangements in September 2016 for the project components to be undertaken by Indian side.

Table 9.2.1 Sorted Reasons for Project Implementation

Implementation Arrangements	Projects to be studied / to be undertaken	Reasons
JICA Survey Project	Stage V Project	The Project is a large size with huge cost requirements (difficulty to manage by only local fund). In addition, the Project is very urgent among proposed projects and one-time construction is advantageous technically, economically and for the augmentation of services in the entire BBMP area. Revised DPR was submitted to GoK for financial assistance at the beginning of September, 2016.
	Major Facilities for 110 Villages Sewerage Project	Need of the introduction of technical expertise for planning/design, construction and O&M of sewerage facilities for maintaining stable and higher quality of effluent discharged from STPs. A revised proposal in combination of Stage V Project and Sewerage for 110 Villages was submitted to GoK for financial assistance.
Undertakings by Indian side	110 Villages Water Supply Project	Need of immediate water supply: GoK assistance (67% approved in October, 2016) and BWSSB BCC Funds (12 Billion INR) can be expected to start work in 2017. Need of system completion connecting to distribution networks to be constructed by BWSSB in advance: Facilities required to connect between planned GLRs and OHTs, OHTs and pumping facilities, which are connected to distribution pipe networks constructed by on-going project. On-going water supply project for ULBs may be referred to. Staged expansion of water supply systems is adoptable without large investment at one time.
	Stage V related project to share water to Core/ULBs	Need of additional work for Core/ULBs, beyond proposed project for 110 Villages: Branch Feeder Pipes to share water to Core/ULBs.
	Lateral Sewers for 110 Villages Sewerage Project	The project can be started during the implementation of Stage V project expecting finance from BCC (Beneficiary Capital Contribution) / GBWASP / AMRUT (Atal Mission for Rejuvenation and Urban Transformation) / GoK.
	UFW Reduction Project	BWSSB has experience in managing UFW reduction project. GoK (approved in Oct., 2016) /BWSSB BCC fund is expected.

Chapter 10 Scope of Work for JICA Survey Projects

10.1 CWSS Stage V Project

10.1.1 Planned Water Supply Facilities and Their Respective Design Flow

This Project was planned to supply water for 110 Villages using 775 MLD from Cauvery River having obtained water right from GoK. Required facilities include those from intake to distribution reservoirs located in Bengaluru City.

The design flow for the Stage V facilities is the total supply amount (775 MLD) required for 110 Villages (355 MLD) and the amount to be shared to Core and ULB areas (420 MLD) for the medium target year 2024. For 110 Villages water supply, water supply amount (equivalent to water demand) required by zone by target year is summarized in Table 10.1.1 referring to "Chapter 5 Water Demand Projection for the Three (3) Areas by Target Year". Major factors adopted for water demand projection are as follows;

- Per capita water consumption rate through the future: 150 lpcd
- UFW (Water Losses) % for the water supply systems to be newly constructed: 16%

The water demand for 110 Villages reached to about 800 MLD in 2049, which is 25 MLD larger than the privileged 775 MLD from Cauvery River. The additional need should be supplemented by groundwater (available potential groundwater amount in 110 Villages is assumed at 100 MLD in the water balance study).

Table 10.1.1 Water Demand and Water Balance by Target Year for 110 Villages

Sn	Name of Zone	Area (in Sq.Km.)	2011 population as per census	Projected Population (Person)			Water Demand (MLD)		
				2024	2034	2049	2024	2034	2049
1	Bytrayanpura (26 Villages)	55.0	241,074	412,912	588,875	933,240	74	105	167
2	Mahadevpura (23 Villages)	51.0	223,510	382,787	545,911	865,154	68	97	154
3	Bommanahalli (33 Villages)	64.3	282,669	484,150	690,468	1,094,248	86	123	195
4	R.R Nagar (17 Villages)	31.4	164,307	375,369	524,868	817,285	67	94	146
5	Dasarahalli (11 Villages)	23.5	191,955	328,782	468,878	743,073	59	84	133
Total		225.2	1,103,515 **1,100,000**	1,984,000 **1,980,000**	2,819,000 **2,820,000**	4,453,000 **4,450,000**	354 **350**	503 **500**	795 **800**
Water Source									
	Cauvery						**775**	**775**	**775**
	Ground water						**100**	**100**	**100**
	Balance						**521**	**372**	**80**

Note: It is ideal to reduce groundwater use increasing the use of surface water. In 2034, the balance is 272 MLD after supply of transmitted water from Cauvery River to 110 Villages.

Design criteria and flow for the facilities are shown in Table 10.1.2 including major facilities and pipe-lines.

Table 10.1.2 Design Criteria and Flow for Major Facilities for Stage V Project

Facility	Design Criteria	Design Flow (MLD)
Intake Facility	Water production of 775 MLD	775
Conveyance Pipeline	ditto	775
WTP	ditto	775
Pumping Station	ditto	775
Clear Water Reservoir	ditto	775
Transmission Pipeline	ditto	775
GLR	12 hours of detention time	7 Nos.

10.1.2 Study on the Configuration of Major Facilities in Bengaluru City with Reference to Water Distribution to 110 Villages and Core/ULBs

(1) Required Number and Locations of GLRs in Consideration of their Respective Service Areas in 110 Villages

The water supply and sewerage plan for 110 Villages has been studied since 2008. The water source expected in the DPR prepared in 2013 was the part of water developed by the CWSS Stage IV, Phase 2 Project. Since water shortage had not been solved even after completing the Stage IV, Phase 2 Project, another project was planned as CWSS Stage V including water source development of 10 TMC (775 MLD) with WTP and transmission pipelines. GLRs and distribution systems are planned under the same concept both in the 110 Villages DPR and the CWSS Stage V DPR, where transmitted water from Cauvery River is planned to storage at the GLRs followed by OHTs in the 110 Villages.

There are differences in number and locations of the GLRs planned between the DPRs for 110 Villages Water Supply and Sewerage project, and that for CWSS Stage V project. The DPR for 110 Villages Water Supply and Sewerage Project planned a total of 10 GLRs (5 existing, 3 on-going and 2 new GLRs) to deliver 775 MLD, while the DPR for Stage V planned a total of 12 GLRs including new seven (7) , two (2) existing and three (3) on-going to deliver 775 MLD. As of March, 2017, three (3) on-going GLRs are under construction by BDA.

It was confirmed in the field that planned sites at Gottigere and Singapura for the new GLRs fall on vacant land. As the result of the study on the GLRs, the adequacy of the plan for GLRs by Stage V Project (advantageous conditions including higher elevation, location to cover subject service area and public land availability) was confirmed. A comparison of water demand between the two plans in the respective service areas by existing and proposed GLRs is shown in Table 10.1.3.

Table 10.1.3 Comparison of Water Demand between the Two Plans by Existing and Proposed GLRs

Zone		CWSS Stage V (applied)		110 Villages	
		Name of GLR E: existing P: proposed	Water Demand (MLD)	Name of GLR E: existing P: proposed	Water Demand (MLD)
1	Bytrayanapura (26 Villages)	GKVK -E	20	GKVK -E	38
		Chokkanahalli -P	128	CRPF -P	128
		Vasudevapura -P	17		
		Sub-Total	165	Sub-Total	166
2	Mahadevpura (23 Villages)	Kadugodi -P	85	HUDI -E	128
		Doddakanahalli -P	43		
		OMBR -E	26	OMBR -E	26
		Sub-Total	154	Sub-Total	154
3	Bommanahalli (33 Villages)	Doddakanahalli -P	44		
		Gottigere -P	150	Gottigere -P	195
		Sub-Total	194	Sub-Total	195
4	R.R. Nagar (17 Villages)	Gottigere -P	66	Gottigere -P	75
		BDA SMV 6 -E	28	BDA *	38
		BDA BSK 6 -E	19		
		Sub-Total	113	Sub-Total	113
5	Dasarahalli (11 Villages)	Lingaderanahalli -P	92	Hegganahalli-2 -E	92
		Singapura -P	40	Singapura -P	40
		Sub-Total	132	Sub-Total	132
Total			758 Say: 760		760

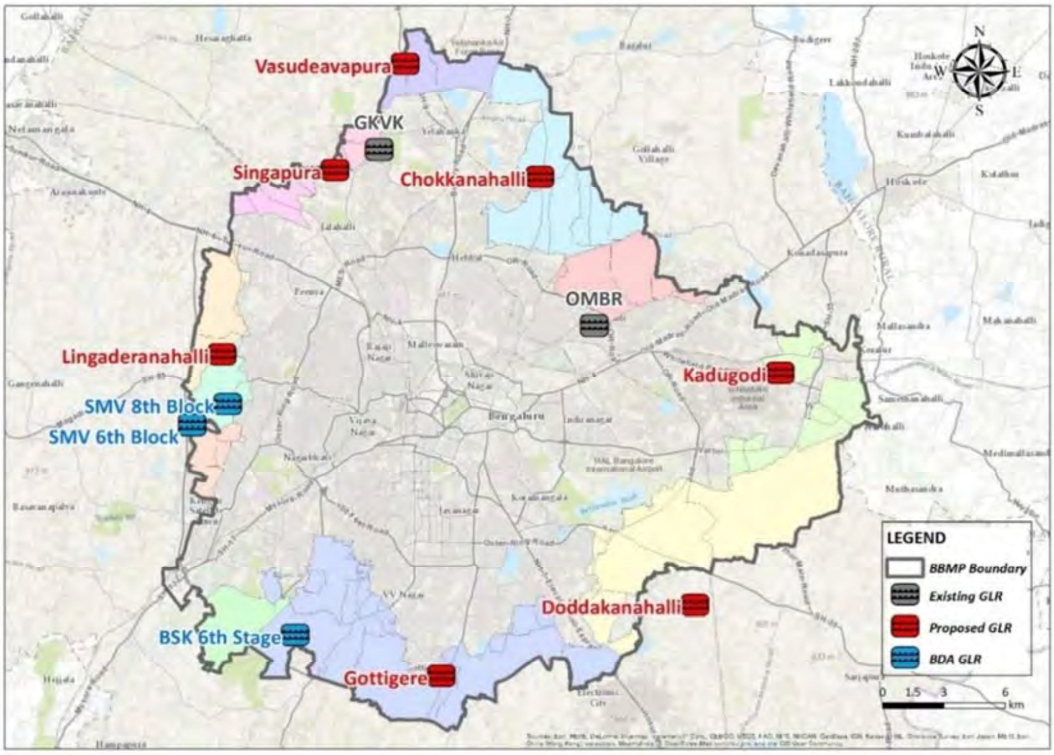
Note: It's planned to provide water to BDA service area by connecting to feeder main in 110 Villages DPR

Note: In CWSS Stage V DPR, it's planned to send water to 2 GLRs under BDA

The following are the relationship on the distribution systems between the two (2) plans.

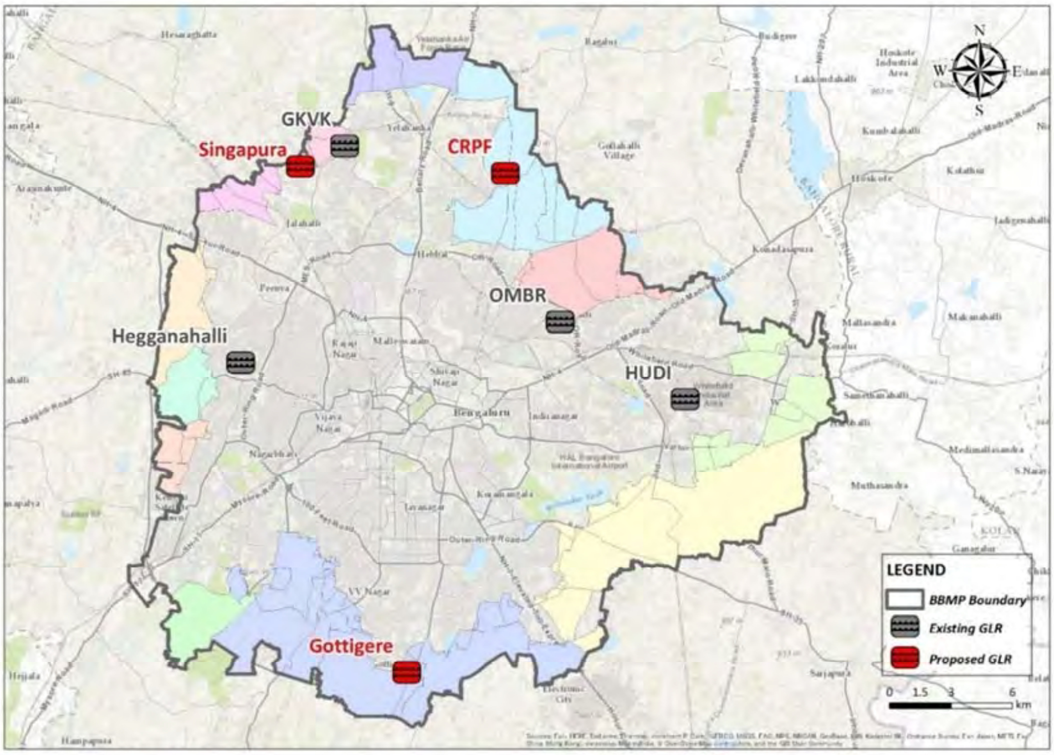
- The locations of GLRs are different each other, but the service areas by GLRs are almost same: CRPF and Chokkanahalli in Zone 1, HUDI and Kadugodi in Zone 2, Hegganahalli and Lingaderanahalli in Zone 5.
- Newly planned distribution systems (in Stage V plan): Vasudevapura GLR in Zone 1 is newly planned to cover the service area separated from the exiting GKVK GLR large service area. The other new system is planned at Doddakanahalli in Zone 2, which is divided from the Gottigere service area.
- Additional construction of three (3) GLRs in BDA areas in R.R. Nagar zone (in Stage V plan), although there is no plan on the GLRs in 110 Villages water supply plan.

Figure 10.1.1 and Figure 10.1.2 present existing and proposed GLR locations and their service areas for adopted GLR arrangements in the both DPRs.



Source: JICA Survey Team

Figure 10.1.1 Locations of GLRs in DPR for Stage V Project



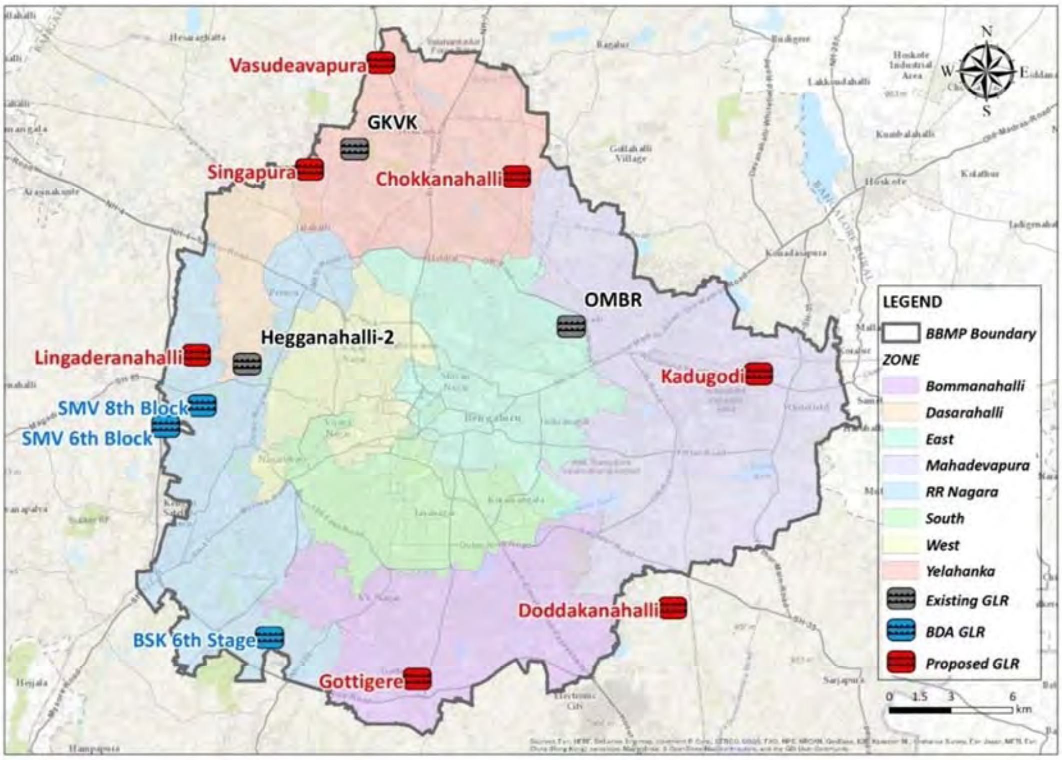
Source: JICA Survey Team

Figure 10.1.2 Locations of GLRs in DPR for 110 Villages

As the result of the study on the requirements and location (near the service area and higher elevation as well as available public land) of GLRs for 110 Villages water supply, the plan in the DPR for Stage V project were basically adopted. However, utilization of an additional existing GLR was recommended due to the following reasons.

Water demand to be covered by the proposed Lingaderanahalli GLR is calculated at 92 MLD. However, available land area for the GLR is limited allowing for the retention time of only 4.5 hours, which is short to achieve the purpose of the GLR. As the solution to ensure required retention time, the subject service area was divided into two (2) sub-areas. Then, one (1) of the divided service area was planned to receive water from the existing Hegganahalli-2 GLR, which has sufficient capacity to manage the requirement. Finally a total of three (3) existing GLRs: GKVK, OMBR and Hegganahalli-2 will be connected by planned city trunk main pipelines. Figure 10.1.3 presents the locations of GLRs to be used for this project and a total of 13 GLRs will be used for 110 Villages water supply as shown in Table 10.1.4.

As described hereinbelow, OHTs are planned in each village for distribution and the water is from GLRs shown in Figure 10.1.3. The designed detention time is appeared in Table 10.1.20 and all proposed GLRs have more than 10 hours of it except Lingaderanahalli GLR as its limited area. Hegganahalli-2 GLR is an existing GLR near Lingaderanahalli GLR and it has enough capacity and elevation to distribute water to some villages in Lingaderanahalli service area. Thus in this study, Hegganahalli-2 GLR is planned to distribute 45 MLD and Lingaderanahalli GLR provide 47 MLD.



Source: JICA Survey Team

Figure 10.1.3 Locations of GLRs to be Applied for 110 Villages Water Supply

Table 10.1.4 Population and Water Demand for Each GLRs

SN.	Name of GLR	Zone	No. of Villages fed from GLR	Population			Water Demand (MLD)			Breakdown of Water Source in 2049	
				2024	2034	2049	2024	2034	2049	Cauvery	Groundwater
1	Gottigere	Bommanahalli Zone	23	319,418	457,952	727,076	57	82	130	130	
		RR Nagar Zone	8	173,223	243,976	381,517	31	44	68	68	
		Sub Total	**31**	**492,641**	**701,928**	**1,108,593**	**88**	**125**	**198**	**198**	
2	Doddakanahalli	Bommanahalli Zone	10	162,027	231,709	367,172	29	41	66	66	
		Mahadevapura Zone	10	107,845	153,959	243,600	19	27	44	44	
		Sub Total	**20**	**269,872**	**385,669**	**610,772**	**48**	**69**	**110**	**110**	
3	Kadugodi	Mahadevapura Zone	9	213,335	303,839	479,150	38	54	86	86	
4	Chokkanahalli	Byatarayanapura Zone	18	321,209	458,534	725,721	57	82	130	130	
5	Vasudevapura	Byatarayanapura Zone	6	40,839	59,221	94,543	7	11	17	17	
6	Singapura	Dasarahalli Zone	5	100,502	143,726	227,750	18	26	41	41	
7	Lingaderanahalli	Dasarahalli Zone	4	153,181	168,642	266,650	27	30	48	48	
8	Hegganahalli-2	Dasarahalli Zone	2	73,121	148,062	248,673	13	26	44	44	
9	OMBR	Mahadevapura Zone	4	59,936	87,948	142,404	11	16	25	25	
10	GKVK	Byatarayanapura Zone	2	48,507	70,383	112,976	9	13	20	20	
		Total 1 =	**101**	**1,773,143**	**2,527,951**	**4,017,232**	**316**	**452**	**719**	**719**	
1	BDA SMV 6th	RR Nagar Zone	2	42,245	60,413	95,731	8	11	17	11	6
2	BDA SMV 8th	RR Nagar Zone	1	55,204	77,914	121,711	10	14	21	16	5
3	BDA BSK 6th	RR Nagar Zone	6	113,408	152,721	218,326	21	27	38	29	9
		Total 2 =	**9**	**210,857**	**291,049**	**435,768**	**39**	**52**	**76**	**56**	**20**
		Grand Total =	**110**	**1,984,000**	**2,819,000**	**4,453,000**	**355**	**504**	**795**	**775**	**20**

(2) Arrangements for Water Distribution Systems and City Trunk Mains for 110 Villages Water Supply

The distribution system in the DPR for 110 Villages water supply was planned in provision of 137 units of OHTs to maintain required water pressure and adjust the fluctuation of water demand through the day, receiving daily demand required from GLRs. An OHT is, in principle, planned for each village. Pumping facilities are planned between relevant GLR and OHT, as required to ensure required water head for the service area. The capacity of pumping facilities is planned to meet daily average demand, while the distribution main pipelines after OHT are planned for the peak demand (hourly max demand). The planning conditions in the above are reasonable and to be adopted for the design of permanent distribution facilities, although the number of OHTs shall be reviewed during D/D stage entailing topographic survey.

BWSSB started a bidding in November 25, 2016 for the construction of distribution systems for 110 Villages using saved water through UFW reduction project in the Core area and sharing some water supplied for the ULBs. The services are planned as a temporary measure for next five (5) years from 2019 to 2023 until completion of Stage V project.

According to the bid documents for the construction of distribution facilities for 110 Villages, construction of OHTs are canceled. Instead of the application of a gravity supply system, a direct pumping method is adopted. As available water amount to be supplied for this temporary measure may be limited, water supply will be insufficient. All required facilities shall be provided before 2024 (the planned year for the completion of Stage V project) to establish permanent distribution systems. For the requirements, preliminary study is made in Chapter 11 as the project to be undertaken by Indian side.

There are many disadvantages in application of the direct pumping method, which makes stable operation difficult, and allows more leakage because of sending water with higher water pressure through the day, and even causes the cancellation of 24/7 water supply. The need of OHTs, especially for a smaller water supply system is discussed as the review results of existing DPR in Chapter 11.

Hydraulic profiles for the City Trunk Mains between Tataguni Pumping Station and GLRs are shown in Figure 10.1.4 and Figure 10.1.5 for the Western route and Eastern route, respectively. In the Western route, water is transmitted by pumping to the farthest GLR, while water flows by gravity to concerned GLRs after Gottigere GLR in the Eastern route.

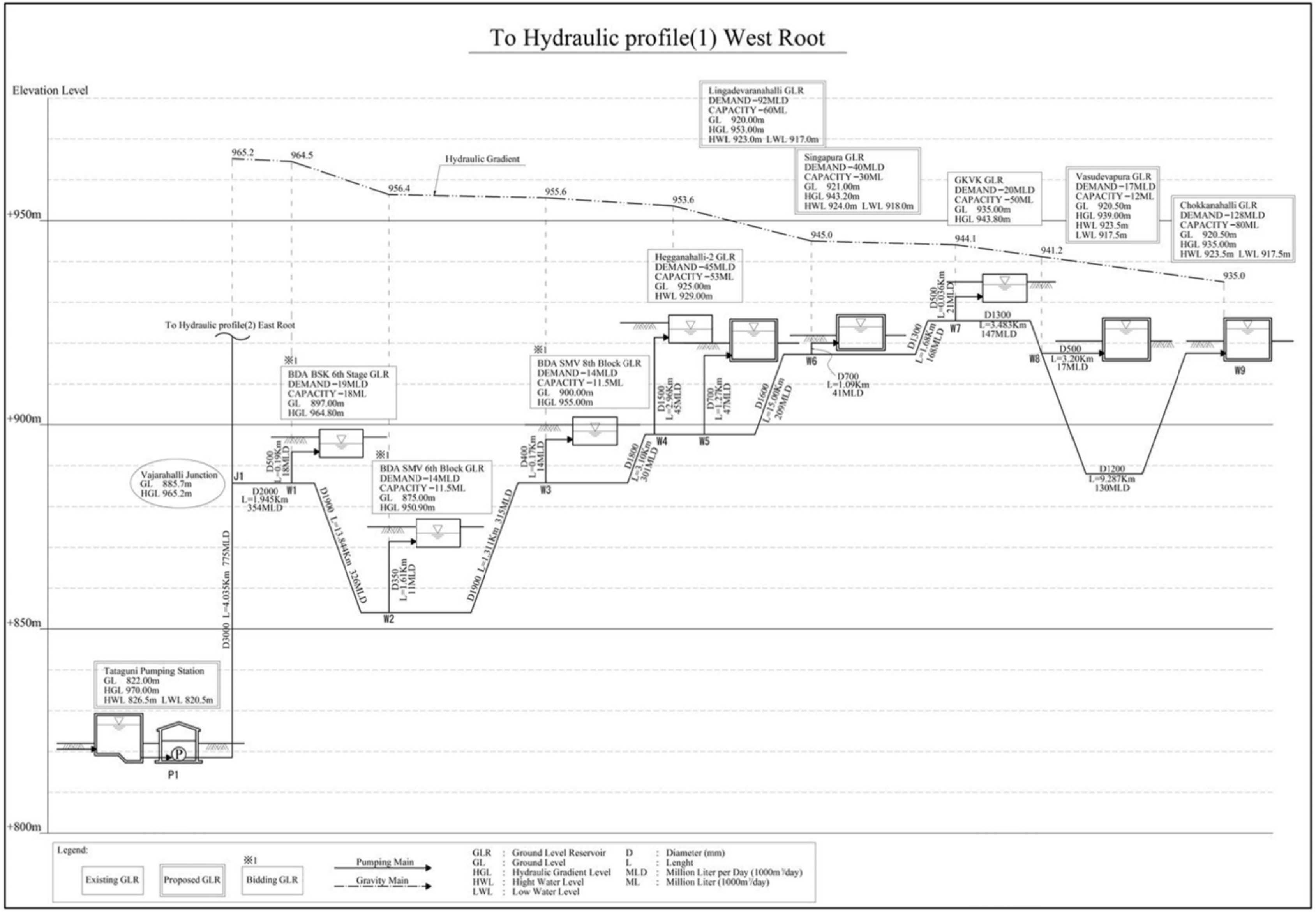


Figure 10.1.4 Hydraulic Profile of City Trunk Main in the West Route

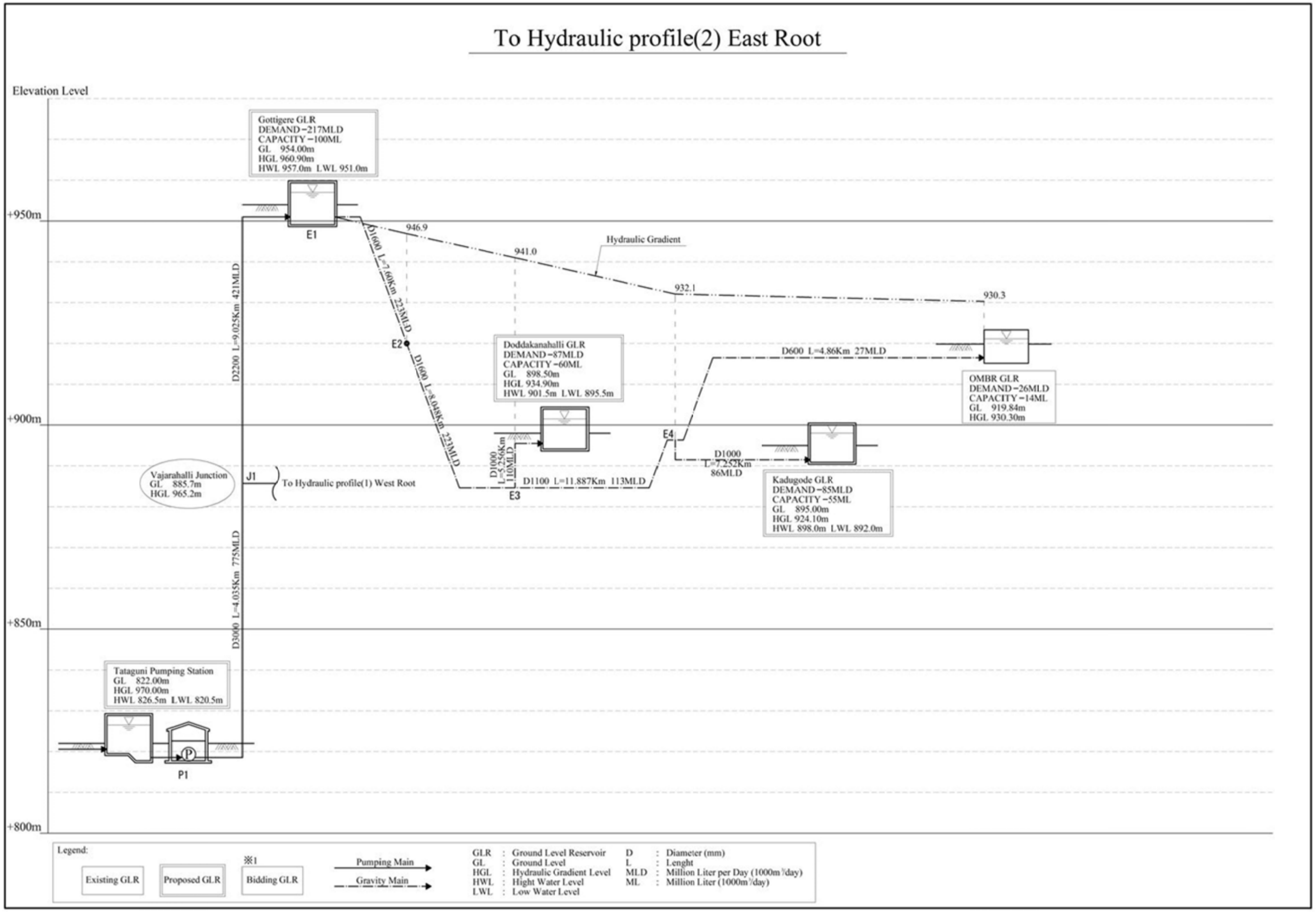


Figure 10.1.5 Hydraulic Profile of City Trunk Main in the East Route

10.1.3 Water Intake Facility and Conveyance Line

(1) Water Intake Facility

The raw water is taken from the Cauvery River at Shiva Anicut (weir) through a head regulator into a canal which flows for about 1.9 km to Forbes Sagar/ SBR (Shiva Balancing Reservoir). From the balancing reservoir, some water flows through the Shivasamudrum power channel to the Shiva Power station where it is used for power generation and then returns to the river. Another canal controlled by a head regulator leaves Forbes Sagar and flows for about 8.5 km to NBR (Netkal Balancing Reservoir).

The 1,750 mm dia. water transmission pipeline was developed by Stage I and II projects, 1,950 mm dia. pipeline by Stage III and 1,900 mm dia. pipeline by Stage IV, Phase-I project. Recently in the year 2012, under Stage IV, Phase 2 project, 3,000 mm dia. pipeline has been laid from Forbes Sagar to NBR and 2,600 mm dia. pipeline has been laid from NBR to TK Halli. All pipelines run parallel up to the WTP complex at TK Halli.

A conveyance pipeline with 2,750 mm dia. has been laid by BWSSB from the intake point at SBR to NBR for a length of 6.3 km for Stage V project, as planned in CWSS Stage V DPR. But the use of the pipeline was once changed by BWSSB for the water transmission of Stage I to III instead of Stage V, however, BWSSB decided to use for Stage V as Figure 10.1.6 shows. Presently, the work for proposed pipeline with 2,750 mm dia. for 9.95 km from NBR to TK Halli for Stage V has been started (BWSSB's own fund).

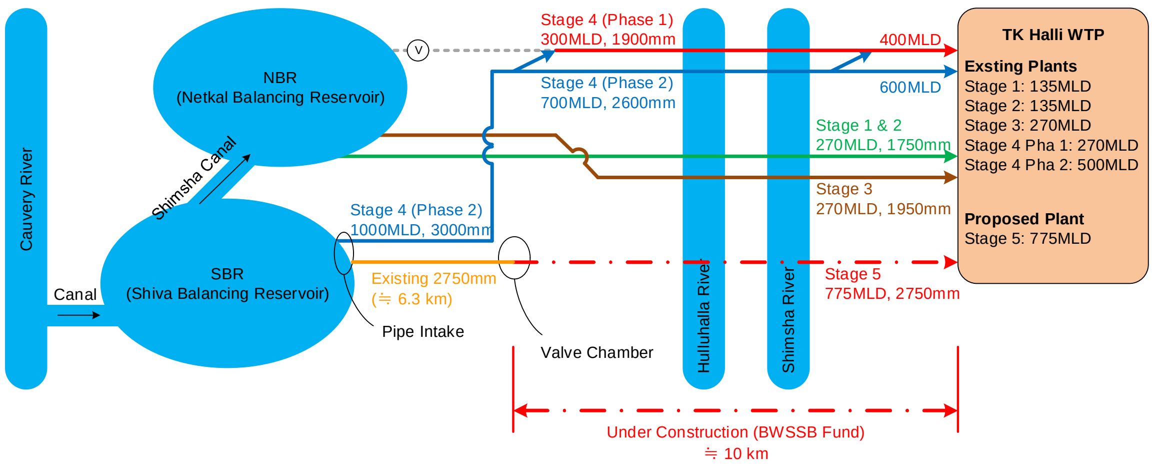


Figure 10.1.6 On-going and Proposed Conveyance Pipelines

The water intake is planned from pipe intake point which was constructed in Stage IV Phase 2 project. The intake amount shall be 775 MLD for the Stage V project. Photo 10.1.1 shows the intake point. There are three (3) gates for water intake and three (3) intake pipes are installed;

- Left : 3,000 mm for stage IV to connect to TK Halli
- Center : 3,000 mm extended for only 30 m long, this is for future use
- Right : 2,750 mm to connect to NBR, which is to be used for Stage V project

Photo 10.1.1 Intake Facility
(Right & Center Gates are Viewed)

Figure 10.1.7 Location of Conveyance Pipeline from Intake to WTP

Intake water for Stage I to Stage IV passes Forbes Sagar / SBR, where sedimentation effect of sand and grids is confirmed. The water taken for Stage V is also planned to pass the SBR, thus, a grid chamber is not proposed at the WTP.

(2) Conveyance Line

As described above, the pipeline with 2,750 mm dia. made of MS for 6.3 km from SBR to NBR is not required for the Stage V project. The location of conveyance pipeline from intake to WTP is shown in Figure 10.1.7. An application of gravity flow was confirmed hydrologically for the pipeline. Table 10.1.5 summarizes on-going and proposed conveyance pipelines.

Table 10.1.5 On-going and Existing Conveyance Pipelines (Excluding JICA Survey Project Scope)

Location		Specifications
1	SBR to NBR Gravity Flow	Use Existing one MS Pipeline: 6.3 km, 2,750 mm diameter
2	NBR to TK Halli Gravity Flow	On-going (in tender process) MS Pipeline: 9.95 km, 2,750 mm diameter Bridges for River crossings: two (2) sites at Hulluhalla and Shimsha rivers

10.1.4 Water Treatment Plant (WTP)

(1) Physical Conditions in the Planned WTP Area

i. Location: Adjacent to TK Halli WTP compound (BWSSB property: refer to Photo 10.1.2)

ii. Area: 38 acers (15.4 ha)

iii. Current Land Use: Staff quarters and school are located

iv. Land Use in surrounding area of planned WTP

West: BWSSB Quarters

South: WTP (TK Halli) across Bima River

East: Agriculture use

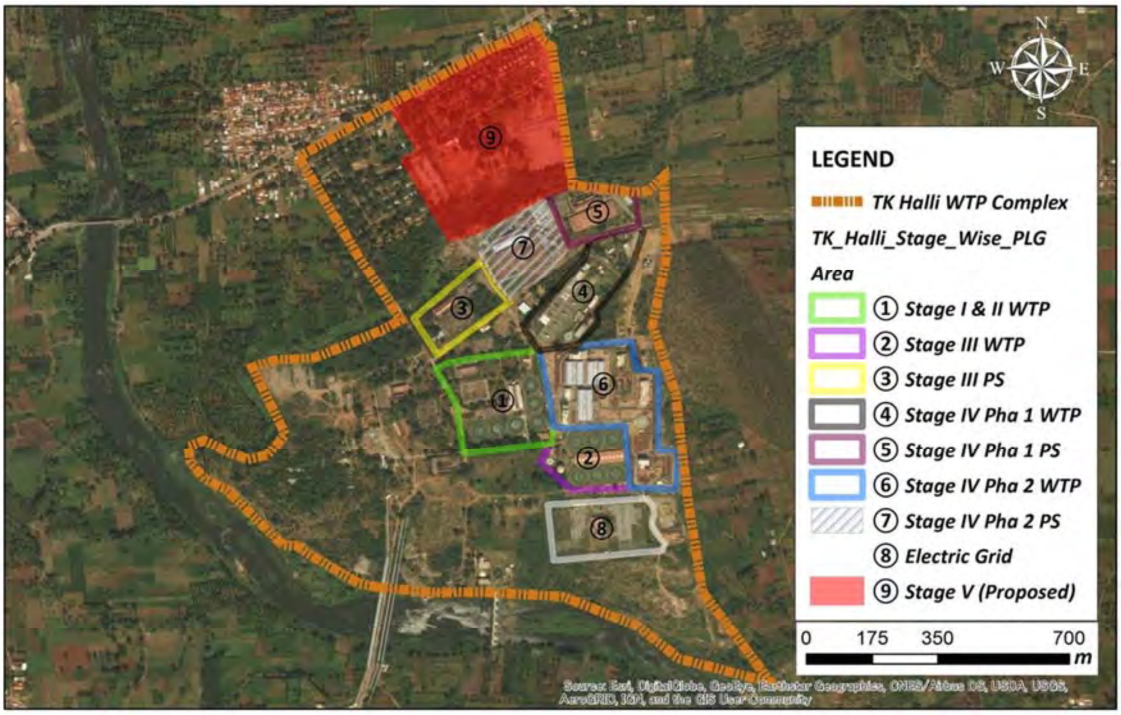
North: Residential area across a road

v. Existing and Design Elevation

Existing elevation: North West +597.5 m and South East +586.8 m

Design Elevation: +595 m to +590 m

vi. High Flood Level: +586 m



Source: JICA Survey Team

Photo 10.1.2 Layout of TK Halli WTP Complex

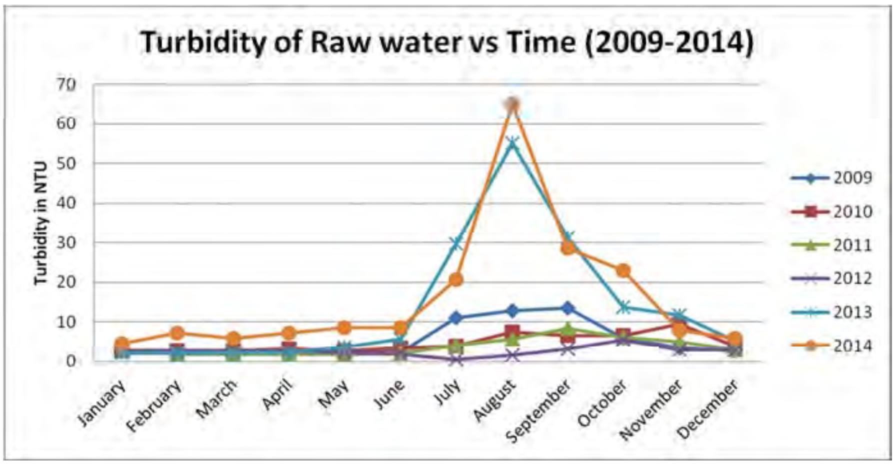
Source: JICA Survey Team

Photo 10.1.3 Proposed WTP Site

(2) Basic Conditions for Design of WTP and Treatment Process

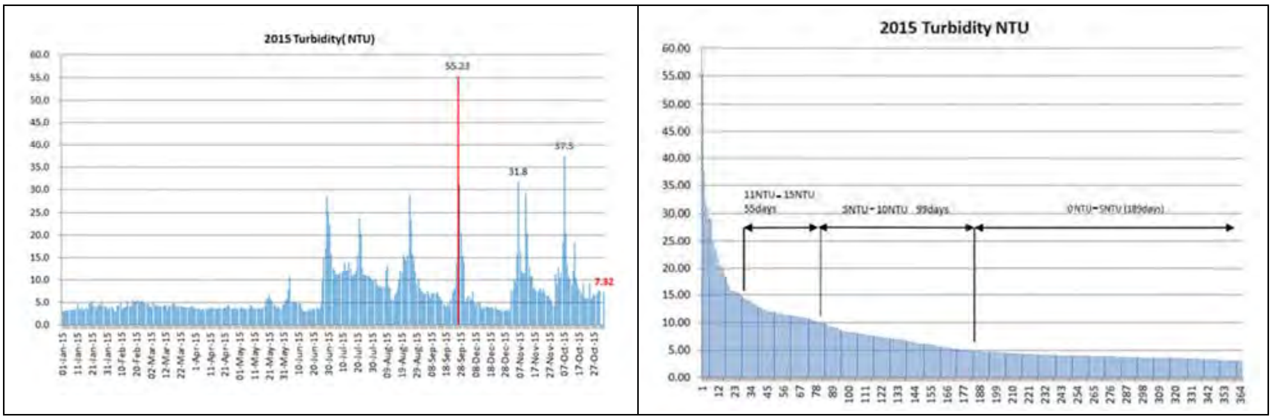
1) Raw Water Quality

Data on raw water quality were collected for the period from 2009 to 2014. Turbidity was analyzed as shown in Figure 10.1.8. The turbidity is commonly less than 5 NTU, but rises during July to October (monsoon season) between 20 and 65 NTU. Figure 10.1.9 shows the daily fluctuation of the turbidity in 2015. The left graph shows time basis and the right one shows the results of frequency distribution analysis. The highest turbidity is 55 NTU, but not exceeding 5 NTU for 189 days.



Source: BWSSB

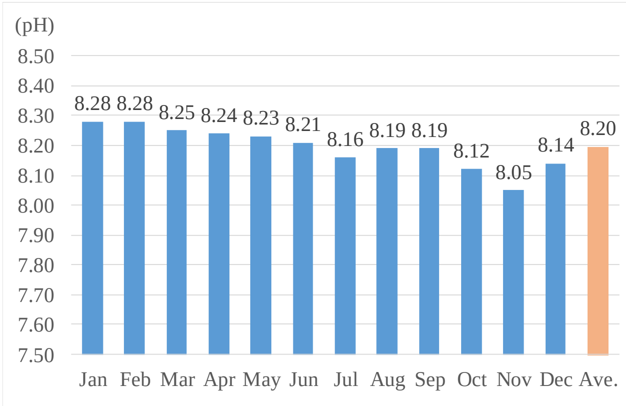
Figure 10.1.8 Raw Water Turbidity Variation from 2009 to 2014



Source: BWSSB

Figure 10.1.9 Raw Water Turbidity in 2015

Monthly average pH in 2015 are shown in Figure 10.1.10. It varies from 8.05 in November to 8.28 in January and February. Considering other water quality examination reports, the raw water quality criteria is shown in Table 10.1.6.



Source: BWSSB

Figure 10.1.10 Raw Water pH in 2015

Table 10.1.6 Raw Water Quality Criteria

Raw Water Parameter	Units	Design Value	Design value of DPR
Turbidity	NTU	100 max Ave.: 16	100 max < 20 NTU: 80%
pH	pH units	7.0 min 8.5 max	7.0 min 9.0 max
Alkalinity	mg/L as $CaCO_3$	200 max	30 min 200 max
Total hardness	mg/L as $CaCO_3$	160 max	30 min 160 max
Total dissolved solids	mg/L	500 max	70 min 350 max
Calcium	mg/L	75 max	5 min 40max
Iron	mg/L	1.0 max	0.3 min 1.0 max
Magnesium	mg/L	28 max	3 min 28 max
Total Coliforms	MPN per 100	2000 max	2000 max
Temperature	°C	19 min 36 max Ave.: 26	19 min 36 max Ave.: 26

Source: JICA Survey Team

2) Required Water Quality of Treated Water

The treated water quality requirements are specified to meet the CPHEEO Manual (May 1999 - Third Edition, Ministry of Urban Development), which are shown in Table 10.1.7.

Table 10.1.7 Guidelines for Drinking Water in CPHEEO

RECOMMENDED GUIDELINES FOR PHYSICAL AND CHEMICAL PARAMETERS

Sl. No.	Characteristics	*Acceptable	**Cause for Rejection
1.	Turbidity (NTU)	1	10
2.	Colour (Units on Platinum Cobalt scale)	5	25
3.	Taste and Odour	Unobjectionable	Objectionable
4.	pH	7. 0 to 8.5	<6.5 or > 9.2
5.	Total dissolved solids (mg/l)	500	2000
6.	Total hardness (as $CaCO_3$) (mg/l)	200	600
7.	Chlorides (as Cl) (mg/l)	200	1000
8.	Sulphates (as SO_4) (mg/l)	200	400
9.	Fluorides (as F) (mg/l)	1.0	1.5
10.	Nitrates (as NO_3) (mg/l)	45	45
11.	Calcium (as Ca) (mg/l)	75	200
12.	Magnesium (as Mg) (mg/l)	≤ 30	150
	If there are 250 mg/l of sulphates, Mg content can be increased to a maximum of 125 mg/l with the reduction of sulphates at the rate of 1 unit per every 2.5 units of sulphates		
13.	Iron (as Fe) (mg/l)	0.1	1.0
14.	Manganese (as Mn) (mg/l)	0.05	0.5
15.	Copper (as Cu) (mg/l)	0.05	1.5
16.	Aluminium (as Al) (mg/l)	0.03	0.2
17.	Alkalinity (mg/l)	200	600
18.	Residual Chlorine (mg/l)	0.2	>1.0
19.	Zinc (as Zn) (mg/l)	5.0	15.0
20.	Phenolic compounds (as Phenol) (mg/l)	0.001	0.002
21.	Anionic detergents (mg/l) (as MBAS)	0.2	1.0
22.	Mineral Oil (mg/l)	0.01	0.03
	TOXIC MATERIALS		
23.	Arsenic (as As) (mg/l)	0.01	0.05
24.	Cadmium (as Cd) (mg/l)	0.01	0.01
25.	Chromium (as hexavalent Cr) (mg/l)	0.05	0.05
26.	Cyanides (as CN) (mg/l)	0.05	0.05
27.	Lead (as Pb) (mg/l)	0.05	0.05
28.	Selenium (as Se) (mg/l)	0.01	0.01
29.	Mercury (total as Hg) (mg/l)	0.001	0.001
30.	Polynuclear aromatic hydrocarbons (PAH) (µg/l)	0. 2	0. 2
31.	Pesticides (total, mg/l)	Absent	Refer to WHO guidelines for drinking water quality Vol I. – 1993
	RADIO ACTIVITY+		
32.	Gross Alpha activity (Bq/l)	0.1	0.1
33.	Gross Beta activity (Bq/l)	1.0	1.0

Source: CPHEEO Manual

Based on the above standards, the treated water quality criteria for design of facilities are shown in Table 10.1.8. Regarding to Iron removal, it is supposed to be achieved by the cascade aerator as the density is low in raw water.

Table 10.1.8 Treated Water Quality Criteria

Item	Performance Requirement
Turbidity	Less than 1 NTU for 100% of the time; less than 0.5 NTU 90% of the time
pH	7.0 to 8.5
Color	Less than 5 units Pt/Co scale
Iron	Less than 0.1 mg/L
Al	Less than 0.03 mg/L
Coliforms	Total Coliforms 0/100 mL (Nil)

Source: JICA Survey Team

3) Treatment Process

A typical treatment flow in CPHEEO Manual is shown in Figure 10.1.11. The manual says as follows;

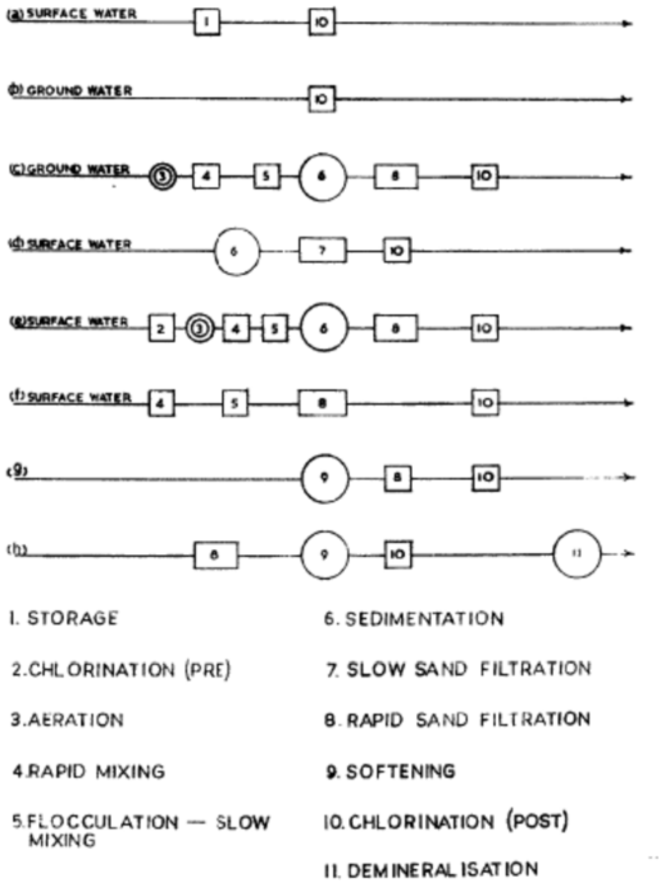
- In case of surface water where the water has turbidity below 10 NTU and free from odor and color, plain disinfection by chlorination is adopted before supply.
- In surface water with turbidities not exceeding 50 NTU and where sufficient area is available, plain sedimentation followed by slow sand filtration and disinfection are practiced.
- Conventional treatment process including pre-chlorination, aeration, flocculation (rapid and slow mixing) sedimentation, rapid gravity filtration and post chlorination are adopted for highly polluted surface waters with algae or other microorganism.

Based on the raw water turbidity as indicated, the conventional treatment process was considered as shown in Figure 10.1.11.

The processes for aeration and pre-chlorination seems not to be required under present raw water quality, however, they are considered in the previous projects for the following reasons:

- Raw water is stored in SBR and algae may grow in the tank,
- DO may be exhausted in the underground pipeline of 16 km
- A conventional treatment process is adopted and operated at all existing WTPs.

Therefore, the processes for aeration and pre-chlorination are employed for this project. The schematic diagram for proposed WTP is shown in Figure 10.1.12.



Source: CPHEEO Manual

Figure 10.1.11 Typical Treatment Flow in CPHEEO Manual

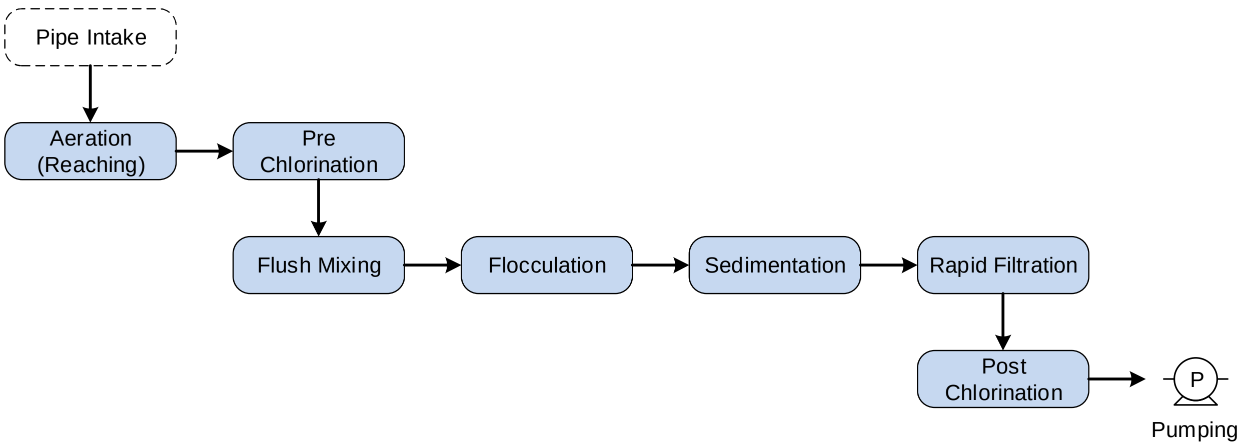


Figure 10.1.12 Proposed Conventional Water Treatment Process

(3) Disinfection Method

Chlorination facility is planned to provide safe water to consumers, holding disinfection effect in water distribution pipelines. Liquid chlorine is applied at the existing WTPs. The same manner of disinfection shall be used for this project.

(4) Sludge Treatment Process

The discharge of treated sludge into the Shimsha River is not permitted. A lot of sludge will be generated in application of conventional treatment process for design flow of 775 MLD. For the treatment of the sludge, it is preferable to apply a mechanical dewatering process instead of a sludge drying bed from the view point of foot print required within the limited area. A centrifuge type of dewatering equipment has been adopted in the existing Stage IV Phase 2 project as it has advantage in maintenance and cost performance. Then the same type of the equipment is recommended for this project.

10.1.5 Transmission Pipeline and Pump Station with Water Hammer Countermeasures

(1) Design Condition

i. Hazen Williams C Value of 140 is adopted for centrifugally lined MS pipes as shown in CPHEEO Manual (refer to C value in Table 10.1.9).

ii. Velocity of water in the pipeline is assumed to be 0.6 m/s to 1.8 m/s.

Table 10.1.9 C Value of Hazen Williams Formula

Pipe Material	Recommended C Values	
	New Pipes@	Design Purpose
Unlined Metallic Pipes		
Cast Iron, Ductile Iron	130	100
Mild Steel	140	100
Galvanized Iron above 50 mm dia. #	120	100
Galvanized Iron 50 mm dia and below used for house service connections. #	120	55
Centrifugally Lined Metallic Pipes		
Cast Iron, Ductile Iron and Mild Steel Pipes lined with cement mortar or Epoxy		
Up to 1200 mm dia	140	140
Above 1200 mm dia	145	145

Source: CPHEEO Manual

(2) Diameter of Transmission Pipeline

If diameter of pipe becomes larger, purchase cost becomes higher, on the contrary O&M cost may be reduced as a result of decreasing of friction losses. The diameter of transmission pipeline was determined in Stage V project considering Life Cycle Cost (LCC). The design diameter arrived at 3,000 mm in the LCC analysis after comparative study with a variation from 2,800 mm dia. to 3,000 mm dia. (The difference is less than 1%).

(3) Pipe Materials

Usually Ductile Iron (DI) pipe and Mild Steel (MS) pipe are used for water supply. For a larger diameter pipes (more than 1,000 mm dia.), as the low cost and good in the joint connection, MS pipe is selected. For the procurement of larger diameter pipes, there are two alternatives; 1) purchase fabricated pipe or 2) purchase raw material and make pipes on site. In the application of later method, the procedure of fabrication is required followed by welding, inner/ outer lining, and it is important to make sure of quality assurance. The fabrication on site was adopted in the Stage IV Phase 2 project. Employing the same manner for this project, the procurement procedure shall be determined through the evaluation of the price and technical proposal from suppliers.

(4) Design Criteria for MS Pipe

- The pipeline will be buried with a minimum cover of 1.20 m under the existing ground level.
- The wall thickness of buried steel pipe shall be sized taking into consideration the pressures/forces impacting internally and/or externally to the pipes as follows;
  - ⇒ Earth pressure due to backfill
  - ⇒ Uniform collapse pressure
  - ⇒ Super imposed concentrated or distributed line loads of vehicles at road crossings
  - ⇒ Buoyancy forces on empty pipelines
  - ⇒ Handling stresses
  - ⇒ Sub-soil water pressure
- Pipe laying shall be followed by AWWA manual M11.
- The internal design pressure shall be considered 1.5 times the working pressure.

(5) Transmission Pipeline

1) TK Halli to Harohalli

The 3000 mm dia. proposed MS clear water transmission pipeline will be approximately 43.9 km long from TK Halli to Harohalli. As seen from the ground profile, the ground elevation varies from 590 m at the beginning to a maximum of elevation 700 m at 21 km chainage near JK Doddi. There is however a low point (elevation 620 m) at 30 km chainage and again rising to the same elevation 690 m at about 40 km chainage. The pipe ends at 43.9 km chainage at the Harohalli pumping station at an elevation of 690 m.

2) Harohalli to Tataguni

The transmission pipeline length from Harohalli to Tataguni is approximately 21.5 km, According to the ground profile, the ground elevation varies from 690 m at Harohalli to 820 m at Tataguni with no significant peak. The lowest point (elevation 670 m) in this stretch is at about 49.5 km from TK Halli.

3) Tataguni to City Entry (Vajarahalli)

The stretch from Tataguni to Vajarahalli crossing involves about 4.05 km of pipeline along the existing pipeline route. The total length of the transmission line is 69.45 km including above mentioned 4.05 km.

The outline of transmission pipeline is shown in Table 10.1.10.

Table 10.1.10 Length of Transmission Pipeline

Type of Transmission System	Reach	Diameter (mm)	Length (km)
Clear Water Transmission System	TK Halli to Harohalli	3,000	43.9
	Harohalli to Tataguni	3,000	21.5
	Tataguni to Vajarahalli	3,000	4.05
	Total		69.45

Source: JICA Survey Team

(6) Pump Stations

1) Outline of Pump Stations

The three stage pumping to deliver treated water from TK Halli to Bengaluru shall include installation of new pumping stations at TK Halli, Harohalli and Tataguni. The site boundaries for each of these pumping stations were identified by BWSSB. The proposed site for CWR and PS at TK Halli is planned at the WTP compound adjacent to Stage IV, Phase 1 and 2 CWRs and pumping stations, which is near Bhima River.

The proposed site for PS and CWR at Harohalli is identified near the Stage I and II CWRs. The site falls on generally flat area. The proposed site for PS and CWR at Tataguni is identified near the Stage IV phase 2 pumping station. Design flow and pipe length are presented in the Table 10.1.11.

Table 10.1.11 Design flow and pipe length for Pumping Station Design

S/N	Section	Design Flow (MLD)	Length (km)
1	TK Halli - Harohalli	775	43.90
2	Harohalli - Tataguni	775	21.50
3	Tataguni–Vajarahalli Junction	775	4.05
Total		-	69.45

Source: JICA Survey Team

2) Clear Water Reservoirs (CWRs) at Pumping Stations

The capacities and water level of the proposed CWRs at three locations are indicated in the Table 10.1.12.

Table 10.1.12 Capacity of Clear Water Reservoir and Planned Water Level

S/N	Description	Capacity (m^3)	Minimum Water Level in CWR (m)	Maximum Water Level in CWR (m)	HRT (Hr)
1	TK Halli	68,000	585.03	591.03	2
2	Harohalli	34,000	687.50	693.50	1
3	Tataguni	34,000	820.00	826.00	1

Source: JICA Survey Team

3) Discharge Flow Rate

In the DPR, eight (8) units of pump facilities are planned to operate at each pumping station. The capacity of pump unit is planned at 4,160 m^3/h. Thus, the total discharge rate is 798.72 MLD at each pumping station. The specification for the pump unit in the DPR is planned with safety/surplus factor of 3% to the required design flow (775 MLD). However, in this study, the discharge flow rate of the pump does not consider the safety factor.

4) Total Head of Clear Water Pump

Comparative study was made between required total head and proposed total head in the DPR as shown in the Table 10.1.13. The proposed heads in the DPR meet required heads, thus, those in DPR are adopted.

Table 10.1.13 Comparison of Total Head of CW Pumps

Name of PS	Discharge of Pumps (m^3/h)	Static Head* (m)	Head Loss** (m)	Required Total Head (m)	Total Head in DPR (m)
TK Halli	32,320	108.47	19.20	127.67	130
Harohalli	32,320	139.00	11.41	150.41	152
Tataguni	32,320	136.50	9.71	146.21	150

Source: JICA Survey Team

* Maximum Water Level of the destination - Minimum water Level of the pump well

** The amount calculated by Hazzan formula as c=140 +3 m (as loss of around pump) +1 m (residual pressure)

5) Type of Pump

As mentioned in the DPR, horizontal shaft double suction volute pump with single stage impeller is the most efficient type, which is also used in the Stage IV Phase 2. Therefore, it is adopted in this project.

6) Number of Pump Units

Number of economical pump units to be operated was studied for each pumping station. As the result of a comparative study on purchase cost, electric power consumption and foot print in cases of nine (9) units (proposed six (6) units working and three (3) units standby) and 12 units (planned in the DPR, eight (8) units working and four (4) units standby) of pump facility, nine (9) units of pump operation was recommended.

a) Purchase Price of CW Pumps

A comparison of relative purchase price of the pump units is shown in Table 10.1.14. The purchase cost for nine (9) pump units is 5.6% cheaper than that of 12 pump units.

Table 10.1.14 Comparison of Unit Cost of Transmission Pumps

Alternatives	Pump Station	Pump Discharge Rate (m^3/Hour/Unit)	Nos. of Pump Unit	Relative Unit Cost	Relative Cost
12-pumps (Working 8+ Standby 4)	TK Halli	4,040	12	100.0 (Index)	1,200 (Index)
	Harohalli				
	Tataguni				
9-pumps (Working 6 + Standby 3)	TK Halli	5,390	9	125.8 (Index)	1,132 (Index)
	Harohalli				
	Tataguni				

Source: JICA Survey Team

b) Electrical Power Consumption

Since the total discharge flow rate and pump head required are pre-conditions, required pump input conditions are to be fixed. The difference of electrical power consumption depends on the efficiencies of pump and motor units. The highest efficiencies among data collected from the manufacturers are shown in Table 10.1.15. Consequently, the 9 pump units plan is 1% more efficient and annual electrical consumption cost is 20 Million INR cheaper than the 12 pump units plan.

Table 10.1.15 Electrical Power Consumption Cost of CW Pumps

Alternatives	Pump Station	Pump Discharge Rate (m^3/h)	Pump Efficiency (%)	Motor Efficiency (%)	Total Efficiency (%)	Electrical Power Consumption Cost * (Million INR/yr)
12-pumps (Working 8 + Standby 4)	TK Halli	4,040	86	96	82.56	1,809
	Harohalli					
	Tataguni					
9-pumps (Working 6 + Standby 3)	TK Halli	5,390	87	96	83.52	1,789
	Harohalli					
	Tataguni					

* Calculated as 4.5 INR per kWh, Cost = 0.163*775,000 m^3/d /60 /total efficiency x (130 m+152 m+150 m) x 365 d/y x 4.5 INR/kWh

Source: JICA Survey Team

c) Footprint for the Installation of Transmission Pump units

It is possible to accommodate nine (9) pump units at the planned Pumping Station, where 12 pump units are planned to install in the related DPR.

(7) Countermeasures against Water Hammer

1) Considerations for the Selection of Countermeasures

Generally, water hammer occurs caused by sudden changes in flow velocity in a pipeline in short period. In the actual operation of the facilities, it may occur at the time of starting and stopping pump operation, and opening or closing valves. Since the most serious problem occurs at the time of sudden stop of all working pump units affected by power failure, a transient analysis shall be made with an assumption of parallel operation of all six (6) pump units. In the DPR for Stage V, the protective devices against water hammer are proposed, as shown in Table 10.1.16. However, its analysis was only based on past experience, and actual transient analysis for this project had not been carried out. Thus, the protective devices were reviewed and the hydraulic transient analysis along the transmission pipeline was made in use of hydraulic transient modelling software, PIPE 2008 of KYPIPE LLC.

Table 10.1.16 Surge Protection of the PSs (DPR)

Pump Station	Protective Device	Facility	Location	Remarks
TK Halli	Air Chambers	9 units of chamber (each 100m^3)	Near the PS.	
	One-way Surge Tank	20 m Dia. 4m high	At JK Doddi.	Chainage 20.47 km
Harohalli	Air Chambers	7 units of chamber (each 100m^3)	Near the PS.	
Tataguni	Air Chambers	7 units of chamber (each 100m^3)	Near the PS.	

Source: JICA Survey Team

General countermeasures including item (1) to (7) are shown in Table 10.1.17. Considering the length and flow rate of pipelines for this project, “(2) Conventional surge tank”, “(3) One-way surge tank”, and “(4) Air chambers” are likely to be adoptable, while, other countermeasures may be difficult to apply as enumerated below.

“(1) Flywheels” are not effective in case of a long pipelines and “(5) Air valves” are not reliable as the main water hammer protection equipment, because they have a fear of clogging. “(6) Enlarging pipe diameter” is not economical and not practical. Although “(7) Change of pipeline level/route” may be applicable in some cases, but the effects are limited.

The following are the comparison among potential countermeasures as mentioned above. Installation of “(4) Air chambers” are the most suitable right after the pump's discharge with high pressure comparing with “(2) Conventional surge tank” and “(3) One-way surge tank”, because these are opened to atmosphere to observe water hammer without maintaining water level in the tank.

However, the effective range of “(4) Air chambers” to the water hammer is limited with reference to the length of pipeline even if tank capacity per unit and number of units are increased. The pipeline for this project is extraordinary long. In this case, a combination of other device(s) with (4) Air chambers is required, probably selecting from “(2) Conventional surge tank” and/or “(3) One-way surge tank”.

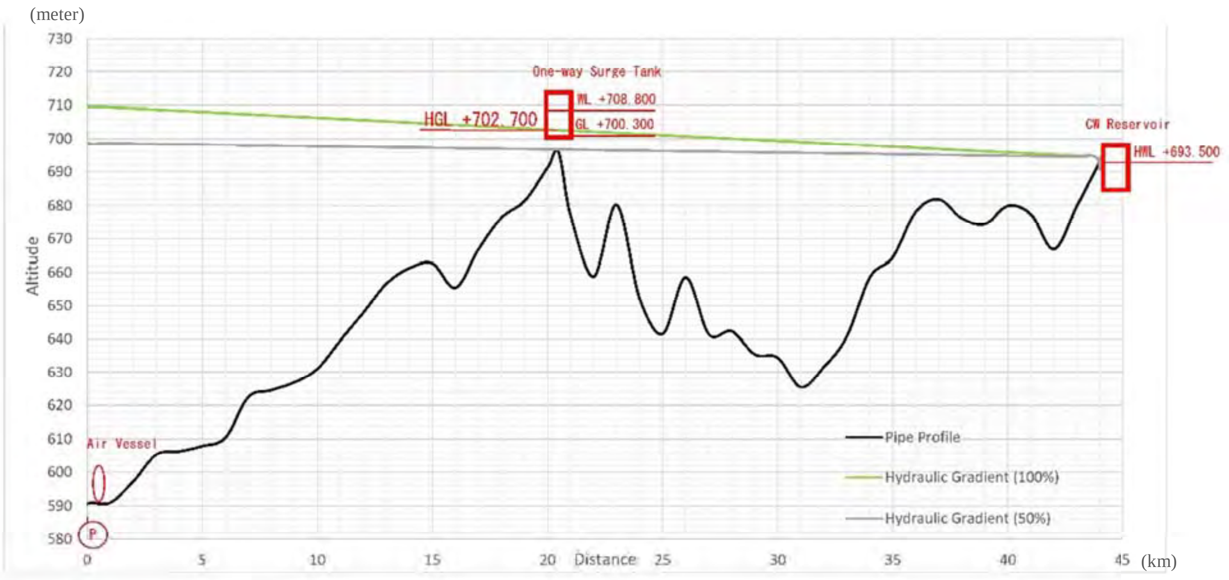
Table 10.1.17 Water Hammer Countermeasures

Countermeasures	Principle	Feature	Notes
(1) Flywheels	The flywheels that are equipped with between the pump and the motor keep rotational energy to a certain extent when the motor stops, which alleviates the amplitude of pressure drop.	Simple structure and few maintenance.	No effective measure for large pump at long pipeline. The upper size of flywheel is limited by the size of motor.
(2) Conventional surge tank	When a pressure drop occurs in the pipeline, the tank supplies water through the connecting pipe to decrease the impact of pressure drop. The tank is opened to the atmosphere.	Simple structure without check valves.	The tank level and height are limited by the hydraulic gradient level.
(3) One way surge tank		When the hydraulic gradient level is high, the tank’s height can be more compact than conventional surge tank.	Check valves are required to secure water level properly in the tank.
(4) Air chambers	When a pressure drop occurs in the pipeline, the air pressurized in the chamber forces water out into the pipeline immediately to decrease the impact of pressure drop.	The chambers can be effective even if right after the pumps because it can store the high pressure energy.	If the pipeline is far long, the effects become smaller.
(5) Air valves	When a negative pressure is generated in the pipeline, air is taken into the pipeline through the air valve.	Reasonable in price and conveniently used.	Due to fear of clogging by foreign material, it should not be counted as countermeasure of water hammer.
(6) Enlarging pipe diameter	The pressure drop is relieved by lowering flow velocity.	If pipeline is short, it may be reasonable.	Not reasonable at most of case.
(7) Change of pipeline level/route	Lowering the pipe level where the negative pressure occurs can relieve the pressure drop.		At most of case, it is difficult, because underground pipe may have to be deeper or for other reasons like as land acquisition.

Source: JICA Survey Team

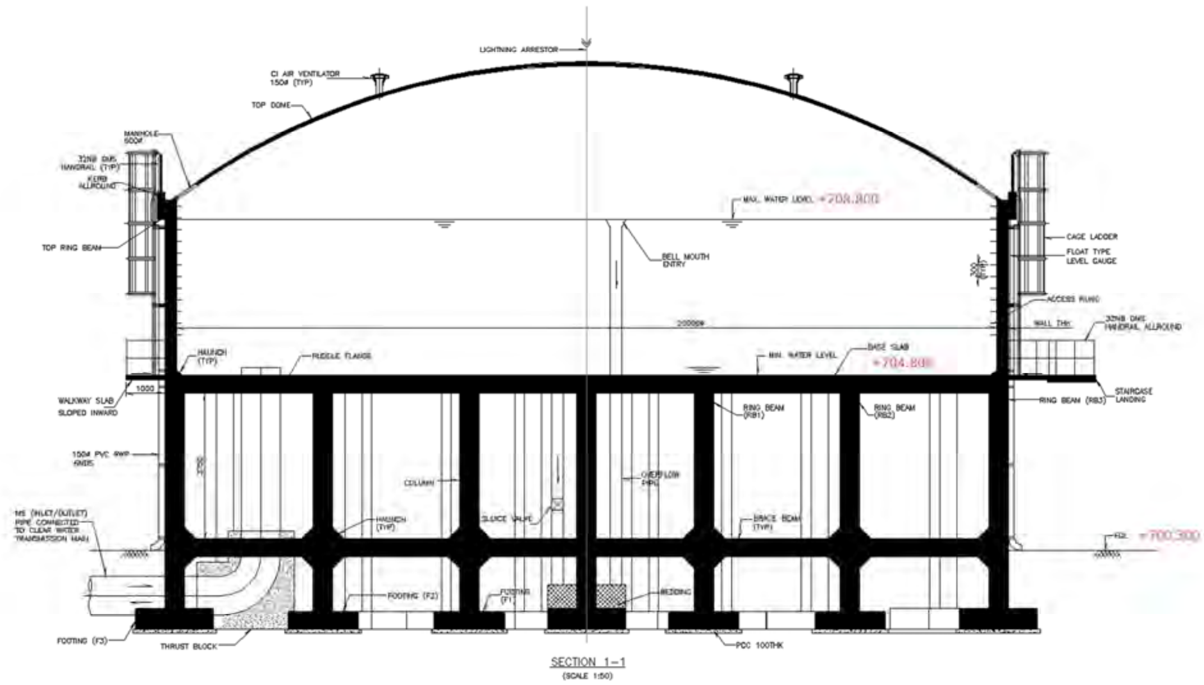
2) Transmission Pipeline from TK Halli PS to Harohalli CWR

One-way surge tank is recommended in the existing DPR. It was found in the hydraulic profile along pipeline, that the installation level of the surge tank is not adequate, because the tank’s planned water level, +708.800 m, is higher than the hydraulic gradient level, +702.700 m. For the water hammer protection, the water level in the tank should be lower than hydraulic gradient level. (refer Figure 10.1.13 and Figure 10.1.14) Therefore, proposed plan in the DPR was revised. Referring to the hydraulic profile, a conventional surge tank with a diameter of 20 m was planned at the same place where the one-way surge tank is planned in the DPR, aside from Air Chambers just after pump units.



Source: JICA Survey Team

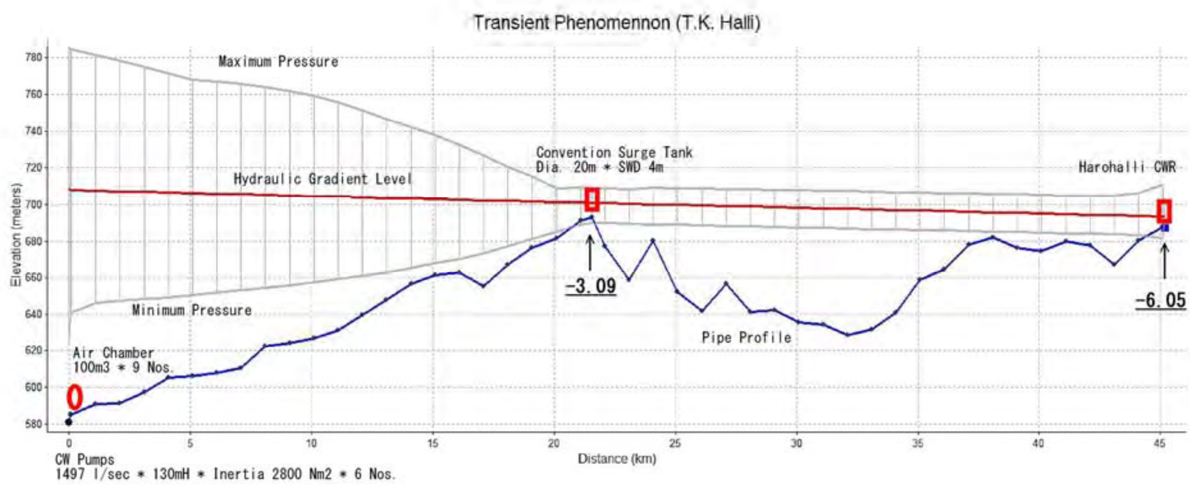
Figure 10.1.13 Hydraulic Profile of Transmission Pipeline from TK Halli PS to Harohalli



Source: TCE, 7899A-150-WS-6039 in DPR CWSS STAGE V

Figure 10.1.14 Section of One-way Surge Tank in DPR

Nine (9) units of air chambers with a capacity of 100 m^3 per unit and a conventional surge tank with a diameter of 20 m are recommended, as shown in Figure 10.1.15. The maximum negative pressure after power failure is estimated at 6.05 m at the distance from approx. 45 km from the PS, which is within safety range, because it is not more than seven (7) m as a criterion for judgement.

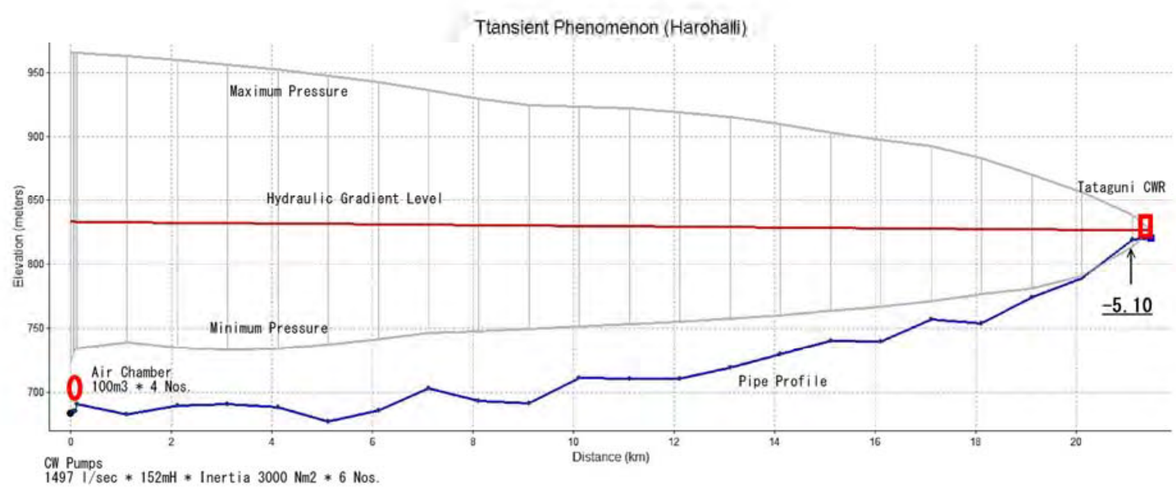


Source: JICA Survey Team

Figure 10.1.15 Transient Phenomenon after Power Failure (TK Halli)

3) Transmission Pipeline from Harohalli PS to Tataguni CWR

According to the analysis, four (4) units of air chambers that have a capacity of 100 m^3 per unit, number of which is reduced from the DPR plan, are suitable, because the negative pressures are not more than 7m along entire transmission pipeline route from Harohalli PS to Tataguni CWR. The maximum negative pressure is 5.10 m at the distance of 21 km from the Harohalli PS, as shown Figure 10.1.16.

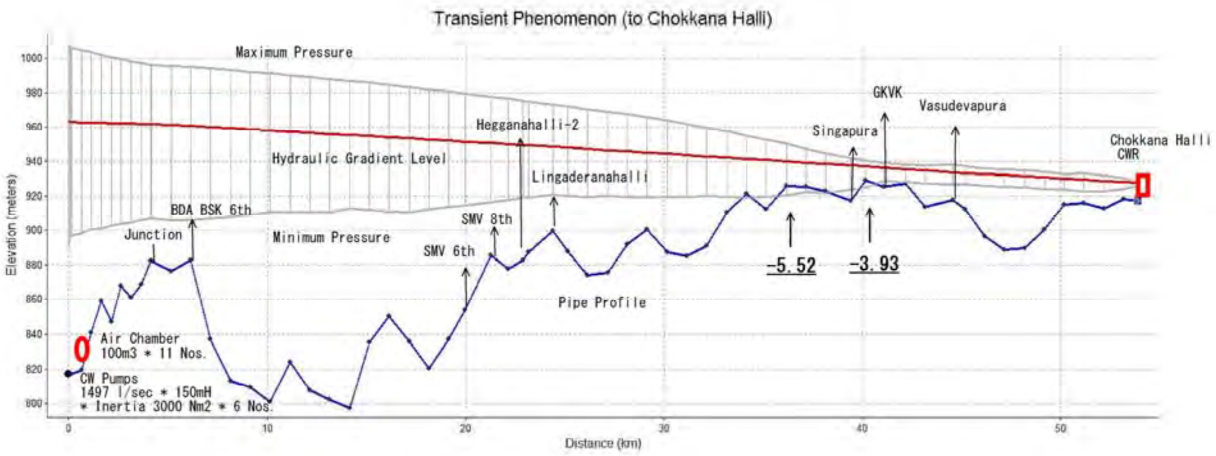


Source: JICA Survey Team

Figure 10.1.16 Transient Phenomenon after Power Failure (Harohalli)

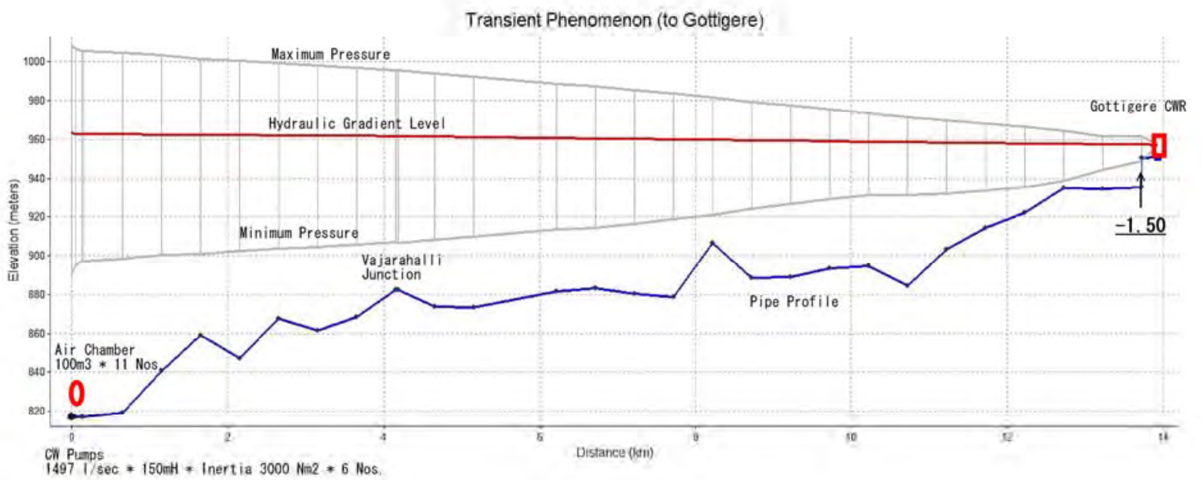
4) Transmission Pipeline from Tataguni PS to Chokkanahalli GLR and to Gottigere GLR

Based on the analysis, seven (7) units of air chambers planned in the DPR are not recommended. The air chambers should be increased from seven (7) to eleven (11) chambers to lower the negative pressure to less than 7m. The transient phenomenon in the case of eleven (11) air chambers is shown in Figure 10.1.17 and Figure 10.1.18 for the two (2) GLRs.



Source: JICA Survey Team

Figure 10.1.17 Transient Phenomenon (from Tatagini PS to Chokkanahalli GLR)



Source: JICA Survey Team

Figure 10.1.18 Transient Phenomenon (from Tatagini PS to Gottigere GLR)

5) Proposed Surge Protection

As the result of hydraulic transient analysis using a hydraulic transient modelling software, PIPE 2008 of KYPIPE LLC, required surge protection devices are summarized in Table 10.1.18.

Table 10.1.18 Proposed Surge Protection (revised from the DPR)

Name of PS	Protective Device	Description	Location	Remarks
TK halli	Air Chambers	9 units (each 100 m^3)	Near the CWPS.	
	Conventional Surge Tank	20 m Dia. 4 m height	At JK Doddi.	Chainage 20.47 km
Harohalli	Air Chambers	4 units (each 100 m^3)	Near the CWPS.	
Tataguni	Air Chambers	11 units (each 100 m^3)	Near the CWPS.	

Source: JICA Survey Team

10.1.6 City Trunk Mains and GLRs

(1) City Trunk Mains

The clear water from Tataguni pumping station is conveyed to different city GLRs located along eastern and western routes in Bengaluru city. The clear water shall be pumped from Tataguni pumping station to all the GLRs along the western route and up to the Kadugodi GLR in the eastern route. There are eight (8) GLRs along the western road, namely, BDA BSK, BDA SMV 6th stage (Kodigehalli), BDA SMV 8th stage (Herohalli), Lingaderanahalli, Singapura, GKVK, Vasudevapura and Chokkanahalli GLRs. No booster pumping stations are required for the proposed trunk mains. There are four (4) GLRs along the eastern road. The clear water is at first pumped to Gottigere GLR from Tataguni in order to send water to Doddakanahalli, Kadugodi, and OMBR GLRs by gravity. Table 10.1.19 shows specifications on City Trunk Mains.

Table 10.1.19 Specifications City Trunk Main Pipes

East Route

Label	Start Node		Stop Node		Diameter (mm)	Material	Length (m)	Flow (MLD)	Velocity (m/sec)
ER-1	C-1	Tataguni PS	C-2	Vajarahalli	3,000	Mild Steel	3,800	775	1.27
ER-2	C-2	Vajarahalli	C-20	Gottigere GLR	2,200	Mild Steel	8,638	419	1.28
ER-3	C-2	Vajarahalli	C-3	BSK 6th Block Tapping	2,000	Mild Steel	1,853	356	1.31
ER-4	C-3	BSK 6th Block Tapping	C-4	BSK 6th Block GLR	600	DI	199	29	1.19
ER-5	C-3	BSK 6th Block Tapping	C-5	SMV 6th Block Tapping	1,900	Mild Steel	13,147	327	1.33
ER-6	C-5	SMV 6th Block Tapping	C-6	SMV 6th Block GLR	350	DI	1,538	11	1.32
ER-7	C-5	SMV 6th Block Tapping	C-7	SMV 8th Block Tapping	1,900	Mild Steel	1,245	316	1.29
ER-8	C-7	SMV 8th Block Tapping	C-8	SMV 8th Block GLR	400	DI	164	16	1.47
ER-9	C-7	SMV 8th Block Tapping	C-9	Pipeline Rd. JCT near Herohalli Lake	1,800	Mild Steel	3,274	300	1.36
ER-10	C-9	Pipeline Rd. JCT near Herohalli Lake	C-10	Hegganahalli-2 GLR	1,500	Mild Steel	2,940	223	1.46
ER-11	C-9	Pipeline Rd. JCT near Herohalli Lake	C-11	Lingaderanahalli Tapping	1,600	Mild Steel	244	256	1.47
ER-12	C-11	Lingaderanahalli Tapping	C-12	Lingaderanahalli GLR	700	DI	421	48	1.44
ER-13	C-11	Lingaderanahalli Tapping	C-13	M S Palya Circle	1,600	Mild Steel	14,250	208	1.20
ER-14	C-13	M S Palya Circle	C-14	Singapura GLR	700	Mild Steel	1,043	41	1.23
ER-15	C-13	M S Palya Circle	C-15	GKVK Tapping	1,300	Mild Steel	1,596	167	1.46
ER-16	C-15	GKVK Tapping	C-16	GKVK GLR	500	DI	34	20	1.18
ER-17	C-15	GKVK Tapping	C-17	Yelahanka JCT	1,300	Mild Steel	3,309	147	1.28
ER-18	C-17	Yelahanka JCT	C-18	Vasudevapura GLR	500	DI	3,043	17	1.00
ER-19	C-17	Yelahanka JCT	C-19	Chokkanahalli GLR	1,200	Mild steel	8,775	130	1.33
						Total	**69,513**		

West Route

Label	Start Node		Stop Node		Diameter (mm)	Material	Length (m)	Flow (MLD)	Velocity (m/sec)
WR-1	C-20	Gottigere GLR	C-21	Doddakanahalli Tapping	1,600	Mild Steel	15,656	221	1.27
WR-2	C-21	Doddakanahalli Tapping	C-22	Doddakanahalli GLR	1,100	Mild Steel	5,256	110	1.34
WR-3	C-21	Doddakanahalli Tapping	C-23	Kadugodi Tapping	1,100	Mild Steel	11,936	111	1.35
WR-4	C-23	Kadugodi Tapping	C-24	Kadugodi GLR	1,000	Mild Steel	7,238	86	1.27
WR-5	C-23	Kadugodi Tapping	C-25	OMBR GLR	500	DI	4,863	25	1.47
						Total	**44,949**		

*The pipeline diameter is considered by the water demand of the year 2049 and only ER-10 pipeline is considered by the demand in the year of 2024 (13 MLD) and the sharing water to Core and ULB areas (210 MLD).

Source: JICA Survey Team

(2) Capacity of Ground Level Reservoir

The manual on Water Supply and Treatment, CPHEEO states that a GLR shall have a capacity of eight (8) to 12 hours for the HRT, while 15 hours for HRT is applied in the DPR except for some GLRs. Table 10.1.20 Proposed Reservoir Capacities shows proposed capacities of the planned GLRs.

Table 10.1.20 Proposed Reservoir Capacities

S/N	Name of GLR	Demand (MLD)	Proposed GLR Capacity (ML)	HRT		
				Proposed (Hrs)	12hr (ML)	15hr (ML)
1	Gottigere GLR	198	112.9	13.7	108.50	135.60
2	Doddakanahalli GLR	110	48.0	10.5	43.50	54.40
3	Kadugodi GLR	86	48.0	13.4	42.50	53.10
4	Chokkanahalli GLR	130	64.8	12.0	64.00	80.00
5	Vasudevapura GLR	17	10.8	15.2	8.50	10.60
6	Singapura GLR	41	24.0	14.0	20.00	25.00
7	Lingaderanahalli GLR	47	17.8	9.1	46.00	57.50
Total		629	326.3			

Source: JICA Survey Team

10.1.7 SCADA System

(1) Centralized SCADA System

It is proposed to have a centralized SCADA centre (herein referred to as CSC) to integrate all local data from Water Supply and distribution System, and the sewerage system to be established under Stage V. The proposed centralized SCADA centre shall be established at Shimsha Bhavan, adjacent to the existing centralized SCADA servers installed under Stage IV Phase 2.

It is to be noted that the existing Centralized SCADA centre installed in stage IV Phase 2 is currently under operation and maintenance period by the contractor. The SCADA servers are sized to integrate data from water supply system and the sewerage system only installed in the stage IV Phase-II. Further, due to the rapid advancement in the field of control and automation technologies , IT software & hardware, the current system shall be required to be completely overhauled and replaced in a few years. Hence it is required to have a complete new setup of SCADA servers, software and IT software's and hardware to integrate the water supply system and the sewerage system to be established under Stage V.

The proposed CSC shall be broadly divided into two server series, each catering to water supply system and the sewerage system, respectively to be established under Stage V.

- Water SCADA (Water Supply System)
- Sewerage SCADA (Sewerage System)

1) Water SCADA (Water Supply and distribution System)

The water SCADA server to be established shall be designed to integrate the following facilities on a minimum:

a) Proposed Water treatment plant (WTP) at TK Halli
b) Proposed water pumping stations at TK Halli, Harohalli, Tataguni
c) Proposed Ground level reservoir (GLR) to be established under Stage V
d) Existing & proposed overhead tanks (OHT)
e) Existing Master SCADA servers for UFW and AMR packages
f) Existing centralized SCADA center for Stage IV Phase 2
g) Proposed UFW Master SCADA system and AMR Master SCADA system for Stage V

Note: The SCADA servers shall be designed to accept bulk data transfer from the local facilities.

2) Sewerage SCADA (Sewerage System)

The sewerage SCADA server to be established shall be designed to integrate the following facilities on a minimum:

a) Proposed Sewage treatment plants (STPs) along with proposed terminal sewage pumping stations to be established under Stage V
b) Proposed intermediate sewage pumping stations (ISPSs)
c) Existing centralized SCADA center for Stage IV Phase 2 for sewerage SCADA

The above mentioned facilities shall be equipped with a fully automated PLC based SCADA system confirming to OPC & IEC standards for integration.
The PLC based SCADA system design at the above mentioned facilities shall incorporate a configuration which shall enable the integration of these facilities with the CSC at Shimsha Bhavan.

3) Proposed CSC Water SCADA and Sewerage SCADA Software and Hardware:
The CSC system for Water and Sewerage SCADA shall consist of the following software and hardware on a minimum:

a) Redundant SCADA servers
b) SCADA server software shall be of un-limited tags. (The software tags shall be configured for future expansion of I/O's with minimal programming effort)
c) Blade servers of optimum capacity shall be installed for Water SCADA server.
d) A LED based video wall shall be installed and configured as a Water SCADA mimic to provide display facilities for plant status data and process values, event /alarm indications and historical and real time trends.
e) SCADA software and Programming shall conform to latest OPC specifications and IEC Standards.
f) Multi-layered SCADA security with hardware based firewalls, system data encryption shall be implemented for securing the data in the network.
g) Historian Package server for analyzing historic data shall be established.
h) Online and Offline printing would be implemented for alarm/event analysis and trend support.

Note: It is also preferable to minimize the number of SCADA components manufacturers in order to have uniformity of the components and standardize the same.

Table 10.1.21 to Table 10.1.24 illustrate the typical data that shall be monitored by the Water SCADA & Sewerage SCADA servers on a routine basis:

- Table-1: Typical Data from Water Treatment Plants at TK Halli
- Table-2: Typical Data Collection from Water Pumping Stations (TK Halli, Harohalli, and Tataguni)
- Table-3: Typical data from Ground level reservoirs and Overhead tanks
- Table-4: Typical Data from Sewage Treatment Plants

Table 10.1.21 Typical Data from Water Treatment Plants at TK Halli

S/N	Description	Parameter
1	Plant Inlet	Flow
2	Combined Filtrate Channel	Flow
3	Raw Water Quality Parameters	Alkanity, pH, Turbidity
4	Settled Water Quality Parameters	Turbidity, pH
5	Clear Water Quality Parameters	Alkanity ,pH, Turbidity, Residual Chlorine

S/N	Description	Parameter
6	PLC Panel	PLC diagnostics, Hot-Standby Status
7	Communication/Interface Panel	Panel Hardware diagnostics
8	Local Plant information	Redundancy Status, status of every equipment, chemical consumption through reports generated by the system, general plant operating status, etc..
9	Pumps	Pump status, pump performance characteristics, working hours
10	Balancing Reservoir	Flow, Levels, Motorized gate status
11	Electrical Parameters	Primary: Voltage, Secondary: Voltage, Ampere, Power Factor, Frequency, Power (kW), Power integration / consumed (kWHr)

Table 10.1.22 Typical Data Collection from Pumping Stations (TK Halli, Tataguni, and Harohalli)

S/N	Description	Tag
1	Pumps	Pump status, Pump performance characteristics, Temperature and Vibration on both the pumps and the motors
2	Process/Plant Flow, Pressure	Individual Pump Discharge Flow, Total Plant Outlet Flow and Pressure on the common delivery pipe
3	Surge Vessel	Surge Vessel status
4	Water Reservoirs	Level status
5	Analytical Parameters	Residual Chlorine Level
6	Electrical Parameters	Primary: Voltage, Secondary: Voltage, Ampere, Power Factor, Frequency, Power (kW), Power integration / consumed (kWHr) Each Pump: Ampere, Power Factor, Power (kW), Power integration / consumed (kWHr)
7	PLC Panel	PLC diagnostics, Hot-Standby Status
8	Communication/Interface Panel	Panel Hardware diagnostics
9	Surge Tank	Surge Tank status

Table 10.1.23 Typical Data from GLR & OHT

S/N	Description	Tag
1	Flow	Total Inlet Flow, Outlet Flow
	Level	Level in GLR, OHT
	Analytical Parameters	Residual Chlorine
	Pump	Pump status, Running Hours, Maintenance schedules

Table 10.1.24 Typical Data from Sewage Treatment Plants

S/N	Description	Tag
1	Flow	Total Inlet Flow, Plant Outlet Flow
2	Analytical Parameters	Dissolved Oxygen Parameters, ORP, Residual Chlorine, Turbidity (Sludge Density of Sludge Feed to Dewatering Unit)
3	Terminal Sewage Pump	Pump status
4	Electrical Parameters	Primary: Voltage, Secondary: Voltage, Ampere, Power Factor, Frequency, Power (kW), Power integration / consumed (kWHr) Each Sewage Pump: Ampere, Power Factor, Power (kW), Power integration / consumed (kWHr)
5	PLC Panel	PLC diagnostics, Hot-Standby Status
6	Communication/Interface Panel	Panel Hardware diagnostics
7	Local Plant information	Redundancy Status, status of every equipment, chemical consumption through reports generated by the system, general plant operating status, etc.

(2) Communication Network

The centralized SCADA centre (CSC) shall be equipped with both wired and wireless communication technologies to monitor both water SCADA (Water supply and distribution system) and Sewerage SCADA (Sewerage system).

The CSC shall communicate with the water treatment plant at TK Halli and the water pumping station at TK Halli, Tataguni and Harohalli locations via redundant Fibre optic cable (FOC) network. The FOC shall be laid all along the pipeline proposed under the stage V project up to Shimsha Bhavan. The FOC network shall allow for real time monitoring of the facilities and allow for larger bandwidth to be transmitted and integrated.

The ground level reservoirs and overhead tanks control system shall communicate with the CSC servers via redundant GPRS (General Packet Radio Services) wireless communication network.

The sewerage treatment plants, ISPS shall communicate with the CSC servers via redundant GPRS wireless communication network.

Summary of communication networks is shown in Table 10.1.25.

Table 10.1.25 Summary of Communication Networks

S/N	Description	Communication Technology	Functionality
1	Water Treatment Plants, Water pumping stations, Proposed ground level reservoirs)	Fiber optic cable (FOC) network	Monitoring
2	Existing ground level reservoirs and overhead tanks	GPRS	Monitoring
3	Sewerage Treatment plants, ISPS	GPRS	Monitoring

(3) SCADA System Functionality and Security

The SCADA system shall follow the International Standards Organization (ISO), Open Systems Interconnect (OSI), reference model guidelines. All central system hardware and software devices shall be interconnected using a bus topology data highway. The communications protocol used shall generally meet the requirements of the ISO.

The system shall provide efficient and safe operation of the process plant by detecting alarm and error conditions, alerting the operator to these conditions both visually and audibly, monitoring all important system parameters and providing facilities for plant optimization. The System shall perform all the necessary functions for the optimum monitoring of the entire system.

For each abnormal condition, Plant failure, Plant unavailable or failure to respond to a command within a given period, the HMI shall provide the appropriate alarm. Printed and archived alarms shall be time and date stamped for occurrence and acceptance. Alarms, logs and reports shall be output to separate printers. Alarms shall be in red. The ability to generate alarms within the system software based upon digital and / or analogue events and set points shall be provided.

Provision will be made for the adding of further software tasks as and when required. All software functions will be user friendly, with instruction and messages to aid the operator. The servers shall utilize a real time multi-tasking and networked operating system with a proven track record in real time control applications. The Application Software shall provide communication with other industrial standard open networks. The Software shall support Object Linked Embedding for Process Control (OPC).The System shall support fully distributed 64 bit Client/Server architecture. The System shall include Visual Basic for Applications (VBA) as a built-in programming language. Facility shall be available for building custom objects using VBA, Object oriented graphics and tools to easily build reusable control strategies.

The SCADA software shall support ODBC Application Program Interface (API) capable of collecting and writing secure real-time electronic records to one or more relational database. The software shall support OPC standards as both a client and a server for fast and reliable communications with a wide variety of hardware devices. Software shall provide Active-X controls with selection of third-party Active-X controls for ready-made solutions without VBA programming. The SCADA software shall use SQL server as the integral database. A standard software package, such as Crystal Report shall be provided to facilitate generation of free format, intuitive and presentation quality reports.

VDU mimics will display dynamic color details of flow rates and pressures, pump status, well levels, alarms, electrical power supplies and other general equipment status conditions. All requests and commands shall be via icons, whether menu linked or linked to equipment control actions. A permanent dynamic alarm banner shall be displayed at the bottom or top of each operator screen. Each control action will be routed through a series of confirmation routines.

The reports shall be available for printing in graph or tabular format. Dynamic trend displays shall also be available for all analogue flow, level and pressure values. Custom, as well as preconfigured reports and trends shall be available to a higher level of entry.

An operator helping utility shall be provided, offering help linked to the particular action being carried out by the operator at that time. At least one help screen per screen page shall be available. This facility shall be preconfigured with an option for updating by operators, via a password entry.

The Application Server software shall be configurable to provide for the monitoring and control of all points, loops, and systems through graphic display screens and hard copy reports. These shall include:

- Parameter Displays for signal control
- Control Loop Status Displays
- Real Time and Historical Data Trend Displays
- Event Displays and Log Reports
- Alarm Displays and Log Reports
- Equipment Diagnostic Displays and Reports.

The system shall provide on-line diagnostics that display the current status and operation of the local area network and its nodes. The diagnostic display shall include the LAN adapter status for the machine showing the display, as well as the current number of messages, errors and retries.

The system shall conform to and take advantage of industry standards.

1) SCADA Security

The key to efficient management of network is the availability of the real time information and remote operation/monitoring of the utility distribution network. The distribution is effected from the transmission level through a number of geographically distributed local stations. The centralized SCADA system involves installation of Remote Terminal Units (RTU) /transmitters at the local stations/I&D structures & sewers locations which interfaces with the receiver system at the centralized location. These distributed RTUs communicate with the centralized SCADA Center through various communication media such as Radio, Fiber optic, Leased Line, Public communication networks like PSTN, GPRS etc.

This defines a new meaning to SCADA system security, as multiple remote sites are connected a master control center. The SCADA system security has to be clearly defined in order to achieve a better security model for the proposed Master Control center.

SCADA systems are vulnerable for internal & external threats.

- Internal Threats: SCADA systems may suffer sabotage by disgruntled insiders/employees, acting individually or collectively.
- External Threats: SCADA systems may be attacked by external agencies to spread mayhem among the general public, disrupt operations & for terrorist activities.

a) Probable Consequences:

- Enterprise network security may be breached, may have financial consequences, customer privacy is compromised, systems may need to be rebuilt, spam gets sent, etc.
- SCADA security breach property can be destroyed and people can be hurt or killed

b) Proposed SCADA Security (Local SCADA/Remote Sites)

The local SCADA stations/remote sites installed shall be programmed for better SCADA security.

A three level of SCADA security would be implemented at the local level

- Plant Operators (restricted Log-In Facility limited to only monitoring of plant process operations)
- Plant Supervisor (Access to some restricted areas, but restricted from gaining access to other screens. E.g.: Programs, database, Security configuration)
- Engineer (Systematic access to system administration layers of security privileges would be incorporated)
- A SCADA password management model will be implemented.

c) Proposed SCADA security between Remote sites and CSC

The SCADA integration turnkey contractor shall be responsible for implementing a comprehensive SCADA security model which shall ensure total security of the local SCADA system and the integration component.

2) Protecting the SCADA Network

a) The first step

The first step towards securing SCADA systems is creating a written security policy, an essential component in protecting the corporate network. Failure to have a policy in place exposes the center to attacks, revenue loss and legal action. A security policy should also be a living document, not a static policy created once and shelved. The management team needs to draw very clear and understandable objectives, goals, rules and formal procedures to define the overall position and architecture of the plan.

Key personnel such as senior management, IT department, and human resources department all should be included in the plan. It should also cover the following key components:

- Roles and responsibilities of those affected by the policy
- Actions, activities and processes that are allowed and those that are not allowed
- Consequences of non-compliance

b) Vulnerability Assessment

A key aspect of preparing a written security policy is to perform a vulnerability assessment prior to completing the written policy. A vulnerability assessment is designed to identify both the potential risks associated with the different aspects of the SCADA-related IT infrastructure and the priority of the different aspects of the infrastructure. This would typically be presented in a hierarchical manner, which in turn sets the priority to address security concerns and the level of related funding associated with each area of vulnerability.

For example, within a typical SCADA environment, key items and the related hierarchy could be as follows:

- Operational Availability of Operator Stations
- Accuracy of Real Time Data

- Protection of System Configuration Data
- Interconnection to Business Networks
- Availability of Historical Data
- Availability of Casual User Stations

A vulnerability assessment also acts as a mechanism to identify holes or flaws in the understanding of how a system is architected and where threats against the system may originate.

To successfully complete a vulnerability assessment, a physical audit of all the computer and networking equipment, associated software and network routings needs to be performed. A clear and accurate network diagram should be used to present a detailed depiction of the infrastructure following the audit.

After defining the hierarchy and auditing the different system components, the following areas of vulnerability need to be addressed, as they relate to each component, as part of the assessment process:

i. Network and operating environment security

- Application security
- Intrusion detection
- Regulation of physical access to the SCADA network

It should also be understood when dealing with the SCADA infrastructure that there are commonalities and differences between SCADA-related IT security and IT security focused on typical business systems. For example, in a business systems environment, access to the server is typically the key focus. Whereas in a SCADA environment, the access focus is at the operator console level. This difference produces both alternate network topologies to provide the necessary availability as well as a different focus on what elements of the SCADA system would be of highest priority to safeguard against security breaches.

ii. Further Security Measures

As previously mentioned, SCADA networks were once separate from other networks and physical penetration of the system was needed to perpetuate an attack. As corporate networks became electronically linked via the Internet or wireless technology, physical access was no longer necessary for a cyber-attack. One solution is to isolate the SCADA network; however, this is not a practical solution for budget-minded operations that require monitoring plants and remote terminal units (RTU) from distant locations. Therefore, security measures need to be taken to protect the network, and some common security mechanisms apply to virtually all SCADA networks, which have any form of wide area (WAN) or Internet-based access requirements. The Core elements of each method are discussed in the following:

iii. Firewalls

A firewall is a set of related programs, located at a network gateway server that protects the resources of a private network from outside users. A firewall, working closely with a router program, examines each network packet to determine whether to forward it toward its destination. A firewall also includes or works with a proxy server that makes network requests on behalf of workstation users. A firewall is often installed in a specially designated computer separate from the rest of the network, so that no incoming request can get directly at private network resources.

In packet switched networks such as the Internet, a router is a device or, in some cases, software in a computer, that determines the next network point to which a packet should be forwarded toward its destination. The router is connected to at least two networks and decides which way to send each information packet based on its current understanding of the state of the networks to which it is connected. A router is located at any gateway (where one network meets another), including each point of presence on the Internet. A router is often included as part of a network switch.

It is imperative to utilize a secured firewall between the corporate network and the Internet. As the single point of traffic into and out of a corporate network, a firewall can be effectively monitored and secured. It is important to have at least one firewall and router separating the network from external networks not in the company's dominion. On larger sites the control system needs to be protected from attack within the SCADA network. Implementing an additional firewall between the corporate and SCADA network can achieve this aim and is highly recommended. Figure 10.1.19 illustrates additional firewall.

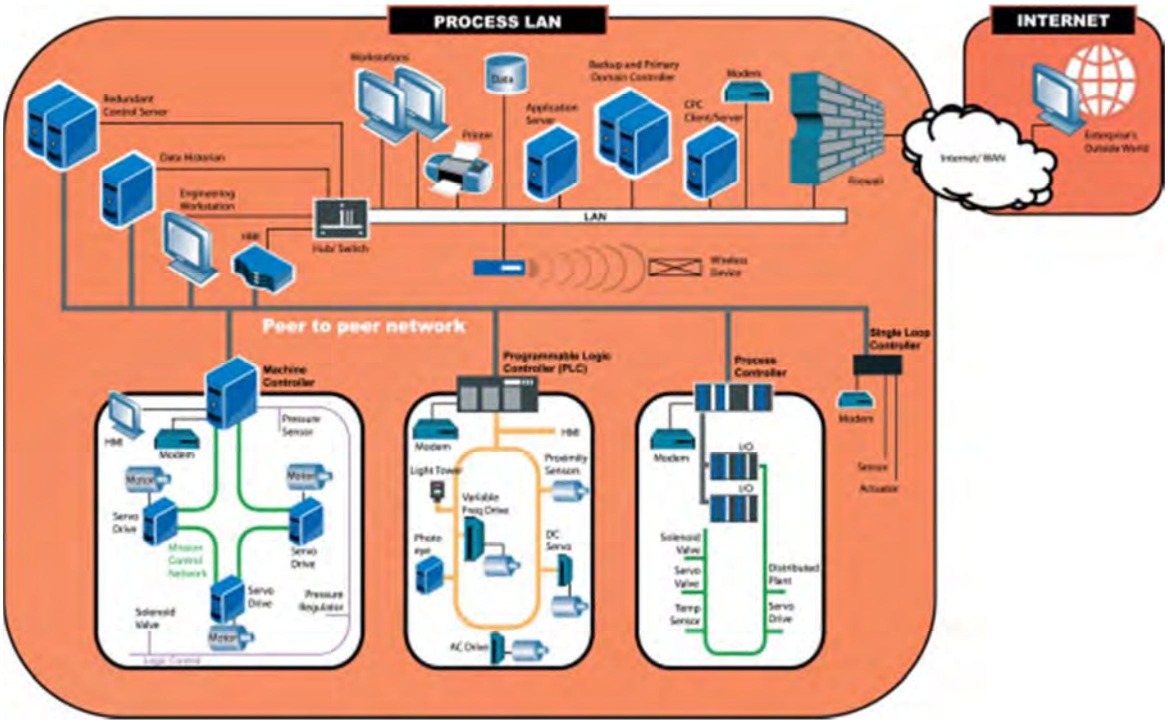


Figure 10.1.19 Additional Firewall

In practice, most utilities use a combination of network, host and/or application-based IDS systems for observing network activity while also monitoring key hosts and applications more closely.

To summarize the above:

- Comprehensive SCADA password management model should be implemented (both local SCADA/remote sites & Master SCADA control center)
- Ghost password (authentication credentials of long-gone employees that are still active.) should be removed.
- Data encryption should be implemented.
- Firewalls should be implemented at both remote site end and the CSC end.
- Double layer data encryption should be implemented for transmitted data.
- Un-authorized access to CSC should be prevented by implementing bio-metric security model.

SCADA System firewall rule base: - In simple terms, firewall should enforce the following rules:

- No communication is allowed from the Untrusted Enterprise to the Trusted SCADA
- No communication is allowed from the Trusted SCADA to the Untrusted Enterprise
- A set of least privilege rules allows only necessary communication between the Untrusted Enterprise and the Semi-trusted DMZ
- A set of least privilege rules allows only necessary communication between the Semi-trusted DMZ and the Trusted SCADA

10.1.8 Recommended Scope of Work

The scope of work for water supply facilities with reference to Stage V Project is summarized in Table 10.1.26 which includes additional work, Branch Feeding Pipes (to be undertaken by Indian side). Figure 10.1.20 presents outline of JICA Survey Project for Stage V.

Table 10.1.26 Recommended Scope of Work for Water Supply Facilities (Stage V)

Facility	Capacity (MLD）	Contents
Raw Water Intake	775	Utilize existing Facility
Raw Water Conveyance (Indian side project)	775	Diameter 2,750mm Length Approx. 6.3 km Existing and 10 km on-going (Gravity flow)
Water Treatment Plant	Production 775	Adjacent to existing WTP in TK Halli Water Treatment: Rapid sand filtration Disinfection: Liquid Chlorine Sludge Treatment: Centrifuge
Water Transmission Pipeline	775	Transmission Pipe: Dia. 3,000 mm Length Approx. 70 km Pump Station: 3 Nos（including CWR） ・TK Halli, ・Hallohali, ・Tataguni Conventional surge tank: 1 Nos; Air Chambers for all PSs
City Trunk Main and GLRs	775	Length Approx.114 km （Dia. 500 mm - 3,000 mm） GLR 13 Nos. （New 7 Nos., Total Capacity 326,280 m^3）
Branch Feeding Pipes to share water to Core/ULBs (Indian side Project)	360	・Dia. 1,100 mm - 1,400 mm, 11.5 km (Vajarahalli JCT - CLR GLR) ・Dia. 600 mm - 1,400 mm, 17.4 km (Hegganahalli-2 - HGR GLR)

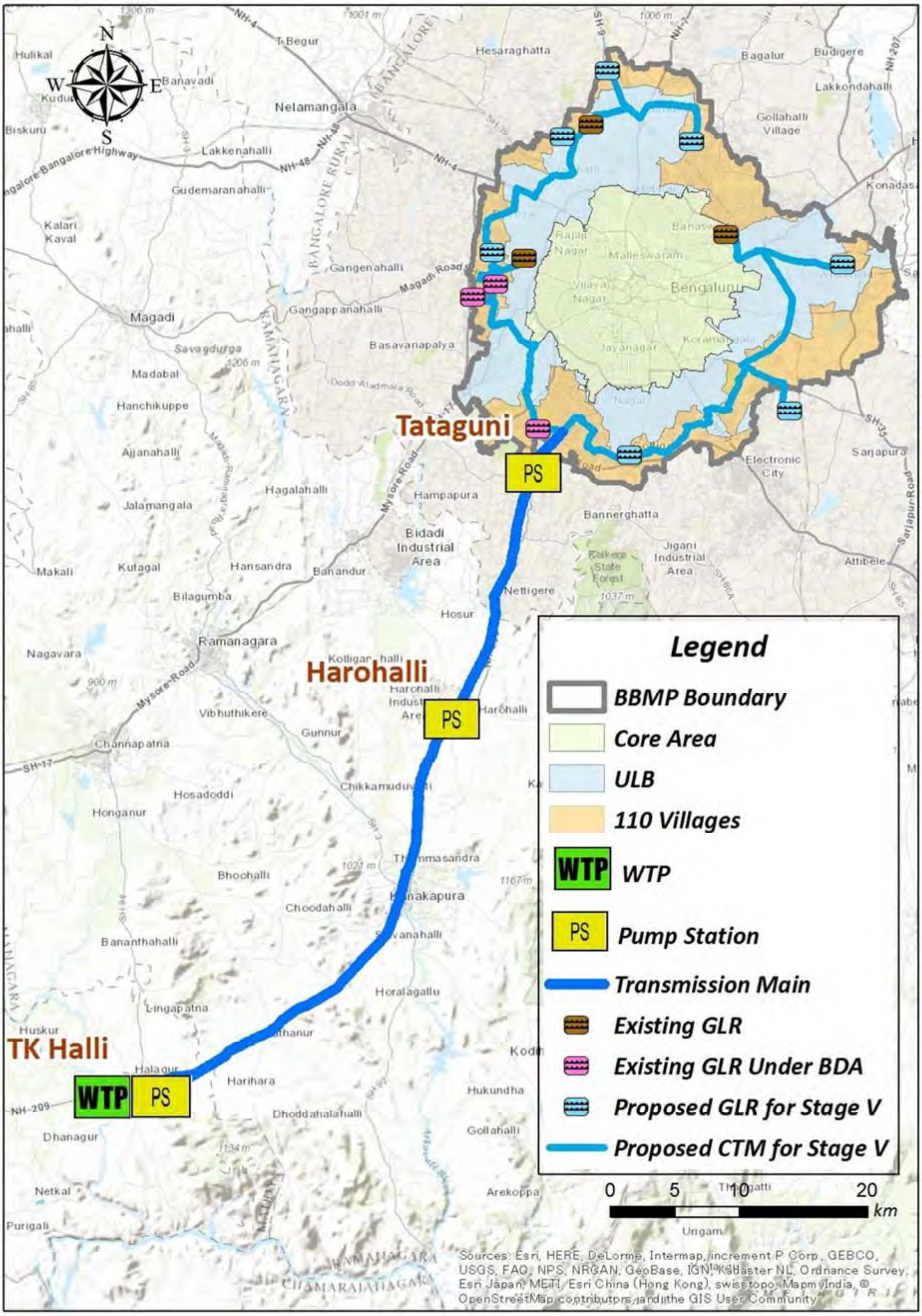


Figure 10.1.20 Outline of JICA Survey Project

10.2 Construction of Major Sewerage Facilities for 110 Villages

10.2.1 Projection of Population for 110 Villages and ULBs by Zone

There are 5 zones in the project area for the development of 110 Villages sewerage project. Population projection for major three areas in the BBMP area is made in Chapter 5, 5.1 Population projection by Area. In this sub-section, population for component villages and ULBs by zone for base year and target years are projected using a uniform growth rates to all villages. Population in 2034 and 2049 for all zones are projected at about 1.7 times and 2.7 times of the population in 2019. Table 10.2.1 presents projected population for the five zones for target years.

Table 10.2.1 Projection of Population for 110 Villages and ULBs by Zone

Zone	ULB/ Villages	CMC/TMC/ 110 Villages	Population			Total		
			2019	2034	2049	2019	2034	2049
1.Bytra-yanapura	ULB	Bytrayanapura	408,589	708,064	1,122,021	952,683	1,650,931	2,616,091
		Yelahanka	204,245	353,946	560,874			
		Sub-total	*612,834*	*1,062,010*	*1,682,895*			
	26 Villages		339,849	588,921	933,196			
2.Mahade-vpura	ULB	K.R. Puram	403,596	699,410	1,108,308	1,052,915	1,824,633	2,891,348
		Mahadevpura	334,266	579,266	917,924			
		Sub-total	*737,862*	*1,278,676*	*2,026,232*			
	23 Villages		315,053	545,957	865,116			
3.Bomana-halli	ULB	Bomanahalli	*487,626*	*845,032*	*1,339,064*	886,108	1,535,555	2,433,259
	33 Villages		398,482	690,523	1,094,195			
4.R.R. Nagar	ULB	R. R. Nagar	208,907	362,025	573,676	611,543	1,046,397	1,643,610
		Kengeri	92,018	159,462	252,689			
		Sub-total	*300,925*	*521,487*	*826,365*			
	17 Villages		310,618	524,910	817,245			
5.Dasara-halli	ULB	Dasarahalli	*635,833*	*1,101,865*	*1,746,050*	906,439	1,570,779	2,489,087
	11 Villages		270,606	468,914	743,037			
Total ULB			**2,775,080**	**4,809,070**	**7,620,606**	**4,409,688**	**7,628,295**	**12,073,395**
Total 110 Village			**1,634,608**	**2,819,225**	**4,452,789**			

Note: CMC: City Municipal Corporation, TMC: Town Municipal Corporation
Source: JICA Survey Team

The overall population in 2049 are projected at 12,073 thousand, which is broken down into ULB 7,621 thousand and 110 Villages 4,452 thousand. The zone with maximum population among the five zones is Mahadevpura (2,891 thousand in 2049), while the minimum one is R.R. Nagar (1,644 thousand in 2049). Population projection by zone is presented below.

(1) Bytrayanapura Zone

This zone consists of 2 ULBs and 26 villages. The population of the ULBs are about 60% of the zone total from base year 2019. Average population of the villages are projected at about 13 thousand in 2019 to 36 thousand in 2049 (see Table 10.2.2).

Table 10.2.2 Population Projection for Bytrayanapura Zone

No	ULB/110Villages	CMC/TMC/Village	Population		
			2019	2034	2049
1	26 Villages	Anantha Pura	9,849	17,068	27,044
2		Doddabetthalli	17,007	29,473	46,701
3		Chikkabetthalli	24,858	43,075	68,255
4		Harohalli	13,342	23,120	36,635
5		Kenchnehalli	6,789	11,763	18,640
6		Govindapura	4,309	7,466	11,832
7		Vasudvapura	520	902	1,432
8		Manchenhalli	369	639	1,012
9		Kattigenahalli	28,383	49,185	77,938
10		Srinivasapura	3,246	5,626	8,915
11		Bellhalli	4,085	7,078	11,217
12		Tirumenhalli	1,753	3,037	4,813
13		Chokkanahalli	3,570	6,185	9,799
14		Dasrahalli	20,130	34,880	55,268
15		Rachnehalli	13,078	22,662	35,911
16		Thanisandra	57,090	98,932	156,766
17		Chalakere	47,911	83,022	131,554
18		Horamavau Agara	24,182	41,905	66,405
19		Amani Byaratahikane	977	1,692	2,679
20		Geddalahalli	10,887	18,866	29,895
21		Kottanur Narayanpura	10,068	17,448	27,648
22		Kottanur	11,961	20,726	32,841
23		N Naganehalli	2,712	4,699	7,447
24		Kylasanahalli	7,838	13,583	21,523
25		Byrathi	9,753	16,904	26,788
26		Bilishivalli	5,183	8,985	14,238
Sub-total			339,849	588,921	933,196
27	2 ULBs	Bytrayanapura	408,589	708,064	1,122,021
28		Yelahanka	204,245	353,946	560,874
Sub-total			612,834	1,062,010	1,682,895
Total			**952,683**	**1,650,931**	**2,616,091**

Source: JICA Survey Team

(2) Mahadevpura Zone

This zone consists of 2 ULBs and 23 villages. The population of the ULBs are about 70% of the zone total from base year 2019. Average population of the villages are projected at about 14 thousand in 2019 to 38 thousand in 2049 (see Table 10.2.3).

Table 10.2.3 Population Projection for Mahadevpura Zone

No	ULB/110Villages	CMC/TMC/Village	Population		
			2019	2034	2049
1	23 Villages	Balagere	5,397	9,352	14,818
2		Bellanduramanikere (B) (P)	656	1,138	1,804
3		Belthur	36,862	63,876	101,218
4		Channasandra	33,415	57,903	91,752
5		Devarabeesanahalli	10,839	18,783	29,763
6		Gunjur	13,107	22,713	35,991
7		Hagadur	29,966	51,927	82,283
8		Kadabeesanahalli	5,185	8,986	14,239
9		Kariyammana Agrahara	4,865	8,432	13,361
10		Kadugodi Plantation	17,543	30,401	48,172
11		Khanekandya (B)	656	1,138	1,804
12		Kumbena Agrahar (P)	3,376	5,850	9,270
13		Nagondhalli	3,977	6,892	10,920
14		Panathur	8,591	14,887	23,590
15		Ramagondanahalli	8,462	14,664	23,237
16		Siddapura	4,537	7,862	12,458
17		Sorahunise	12,311	21,334	33,807
18		Tubarahalli	35,063	60,760	96,280
19		Varthur	26,637	46,159	73,143
20		Kalkere	23,566	40,836	64,710
21		Horamavu	14,567	25,243	39,999
22		K.Channasandra	10,906	18,899	29,947
23		Varanasi	4,571	7,920	12,550
Sub-total			315,053	545,957	865,116
24	2 ULBs	K.R. Puram	403,596	699,410	1,108,308
25		Mahadevpura	334,266	579,266	917,924
Sub-total			737,862	1,278,676	2,026,232
Total			**1,052,915**	**1,824,633**	**2,891,348**

Source: JICA Survey Team

(3) Bommanahalli Zone

This zone consists of 1 ULB and 33 villages. The population of the ULB is about 55% of the zone total from base year 2019. Average population of the villages are projected at about 12 thousand in 2019 to 33 thousand in 2049 (see Table 10.2.4).

Table 10.2.4 Population Projection for Bommanahalli Zone

No	ULB/110Villages	CMC/TMC/Village	Population		
			2019	2034	2049
1	33Villages	Alahalli	26,225	45,444	72,011
2		Ambalipura	4,062	7,039	11,154
3		Anjanapura	8,146	14,117	22,369
4		Basapura	2,990	5,182	8,211
5		Basavanapura	9,742	16,882	26,751
6		Beguru	50,076	86,776	137,503
7		Bellandur	23,784	41,214	65,308
8		Chandrashekarapura	882	1,528	2,421
9		Doddakallasandra	8,100	14,037	22,242
10		Gollahalli	9,749	16,894	26,770
11		Gottigere	21,471	37,207	58,958
12		Haraluru	8,001	13,865	21,971
13		Junnasandra	5,352	9,274	14,695
14		Kaikondranahalli	8,778	15,211	24,103
15		Kalenaagrahara	7,339	12,717	20,151
16		Kambathahalli	4,125	7,148	11,327
17		Kammanahalli	15,545	26,938	42,686
18		Kasavanahalli	8,058	13,964	22,127
19		Kudlu	49,472	85,730	135,846
20		Parappana Agrahara	16,898	29,282	46,400
21		Pillaganahalli	5,314	9,208	14,592
22		Raghuvanahalli	2,733	4,736	7,505
23		Talaghattapura	15,733	27,262	43,199
24		Thippasandra	1,789	3,100	4,911
25		Vajarahalli	9,595	16,627	26,348
26		Yelenahalli	2,183	3,782	5,993
27		Bharathena Agrahara	1,684	2,917	4,624
28		Bhoganahalli	3,851	6,674	10,574
29		Chikkabelandur	9,500	16,463	26,088
30		Chikkathoguru	5,043	8,739	13,847
31		Doddakannahalli	19,384	33,590	53,225
32		Doddathoguru	20,235	35,064	55,562
33		Naganathapura	12,645	21,912	34,720
Sub-total			398,482	690,523	1,094,195
34	1 ULB	Bommanahalli	487,626	845,032	1,339,064
Total			**886,108**	**1,535,555**	**2,433,259**

Source: JICA Survey Team

(4) R.R. Nagar Zone

This zone consists of 2 ULBs and 17 villages. The population of the ULB is about 49% of the zone total from base year 2019. Average population of the villages are projected at about 18 thousand in 2019 to 48 thousand in 2049(see Table 10.2.5).

Table 10.2.5 Population Projection for R.R. Nagar Zone

No	ULB/110Villages	CMC/TMC/Village	Population		
			2019	2034	2049
1	17 Villages	Vasanthapura	43,207	74,872	118,641
2		Ullalu	30,733	53,256	84,389
3		Sonnenhalli	4,037	6,996	11,085
4		Ganakallu	10,413	18,044	28,592
5		Hemmeigepura	54,105	88,258	125,642
6		Somapura	33,716	50,572	79,827
7		Varahasandra	2,004	3,473	5,502
8		Manavarthkavalu	1,484	2,571	4,074
9		Lingdernahalli	2,619	4,538	7,190
10		Hosahalli	5,193	8,998	14,258
11		Arehalli	10,420	18,056	28,612
12		Vaddarpalya	2,617	4,536	7,187
13		Uttrahalli	38,164	66,133	104,794
14		Subramanyapura	17,563	30,435	48,226
15		Gubbullalu	7,828	13,564	21,495
16		Turahalli	3,056	5,295	8,392
17		Giddakonenhalli	43,461	75,313	119,339
Sub-total			310,618	524,910	817,245
18	2 ULBs	R. R. Nagar	208,907	362,025	573,676
19		Kengeri	92,018	159,462	252,689
Sub-total			300,925	521,487	826,365
Total			**611,543**	**1,046,397**	**1,643,610**

Source: JICA Survey Team

(5) Dasarahalli Zone

This zone consists of 1 ULB and 11 villages. The population of the ULBs are about 70% of the zone total from base year 2019. Average population of the villages are projected at about 25 thousand in 2019 to 68 thousand in 2049. The large figure in average population is caused by 4 large-size villages with 35 to 87 thousand population in base year (see Table 10.2.6).

Table 10.2.6 Population Projection for Dasarahalli Zone

No	ULB/110Villages	CMC/TMC/Village	Population		
			2019	2034	2049
1	11 Villages	Abbigere	12,548	21,744	34,456
2		Chikkasandra	13,941	24,156	38,277
3		Shettihalli	10,129	17,550	27,810
4		Sidedahalli	43,740	75,795	120,103
5		Kariobanhalli	35,083	60,794	96,333
6		Handrahalli	17,541	30,396	48,165
7		Myadarahalli	2,365	4,097	6,492
8		Doddabidarakallu	35,092	60,808	96,356
9		Lingadeeranahalli (B)	8,770	15,196	24,081
10		Herohalli	86,924	150,627	238,683
11		Hosahalli	4,473	7,750	12,282
Sub-total			270,606	468,914	743,037
12	1 ULB	Dasarahalli	635,833	1,101,865	1,746,050
Total			**906,439**	**1,570,779**	**2,489,087**

Source: JICA Survey Team

10.2.2 Projection of Sewage Volume for Target Years for 110 Villages and ULBs by Zone

Present and planned sewage volume for the total of 110 Villages is estimated in Chapter 7. Population by village are projected in previous sub-section 10.2.1. Sewage volume through the future is estimated in this sub-section by zone using per capita sewage generation rate of 132 lpcd, as studied in Sub-section 7.1. Sewage volume for target years by zone is summarized in Table 10.2.7.

Table 10.2.7 Projection of Sewage Volume for Target Years by Zone

Zone Name	Population		Sewage Flow（MLD）	
	2034	2049	2034	2049
Bytrayanapura	1,650,931	2,616,091	219	346
Mahadevpura	1,824,633	2,891,348	241	383
Bommanahalli	1,535,555	2,433,259	203	322
R.R. Nagar	1,046,397	1,643,610	139	218
Dasarahalli	1,570,779	2,489,087	208	329

Source: JICA Survey Team

Sewage volume of component villages and ULBs for target years are presented by zone as follows;

(1) Bytrayanapura Zone

Table 10.2.8 shows planned sewage flow for target years. Total sewage flow to be generated in 2034 (Stage I target year) in the zone is estimated at 218,580 m^3/d, more than 60 % of which is generated in the ULBs.

Table 10.2.8 Projection of Sewage Volume for Bytrayanapura Zone

No	ULB/110Villages	CMC/TMC/Village	Population		Sewage Flow(m^3/day)	
			2034	2049	2034	2049
1	26 Villages	Anantha Pura	17,212	27,274	2,270	3,600
2		Doddabetthalli	29,722	47,097	3,920	6,220
3		Chikkabetthalli	43,439	68,834	5,730	9,090
4		Harohalli	23,316	36,946	3,080	4,880
5		Kenchnehalli	11,863	18,798	1,570	2,480
6		Govindapura	7,529	11,932	990	1,580
7		Vasudvapura	910	1,444	120	190
8		Manchenhalli	644	1,021	90	130
9		Kattigenahalli	49,601	78,599	6,550	10,380
10		Srinivasapura	5,674	8,991	750	1,190
11		Bellhalli	7,138	11,312	940	1,490
12		Tirumenhalli	3,063	4,854	400	640
13		Chokkanahalli	6,237	9,882	820	1,300
14		Dasrahalli	35,175	55,737	4,640	7,360
15		Rachnehalli	22,854	36,216	3,020	4,780
16		Thanisandra	99,769	158,096	13,170	20,870
17		Chalakere	83,724	132,670	11,050	17,510
18		Horamavau Agara	42,260	66,969	5,580	8,840
19		Amani Byaratahikane	1,706	2,702	230	360
20		Geddalahalli	19,026	30,149	2,510	3,980
21		Kottanur Narayanpura	17,596	27,883	2,320	3,680
22		Kottanur	20,901	33,120	2,760	4,370
23		N Naganehalli	4,739	7,510	630	990
24		Kylasanahalli	13,698	21,706	1,810	2,870
25		Byrathi	17,047	27,015	2,250	3,570
26		Bilishivalli	9,061	14,359	1,200	1,900
Sub-total			593,904	941,116	78,400	124,250
27	2 ULBs	Bytrayanapura	708,064	1,122,021	93,460	148,110
28		Yelahanka	353,946	560,874	46,720	74,040
Sub-total			1,062,010	1,682,895	140,180	222,150
Total			**1,655,914**	**2,624,011**	**218,580**	**346,400**

Source: JICA Survey Team

(2) Mahadevpura Zone

Table 10.2.9 shows planned sewage flow for target years. Total sewage flow to be generated in 2034 (Stage I target year) in the zone is estimated at 241,450 m^3/d, more than 70% of which is generated in the ULBs.

Table 10.2.9 Projection of Sewage Volume for Mahadevpura Zone

No	ULB/110Villages	CMC/TMC/Village	Population		Sewage Flow(m^3/day)	
			2034	2049	2034	2049
1	23 Villages	Balagere	9,431	14,944	1,240	1,970
2		Bellanduramanikere (B) (P)	1,148	1,819	150	240
3		Belthur	64,417	102,077	8,500	13,470
4		Channasandra	58,393	92,531	7,710	12,210
5		Devarabeesanahalli	18,942	30,016	2,500	3,960
6		Gunjur	22,905	36,296	3,020	4,790
7		Hagadur	52,366	82,981	6,910	10,950
8		Kadabeesanahalli	9,062	14,360	1,200	1,900
9		Kariyammana Agrahara	8,503	13,474	1,120	1,780
10		Kadugodi Plantation	30,658	48,581	4,050	6,410
11		Khanekandya (B)	1,148	1,819	150	240
12		Kumbena Agrahar (P)	5,900	9,349	780	1,230
13		Nagondhalli	6,950	11,013	920	1,450
14		Panathur	15,013	23,790	1,980	3,140
15		Ramagondanahalli	14,788	23,434	1,950	3,090
16		Siddapura	7,929	12,564	1,050	1,660
17		Sorahunise	21,515	34,094	2,840	4,500
18		Tubarahalli	61,274	97,097	8,090	12,820
19		Varthur	46,550	73,764	6,140	9,740
20		Kalkere	41,182	65,259	5,440	8,610
21		Horamavu	25,457	40,339	3,360	5,320
22		K.Channasandra	19,059	30,201	2,520	3,990
23		Varanasi	7,987	12,657	1,050	1,670
Sub-total			550,577	872,459	72,670	115,140
24	2 ULBs	K.R. Puram	699,410	1,108,308	92,320	146,300
25		Mahadevpura	579,266	917,924	76,460	121,170
Sub-total			1,278,676	2,026,232	168,780	267,470
Total			**1,829,253**	**2,898,691**	**241,450**	**382,610**

Source: JICA Survey Team

(3) Bommanahalli Zone

Table 10.2.10 shows planned sewage flow for target years. Total sewage flow to be generated in 2034 (Stage I target year) in the zone is estimated at 203,460 m^3/d, about 50% of which is generated in the ULB.

Table 10.2.10 Projection of Sewage Volume for Bommanahalli Zone

No	ULB/110Villages	CMC/TMC/Village	Population		Sewage Flow(m^3/day)	
			2034	2049	2034	2049
1	33 Villages	Alahalli	45,829	72,622	6,050	9,590
2		Ambalipura	7,099	11,249	940	1,480
3		Anjanapura	14,236	22,559	1,880	2,980
4		Basapura	5,226	8,281	690	1,090
5		Basavanapura	17,025	26,978	2,250	3,560
6		Beguru	87,510	138,670	11,550	18,300
7		Bellandur	41,563	65,862	5,490	8,690
8		Chandrashekarapura	1,541	2,442	200	320
9		Doddakallasandra	14,156	22,431	1,870	2,960
10		Gollahalli	17,037	26,997	2,250	3,560
11		Gottigere	37,522	59,458	4,950	7,850
12		Haraluru	13,982	22,157	1,850	2,920
13		Junnasandra	9,352	14,820	1,230	1,960
14		Kaikondranahalli	15,340	24,308	2,020	3,210
15		Kalenaagrahara	12,825	20,322	1,690	2,680
16		Kambathahalli	7,208	11,423	950	1,510
17		Kammanahalli	27,166	43,048	3,590	5,680
18		Kasavanahalli	14,082	22,315	1,860	2,950
19		Kudlu	86,455	136,999	11,410	18,080
20		Parappana Agrahara	29,530	46,794	3,900	6,180
21		Pillaganahalli	9,286	14,716	1,230	1,940
22		Raghuvanahalli	4,776	7,569	630	1,000
23		Talaghattapura	27,493	43,566	3,630	5,750
24		Thippasandra	3,126	4,953	410	650
25		Vajarahalli	16,768	26,572	2,210	3,510
26		Yelenahalli	3,814	6,044	500	800
27		Bharathena Agrahara	2,942	4,663	390	620
28		Bhoganahalli	6,730	10,664	890	1,410
29		Chikkabelandur	16,602	26,309	2,190	3,470
30		Chikkathoguru	8,813	13,965	1,160	1,840
31		Doddakannahalli	33,874	53,677	4,470	7,090
32		Doddathoguru	35,361	56,034	4,670	7,400
33		Naganathapura	22,097	35,015	2,920	4,620
Sub-total			696,366	1,103,482	91,920	145,650
34	1 ULB	Bommanahalli	845,032	1,339,064	111,540	176,760
Total			**1,541,398**	**2,442,546**	**203,460**	**322,410**

Source: JICA Survey Team

(4) R.R. Nagar Zone

Table 10.2.11 shows planned sewage flow for target years. Total sewage flow to be generated in 2034 (Stage I target year) in the zone is estimated at 138,700 m^3/d, about 55% of which is generated in the ULB.

Table 10.2.11 Projection of Sewage Volume for R.R. Nagar Zone

No	ULB/110Villages	CMC/TMC/Village	Population		Sewage Flow(m^3/day)	
			2034	2049	2034	2049
1	17 Villages	Vasanthapura	75,505	119,648	9,970	15,790
2		Ullalu	53,707	85,105	7,090	11,230
3		Sonnenhalli	7,055	11,179	930	1,480
4		Ganakallu	18,197	28,835	2,400	3,810
5		Hemmeigepura	89,005	126,708	11,750	16,730
6		Somapura	51,000	80,505	6,730	10,630
7		Varahasandra	3,502	5,549	460	730
8		Manavarthkavalu	2,593	4,109	340	540
9		Lingdernahalli	4,576	7,251	600	960
10		Hosahalli	9,074	14,379	1,200	1,900
11		Arehalli	18,209	28,855	2,400	3,810
12		Vaddarpalya	4,574	7,248	600	960
13		Uttrahalli	66,693	105,683	8,800	13,950
14		Subramanyapura	30,692	48,635	4,050	6,420
15		Gubbullalu	13,679	21,677	1,810	2,860
16		Turahalli	5,340	8,463	700	1,120
17		Giddakonenhalli	75,950	120,352	10,030	15,890
Sub-total			529,351	824,181	69,860	108,810
18	2 ULBs	R. R. Nagar	362,025	573,676	47,790	75,730
19		Kengeri	159,462	252,689	21,050	33,350
Sub-total			521,487	826,365	68,840	109,080
Total			**1,050,838**	**1,650,546**	**138,700**	**217,890**

Source: JICA Survey Team

(5) Dasarahalli Zone

Table 10.2.12 shows planned sewage flow for target years. Total sewage flow to be generated in 2034 (Stage I target year) in the zone is estimated at 207,870 m^3/d, about 70% of which is generated in the ULBs.

Table 10.2.12 Projection of Sewage Volume for Dasarahalli Zone

No	ULB/110Villages	CMC/TMC/Village	Population		Sewage Flow(m^3/day)	
			2034	2049	2034	2049
1	11 Villages	Abbigere	21,928	34,748	2,890	4,590
2		Chikkasandra	24,360	38,602	3,220	5,100
3		Shettihalli	17,699	28,046	2,340	3,700
4		Sidedahalli	76,436	121,122	10,090	15,990
5		Kariobanhalli	61,308	97,151	8,090	12,820
6		Handrahalli	30,653	48,574	4,050	6,410
7		Myadarahalli	4,132	6,547	550	860
8		Doddabidarakallu	61,323	97,174	8,090	12,830
9		Lingadeeranahalli (B)	15,325	24,285	2,020	3,210
10		Herohalli	151,902	240,709	20,050	31,770
11		Hosahalli	7,816	12,386	1,030	1,630
Sub-total			472,882	749,344	62,420	98,910
12	1 ULB	Dasarahalli	1,101,865	1,746,050	145,450	230,480
Total			**1,574,747**	**2,495,394**	**207,870**	**329,390**

Source: JICA Survey Team

10.2.3 Establishment of Sewerage Systems for 110 Villages by Zone Together with Locations of STPs

(1) Alternative Study on Sewerage Systems by Zone

1) Planned Sewerage Systems in the DPR for 110 Villages Water Supply and Sewerage Project

Sewerage systems for the 110 Villages are generally determined considering watershed/s in the study village/s referring to the locations of rivers, drainages and lakes. Accordingly, the sewage generated in each sewerage system is basically collected by gravity.

Giving priority to geographical conditions for the establishment of sewerage systems, some generated sewage in the villages and ULBs concerned in each sewerage system flows either into planned STP in the village or into the STP planned for the ULB.

A total of 33 sewerage systems are either existing (7 systems), on-going (under construction: 13 systems including 3 expansion systems at existing systems) or proposed in the DPR (16 systems) for sewerage services to cover 110 Villages and part of 8 ULBs. Table 10.2.13 shows existing/on-going and proposed sewerage systems by zone in the project area. The sewerage systems for the 110 Villages including part of ULBs are presented in Figure 10.2.1.

Table 10.2.13 Existing/On-going/Proposed STPs by Zone in the Project Area

No	Zone	STP					Status of On-going Project
		No	Name	Existing	On-going	Proposed	
1	Bytrayanapura	1	Kattigenahalli			○	
		2	Yelahankakere			○	
		3	Doddabettahalli			○	
		4	Bilishivalli			○	
		17	Puttenahalli		○		Under planning
		18	Jakkur	○	○		Upgrading of existing STP constructed in Phase 1 Project
		19	Horamavu		○		Under construction in Phase 2 Project
		20	Allalasandra	○			Phase 1 Existing (Tertiary Treatment)
		21	Raja Canal	○	○		Under Construction in Phase 2 Project
2	Mahadevpura	5	Hagadur			○	
		22	Varthur Kodi		○		Under planning
		23	Amanikere		○		Under construction in Phase 2 Project
		24	Kadugodi		○		Under construction in Phase 2 Project
		25	Yellamalappa Chetty		○		Under construction in Phase 2 Project
		26	Kadabesanahalli	○			
		27	K R Puram	○			
3	Bommanahalli	6	Naganathapura			○	
		7	Pillaganahalli			○	
		8	Talaghattapura			○	

No	Zone	STP					Status of On-going Project
		No	Name	Existing	On-going	Proposed	
		28	Anjanapura		○		BDA Project: under planning
4	R.R. Nagar	9	Somapura			○	
		10	Hemigepura 1			○	
		11	Hemigepura 2			○	
		29	Doddabele (Chodenapura)		○		Under construction
		30	Kengeri		○		Under construction in Phase 2 Project
		31	Mailasandra	○			
5	Dasarahalli	12	Daddabidarakallu			○	
		13	Karivobanahalli			○	
		14	Herohalli			○	
		15	Hosahalli			○	
		16	Chikkabanavara-2			○	
		32	Chikkabanavara		○		Under construction in Phase 2 Project
		33	Nagasandra	○	○		Under construction in Phase 2 Project
Total Number				7	13	16	

Note: On-going projects include under construction and/or under planning/bidding process

Source: BWSSB

2) Alternative Study on Proposed 16 Sewerage Systems

Proposed sewerage systems in the DPR were reviewed in view of adequacy of the service areas to be covered by respective sewerage systems, economic advantages in capital and O&M cost and environmental considerations. The following are specific conditions considered for the study.

- Topographic conditions in the planned service area
- Planned location of STP site and its land availability
- Merging possibility of the study sewerage system into the neighboring sewerage system
- Conservation of water environment, especially for the protection of the lakes

The planned sites for the STPs in the DPR were confirmed in the field survey and inadequate sites in terms of ownership, available land area and environmental conditions were replaced by alternative sites through joint work by JICA Survey Team and BWSSB personnel in charge of land acquisition. In case that the new sites are identified, BWSSB shall proceed required procedures for land acquisition. BWSSB decided the location of all STP sites for the project and started the procedures to acquire the land.

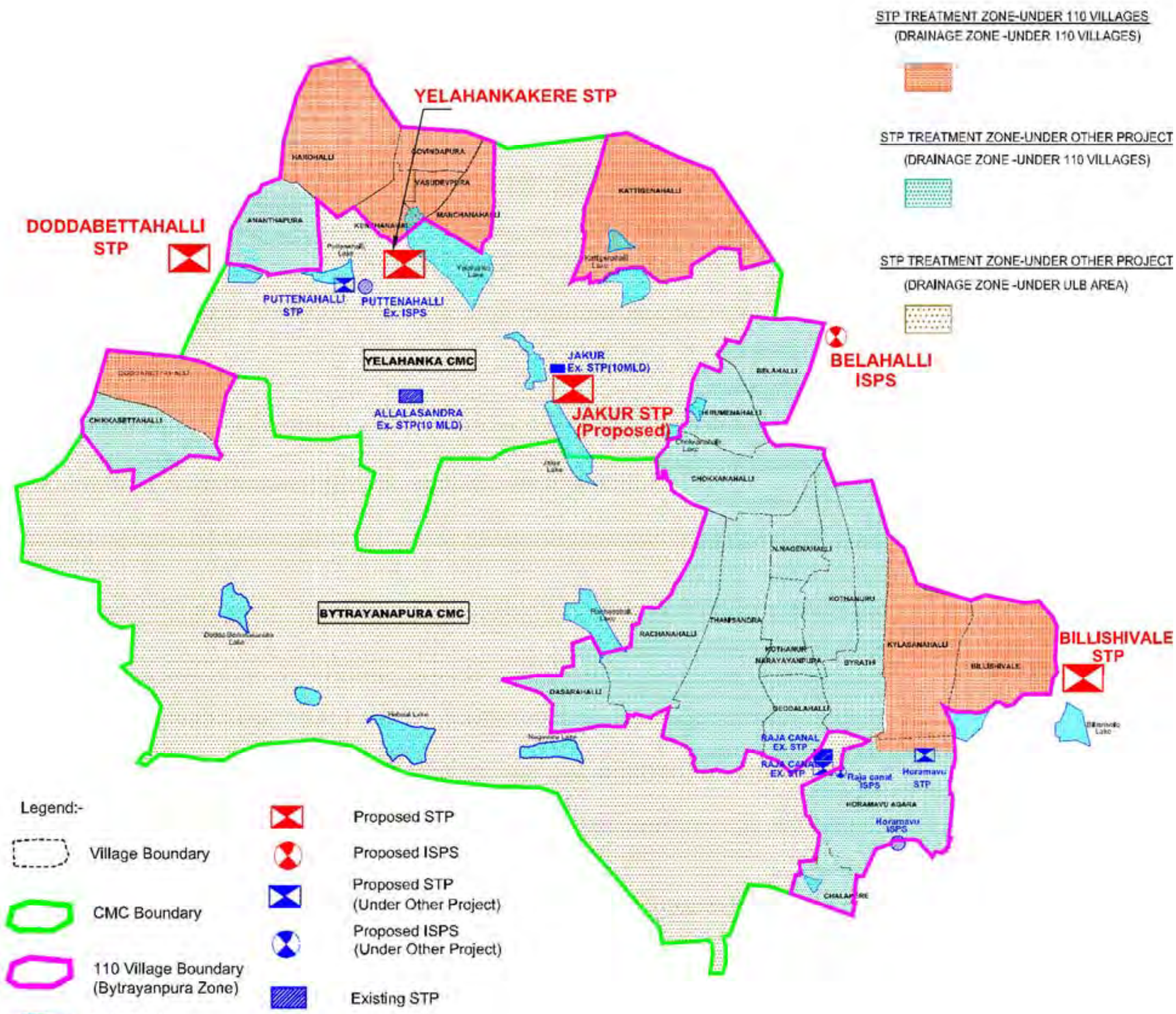
Source: JICA Survey Team

Figure 10.2.1 Sewerage Systems for 110 Villages Including Part of ULBs

The followings are study results on sewerage systems by zone with reference to the plans in the DPR.

a) Bytrayanapura Zone

Four (4) sewerage systems are proposed for this zone in the DPR as shown in Figure 10.2.2. Relevant information and study results are summarized by the planned sewerage system.



Source: JICA Survey Team

Figure 10.2.2 Proposed Sewerage Systems in Bytrayanapura Zone

i. Kattigenahalli (Jakkur) Area

The area is topographically mild being occupied by built-up area. The area belongs to Kattigenahalli Lake drainage area. The site for the STP was planned in the DPR near the upstream of the lake, where the sewage flows in. But presently the site is under development by the private sector. Also, outer ring road is planned around the area. Thus, the new site at Jakkur existing STP was selected, which is located about 4.6 km downstream from originally planned site. Existing sludge drying bed will be demolished for the construction of a new STP. BWSSB has already started the rehabilitation/arrangement of the existing plant to make the required land available.

The sewage generated in the study area was hydrologically confirmed to be collected by gravity to the newly selected STP site. A main sewer line is planned along existing drainage to finally connect to the planned STP. Photo 10.2.1 shows alignment of the main sewer line and location of STP site.

Location of STP & Alignment of Main Sewer Line

Proposed site at Jakkur STP

Photo 10.2.1 Location of No.1 STP and Alignment of Main Sewer Line

ii. Yelahankakere Area

This area is generally plain area. Land development at present seems to be in the initial stage, although a railway crosses the area. The sewerage system is planned for the drainage area of Yelahankakere Lake. The site for the STP in the DPR was planned near the south-western edge of the lake, where sewage in the drainage flows in. But, it was found that the land is owned by the private sector and it is under development.

A new site at the northern edge of the lake was found, where sewage in the study area flows into the lake. The land is owned by public authority without development plan so far. In the beginning of January, 2017, BWSSB finally selected a new STP site with larger land area available at the eastern edge of the lake. The land area at this site is sufficient enough to treat additional sewage from Kattigenahalli Area. The main sewer line is planned along existing drainage to connect to the planned STP. Photo 10.2.2 shows alignment of the main sewer line and location of STP site.

Location of STP & Alignment of Main Sewer Line

Proposed STP Site

Photo 10.2.2 Location of No.2 STP and Alignment of Main Sewer Line

iii. Doddabettahalli Area

The land development in the area seems to have been initiated recently, although there are some built-up areas. The service area is planned for the drainage area of Veerasagara Lake, where there is not so much undulation. The STP site was planned in the DPR near Veerasagara Lake, where sewage flows in. But land has been under development at the candidate STP site. An alternative site was found about 1.2 km away from the planned original site. The collection of sewage by gravity to the newly selected STP was technically confirmed and the site was determined for this project.

An alternative plan was studied to merge the study area into Yelahankakere sewerage system sending sewage via ISPS in the fact that there exists an illegal house in the selected STP site. However, this alternative plan was not adopted and BWSSB will ensure above mentioned site for the STP with a careful arrangement with an illegal house. The main sewer line is planned along existing drainage. Photo 10.2.3 shows alignment of the main sewer line and location of STP site.

Location of STP & Alignment of Main Sewer Line

Proposed STP Site

Photo 10.2.3 Location of No.3 STP and Alignment of Main Sewer Line

iv. Bilishivale Area

This area is generally a plain area. Built-up area is formed all over the study area, which falls on the drainage area of Rampura Lake. The STP site in the DPR was planned near sewage inflow point at the lake. However, the site is located within the lake and currently illegal land reclamation is in progress. An alternative public land was found, which is located about 0.4 km from the original site, where generated sewage can be hydrologically collected by gravity. The main sewer line is planned to install along existing drainage. Photo 10.2.4 shows alignment of the main sewer line and location of STP site.

Location of STP & Alignment of Main Sewer Line	Proposed STP Site

Photo 10.2.4 Location of No.4 STP and Alignment of Main Sewer Line

v. Raja Canal Area

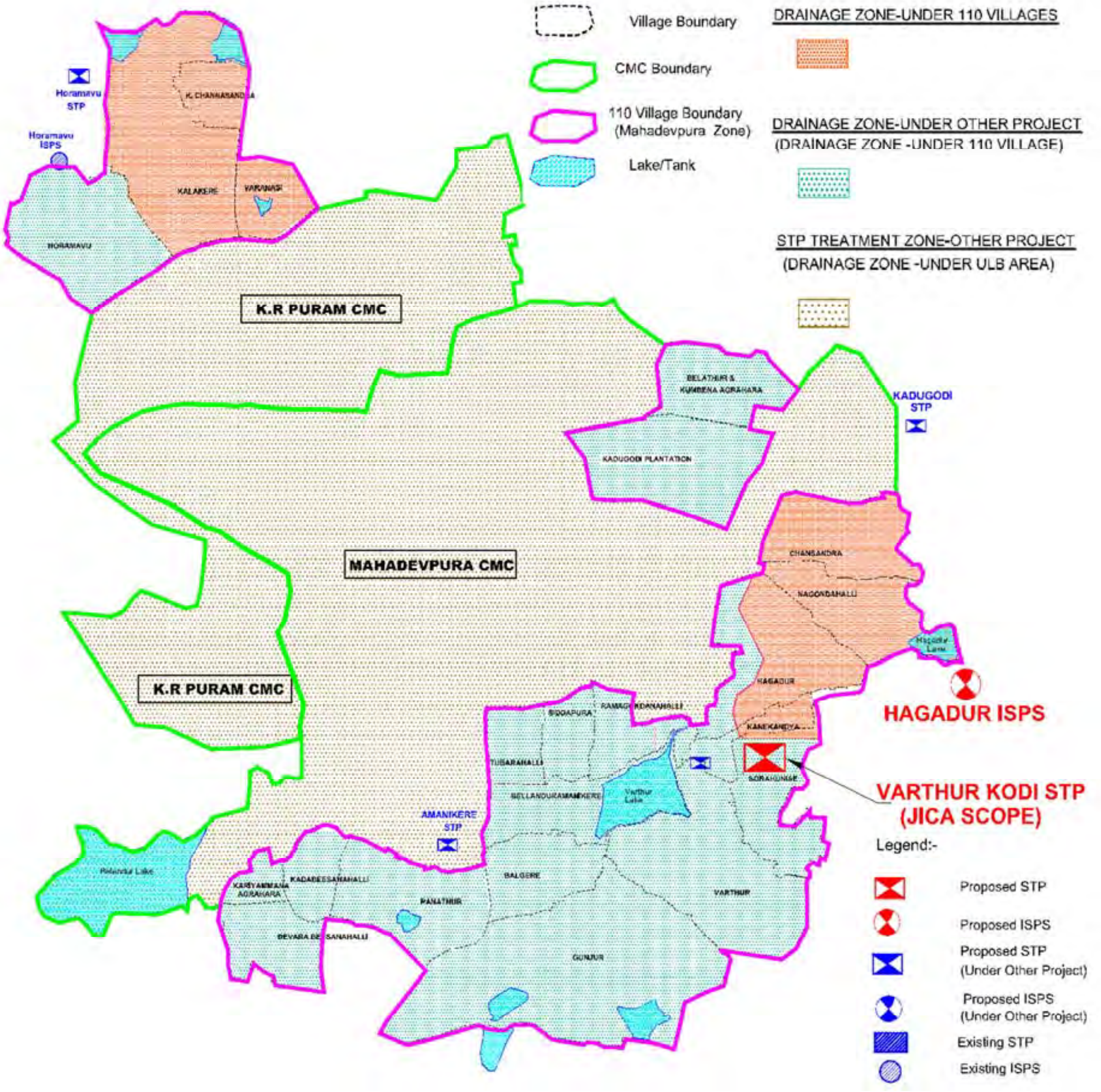
This area has an existing STP (Raja Canal STP) with a capacity of 40MLD and presently under expansion for additional 40MLD under Phase 2 project. An ISPS is planned in the DPR (Bellahalli ISPS) to send sewage to the existing sewerage system. The adequate location of the ISPS, as recommended in DPR is presented in Photo 10.2.5.

Location of Proposed Bellahalli ISPS	Bellahalli ISPS Site

Photo 10.2.5 Location of Bellahalli ISPS and Alignment of Main Sewer Line

b) Mahadevpura Zone

One (1) sewerage system is proposed for this zone in the DPR as shown in Figure 10.2.3. Relevant information and study results are summarized for the sewerage system.



Source: JICA Survey Team

Figure 10.2.3 Proposed Sewerage Systems in Mahadevpura Zone

i. Hagadur Area

The area is developed as the built-up area, where land is undulated. The sewage generated in the study area flows into the rivers. The STP for the sewerage system was planned in the DPR at the confluence site of the two rivers. But the site is owned by private sector and land acquisition seemed to be problem. Thus, a new public owned site, about 0.7 km from the original site, was found, where generated sewage in the study area can be collected by gravity.

However, because of limited land availability, it was planned to merge study area into the Varthur sewerage system which is under planning by BWSSB. The sewage generated in the study area will be sent by ISPS to be constructed at the planned STP site. The Varthur STP for the merged sewerage system is planned to be constructed in this project, because of no financial arrangement for Varthur STP project as of now. There is an issue that an access road shall be developed to the proposed STP site. The main sewer line shall be installed along existing drainage.

Photo 10.2.6 shows an alignment of the main sewer line and location of STP site.

Location of STP & Alignment of Main Sewer line

Proposed ISPS Site

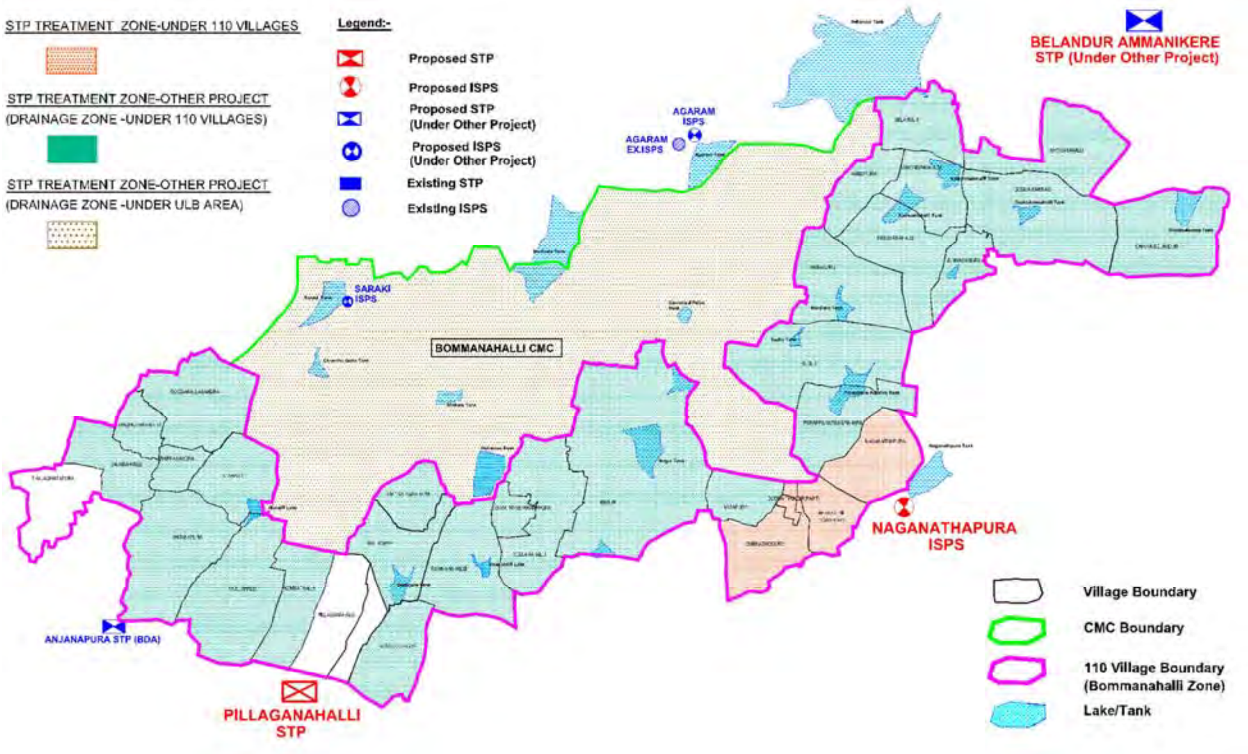
Proposed STP Site

The River along Planned Main Sewer Route

Photo 10.2.6 Location of No.5 STP, Hagadur ISPS and Alignment of Main Sewer line

c) Bommanahalli Zone

Three (3) sewerage systems are proposed for this zone in the DPR as shown in Figure 10.2.4. Relevant information and study results are summarized by the sewerage system.



Source: JICA Survey Team

Figure 10.2.4 Proposed Sewerage Systems in Bommanahalli Zone

i. Naganathapura Area

The area is developed as the built-up area where it is rich in topography. The study area falls on the drainage area of Raisandra Lake, where generated sewage in the study area flows in. Two alternative sites for the STP were proposed in the DPR near the sewage inflow point into Raisandra Lake. One of the proposed public sites was selected for the STP. It was found that the land is not suitable for the construction of the STP and illegal houses exist. However, no alternative STP site was found near the planned site, resulted in the need of the transfer of the sewage to neighboring drainage area.

Under this constraint, available information on the sewerage plan and on-going sewerage project was collected. There is a plan of main sewer line “named as TS426”, about 2.5 km from originally planned STP site, which is planned to connect to the Amanikere STP (under construction). Since the design of the main sewer line will be made under preliminary design of this project and it was found that the Amanikere STP would have allowance in the land area and the capacity of an existing main sewer named TS-4213. Because of the reduction of service area from original plan for Amanikere STP, the sewage collected from Naganathapura area can be sent to the Amanikere STP for the treatment (planned sewage is 13 MLD in 2049).

According to this revised plan, an ISPS shall be constructed at the site where BWSSB selected as an alternative STP site as mentioned above and the main sewer line shall be installed along existing drainage to connect to the planned main sewer line for other planned sewerage system. Photo 10.2.7 shows an alignment of the main sewer line and location of ISPS and STP site.

Location of STP & Alignment of Main Sewer Line

Proposed ISPS Site

Construction of the Facilities at Amanikere STP

Main Sewer Connection Point

Photo 10.2.7 Location of Naganathapura ISPS, Amanikere STP and Alignment of Main Sewer Line

ii. Pillaganahalli Area

The overall area is a built-up area with a mild topography. The sewage generated in the study area flows into the rivers. Two STP sites were proposed in the DPR at the bank of the rivers. One of the site is under development and no more available for the project. Another site, about 1.0 km far from the mentioned above site was selected, which allows for the collection of sewage in the study area by gravity. The main sewer line shall be planned along existing drainage. Photo 10.2.8 shows alignment of the main sewer line and location of STP site.

Location of STP & Alignment of Main Sewer Line

Proposed STP Site

Photo 10.2.8 Location of No.7 STP and Alignment of Main Sewer Line

iii. Talaghattapura Area

The overall area is a built-up area with a gentle topography. The study area falls on the drainage area of Talaghattapura Lake. Two STP sites were proposed in the DPR near Talaghattapura Lake. It was found in the field survey that the land area available for the planned STP sites is not sufficient enough. Thus, a new site with required land area was selected, which is about 1.5 km far from the south western edge of the lake.

The main sewer line shall be installed along existing drainage. Photo 10.2.9 shows alignment of the main sewer line and location of STP site.

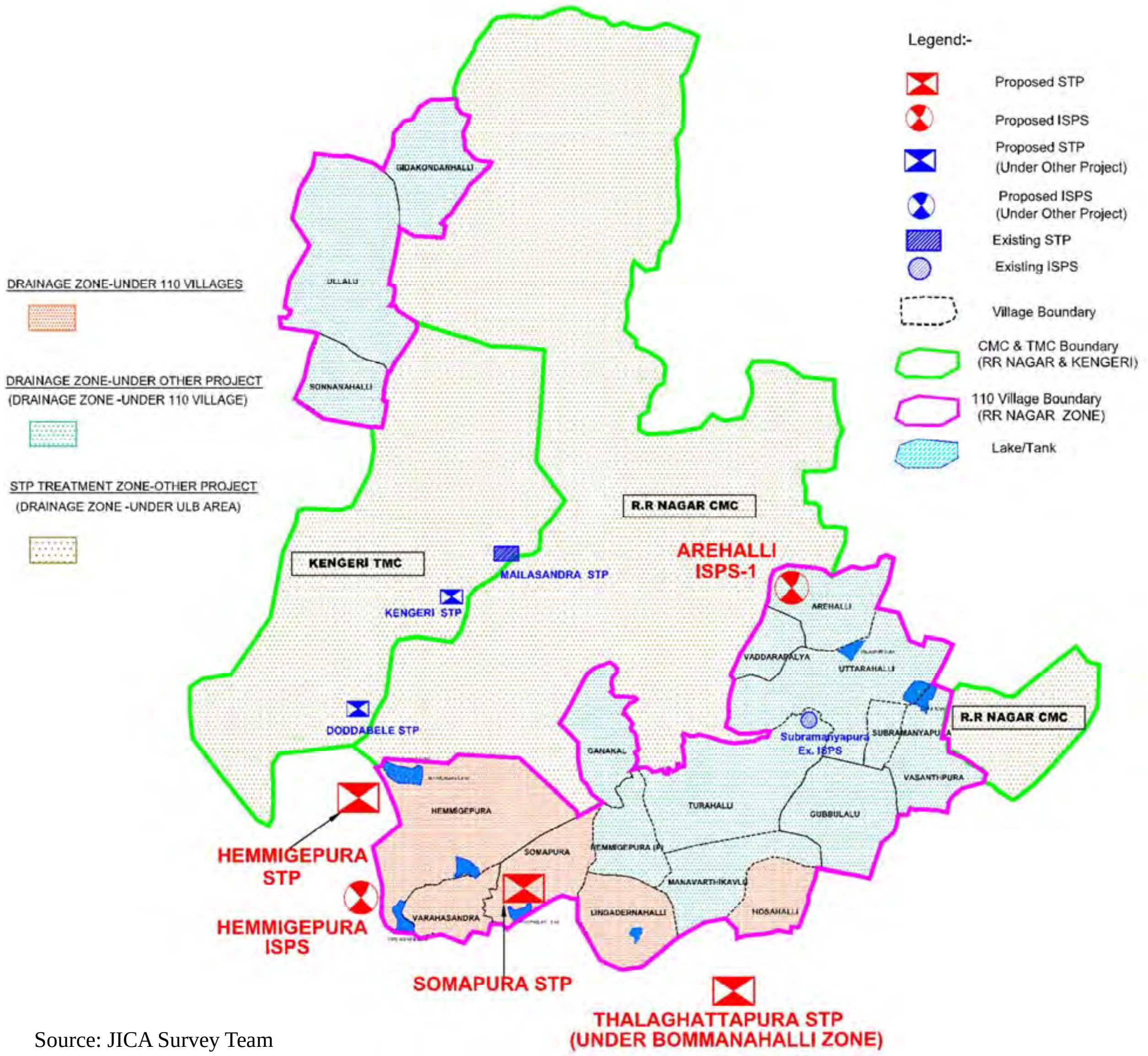
Location of STP & Alignment of Main Sewer Line

Proposed STP Site

Photo 10.2.9 Location of No.8 STP and Alignment of Main Sewer Line

d) R.R. Nagar Zone

Four (4) sewerage systems are proposed for this zone in the DPR as shown in Figure 10.2.5. One of the sewerage systems is planned with an ISPS to send sewage to the existing sewerage system. Relevant information and study results are summarized for the sewerage system.



Source: JICA Survey Team

Figure 10.2.5 Proposed Sewerage Systems in R.R. Nagar Zone

i. Somapura Area

Two (2) highways are located in the northern and western part of the study area. Sanitary sewers are installed in the majority of the study area which is the drainage area of Sompura Lake, where sewage generated in the study area flows in by gravity. The STP site (public land) was planned in the DPR at the point near the lake where sewage flows in. The main sewer line shall be installed along existing drainage. Photo 10.2.10 shows alignment of the main sewer line and location of STP site.

	
Location of STP & Alignment of Main Sewer Line	Proposed STP Site

Photo 10.2.10 Location of No.9 STP and Alignment of Main Sewer line

ii. Hemigepura-1 Area

The part of planned Hemigepura-1 area is provided with sewers in the process of land development, but more than half of the area are not covered with the sewer system. The study area falls on the drainage area of Varahasandra Lake, where generated sewage in the area flows into. The planned STP site for the area in the DPR is located in the public land near Varahasandra Lake, but available land area is limited and no expansion will be allowed because the site is surrounded by privately owned land.

Under the above critical condition on the land acquisition for the Hemigepura-1 area, combined sewage treatment with neighboring Hemigepura- 2 area was studied, "newly selected STP site (refer to Hemigepura- 2 area study in iii) of R.R. Nagar zone)" of which is located near planned STP for Hemigepura-1 area and has sufficient land for the two areas with about 4 ha. The collected sewage in Hemigepura-1area shall be pumped up to the STP planned for Hemigepura-2 area in provision of ISPS at the site planned for the STP for Hemigepura -1 area. The main sewer line will be installed along drainage for the gravity sewer section, while under the road for force main section. As a result of the combined treatment of the Hemigepura -1 and -2 areas, the sewerage system will become Hemigepura sewerage area (see Photo 10.2.11).

	
Location of ISPS and Main Sewer Line	Proposed ISPS Site

Photo 10.2.11 Location of ISPS and Alignment of Main Sewer Line

iii. Hemigepura-2 Area

Most of the Hemigepura-2 area planned in the DPR is covered with a sewer system. The study area falls on the drainage basin of Vrishabhavati River, where generated sewage in the area flows in by gravity. The site for the STP for the study area was planned along Nice Road near Sompura Lake, but it was confirmed in the field that the land is owned by private sector. The land owned by BWSSB was found, just opposite side of the planned land along the Nice Road. The identified land is sufficient area for the STP and allows for the collection of sewage by gravity in the study area. This newly selected site shall be used for the sewerage treatment in the Hemigepura area. The main sewer line will be installed along drainage. As discussed in the study for Hemigepura-1 area, Hemigepura-1 and 2 shall be combined to treat sewage at newly selected Hemigepura STP. A sewage treatment plant (Doddabele STP) is under construction, which is located near planned STP for Hemigepura area. However, the combination of Hemigepura area to this on-going sewerage system was not considered due to limited land area available. Photo 10.2.12 shows newly selected STP site.

	
Location of STP & Alignment of Main Sewer Line	Proposed STP Site

Photo 10.2.12 Location of No.11 STP and Alignment of Main Sewer Line

iv. Kengeri, Mailasandra and Doddabele Area

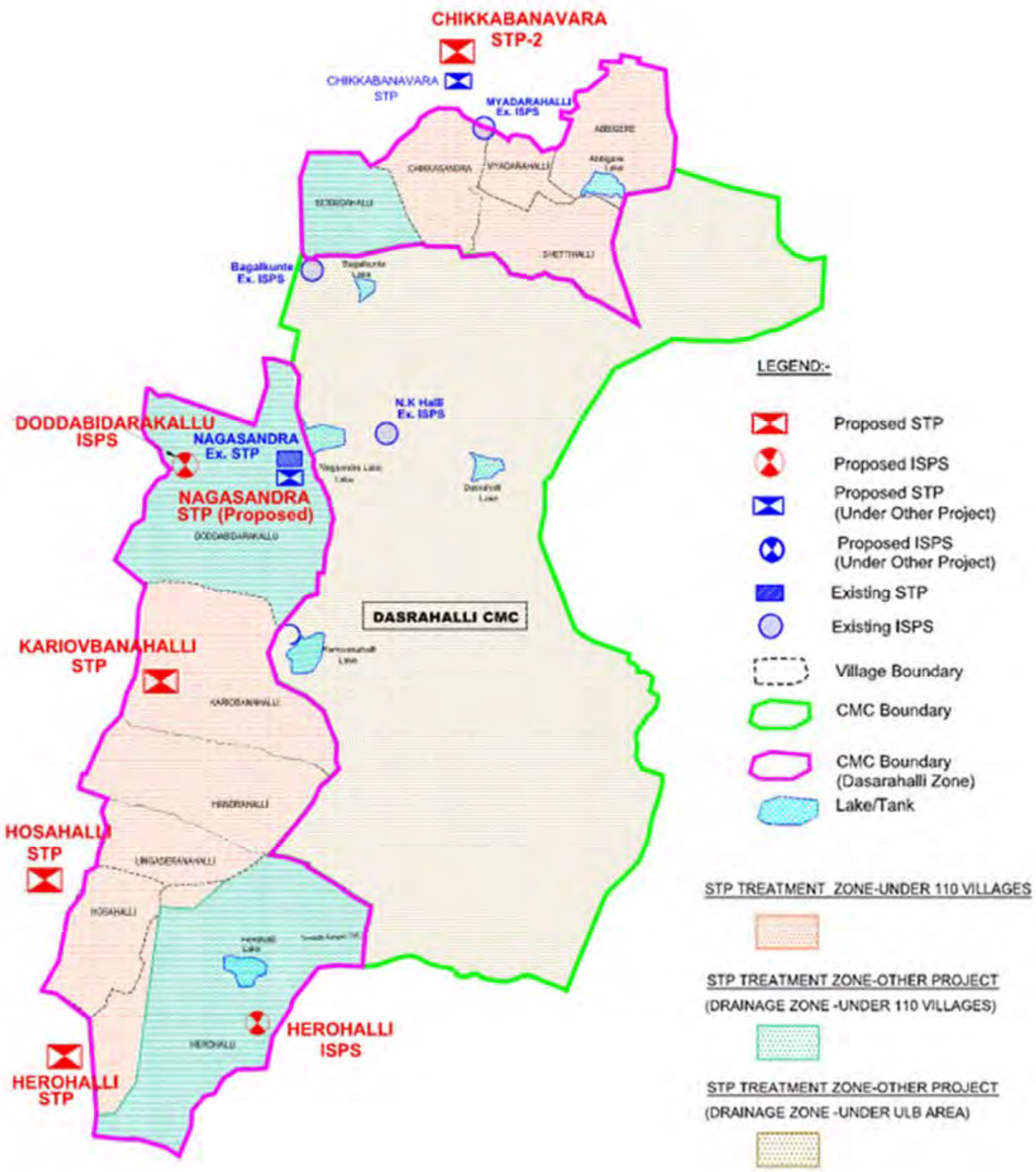
There are three existing STPs (Kengeri, Mailasandra and Doddabele area) in this study area, constructed by Phase 2 and other projects. An ISPS is planned in the DPR (Arehalli ISPS) to send sewage to the existing main sewer (TS 521) to treat at existing STPs. The adequate location of the ISPS shown in DPR is presented in Photo 10.2.13.

	
Location of Arehalli ISPS	Arehalli ISPS Site

Photo 10.2.13 Location of Arehalli ISPS Site and Alignment of Main Sewer Line

e) Dasarahalli Zone

Six (6) sewerage systems are proposed for this zone in the DPR as shown in Figure 10.2.6. An ISPS is also planned in the DPR to send sewage to the existing sewerage system. Relevant information and study results are summarized for the sewerage system.



Source: JICA Survey Team

Figure 10.2.6 Proposed Sewerage Systems in Dasarahalli Zone

i. Daddabidarakallu Area

The land development in the study area has just started with a limited built-up area. Topography in the area is rich with undulation. The study falls on the drainage area of Anchepalya Lake, where generated sewage in the area flows in. The site for the STP in the DPR was planned within the Anchepalya Lake, which is inadequate for sewerage development. It was confirmed that there is no available public land near the planned STP site. There is an on-going sewerage project in the neighboring area (Nagasandra area under JICA loan assistance), where additional public land can be used for the expansion of the STP for Daddabidarakallu Area. For the ISPS to send sewage to be collected in Daddabidarakallu area to Nagasandra STP, a new public land was found near the planned STP site (near Anchepalya Lake). Thus, Daddabidarakallu area shall be merged into Nagasandra sewerage system. The main sewer line shall be installed along existing drainage for gravity sewers and under the road for force main sewers. Photo 10.2.14 presents locations of ISPS and Nagasandra STP.

Locations of proposed ISPS and Existing STP	Site for Proposed ISPS

Existing Nagasandra STP	Proposed STP Expansion Site (Vacant area at Nagasandra Existing STP)

Photo 10.2.14 Location of Daddabidarakallu ISPS, Nagasandra STP and Alignment of Main Sewer Line

ii. Kariovbanahalli Area

The study area is located at the eastern side of highway, where built-up area is formed and rich in topography. The study area falls on the drainage area of Gangodanahallikere Lake. The site for the STP in the DPR is proposed in the opposite side of the lake along Nice Road, where available land area meets the requirement and generated sewage in the study area can be collected by gravity. Thus, the proposed site can be adopted for this project. The main sewer line shall be installed along existing drainage. Photo 10.2.15 shows location of STP site.

	
Location of Proposed STP	Proposed STP Site

Photo 10.2.15 Location of No.13 STP and Alignment of Main Sewer Line

iii. Herohalli Area

The study area is located at the eastern side of the highway, where a smaller size built-up area is formed. The area is in rich in topography. The study area falls on the part of the drainage area of Kodigihalli Lake, where generated sewage in the area flows into. The site for the STP was planned opposite side of study area along the highway, where generated sewage in the study area can be collected by gravity and available land area meets the requirement. The site is employed for the project and main sewer line shall be planned along existing drainage. Photo 10.2.16 shows location of the STP.

	
Location of STP	Proposed STP site

Photo 10.2.16 Location of No.14 and Alignment of Main Sewer Line

iv. Hosahalli Area

The study area is developed as built-up area with undulation in whole area. The study area falls on the drainage area of Kachohalli Lake, where generated sewage in the area flows into. The site for the STP is planned at the opposite side of the highway against Nice road, which is ensured by BWSSB. The site is employed for this project and main sewer line shall be planned along existing drainage. Photo 10.2.17 presents location of the STP.

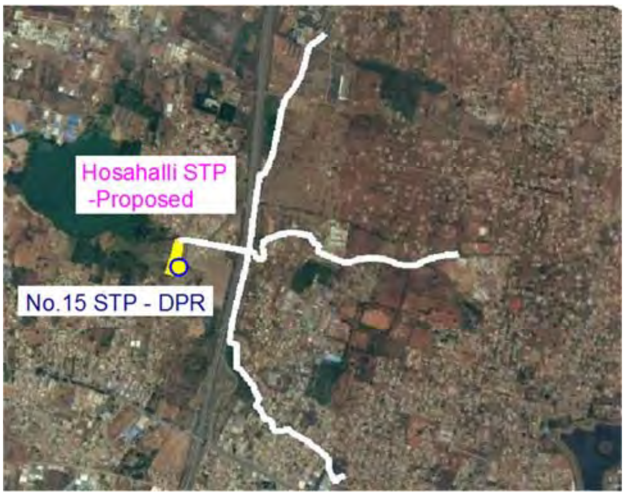
	
Location of STP	Proposed STP Site

Photo 10.2.17 Location of No.15 STP and Alignment of Main Sewer Line

v. Chikkabanavara Area

The study area is same as existing sewerage service area; Chikkabanavara area. The project is planned to augment sewage treatment capacity to the on-going project; currently, Chikkabanavar STP is under construction through Phase 2 Project. For the expansion of the STP, there is no public land in the vicinity of the on-going STP site. A candidate site was found along the lake, where sewage from the on-going STP can be ensured to reach by gravity. Therefore, the newly selected site is employed for the project. The main sewer line shall be installed along existing drainage. Photo 10.2.18 shows location of the STP.

	
Location of STP	Proposed STP Site

Photo 10.2.18 Location of No.16 STP and Alignment of Main Sewer Line

vi. Kengeri, Mailasandra and Doddabele Area

An ISPS is planned in the DPR (Herohalli ISPS). The site of the ISPS is located in the Dasarahalli zone near the border of R.R. Nagar zone. The sewage is sent to the existing sewerage system in R.R. Nagar zone. The adequate location of the ISPS in DPR is shown in Photo 10.2.19.

Location of Herohalli ISPS

Herohalli ISPS Site

Photo 10.2.19 Location of Herohalli ISPS Site and Alignment of Main Sewer Line

(2) Plan of Sewerage Systems by Zone

As a result of the study on sewerage systems covering 110 Villages, a total of 14 sewerage systems is recommended. With regard to the merging arrangements, five units of ISPSs are added to the plan in the DPR. While, a total of 13 STPs is planned including 1 unit of expansion and 12 units of newly construction. The proposed sewerage systems are shown in Table 10.2.14 in comparison with those in the DPR. Figure 10.2.7 shows planned sewerage systems, and locations of planned STPs and ISPSs.

Table 10.2.14 List of Proposed Sewerage Systems

Zone	DPR		Proposed		Remarks
	Sewerage System	STP/ISPS	Sewerage System	STP/ISPS	
Bytrayanapura	Kattigenahalli	Kattigenahalli STP	Yelahankakere	Jakur STP	Kattigenahalli area is merged into existing Jakkur area
	Yelahankakere	Yelahankakere STP		Yelahankakere STP	There is a potential of water re-use
	Doddabettahalli	Doddabettahalli STP	Doddabettahalli	Doddabettahalli STP	
	Bilishivalli	Bilishivalli STP	Bilishivalli	Bilishivalli STP	
Mahadevpura	Hagadur	Hagadur STP	Varthur	Hagadur ISPS Varthur STP	Hagadur area is merged into Varthur area
Bommanahalli	Naganathapura	Naganathapura STP	Amanikere	Naganathapura ISPS	Naganathapura area is merged into Amanikere area
	Pillaganahalli	Pillaganahalli STP	Pillaganahalli	Pillaganahalli STP	
	Talaghattapura	Talaghattapura STP	Talaghattapura	Talaghattapura STP	
R.R. Nagar	Somapura	Somapura STP	Somapura	Somapura STP	

Zone	DPR		Proposed		Remarks
	Sewerage System	**STP/ISPS**	**Sewerage System**	**STP/ISPS**	
	Hemigepura 1	Hemigepura 1 STP	Hemigepura	Hemigepura ISPS	Hemigepura1 area is merged into Hemigepura 2 area
	Hemigepura 2	Hemigepura 2 STP		Hemigepura STP	
Dasarahalli	Daddabidarakallu	Daddabidarakallu STP	Nagasandra	Daddabidarakallu ISPS Nagasandra STP	Daddabidarakallu area is merged into Nagasandra area Expansion of STP
	Karivobanahalli	Karivobanahalli STP	Karivobanahalli	Karivobanahalli STP	
	Herohalli	Herohalli STP	Herohalli	Herohalli STP	
	Hosahalli	Hosahalli STP	Hosahalli	Hosahalli STP	
	Chikkabanavara-2	Chikkabanavara STP	Chikkabanavara-2	Chikkabanavara-2 STP	Additional STP

Note: All STPs except for Jakkur and Nagasandra STP are to be newly constructed. Proposed STP will be newly constructed next to the existing plants in Jakkur and Nagasandra STP.

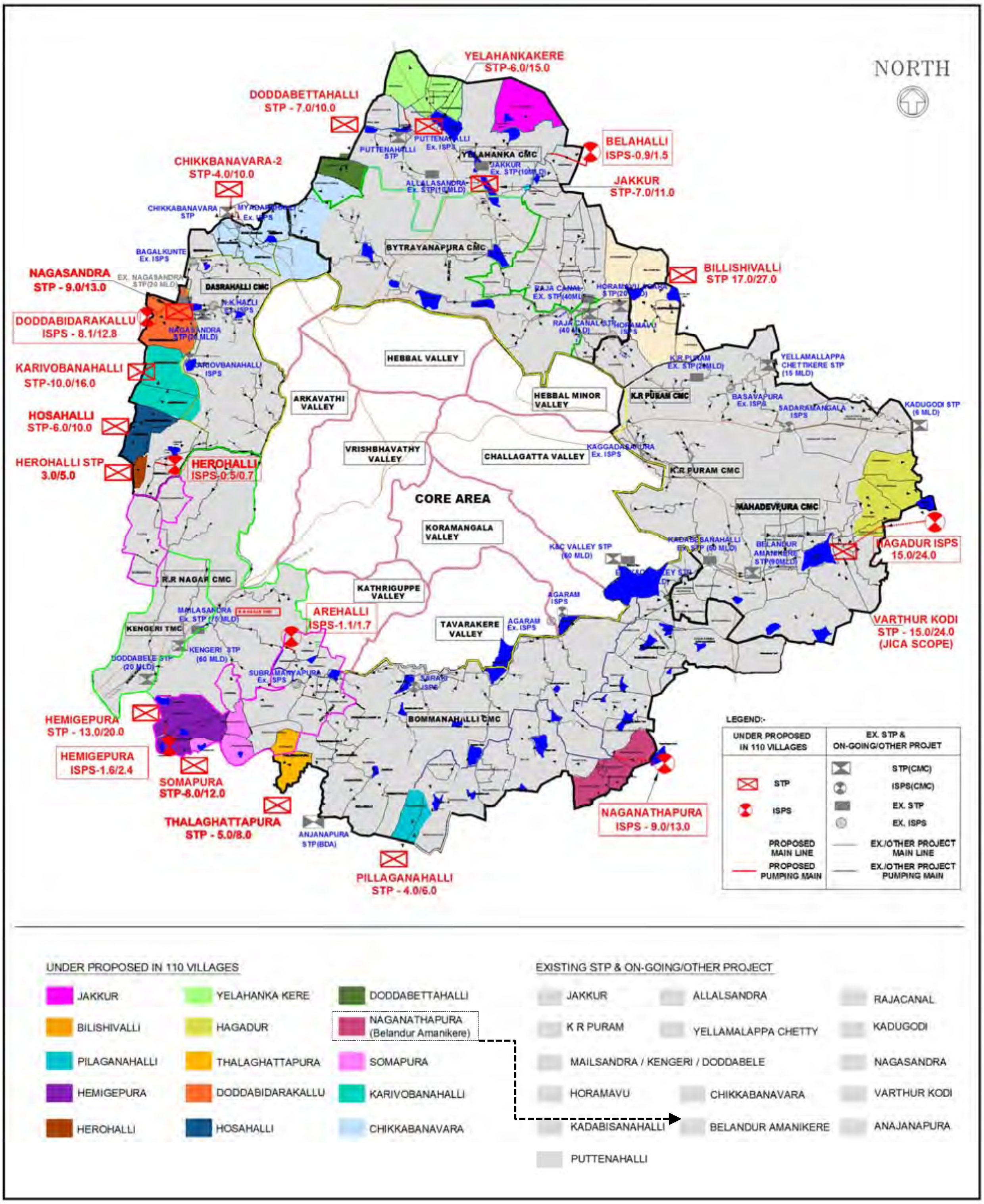
Source: JICA Survey Team

(3) Design Sewage Flow for Planned Sewerage Facilities

Design sewage flow for the planned sewerage facilities is studied applying different target year by facility as follows:

STP for year 2034 and ISPS for year 2049. Design Sewage Flow for Planned Sewerage Facilities are shown in Table 10.2.15 and Table 10.2.16. Sewage flow calculated in DPR is also shown as reference information. The following are some problems found in the DPR and the provided countermeasures.

- Sewage flow for some STPs in the DPR is wrong because of miscalculation/typographical errors.
- There is 5.0 MLD differences in the design flow for No.2 Yelankakere STP in 2049. This is because of the inclusion of 5.0 MLD from neighboring Puttenahalli STP, the capacity of which will be in short in 2049 due to limited land available (Refer to DPR Puttenahalli STP, August 2015).
- The sewage flow for No.3 Doddabettahalli STP is miscalculated in the DPR.
- The sewage flow for No.5 Hagadur STP is different between DPR and JICA Survey; 2.0 MLD in 2034 and 4.0 MLD in 2049. The additional flow was considered by the instruction of BWSSB.
- The sewage flow for No.6 Nganathapura STP in the DPR is calculated using wrong population, resulted in less flow (3.0 MLD).



Source: JICA Survey Team

Figure 10.2.7 Planned Sewerage Systems, and Locations of Planned STPs and ISPSs

- As a result of the study on sewerage systems, Hemigepura-1 and Hemigepura-2 are merged with No. 11 STP. Therefore, the comparison is made for the combined Hemigepura area. The difference of sewage flow between the DPR and JICA Survey is attributed to the additional flow considered in the DPR. The flow is considered for Chodenapura STP (under construction by Phase 2 Project) to treat the sewage flow beyond its capacity.
- In Chikkabanavara area, there is on-going STP with a treatment capacity of 5.0 MLD. Remaining sewage to be generated in Chikkabanavara area is planned to treat together with the sewage to be collected in Chikkabanavara 2 area.

Table 10.2.15 Projected Average Sewage Flow for Planned STPs by Target Year

Zone		STP		Proposed Sewage Flow (MLD)		Sewage Flow in DPR (MLD)		Remarks
No	Name	No	Name	2034	2049	2034	2049	
1	Bytrayanapura	1	Jakkur*	7.0	11.0	7.0	11.0	From Kattigenahalli area by gravity flow
		2	Yelahankakere	6.0	10.0 (15.0)	5.0	15.0	5 MLD is added for 2049 sewage flow
		3	Doddabettahalli	7.0	10.0	4.0	7.0	
		4	Bilishivalli	17.0	27.0	18.0	30.0	
2	Mahadevpura	5	Varthur	15.0	24.0	17.0	27.0	
3	Bommanahalli	7	Pillaganahalli	4.0	6.0	3.0	4.0	
		8	Talaghattapura	5.0	8.0	5.0	8.0	
4	R.R. Nagar	9	Somapura	8.0	12.0	8.0	11.0	
		11	Hemigepura	13.0	20.0	24.0	35.0	Hemigepura 1 in DPR is merged into Hemigepura 2
5	Dasarahalli	31	Nagasandra**	9.0	13.0	8.0	13.0	Daddabidarakallu in DPR is merged into Nagasandra
		13	Karivobanahalli	10.0	16.0	10.0	16.0	
		14	Herohalli	3.0	5.0	3.0	5.0	
		15	Hosahalli	6.0	10.0	7.0	10.0	
		16	Chikkabanavara 2	4.0	10.0	5.0	5.0	Sewage flow beyond the capacity of Chikkabanavara STP is planned to treat at Chikkabanavara 2 STP
Total (14 STPs Proposed)				114	187	129	207	

Note: Jakkur* STP is an existing STP. The sewage flow shown in the table is only for diversion flow from Kattigenahalli area. Nagasandra** STP is an existing STP. The sewage flow shown in the table is only for diversion flow from Doddabidarakallu ISPS.

Source: JICA Survey Team

Table 10.2.16 Projected Sewage Flow for ISPSs by Target Year

Zone		ISPS		Proposed Sewage Flow (MLD)		Sewage Flow in DPR (MLD)		Remarks
No	Name	No	Name	2034	2049	2034	2049	
1	Bytrayanapura	1	Belahalli ISPS	0.9	1.5	1.0	1.6	Proposed in DPR
2	Mahadevpura	5	Hagadur	15.0	24.0	-	-	Hagadur STP in the DPR
3	Bommanahalli	6	Naganathapura	9.0	13.0	(5.0)	(10.0)	Naganathapura STP in the DPR
4	R.R. Nagar	2	Arehalli 1 ISPS	1.1	1.7	0.5	0.75	Proposed in DPR
		3	Hemigepura ISPS	1.6	2.4	-	-	Hemigepura-1 STP in the DPR
5	Dasarahalli	4	Herohalli ISPS	0.5	0.7	0.5	0.75	Proposed in DPR
		7	Doddabidarakallu ISPS	8.1	12.8	-	-	Doddabidarakallu STP in the DPR
Total (7 ISPSs Proposed)				36.2	56.1	2.0	3.1	

Source: JICA Survey Team

For the projection of sewage flow by respective sewerage systems, distribution of population for target years by village was made to concerned STPs. Table 10.2.17 shows a sample of the study in Bytrayanapura Zone. Sewage flow by target year is estimated multiplying per capita sewage rate to the population to be served by planned STP.

There are many cases in the 110 Villages that generated swage is planned to be treated at the STP in the ULBs, while sewage flow to be treated in the concerned village is minimal (2 areas in the 5 zones). The study results for 5 zones are included in 10.2.1 Supporting Report.

Table 10.2.17 Connection of Main Sewers and Population by Target Year by Village: Bytrayanapura Zone (Sample Table)

No	Village	Connection of Main Sewer	Population		Conecting STP	Remarks
			Year 2034	Year 2049		
1	Anantha Pura	O-1 Connecting to C-8 of Yelahanka ULB	7,945	12,589	Puttenahalli STP	
		O-2 Connecting to Existing TS for ULB	9,123	14,455		
		Total	**17,068**	**27,044**		
2	Doddabetthalli	O-1 Connecting to Proposed STP	15,476	24,522	Doddabetthalli STP	
		O-2 Connecting to Proposed STP	13,997	22,179		
		Total	**29,473**	**46,701**		From Village No 3
3	Chikkabetthalli	O-1 Connecting to MH-152 of Doddabettahalli	4,519	7,160	Doddabetthalli STP	To Village No 2
		O-2 Connecting to Mh-242 of Doddabettahalli	9,885	15,663		To Village No 2
		O-3 connecting to Mh-281 of Dodddabettahalli	3,756	5,951		To Village No 2
		O-4 Connecting to MH-1 of TS-821 (ULB)	24,915	39,481	Chikkabanavar STP	Excess Flow goes to Chikkabanavara 2 STP
		Total	**43,075**	**68,255**		
4	Harohalli	O-1 Connecting to MH-1 of TS-121	15,946	25,268	Yelahanka STP	
		O-2 Connecting to MH-32 of TS-121	1,973	3,126		
		O-3 Connecting to MH-37 of TS-121	5,201	8,241		
		Total	**23,120**	**36,635**		
				0		
5	Kenchnehalli	O-3 Connecting to MH-53 of TS-121	3,157	5,002	Yelahanka STP	
		O-1 Connecting to MH-42 of TS-121	2,486	3,939		
		O-2 Connecting to MH-48 of TS-121	6,120	9,699		
		Total	**11,763**	**18,640**		
6	Govindapura	O-1 connecting to Mh-54 of Proposed TS-121	6,448	10,219	Yelahanka STP	
		O-2 Connecting to MH-1 of Vasudevpura	1,023	1,621		To Village No 7, and again come back to Village No 6
		Total	**7,471**	**11,840**		Village No.8
7	Vasudvapura	O-1 Connecting to Mh-75 of Govindapura	902	1,432	Yelahanka STP	To Village No 6
		Total	**902**	**1,432**		From Village No.6
8	Manchenhalli	O-1 Connecting to MH-82 of Govindapura	639	1,012	Yelahanka STP	
		Total	**639**	**1,012**		To Village No 6
9	Kattigenahalli	O-1 Connecting to Proposed STP	49185	77,938	Kattigenahalli STP	
		Total	**49185**	**77,938**		
10	Srinivasapura	All the village goes to ULB Area (Ex-Jakkur STP) in "Green Belt Project"	**5626**	**8,915**	Ex-Jakkur STP	Lateral System Considered in ULB Project
11	Bellhalli	O-1 of MH-58 Connecting to Proposed ISPS	4889	7,749	EX-Jakkur STP	
		MH-157 Connecting to Proposed ISPS	2189	3,468		
		Total	**7078**	**11,217**		To Village No 12
12	Tirumenhalli	O-1 (MH-21 of C-10 Yelahanka ULB)	2,040	3,233	EX-Jakkur STP	
		O-2 (MH-35 of C-10 yelahanka ULB)	693	1,098		
		O-3 Connecting to MH-49 of Chokkanahalli	304	482		To Village No 13
		Total	**3,037**	**4,813**		From Village No 11
13	Chokkanahalli	O-1(MH -35 of C-10 Yelahanka ULB)	3,181	5,039	Raja Canal STP	
		O-2 (MH-549 of C-29 of Bytrayanapura ULB)	1,673	2,651		
		O-3 Connecting to MH-1 of TS-224	1,331	2,109		
		Total	**6,185**	**9,799**		From Village No 12

Source: JICA Survey Team

10.2.4 Plan of Main Sewers

In the DPR, the sewer with a diameter of more than 300mm is defined as “main sewer”, which includes Trunk sewer and Sub-main sewer. The differences between trunk and sub-main sewer are not clear. In this study, a sewer line with more than 300mm in dia. is defined as a main sewer line according to the international practices in the sewerage sector project.

(1) Design Flow

Design flow for main sewer is calculated multiplying a peak factor to daily average sewage volume for the target year 2049 in consideration of the fluctuation of sewage flow through the day. Peak factors are assumed in CPHEEO manual in India as shown in Table 10.2.18.

Table 10.2.18 Peak Factor to be Adopted for Calculation of Sewage Flow

Contributory Population	Peak Factor
UP to 20,000	3.00
Above 20,001 to 50,000	2.50
Above 50,001 to 750,000	2.25
Above 750,001	2.00

Source: CPHEEO 1993

(2) Manner of Design of Sewer line

The main sewer line shall be designed in application of a gravity system as much extent as possible except for the pumping at ISPS. The sewers shall be constructed underground with minimum earth cover of 1.0 m to prevent from scattering of sewage and odor from sewers as well as protection from live loads.

(3) Plan of Sewer Network

In the DPR, sewer networks are planned/designed in consideration of existing land development including road networks and housing areas without city plan for the future. The main sewer line is mainly planned along existing drainages. This arrangement may be adoptable through the future for economical alignment of sewers in view of hydrology. Photo 10.2.20 presents typical drainages, along which main sewer line may be installed. While, sewer lines are sometimes laid under the river bed as shown in Photo 10.2.21. Installation of sewers in the river/drainage is not recommendable because the facilities disturb the river/storm water flow. Sewers shall be, in principle, installed under the road.

	
Existing Drainage in Bytrayanapura Zone	Existing Drainage in Dasarahalli Zone

Photo 10.2.20 Typical Drainage, along which Sewer Line is Planned

	
Excavation of Existing Drainage	Manhole and Pipe Installation in the Existing Drainage

Photo 10.2.21 Installation of Sewer Line under Drainage Bed

(4) Scope of Work for the Construction of Main Sewers in the 110 Villages

In the DPR, three kinds of main sewer lines are referred to as follows:

a) Proposed main sewer lines for new/expansion of sewerage systems for the plan in the DPR
b) Main sewer lines planned /designed by other planned projects
c) Existing main sewer lines

The scope of work for this project covers item a) and the part of item b) which have not yet financially arranged for the construction work. Table 10.2.19 presents required main sewers (diameter and length) by zone based on preliminary design together with those planned in the DPR.

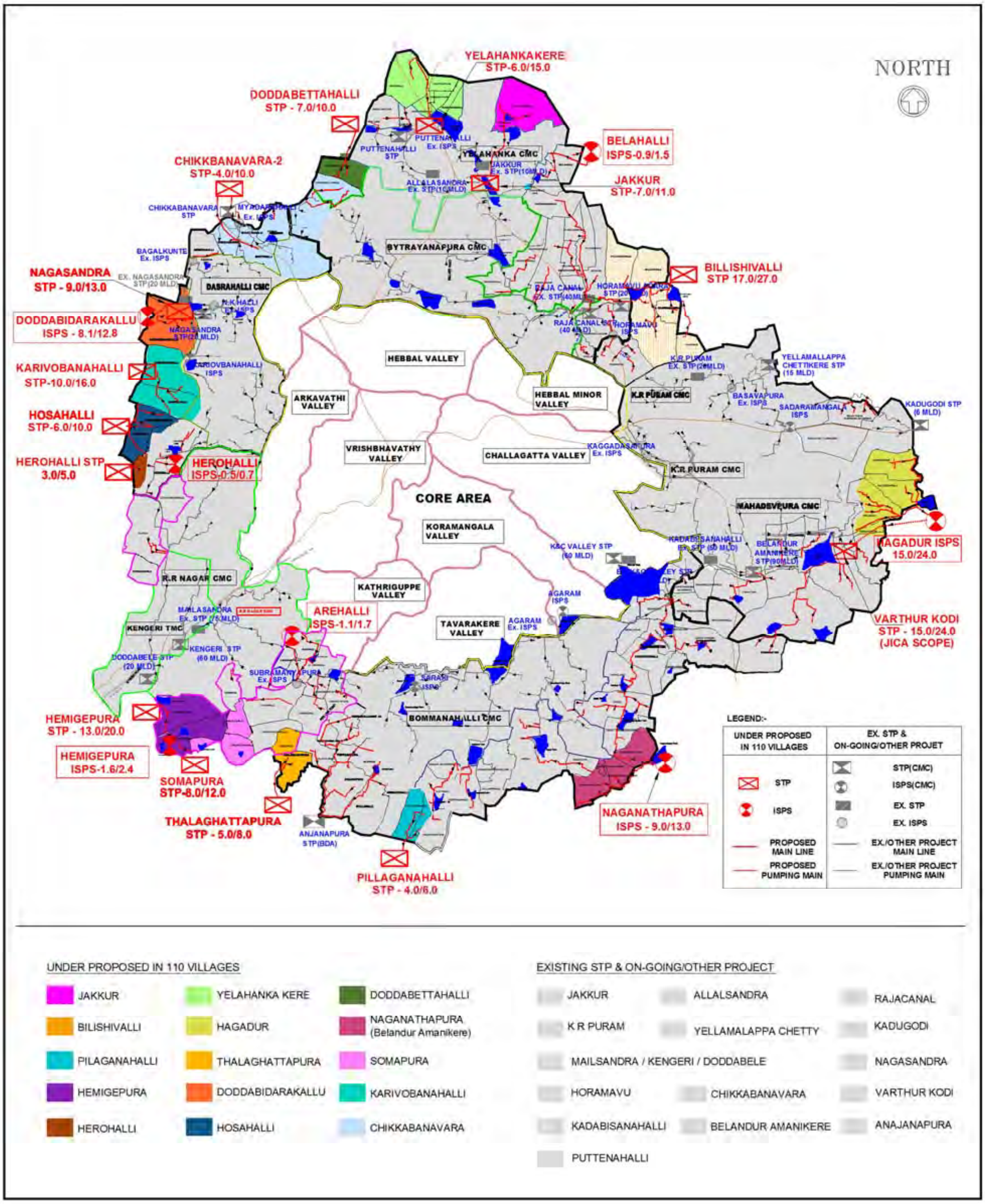
The total length of the main sewers arrive at about 202 km, most of which are planned to be constructed using open-cut method. While, pipe jacking method is employed for about 1% of the total length of the sewer lines for the crossing the highway and railway. The longest main sewer lines are planned for Bommanahalli Zone with about 30% of the total length.

Table 10.2.19 Main Sewer Length by Diameter for the Five (5) Zones

Zone	JICA Survey		DPR	
	Range of Pipe Size	Length (km)	Range of Pipe Size	Length (km)
Bytrayanapura	ϕ 300 ~ ϕ 1,000	50.3	ϕ 300 ~ ϕ 900	44.4
Mahadevpura	ϕ 300 ~ ϕ 800	44.7	ϕ 300 ~ ϕ 900	43.6
Bommanahalli	ϕ 300 ~ ϕ 1,200	65.0	ϕ 300 ~ ϕ 1,000	58.8
R.R. Nagar	ϕ 300 ~ ϕ 500	14.8	ϕ 300 ~ ϕ 900	19.0
Dasarahalli	ϕ 300 ~ ϕ 700	27.5	ϕ 300 ~ ϕ 600	23.9
Total		202.3		189.7

Source: JICA Survey Team

Layout plan of main sewer lines (shown with red lines) for all zones is shown in Figure 10.2.8. Planned main sewers by zone are summarized in comparison with those in the DPR.



Source: JICA Survey Team

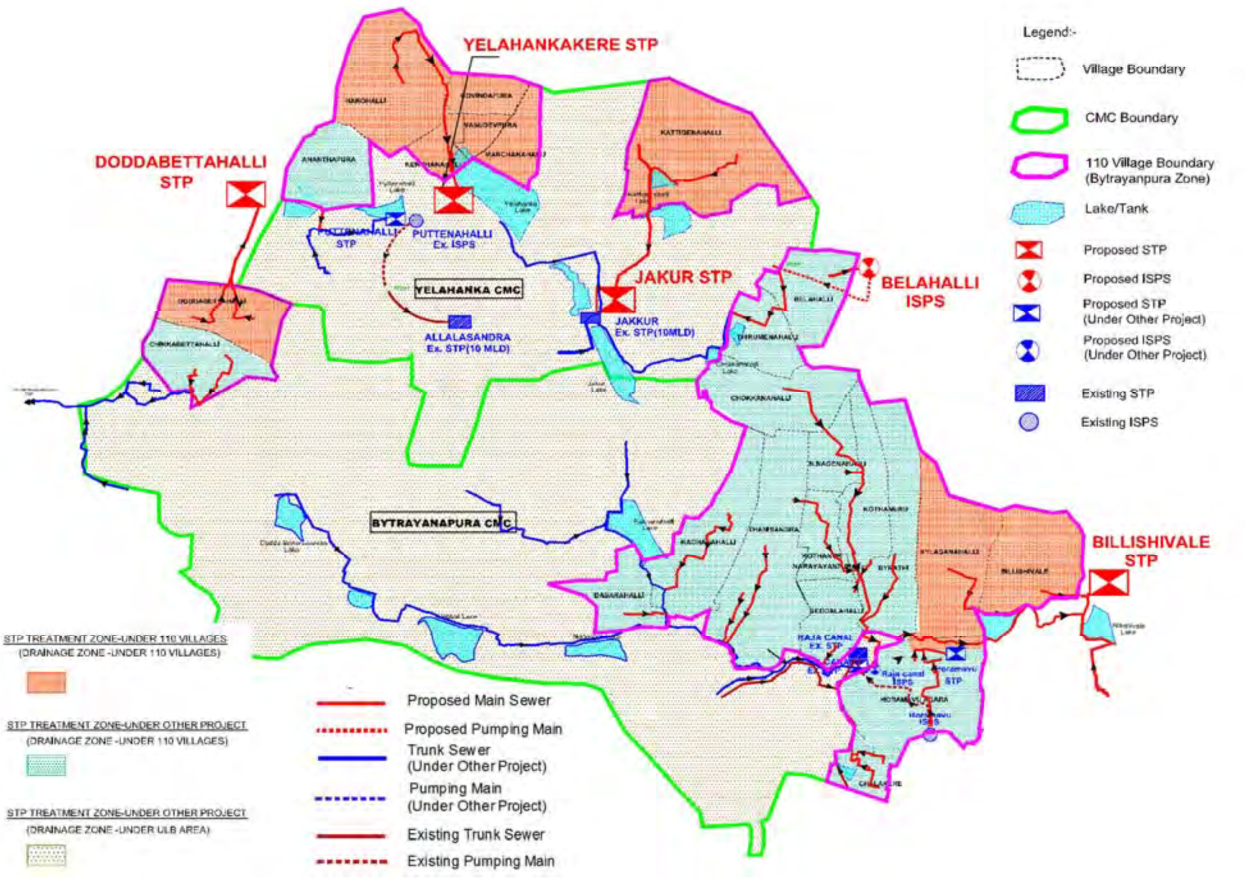
Figure 10.2.8 Layout Plan of Main Sewer Lines for All Zones

1) Bytrayanapura Zone

Total length of main sewer lines for Bytrayanapura Zone is 50.3 km and the longest main sewer line belongs to Raja Canal sewerage system (see Table 10.2.20). Figure 10.2.9 presents layout plan of main sewer lines.

Table 10.2.20 Main Sewer Length in Bytrayanapura Zone

Treatment Area	Range of Pipe Size (mm)	Length (km)		Connection Sewer to STP
		JICA Survey	DPR	
Kattigenahalli	ϕ 300 ~ ϕ 500	6.9	2.1	Proposed Jakkur
Yelahanakakere	ϕ 300 ~ ϕ 600	4.2	4.6	Proposed
Doddabettahalli	ϕ 300 ~ ϕ 400	3.8	2.3	Proposed
Bilishivalli	ϕ 300 ~ ϕ 1000	7.4	7.4	Proposed
Puttenahalli	ϕ 300	1.7	1.7	On-going
Jakkur	ϕ 300	2.1	2.1	Exsting and On-going
Horamavu	ϕ 300	2.6	2.6	On-going
Allalasandra	—	—	—	Exsting
Raja Canal	ϕ 300 ~ ϕ 700	21.6	21.6	Exsting and On-going
Total		50.3	44.4	



Source: JICA Survey Team

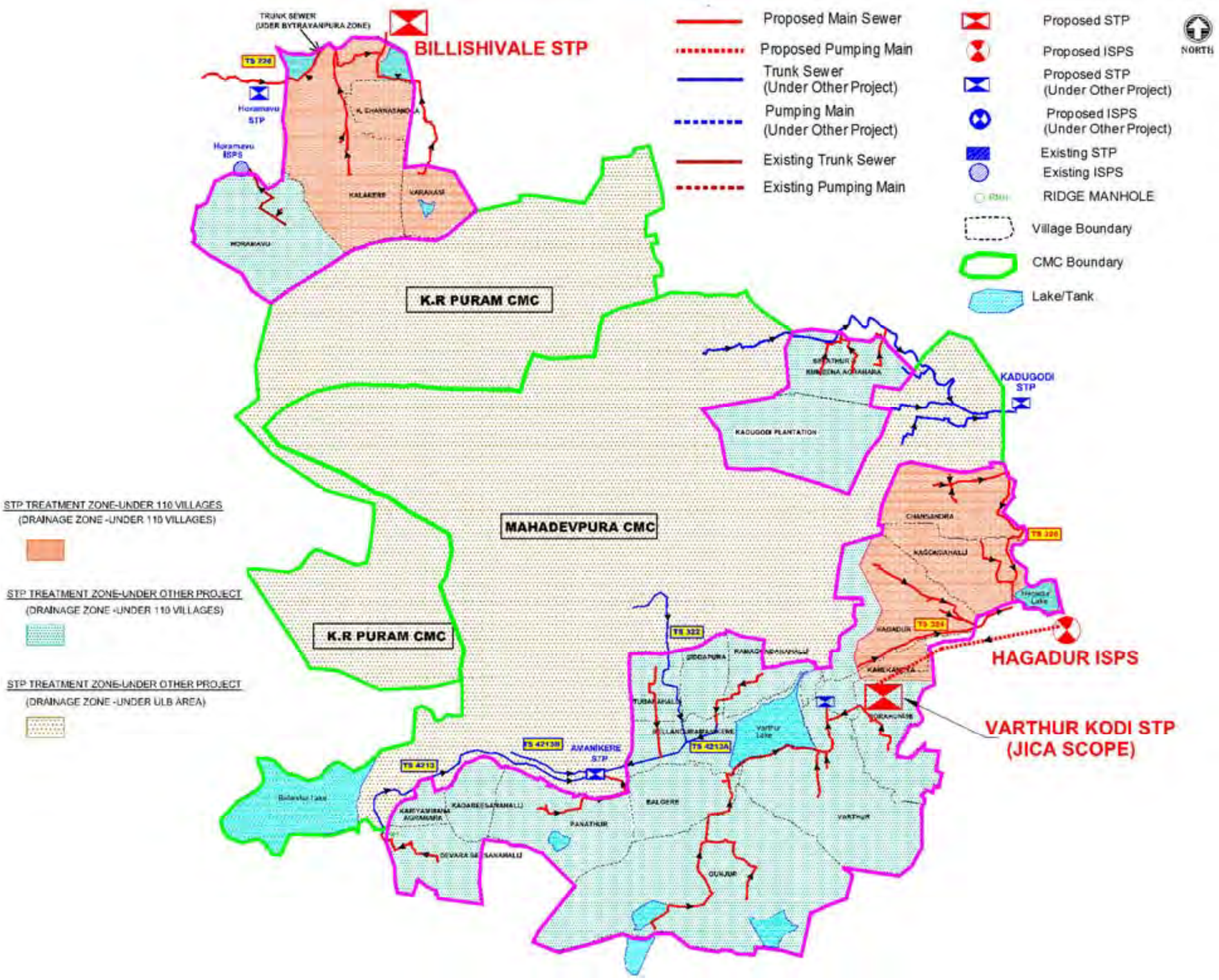
Figure 10.2.9 Layout Plan of Main Sewer Lines in Bytrayanapura Zone

2) Mahadevpura Zone

Total length of main sewer lines for Mahadevpura Zone is 44.7 km and the longest main sewer line belongs to Varthur Kodi sewerage system (see Table 10.2.21). Figure 10.2.10 presents layout plan of main sewer lines.

Table 10.2.21 Main Sewer Length in Mahadevpura Zone

Treatment Area	Range of Pipe Size (mm)	Length (km)		Connection Sewer to STP
		JICA Survey	DPR	
Hagadur	ϕ 300 ~ ϕ 600	12.8	11.7	Proposed
Bilishivalli	ϕ 300 ~ ϕ 800	6.7	6.7	Proposed (Bytrayanapura Zone)
Varthur Kodi	ϕ 300 ~ ϕ 600	12.2	12.2	On-going
Amanikere	ϕ 300 ~ ϕ 500	8.2	8.2	On-going
Kadugodi	ϕ 300 ~ ϕ 450	4.8	4.8	On-going
Total		44.7	43.6	



Source: JICA Survey Team

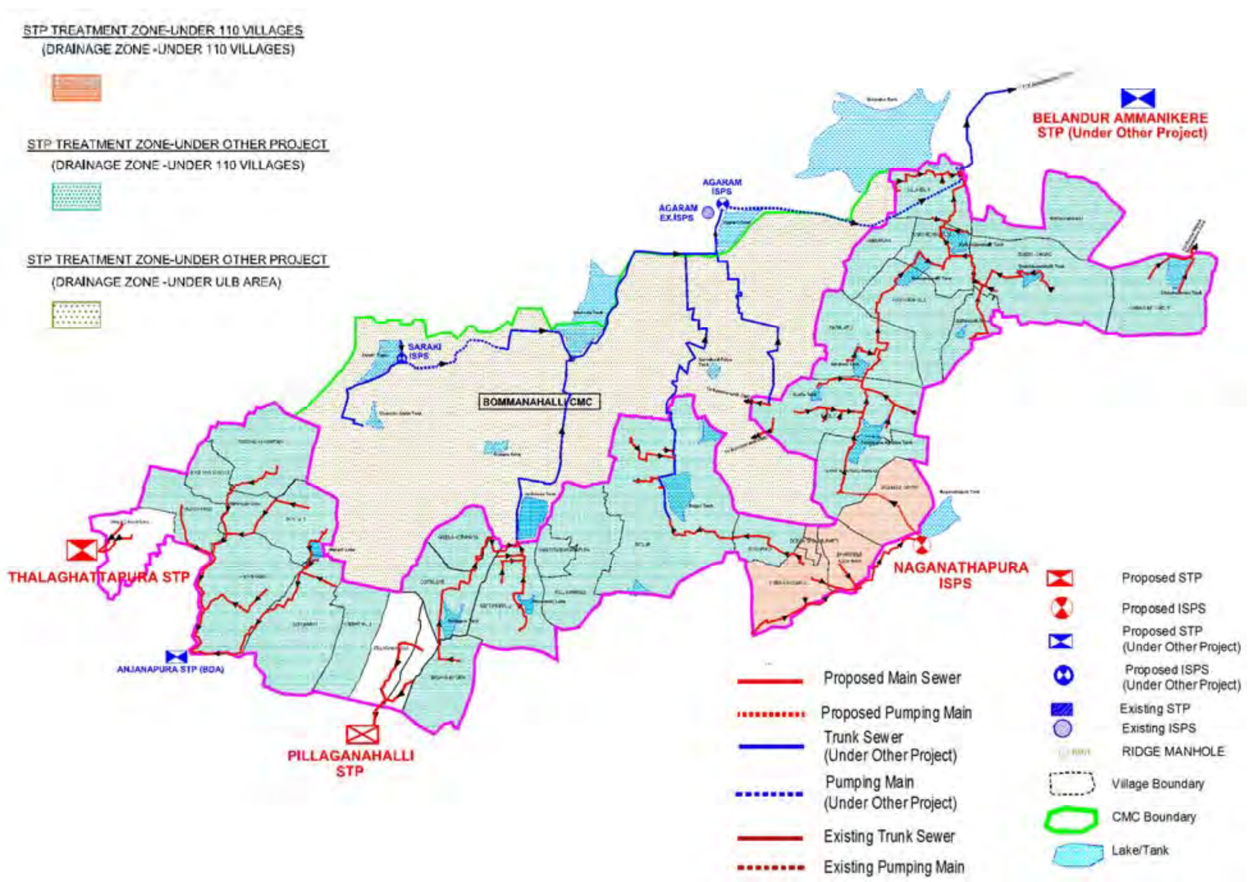
Figure 10.2.10 Layout Plan of Main Sewer Lines in Mahadevpura Zone

3) Bommanahalli Zone

Total length of main sewer lines for Bommanahalli Zone is 65.0 km and the longest main sewer line belongs to Amanikere sewerage system (see Table 10.2.22). Figure 10.2.11 presents main sewer lines in Bommanahalli Zone.

Table 10.2.22 Main Sewer Length in Bommanahalli Zone

Treatment Area	Range of Pipe Size (mm)	Length (km)		Connection Sewer to STP
		JICA Survey	DPR	
Naganathapura	ϕ 300 ~ ϕ 500	6.5	6.5	Proposed
Pillaganahalli	ϕ 300 ~ ϕ 400	2.2	0.9	Proposed
Talaghattapura	ϕ 300 ~ ϕ 700	2.8	1.1	Proposed
Anjanapura	ϕ 300 ~ ϕ 600	16.2	16.2	Proposed
Amanikere	ϕ 300 ~ ϕ 1,200	37.3	34.1	On-going (Mahadevpura Zone)
Total		65.0	58.8	



Source: JICA Survey Team

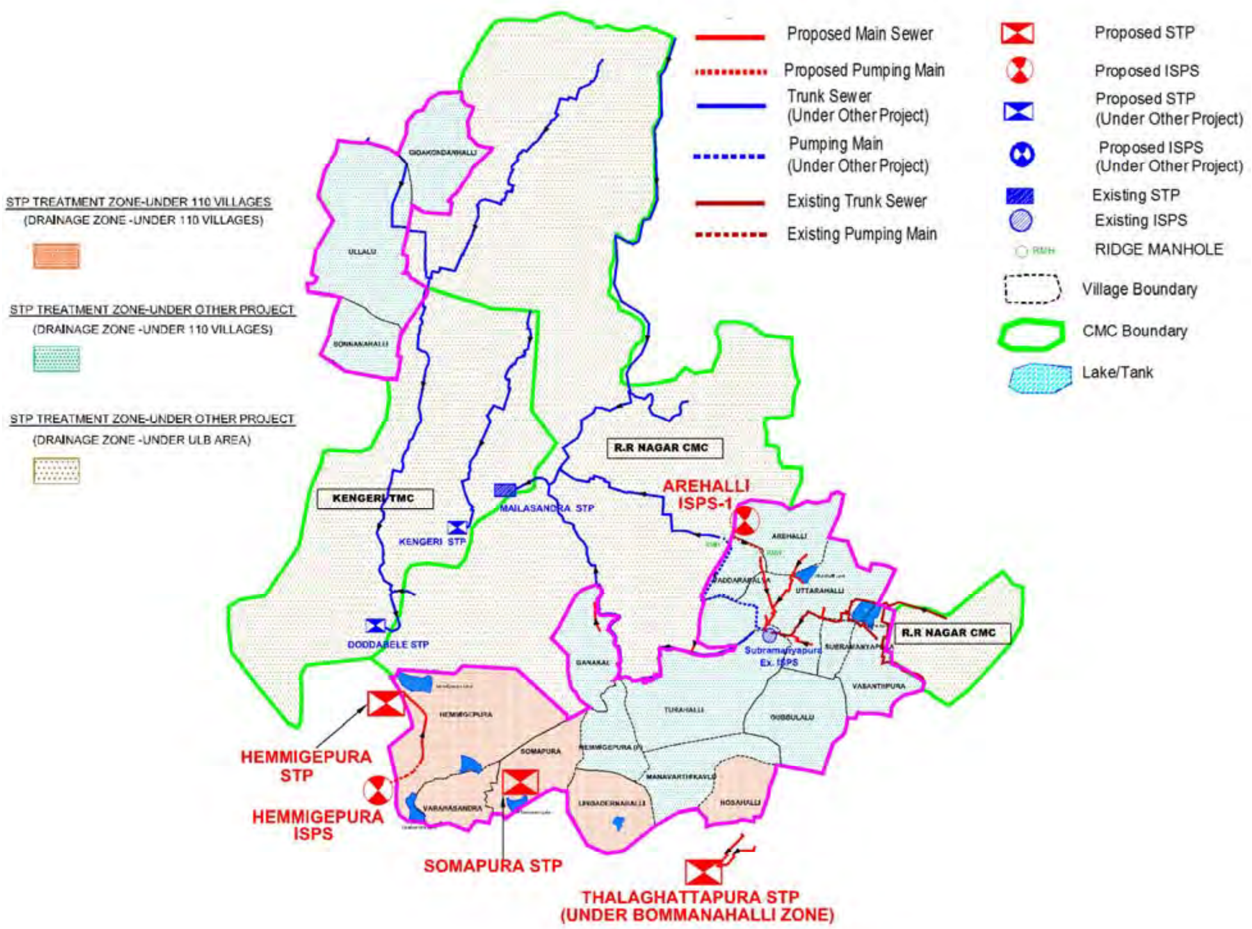
Figure 10.2.11 Layout Plan of Main Sewer Lines in Bommanahalli Zone

4) R.R. Nagar Zone

Total length of main sewer lines for R.R. Nagar Zone is 14.8 km and the longest main sewer line belongs to Doddabele sewerage system (see Table 10.2.23). Figure 10.2.12 presents layout plan of main sewer lines.

Table 10.2.23 Main Sewer Length of R.R. Nagar Zone

Treatment Area	Range of Pipe Size (mm)	Length (km)		Connection Sewer to STP
		JICA Survey	DPR	
Talaghattapura	ϕ 300 ~ ϕ 500	0.8	1.9	Proposed
Somapura	~~ϕ 700~~ (Canceled)	-	1.5	Proposed
Hemigepura	ϕ 300 ~ ϕ 400	1.0	2.6	Proposed
Doddabele	ϕ 300 ~ ϕ 500	13.0	13.0	On-going
Total		14.8	19.0	



Source: JICA Survey Team

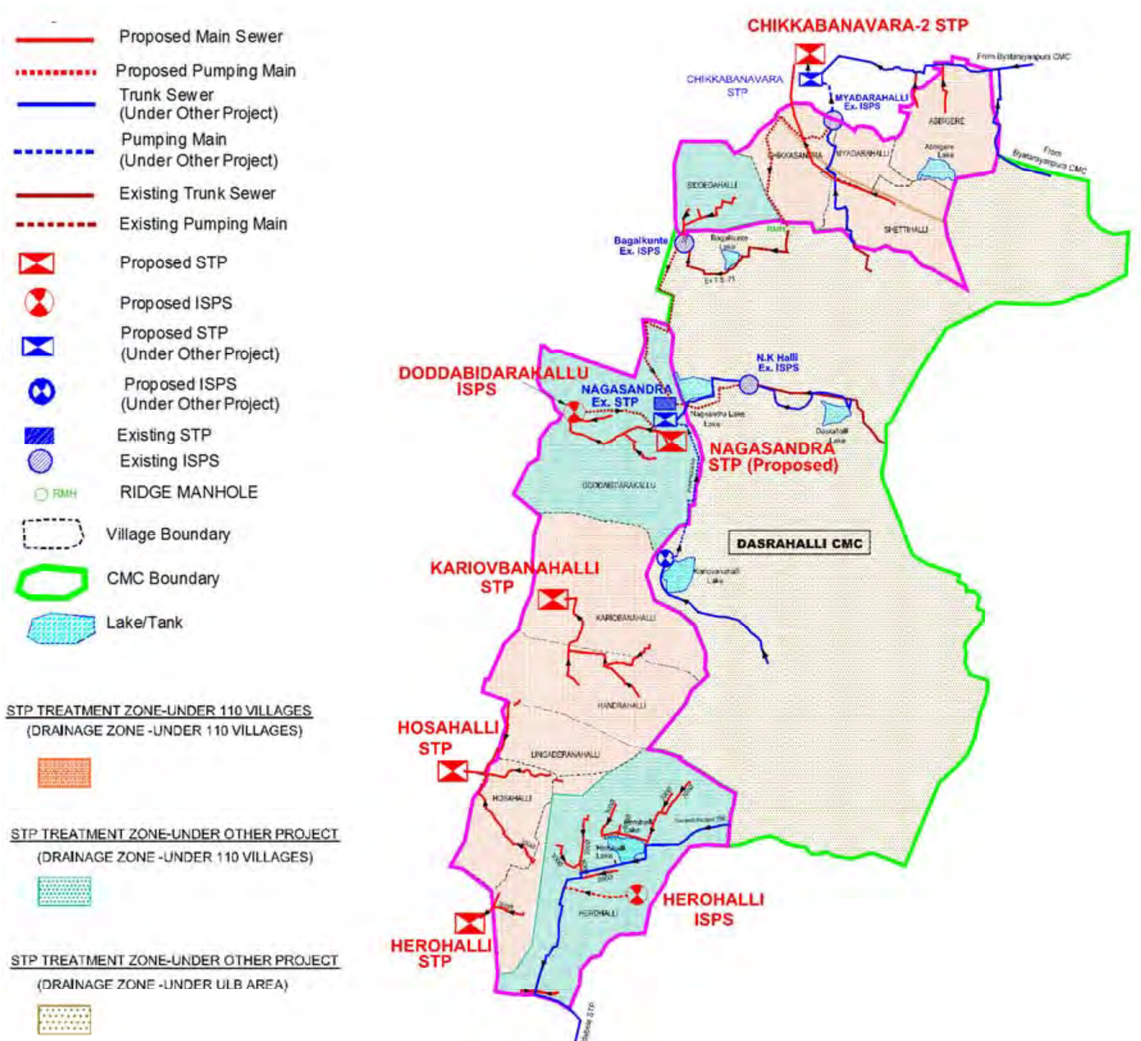
Figure 10.2.12 Layout Plan of Main Sewer Lines in R.R. Nagar Zone

5) Dasarahalli Zone

Total length of main sewer lines for Dasarahalli Zone is 27.5 km and the longest main sewer line belongs to Nagasandra sewerage system (see Table 10.2.24). Figure 10.2.13 presents layout plan of main sewer lines.

Table 10.2.24 Main Sewer Length of Dasarahalli Zone

Treatment Area	Range of Pipe Size (mm)	Length (km)		Connection Sewer to STP
		JICA Survey	DPR	
Nagasandra	ϕ 300 ~ ϕ 600	6.2	6.0	Proposed, Existing and On-going
Kariobavanahalli	ϕ 300 ~ ϕ 700	5.3	4.5	Proposed
Herohalli	ϕ 300 ~ ϕ 400	1.1	0.8	Proposed
Hosahalli	ϕ 300 ~ ϕ 600	4.8	4.4	Proposed
Chikkabanavar	ϕ 300 ~ ϕ 400	5.1	3.2	Proposed
Doddabelli	ϕ 300 ~ ϕ 600	5.0	5.0	On-going (R.R. Nagar Zone)
Total		27.5	23.9	



Source: JICA Survey Team

Figure 10.2.13 Layout Plan of Main Sewer Lines in Dasarahalli Zone

10.2.5 Sewage Treatment Plant

(1) Basic Conditions for Design of Sewerage Facilities

1) Characteristics of the Sewage to be Treated

Sewage generated in the study area is domestic origin. Industrial wastewater must be treated before discharge to public sewer or public water body according to regulations on the effluent control.

2) Required Conditions for Design of STPs

Table 10.2.25 summarizes required conditions for design of STP including design flow, required land area and effluent receiving water body. The public land is, in principle, selected for the construction of the STPs. According to the requirements, land acquisition process shall be proceeded by the BWSSB excepting for the obtained two sites.

Table 10.2.25 Required Conditions for Design of STPs

Zone	STP	Design Flow (MLD)		STP Site area	Effluent Receiving Water Body
		2034	2049	(ha)	
Bytrayanapura	Jakkur	7.0	11.0	0.8	Jakkur Lake
	Yelahankakere	6.0	15.0	2.0	Yelahanka kere Lake
	Doddabettahalli	7.0	10.0	1.0	Attur Lake
	Bilishivalli	17.0	27.0	4.5	Rampura kere Lake
Mahadevpura	Varthur*	15.0	24.0	3.5	Pinakini River
Bommanahalli	Pillaganahalli	4.0	6.0	2.4	Bilvardalli Lake
	Talaghattapura	5.0	8.0	2.6	Talaghattapura kere Lake
R.R. Nagar	Somapura	8.0	12.0	2.4	Somapura Lake
	Hemigepura	13.0	20.0	4.0	Vrishabhavati River
Dasarahalli	Kariobavanahalli	10.0	16.0	1.7	Gangodanahalli kere Lake
	Herohalli	3.0	5.0	3.7	Herohalli Kere Lake
	Hosahalli	6.0	10.0	0.9	Lingadeeranahalli Lake
	Chikkabanavara-2	4.0	10.0	1.2	Chikkabanavara kere Lake
	Nagasandra*	9.0	13.0	3.0	Arkavathi River

Note: The sewage generated in Daddabidarakallu area will be treated at the STP to be expanded at the Nagasandra STP site. Nagasandra* STP is an existing STP. Varthur*STP is planned by other project. The sewage from Hagadur area will be treated at the new STP to be constracted at the Varthur STP site.
Source: JICA Survey Team

3) Environmental Conditions

There is no particular regulation in India for the development of the infrastructures to control odor, noise, vibration, etc. However, recently GoK enacted that any facility should not be constructed within 75 m from the boundary of the lake (Section 14. Acts prohibited in lakes, KARNATAKA ACT NO. 10 of 2015).

The details on this act was confirmed with Lake Authority, especially, in case of important public facilities; sewage treatment plants. Four (4) lakes are planned as receiving water bodies from No.3, 4, 9, and 16 STPs. In this connection, discussions were made by concerned parties if the construction of the STPs is acceptable or not. It was concluded that the plan for the related STPs does not violate the act as far as the site is out of the lake.

(2) Inflow Sewage Quality to the STP

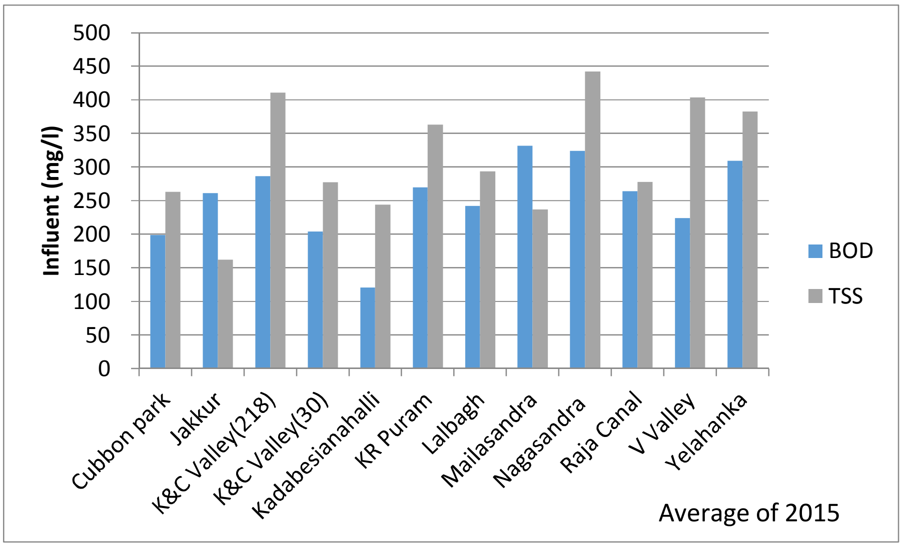
Inflow sewage quality for design of sewerage facilities was determined through comparative studies on the following data/information.

- Inflow sewage quality at existing STPs
- Estimation of inflow sewage quality using unit organic substances in the CPHEEO manual and design per capita sewage generation rate
- Inflow sewage quality employed by on-going project in Bengaluru

(3) Inflow Sewage Quality to Existing STPs

1) Inflow Sewage Quality by Existing STP

An average inflow sewage quality (BOD and SS) in 2015 is shown in Figure 10.2.14 for 12 existing STPs. A comparatively higher sewage quality is reported at V. Valley (180), Yelahanka and Nagasandra STPs. Inflow of industrial wastewater into these STPs may be affected to the quality. While, the quality at Kadabesianahalli STP is lower than average figure, which may be caused by the delay in the construction of sewer networks.

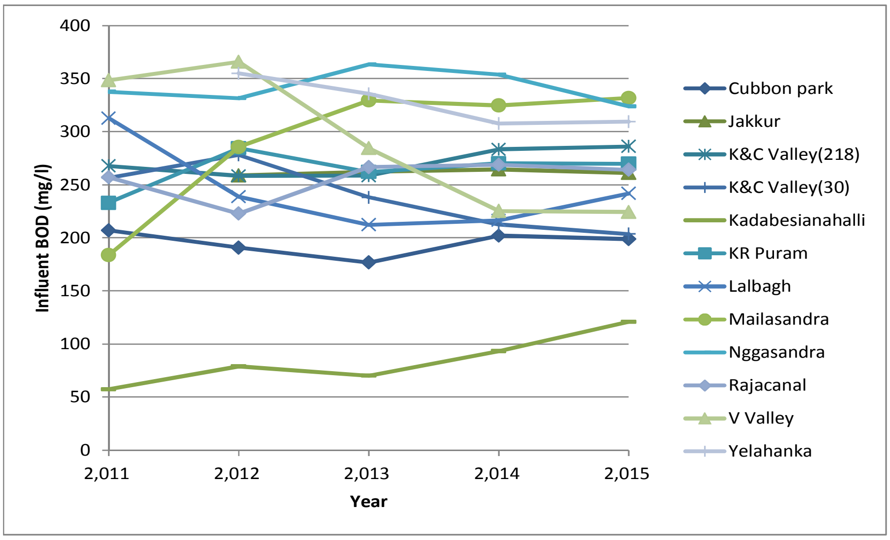


Source: JICA Survey Team

Figure 10.2.14 Average Inflow Sewage Quality in 2015 at 12 Existing STPs

2) Yearly Fluctuation of Inflow Sewage Quality (BOD)

Figure 10.2.15 shows yearly fluctuation of BOD at the existing STPs. According to the statistics, BOD at Kadabesianahalli STP had been increasing in pace with the provision of sewer networks. Likewise, BOD at Mailasandra STP increased from 200 mg/l in 2011 to 330 mg/l in 2013-2015. While at V. Valley STP, BOD decreased from 350 mg/l in 2012 to 220 mg/l in 2014 and 2015. In general, for the subject STPs, BOD values had been fluctuated within the range from 200 mg/l to 350 mg/l.



Source: JICA Survey Team

Figure 10.2.15 Yearly Fluctuation of BOD at Existing STPs

3) Seasonal Fluctuation of Inflow BOD and SS at Three (3) Existing STPs

Monthly data on BOD and SS were collected from three existing STPs; K&C Valley (30) STP, KR Puram STP and Rajacanal STP, which are standard STPs in terms of treatment capacity, no inflow of industrial wastewater and adequate provision of sewer networks as of now. Remaining 9 STPs are omitted because of some conditions as follows: V. Valley (180), Yelahanka and Nagasandra STPs receive industrial wastewater; Kadabesianahalli STP service area is in short in provision of sewer networks at present; Cubbon park, Jakkur, Lalbagh and Yelahanka STPs have treatment capacity of less than 10 MLD; and K&C Valley (218) and Mailasandra STPs have treatment capacity of more than 50 MLD.

As shown in Figure 10.2.16, the average quality from 2011 to 2015 (5 years) in BOD and SS has been fluctuating within a certain range, no big differences between dry and rainy seasons. BOD values are between 200mg/l and 350 mg/l and SS values are in the range of 200mg/l to 450 mg/l.

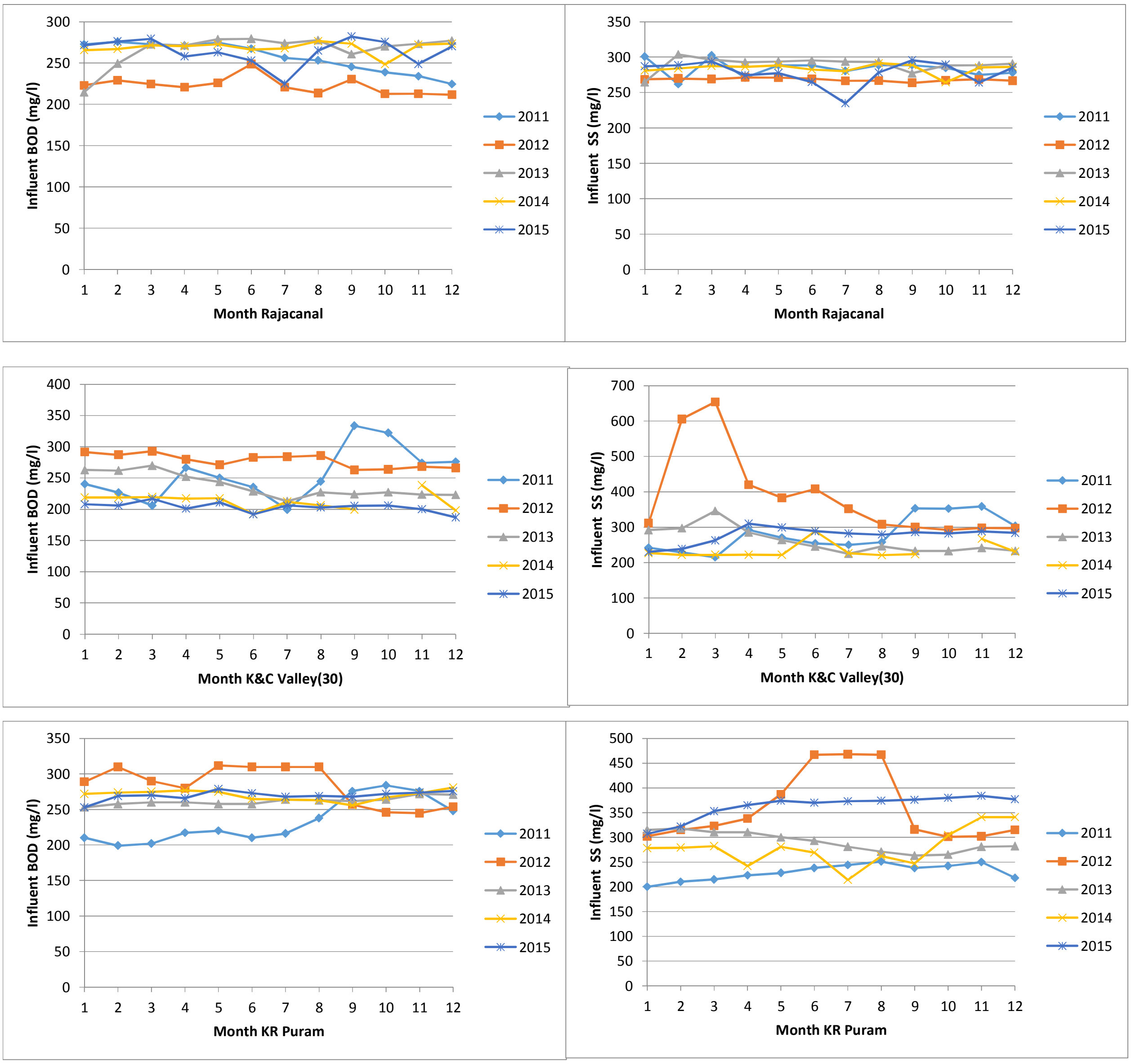


Figure 10.2.16 Monthly Fluctuation of BOD and SS at 3 Existing STPs

Source: JICA Survey Team (Figures at Left side: BOD, at Right side: SS)

With regard to COD, T-N and T-P, collected data from the three STPs are studied on the seasonal fluctuations (see Figure 10.2.17). COD values for the three STPs are different each other; 500 - 700 mg/l at K&C Valley STP, 400 - 600 mg/l at KR Puram STP and at Rajacanal STP 500-600 mg/l in 2011 and 2012, but about 800 mg/l after 2013. Although COD at Rajacanal STP was very high, in general COD value may be regarded as 400 - 800 mg/l.

For nitrogen and phosphorous, there is no available data on yearly fluctuation. Data on TKN and T-P at Kadabesianahalli STP and TKN at K&C Valley (30) STP from January to May in 2016 were obtained. A minimal fluctuations of these values are observed and almost constant value is reported for respective

STPs. TKN value is with a range of 35 to 45 mg/l and T-P is between 4.4 and 6.7 mg/l.

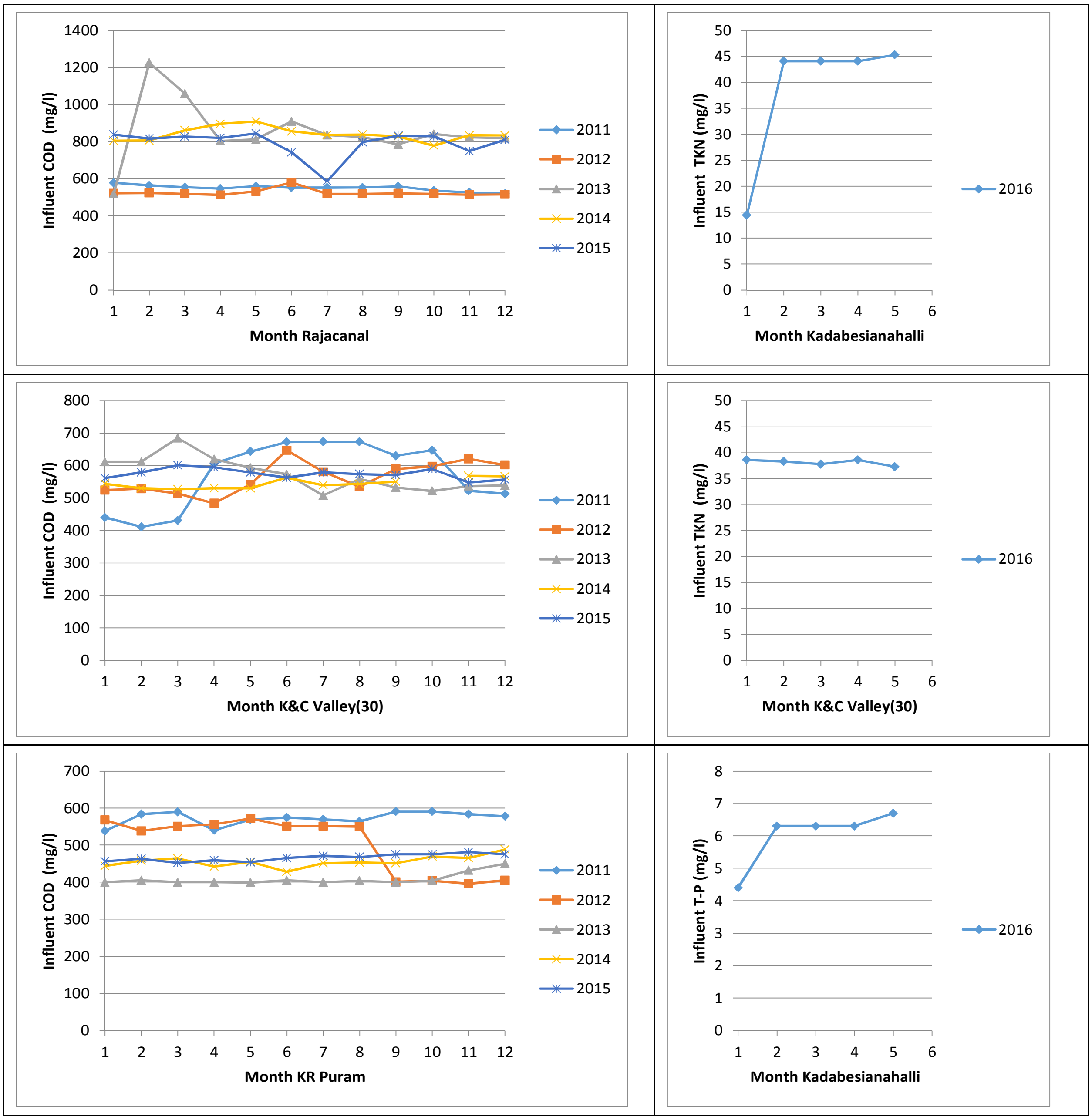


Figure 10.2.17 Monthly Fluctuation of COD, T-N and T-P at the three STPs

Source: JICA Survey Team (Figures at Left side: COD, at Right side: T-N, T-P)

Design values for inflow sewage quality are calculated using per capita organic substances shown in CPHEEO manual and per capita sewage rate (refer to Table 10.2.26).

4) Inflow Sewage Quality Employed by On-going Project in Bengaluru

Presently STP construction project for JICA assisted Phase 2 has been implemented. In the project, BOD 350 mg/l and SS 450 mg/l are employed for the design purpose.

5) Inflow Sewage Quality for Design of Sewerage Facilities

Table 10.2.26 summarizes above study results on inflow sewage quality for design of sewerage facilities. Design values to be adopted for concerned indices are shown in the last column of the table. The following are additional explanations on the finalization of design values.

Table 10.2.26 Comparative Study Results on Design Inflow Sewage Quality

Item	CPHEEO Manual			Existing STP Record	Design Value at Stage4-2*	Apply in this Study
Unit	lpcd	gpcd	mg/l	mg/l	mg/l	mg/l
BOD	132	45-54	340 - 409	200 - 350	350	350
COD	132	72-103	545 - 777	400 – 800	800	800
TSS	132	70-145	530 - 1098	200 - 450	450	450
T-N	132	6 - 12	45.5 - 90.9	14.4- 45.3（TKN）	70（TKN）	70（TKN）
T-P	132	0.6 - 4.5	4.5 - 34.1	4.40- 6.70	7	7

Source: JICA Survey Team, *Raja Canal

- BOD: In consideration of the following, 350 mg/l is recommended. The maximum BOD of the studied three standard STPs is reported at 350 mg/l. The estimated value in use of CPHEEO manual arrived at 340-409mg/l. On-going STP project employed 350 mg/l.
- COD using CPHEEO manual arrived at 545-777 mg/l. In the on-going Phase 2 project, 800 mg/l is adopted. Thus, 800 mg/l is employed.
- For SS, 450 mg/l is adopted referring to the experience at the three existing STPs and CPHEEO manual.
- Available data on T-N and T-P are limited. The value 70 mg/l is comparatively high as a raw sewage quality and also is employed for the on-going Phase 2 project, which is within the range of 45.5-90.9 mg/l according to CPHEEO manual. Likewise, for T-P, 7 mg/l is adopted.

(4) Effluent Quality to be Achieved

Target quality of the effluent to be discharged from planned STPs is assumed according to recommended standards by CPHEEO as shown in Table 10.2.27.

Table 10.2.27 Target Effluent Quality (Recommended by CPHEEO)

Item	BOD	TSS	T-N	T-P	Fecal Coliforms
Target standard	10 mg/l	10 mg/l	10 mg/l	2 mg/l	100 MPN/100mL

Source: JICA Survey Team

Target effluent quality shall comply with the latest discharge standards in India (CPCB New Standards, 27th April 2016). The transition of discharge standards in recent years is shown in Table 10.2.28.

Table 10.2.28 History of Effluent Standards from STP in India

Water Quality Item		NGRBA Guidelines (2010)	CPHEEO Manual (2013)	CPCB New Standards (27th April 2016)
		Effluent Standards for discharge into water bodies	**Recommended Guidelines for Treated Sewage**	**Parameters Limit Not Authorized**
pH	-	5.5-9.0	-	6.5-9.0
BOD_5	mg/l	20	Less than 10	Not more than 10
COD	mg/l	-	-	Not more than 50
TSS	mg/l	30	Less than 10	Not more than 10
NH_4-N	mg/l	-	-	Not more than 5
T-N	mg/l	-	Less than 10	Not more than 10
T-P	mg/l	-	Less than 2	Less than 2
Fecal Coliforms	MPN/100mL	Desirable– 1,000 Permissible– 10,000	Less than 230	Less than 230

Source: JICA Survey Team

(5) Sewage Treatment Methods

1) Sewage Treatment Methods Used at the Existing STPs and On-going STPs

Table 10.2.29 presents information on the existing and on-going STPs. Majority of the existing STPs use EA process, while on-going project adopted SBR process. However, ASP process is also employed for a large-size STPs in consideration of tertiary treatment for reuse of treated sewage. There are some STPs using TF or UASB processes which are economical in O&M of facilities, but it is difficult to meet the required effluent quality for the updated regulations.

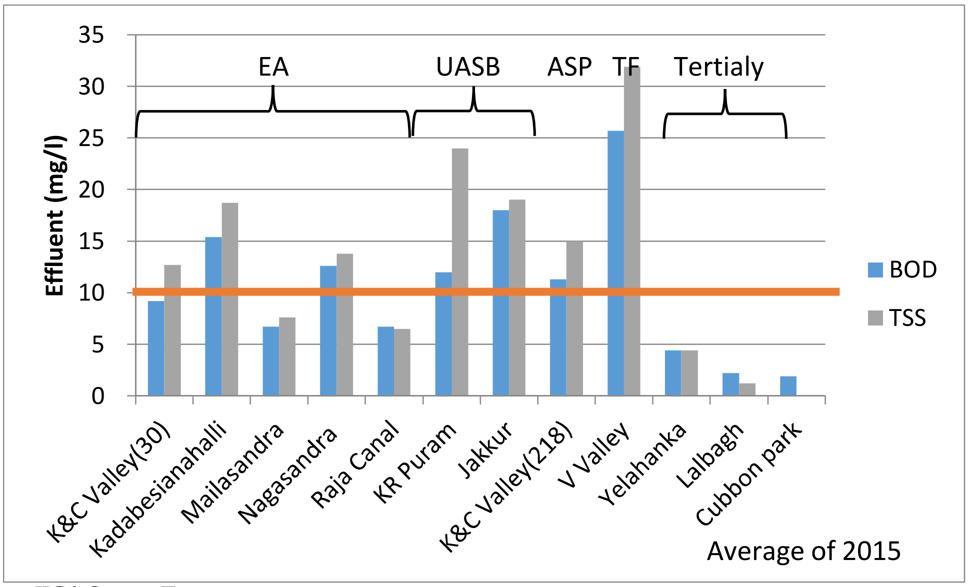
Table 10.2.29 Summary of Treatment Process Applied in BWSSB

No.	STP Name	Area	Treatment Process	Status	Initial Capacity (MLD)
1	K&C Valley (1) (Upgrading)	Core Area	ASP (ASP+PG)	Existing + Under Construction	218 (60)
2	V. Valley	Core Area	TF *Tertiary Treatment for water reuse	Existing	180 *60 of 180
3	Hebbal	Core Area	ASP	Existing	60
4	Raja Canal (Upgrading)	Core Area Bytrayanapura CMC	EA (SBR)	Existing + Under Construction	40 (40)
5	K&C Valley (2)	Core Area	EA	Existing	30
6	Madivara	Core Area	UASB+ OP +Constructed wetlands	Existing	4
7	Cubbon Park	Core Area	MBR	Existing	1.5
8	Labaugh	Core Area	EA	Existing	1.5
9	Kempbudhi (Iti Colony)	Core Area	EA	Existing	1

No.	STP Name	Area	Treatment Process	Status	Initial Capacity (MLD)
10	Mailasandra	R.R. Nagar CMC	EA	Existing	75
11	Kadabesanahalli	Mahadevpura CMC	EA	Existing	50
12	Nagasandra	Dasarahalli CMC	EA	Existing	20
13	K.R. Puram	K.R. Purum CMC	UASB	Existing	20
14	Yelahanka (Allasandara)	Yelahanka CMC	ASP+Filtration	Existing	10
15	Jakkur	Yelahanka CMC	UASB+EA	Existing	10
16	Horamavu Agara	Bytrayanapura CMC	SBR	Under Con-struction in BWSSP Phase 2	20
17	Kachohalli (Agara Lake) - Canceled	Core Area	MBR (Canceled)		3
18	Kadugodi	Core Area	SBR		6
19	Nagasandra	Dasarahalli CMC	SBR		20
20	Chikkabanavara	Dasarahalli CMC	SBR		5
21	Kengeri	R.R. Nagar CMC	ASP + Tertiary Filters		60
22	Bellandur Amanikere	Mahadevpura CMC	ASP		90
23	Doddabele	R.R. Nagar CMC	SBR		20
24	Yellemall-appa Chetty	Mahadevpura CMC	SBR		15

Note: ASP: (Conventional) Activated Sludge Process, TF: Trickling Filter, UASB: Up-flow Anaerobic Sludge Blanket, OP: Oxidation Pond, MBR: Membrane Bio Reactor, PG: Power Generation from Sludge (Digestion Facility),
* Tertiary Treatment: Trickling filters, Densadeg clarifier, Flopac filtration, chlorination unit in V. Valley STP. The chlorinated recycle water is supplied to M/s Karnataka Power Corporation Ltd. at Bidadi and M/s Pulikesh Power Corporation Ltd. at Kumbalgod for their power generation plants.
Source: JICA Survey Team/ BWSSB

According to the sewage treatment experiences by BWSSB at existing STPs, there are many STPs which have achieved the stringent standards (BOD 10mg/l and SS 10mg/l) using EA process without provision of tertiary treatment processes, as shown in Figure 10.2.18. Among the STPs, tertiary treatment process is applied at Yelahanka, Lalbagh, Cubbon Park STPs, the effluent of which meets required standards. On the other hand, the effluent quality at the STPs applying UASB, ASP and TF processes is beyond the requirements of new standards. However, in case of Raja Canal and Mailasandra STPs, effluent meets new standards under operation of EA process in application of old design standards. The effluent quality at Kadabesianahalli STP is beyond new standards seemingly inadequately operated (MLSS is considerably low with 400 mg/l thorough the year).



Source: JICA Survey Team

Figure 10.2.18 Average Effluent Quality in 2015 at Existing STPs Operated by BWSSB

2) Alternative sewage treatment method adoptable

In consideration of new effluent standards, an application of modified aeration tank to remove nitrogen under secondary treatment process is recommended to save construction cost without tertiary treatment facilities (a larger aeration tank shall be provided), which plays a role as tertiary treatment process (A-SRT: 4-5 days) to a certain extent. This arrangement will also allow for the required removal of SS to meet required standard.

In order to satisfy required effluent standards, the need of proper O&M of STP is indispensable. Under adequate O&M of the STP, effluent quality could satisfy the stringent standards as practiced in Japan. Table 10.2.30 presents the experience of secondary treatment plants in Japan with higher level treatment efficiencies (less than 10mg/l BOD and SS).

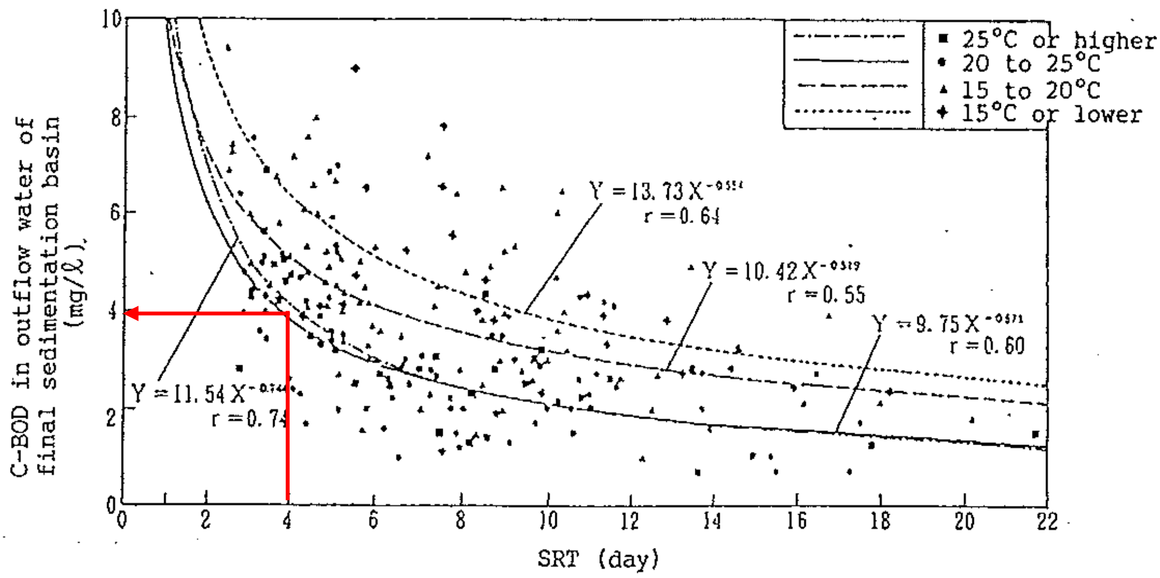
Design of sewage treatment facilities shall be made considering required volume for the aeration tank to remove nitrogen meeting target T-N 10mg/l. Under this arrangement, the volume of aeration tank in this design (A-SRT; retention time of aerobic solid) is larger than common aeration tank used for standard secondary treatment process (design effluent quality, BOD 20 mg/l).

Table 10.2.30 Secondary Sewage Treatment Experience in Japan

No.	Name of STP	Inflow (m3/day)	BOD (mg/L)				SS (mg/L)			
			Inlet		Outlet		Inlet		Outlet	
			Design	Actual	Design	Actual	Design	Actual	Design	Actual
1	Chubu Ryuiki, Ginowan	87,190	240	210	17	3.4	230	171	17	3.0
2	Chubu Ryuiki, Naha	127,320	260	290	18	3.4	200	207	15	2.0
3	Kagoshima City, Nanbu	119,797	210	283	15	2.4	190	304	17	2.0
4	Kagoshima City, Kinko	22,630	210	265	15	5.6	190	196	29	4.0
5	Nobeoka City, Myoda	27,440	180	150	19	2.3	140	130	16	3.0
6	Miyazaki City, Oyodo	34,486	200	160	20	3.0	200	190	20	3.0
7	Miyazaki City, Miyazaki	68,971	200	130	20	3.3	160	130	16	4.0
8	Beppu City, Chuo	43,813	160	125	16	1.7	160	143	24	2.0
9	Oita City, Benten	31,163	250	160	20	1.6	250	120	20	2.0
10	Oita City, Miyazaki	22,098	250	190	20	2.4	250	200	20	2.0
11	Oita City, Harayama	26,258	250	180	20	4.8	250	160	20	3.0
12	Kumamoto Hokubu Ryuiki	45,709	180	160	15	10.0	180	183	18	4.0
13	Yamaga City, Yamaga	18,074	140	174	20	2.1	120	183	20	3.0
14	Kumamoto City, Nanbu	30,200	200	267	15	9.0	140	124	14	8.0
15	Kumamoto City, Tobu	56,098	200	219	15	5.9	180	207	14	4.0
16	Kumamoto City, Chubu	30,258	180	180	15	2.0	140	159	14	3.0
17	Sasebo City, Chubu	36,739	270	202	15	1.4	170	180	15	3.0
18	Nagasaki City, Seibu	43,915	200	230	15	3.3	190	223	15	2.0
19	Nagasaki City, Chubu	44,230	200	223	20	3.4	190	153	40	4.0
20	Matsuyama City, Chuou	92,202	180	135	18	4.8	125	155	13	2.0
21	Imabari City, Imabari	40,381	190	122	19	4.1	150	119	20	2.0
22	Kamobegawa Ryuiki	118,923	174	143	20	2.0	135	181	30	3.0
23	Takamatsu City, Tobu	69,652	200	268	20	8.3	200	234	20	5.0

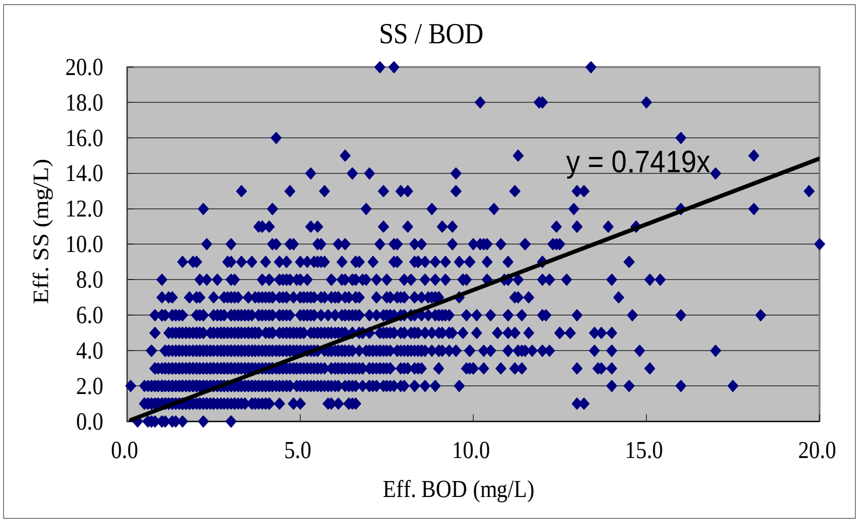
Source: Sewage Works Statistics in Japan

As shown in Figure 10.2.19, BOD is projected at 4 mg/l in application of A-SRT 4 days. The BOD may be less than 8 mg/l in consideration of 2 times of BOD as annual average quality, which is lower than stringent standard. Figure 10.2.20 shows relationship between BOD and SS.



Source: Japan Sewage Works Association

Figure 10.2.19 Relationship between Effluent BOD and SRT



Source: JICA Survey Team

Figure 10.2.20 Relationship between BOD and SS

Based on the experience in Japan, interrelation between BOD and SS is reported at about 0.74 (SS/BOD). In use of the Figure and assuming 8 mg/l of BOD, SS arrives at 6 mg/l (8 mg/l x 0.74), resulted in projected effluent quality both for BOD and SS is less than target quality.

Alternative secondary sewage treatment methods to achieve newly adopted effluent standards are studied to apply for the planned STPs. In other words, without provision of tertiary treatment, modified secondary treatment methods will be employed elaborating design of facilities and O&M measures. Table 10.2.31 shows the experience of secondary treatment processes, which achieved the effluent standards equivalent to the requirements in India.

Table 10.2.31 STPs in Japan Achieved the Effluent Quality Standards of India (2013)

Sewage Process Method	Nos.	Actual Elimination Rate		
		BOD	SS	T-N
Oxidation Ditch	140	98.6%	97.6%	83.1%
Activated Sludge Process	127	98.5%	98.0%	84.1%
Step Flow Multistage Nitrification Denitrification	13	97.1%	96.8%	84.5%
Sequencing Batch Reactor	11	98.6%	98.4%	86.5%
Anaerobic Aerobic Activated Sludge Process	10	98.8%	95.2%	82.8%
Long Aeration Method	8	98.2%	99.0%	88.1%
Advanced Oxidation Ditch	7	99.1%	98.9%	91.5%
Circulated Nitrification / Denitrification Process	6	99.0%	99.1%	89.4%
Anaerobic Anoxic Oxic Process	6	98.7%	98.9%	80.8%

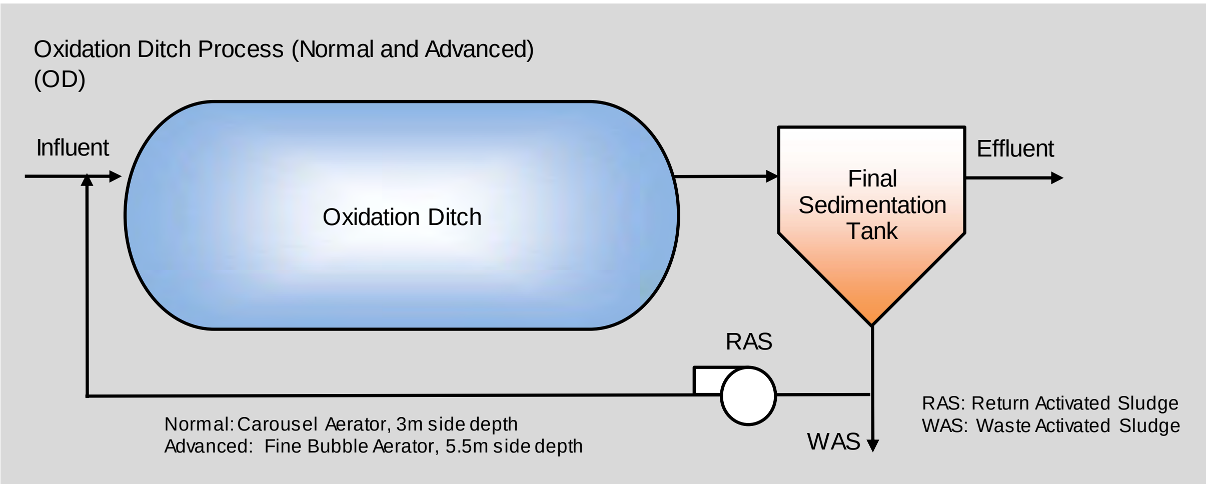
Note: Based on "Statistics of Sewage in Japan 2013" (JSWA, 2015), process which past adopted records are more than 5 nos. are made up.
Source: JICA Survey Team

Based on the above experiences, the candidate processes are listed below.

- Oxidation Ditch Process (OD)
- Sequencing Batch Reactor (SBR)
- Extended Aeration Process (EA)
- Moving Bed Biofilm Reactor (MBBR)
- Anaerobic Anoxic Oxic Process (A2O)
- Membrane Biological Reactor (MBR)

a) Oxidation Ditch Process (OD)

Oxidation ditch (OD: refer to process flow in Figure 10.2.21) is one form of an extended aeration system having certain special features like an endless ditch for the aeration tank and rotors/aerators for the aeration mechanism. The ditch consists of a long continuous channel usually oval in plan. The channel can be earthen with lined sloping sides and lined floor or it may be built in concrete or brick with vertical walls. Sewage is aerated by a surface rotor/aerators placed along the channel. The rotor/aerators not only aerates the sewage but also provides a horizontal velocity to the mixed liquor preventing the sludge from settling in the ditch.



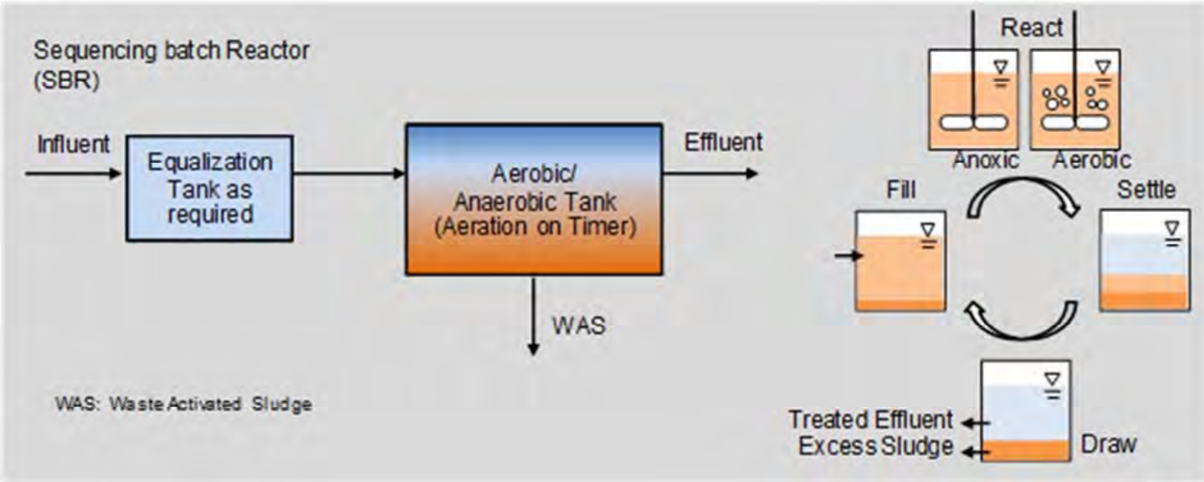
Source: JICA Survey Team

Figure 10.2.21 Process Flow of OD

b) Sequencing Batch Reactor (SBR)

The sequencing batch reactor (SBR: refer to Figure 10.2.22) is a type of activate sludge treatment system which treats sewage by aeration and sedimentation in a single tank. Period of each process can be adjusted flexibly in this process.

Since anaerobic, anoxic and oxic condition can also be flexibly controlled, nitrogen and phosphorus removal corresponding to loading variation is possible according to the operation condition.



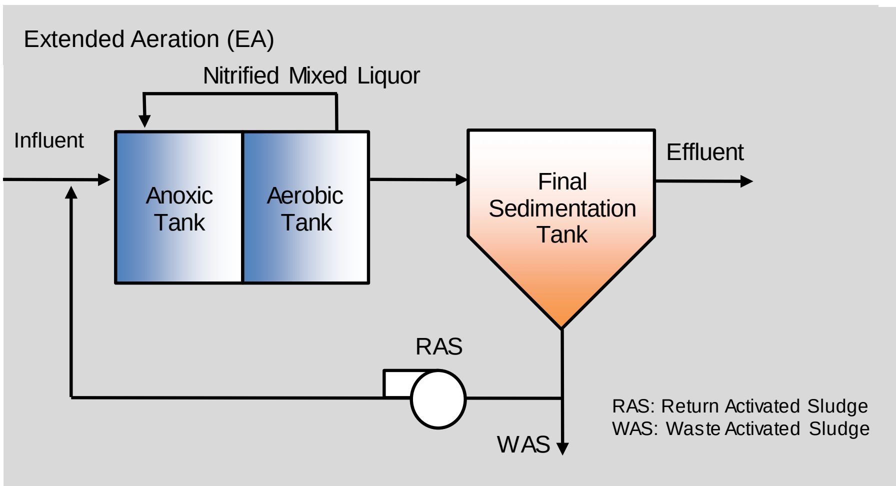
Source: JICA Survey Team

Figure 10.2.22 Process Flow of SBR

It should be noted that an advanced type which is a kind of SBR, has been attracting attention recently India. It performs multi-processes in a single reactor like SBR, and has a proprietary technology for automatic control by DO monitoring, a blower and a decanter etc. This allows for shorter cycle times as well as the omission of a separate denitrification cycle. Hence, no mixers for denitrification are necessary.

c) Extended Aeration Process (EA)

Single-stage systems are those in which nutrient removal is achieved in a single basin and clarifier. Removal of nitrogen is achieved by combined nitrification (under aerobic conditions) and denitrification (under anoxic conditions). A single-stage system using one anoxic zone can achieve 65 to 70% of T-N elimination factor as normal influent. The process flow is shown in Figure 10.2.23.

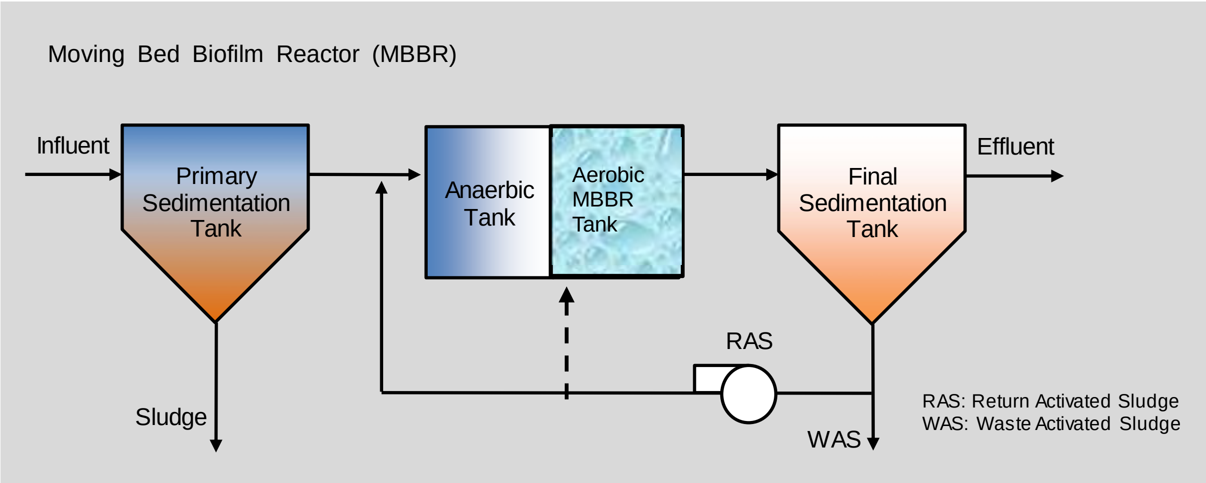


Source: JICA Survey Team

Figure 10.2.23 Process Flow of EA

d) Moving Bed Biofilm Reactor (MBBR)

This process is similar to ASP with plastic membrane. By separate aeration tank with wall as anaerobic zone and aerobic zone, it is possible to eliminate Phosphorus effectively. The process flow is shown in Figure 10.2.24. Organic substrates are supplied from influent sewage into the anaerobic stage and the return sludge comes into contact with the carbon source only in the anaerobic stage. Faster uptake of organic substrates in the anaerobic stage is the key for bacteria to win in the microbial selection in the enhanced biological phosphorus removal process.



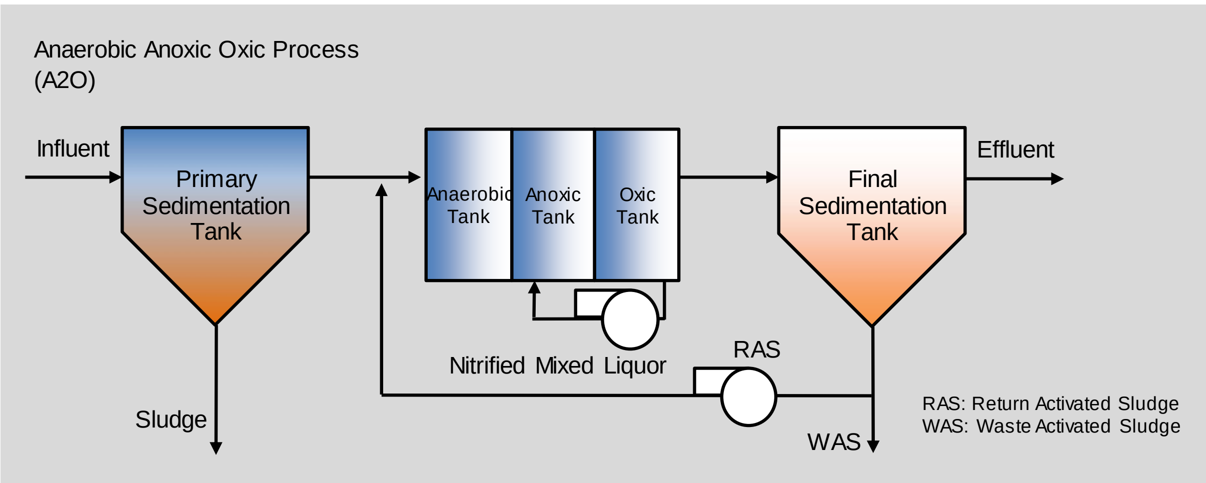
Source: JICA Survey Team

Figure 10.2.24 Process Flow of MBBR

e) Anaerobic Anoxic Oxic Process (A2O)

In this process as shown in Figure 10.2.25, sludge flow returns to reactor in the order of anaerobic tank -anoxic tank-oxic tank, with circulation from oxic tank to anoxic tank as shown in Figure 10.2.25. This enables simultaneous removal of nitrogen and phosphorus as advanced wastewater treatment.

Compared to ASP, the anaerobic tank and anoxic tank are needed for this system, it needs the construction area wider.

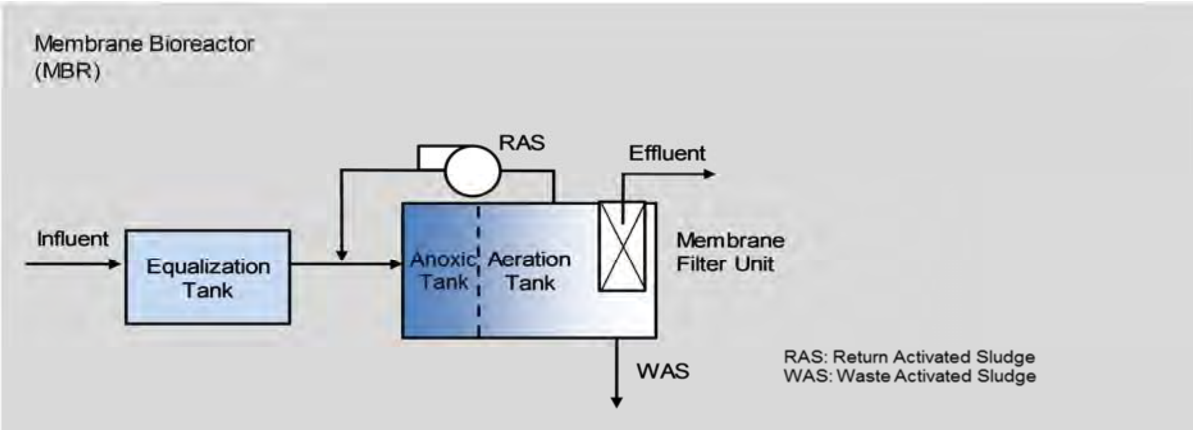


Source: JICA Survey Team

Figure 10.2.25 Process Flow of A2O

f) Membrane Biological Reactor (MBR)

MBR is an activated sludge process similar to ASP. The difference is in the method of separation of liquid and solid. In the MBR process, the bio-solids are separated by membranes. Figure 10.2.26 shows process flow. MBR does not require final sedimentation tanks and the reactor tank volume can be smaller than ASP due to high MLSS concentration. Disinfection is not needed because coliform is removed by the membrane. However, the flow equalization tanks are usually equipped because the flux of membrane is not so flexible to variation of flow. When the site is small, MBR has advantages. Much air supply is required to protect the fouling on the membrane surface which causes power cost high. Chemicals cost for periodical cleaning of membrane and membrane replacement cost is necessary. O&M cost for MBR is higher than that of ASP.



Source: JICA Survey Team

Figure 10.2.26 Process Flow of MBR

3) Evaluation of Candidate Sewage Treatment Process and Recommendation of Processes to be Employed in the Project

Comprehensive evaluation of concerned sewage treatment process was made in application of scoring method. Table 10.2.32 presents scoring results comparing potential treatment methods. Advanced Extended Aeration Process (EA), and Advanced type SBR are selected as appropriate processes, because past record of India is comparatively higher than other processes.

Recommended two (2) processes have been used in Bengaluru; EA is applied at Raja Canal STP and many others, and Advanced type of Sequential Batch Reactor (SBR) is selected for Stage IV Phase-II (on-going) project.

Table 10.2.32 Evaluation of Sewage Treatment Processes

Name	Advanced Oxidation Ditch Process	Sequencing Batch Reactor	Extended Aeration Process	Moving Bed Biofilm Reactor	Anaerobic Anoxic Aerobic Process	Membrane Bioreactor
	Without Primary Sedimentation Tank			With Primary Sedimentation Tank		
	Advanced OD	SBR	EA	MBBR	A2O	MBR
Nitrogen rem oval	5	5	5	5	5	5
Treated Water Quality	4	4	4	4	4	5
Lot for Treatment Process	3	3	3	3	3	3
CAPEX	3	3	3	3	2	2
Easiness of Maintenance	3	3	3	3	2	2
OPEX	4	3	3	3	3	3
Past Record In India	1	4	4	2	1	1
Total	23	25	25	23	20	21
Adoption	Better	Best	Best	Better	Fair	Fair

Note: Evaluation score 5:Best, 4:Better, 3:Fair, 2:Poor, 1:Bad
Source: JICA Survey Team

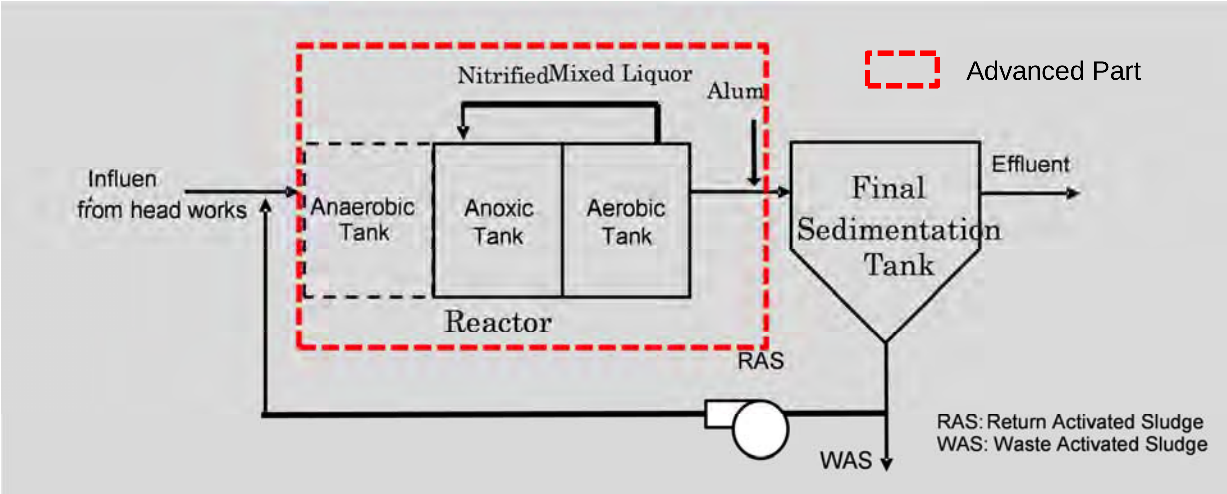
4) Alternative Study for the Treatment Process

Considering above evaluation results, experience at existing STPs in Bengaluru and new stringent effluent standards adopted in April 2015, Extended Aeration process (EA) and Sequencing Batch Reactor process (SBR) are listed as the candidate treatment processes. However, these processes need enhanced nutrient removal to meet the new effluent standards as described below.

a) Extended Aeration (EA) Process with Enhanced Nutrient Removal

EA process consists of a reactor and a final sedimentation tank, where a primary sedimentation tank is omitted. Instead of omission of primary sedimentation tank, the reactor should have a larger volume than ASP. For nitrogen removal, the reactor has anoxic tank and aerobic tank, where nitrification and denitrification are carried out by circulating nitrified mixed liquor from aerobic tank to anoxic tank (see Figure 10.2.27). For phosphorus removal, alum is added to mixed liquor before flowing into the Final Sedimentation Tank. If phosphorus concentration of raw sewage is over 7 mg/l, anaerobic tank should be added to the reactor for biological phosphorus removal, because overdose of alum affects nitrifiers.

There are some existing STPs applying the mentioned above process without dosing Alum, which are K & C Valley STP, Mailasandra STP and Raja Canal STP. It was confirmed that nitrogen is removed to meet the new effluent standard at these STPs. However, phosphorous cannot be removed without dosing Alum.

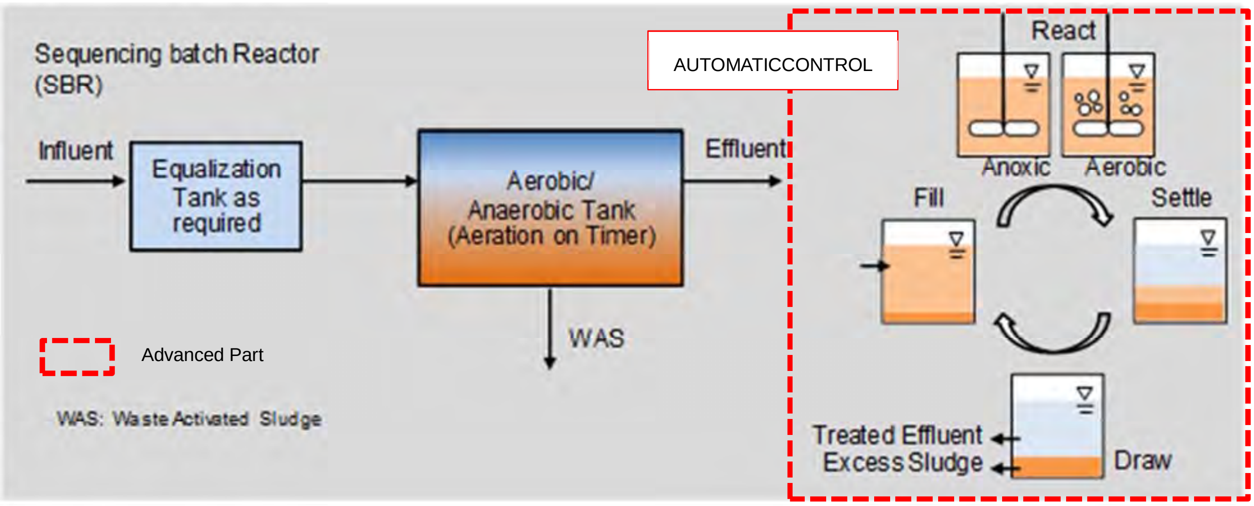


Source: JICA Survey Team

Figure 10.2.27 EA Process with Enhanced Nitrogen and Phosphorus Removal

b) Sequencing Batch Reactor (SBR) with Enhanced Nutrient Removal

SBR-process is carried out in a single tank, where cyclic actions are repeated: fill, aeration, reaction, settling, and decanting (see Figure 10.2.28). To remove nitrogen, either putting anoxic reaction time in a cycle, or making an anoxic zone in a reactor is required. For phosphorus removal, alum is added to the SBR basin at the end of aeration period before settling. If phosphorus in the influent sewage is over 7mg/l, the phosphorus removal to meet effluent standards may not be easy.



Source: JICA Survey Team

Figure 10.2.28 SBR Process with Enhanced Nitrogen and Phosphorus Removal

c) Comparison of Biological Treatment Process

Results of comparison between the biological treatment processes are difference depend on condition like as characteristics of influent sewage so that the condition should be set before the comparison. Therefore, the condition has been set as shown in Table 10.2.33.

To estimate a volume of reactor, the following items are needed;

- Required volume to secure nitrifier in aerobic tank,
- Required volume for denitrification in anoxic tank,
- Circulation rate of nitrified mixed-liquor to achieve desired nitrogen removal performance.

If the above values are appropriate, BOD removal performance also will be achieved.

Table 10.2.33 Assumptions for Comparison of Biological Treatment Processes

Item	Design Value	
Temperature	20 ℃	
MLSS	3,000mg/l	
Water quality	Influent	Effluent
BOD	350mg/l	10mg/l
COD	800mg/l	50mg/l
TSS	450mg/l	10mg/l
T-N	70mg/l	10mg/l
NH4-N	45.5mg/l	5mg/l
T-P	7mg/l	2mg/l

Source: JICA Survey Team

The comparison between those processes that are supposed at the influent sewage characteristics are shown in the Table 10.2.34. Considering performance and easiness of maintenance, Extended Aeration system is recommended. Since the planned STPs are ranged from 3MLD to 17MLD as comparatively low capacity, daily flow fluctuation may be high. Thus, SBR system may require flow equalization tank to balance the flow.

Table 10.2.34 Comparison of Biological Treatment

Process	EA	SBR
Performance to meet new standards.	**4**	**3**
Footprint area	**5**	**5**
Primary Clarifier	No need	No need
Reactor	HRT= 25hr	HRT= 32hr
Final Clarifier	HRT= 7.0hr	No need
Capital expense	**5**	**4**
Operational expense	**4**	**5**
Electrical power	Moderate	Moderate to low
Alum consumption	Moderate	Moderate
Maintenance & repair	Moderate	Moderate
Easiness of maintenance	**4**	**3**
	Flexible operation can be done easily.	At the maintenance of a decanter or diffusers, the operation is not easy.

Process	EA	SBR
Past record in Bengaluru/ India	**5**	**4**
Total Score Evaluation	**27**	**24**

Legend: 5: Excellent, 4: Good, 3: Fair, 2: Poor, 1: Bad, 0: N/A (Not Applicable), EA: Extended Aeration, SBR: Sequenced Batch Reactor

Source: JICA Survey Team

5) Disinfection Process

As agents for disinfection of the effluent, ozone, UV radiation, and chlorine are commonly used at STPs. Disinfection with ozone is used for reuse applications due to its ability to reduce trace constituents. However, capital and power cost is higher than the others (UV and chlorine) in case of no application for effluent reuse.

Disinfection with UV radiation is more compact than chlorine disinfection, and chemical consumption is also less than others. In addition, it does not generate byproducts such as Trihalomethanes (THMs) or Haloacetic acids (HAAs). However, the experience at STPs in India is limited and more stringent water quality control is required because particles affect its germicidal effectiveness. Therefore, an elaborate investigation is necessary to apply this technology.

Chlorine is the most common agent for disinfection having high effectiveness for bacteria and viruses and its continuity. However, it will produce THMs and HAAs in presence of precursors. To meet the environmental standards for “no residual chlorine in effluent allowed for discharging to waterbody”, de-chlorination system may be required. The comparison among the three (3) methods are shown on Table 10.2.35.

Considering cost, experience, and effectiveness for bacteria/ viruses, chlorine is the most applicable and reliable. Provided that high concentration of chlorine is required to meet the new discharge standard of fecal coliform less than 100 MPN/100ml. Moreover, sensitive control of chlorination dosing will be required or de-chlorination system may be required to meet the environmental standards.

Table 10.2.35 Comparison of Disinfection Methods

Items	Chlorine	UV radiation	Ozone
Germicidal Effectiveness	5	4 Depend on TSS	5
Capital expense	4 Larger reactor than the others. HRT > 30min. Tanks for de-chlorination required. Building for chemical dosing facility and storage is required.	3 The most compact reactor. No building required. Less devices than the others.	3 HRT > 10min Special painting for ozone is required in reactor. Most of equipment must be in a building where ozone concentration monitored strictly. Many devices required. (Gas preparation unit, ozone generator, Off gas destruct unit, ozone monitoring system, etc.)

Items	Chlorine	UV radiation	Ozone
Operational expense	4	4	3
Chemicals	Chlorine and chemical for de-chlorination.	No required.	No required.
Electrical Power	Least consumption	More than chlorine	The most
Consumable parts	Dosing facility etc.	UV lamps	Filling material for Off gas destruct units
Easiness of O&M	4	4	3
Track Record	5	3	3
Total Score (Evaluation)	**22**	**18**	**17**

Legend: 5: Excellent, 4: Good, 3: Fair, 2: Poor, 1: Bad, 0: N/A (Not Applicable)

Source: JICA Survey Team

6) Sludge Treatment

a) Common practices on sludge treatment and disposal

During the process of sewage treatment, excess sludge is generated, which shall be treated. The sludge is generated at primary and secondary sedimentation tanks. The moisture content of the sludge is about 99%, requiring concentration for disposal. The method of concentration includes sludge thickening and mechanical dewatering. Power generation is also applied at larger scale STPs using biogas generated at sludge digester. Usually sludge is dewatered by sludge drying bed after sludge thickener. Then, dried sludge is used by farmers as organic fertilizer as shown below.

Excess Sludge → Sludge Thickener → Sludge Drying Bed → Organic fertilizer (Farmer)

The generated sludge at the 14 existing sewage treatment plants in Bengaluru (where information is available) is summarized in Table 10.2.36. Currently, 36.3 tons of sludge is daily generated as by-product of treating 594 MLD of sewage and being disposed of as organic fertilizer.

Table 10.2.36 Sludge Generation at Existing STPs

No.	Location	Sewage treatment capacity (MLD)	Daily average treatment volume (MLD)	Daily generated sludge (tons)	Sludge Disposal
1	K & C Valley (108 + 55 + 55)	218	195	9.5	Organic fertilizer (Agriculture)
2	K & C Valley	30	30	2.0	Ditto
3	Kadabeesenahhali	50	45	1.9	Ditto
4	Lalbaug	1.5	1.5	0. 1	Ditto
5	Cubbon Park	1.5	1.5	0.10	Ditto

No.	Location	Sewage treatment capacity (MLD)	Daily average treatment volume (MLD)	Daily generated sludge (tons)	Sludge Disposal
6	Hebbal	60	56	4.55	Ditto
7	Raja Canal	40	35	2.36	Ditto
8	K.R. Puram	20	22	1.54	Ditto
9	Yalahanka	10	6	0.38	Ditto
10	Jakkur	10	8	0.44	Ditto
11	V. Valley	180	100	6.25	Ditto
12	Mylasandra	75	75	6.09	Ditto
13	Nagasandra	20	18	1.13	Ditto
14	Kempambudhi	1	1	0.06	Ditto
Total		717	594	36.3	-

Source: BWSSB

b) Policy for Sludge Treatment by BWSSB

Currently BWSSB adopts mechanical thickening and mechanical dewatering for the treatment of generated sludge as shown below.

Thickening → Mechanical Dewatering → Simplified composting facility or Storage → Organic fertilizer (Farmer)

Sludge thickener is used for decreasing sludge volume to reduce a capacity of dewatering facility. However, there is less advantageous for applying sludge thickener in the smaller scale STPs according to the experience in Japan. Direct dewatering machine is available and this method is getting popular these days in Japan for smaller size STPs. Therefore, omitting thickener is more economical in case of the STPs with less than 10 MLD capacity.

For BWSSP Phase 2, digestion facility is only applied for K&C valley STP (60 MLD) whose capacity is large. Since, the planned STPs are small ranging from 3 MLD to 17 MLD, generation of sufficient sludge can’t be expected to produce biogas for power generation, even in provision of digestion facilities. Also, the maintenance will be complicated because the number of mechanical equipment will be increased.

The sludge generated at the STPs is expected to be utilized for agriculture, since industrial wastewater is not collected in the sewage systems. However, the demand of fertilizer has been reducing considerably in the urban area. It is necessary to consider disposal of sludge using landfill.

Policy for sludge treatment is summarized as follows;

- The STPs in 110 Villages are located in the outskirts of Bengaluru city and are proximal to farming land. There is higher possibility that farmers may approach the STPs for manure.

- Mechanical methods of dewatering can help in reducing the footprint of the sludge drying beds.
- In case of lack of demand from farmers, provision for disposal on land fill may have to be explored.
- BWSSB should explore the feasibility of installing central sludge management units.
- Direct dewatering without thickening process may be applied for smaller size STPs to minimize the capital cost and O&M.

c) Sludge Thickening

Thickening of sludge is required to reduce the sludge volume before transferring it to digesters/dewatering unit so as to reduce the digester volume and/or dewatering unit. Thickening technologies are explained below.

【Dissolved Air Floatation (DAF)】

DAF is effective in thickening of sludge by introduction of microscopic air bubbles which adheres to incoming solids and form a buoyant blanket. This blanket rises to the surface of the DAF tank and is removed by mechanical means.

【Gravity Thickener】

This conventional means of thickening utilizes the natural tendency of higher density solids to settle down in liquid to concentrate the solids. Gravity thickeners consist of circular tank with conical bottom fitted with centrally driven scrapers.

【Gravity Belt】

It works on the principle of separating liquid from solids by gravity drainage through a porous filter cloths and belts through a system of rollers.

Typical sludge thickening processes are compared in Table 10.2.37.

Due to less energy consumption and no chemical requirement, gravity thickener is recommended for STP with more than 10 MLD capacity in this study. Gravity thickener can be omitted for the STP with a capacity less than 10 MLD, instead applying direct-dewatering. Details are explained in next section.

Table 10.2.37 Comparison of Sludge Thickening Equipment

Items	Gravity Thickener	Dissolved Air Flotation (DAF)	Gravity Belt
Description	Sludge is thickened by the natural tendency where higher density solids are settled down in liquid to concentrate the solids.	Sludge is thickened by introduction of microscopic air bubbles which adheres to incoming solids and form a buoyant blanket. This blanket rises to the surface of the tank and is removed by mechanical means.	Sludge is separated by gravity drainage thorough a porous filter cloths and belts through a system of rollers.

Items	Gravity Thickener	Dissolved Air Flotation (DAF)	Gravity Belt
Performance	3	5	5
Achievable Solid concentration	2-4 %	4-6 %	4-6 %
Solids recovery rate	80-90 %	95 %	95 %
Capital expense	4	2	3
Footprint	Large	Moderate	Moderate
Civil/ Building	Moderate	High	High
ME	Low	High	Moderate
Operational expense	5	3	3
Chemicals	None	None	High
Electrical Power	Low	High	Moderate
Repair	Low	Moderate	Moderate
Easiness of O&M	4	4	4
Required Skill	Low	Moderate	Moderate
Corrosion	High	Moderate	Moderate
Odour problem	Serious	Moderate	Moderate
Track Record India	5	4	3
Total Score (Evaluation)	21	18	18

Legend: 5: Excellent, 4: Good, 3: Fair, 2: Poor, 1: Bad, 0: N/A (Not Applicable)
Source: JICA Survey Team

d) Sludge Dewatering

Dewatering of sludge is required to reduce the sludge volume to dispose so as to reduce the number of truck for sludge disposal and footprint for sludge storage yard at the STP. Thickening technologies are explained below.

【Belt Press】

It works on the principle of separating liquid from solids by press through a porous filter cloths and belts through a system of rollers (see Figure 10.2.29).

Source: http://www.protecsales.com/Belt-Filter-press_Page_2_Im.gif

Figure 10.2.29 Typical Image of Belt Press

【Centrifuge 】

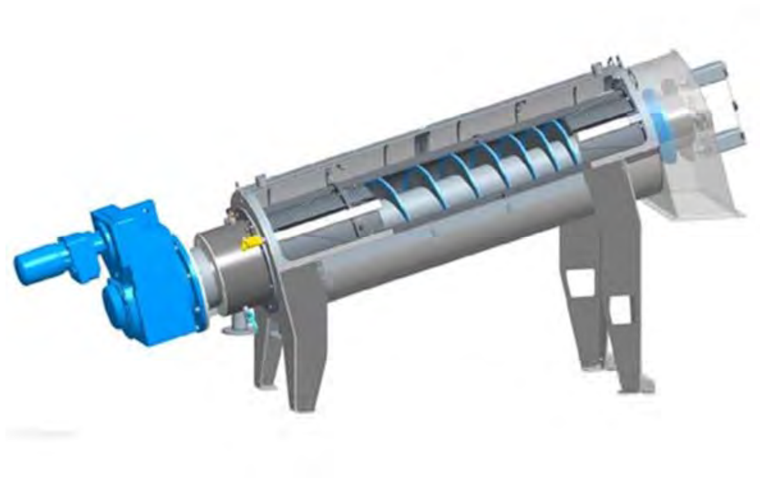
The centrifuge utilizes the centripetal force for the separation of solids from liquid due to the different densities. Usually solid-bowl centrifuges with differential scroll drives are used for sludge thickening (See Figure 10.2.30).

Source: https://www.google.co.jp/search?q=centrifuge+sludge+%EF%BF%BD&tbm

Figure 10.2.30 Typical Image of Centrifuge

【Screw Press】

Screw press is a mechanical system in which thickening is accomplished by gravity drainage at the inlet end of the screw and then by reducing the volume as the sludge being dewatered is conveyed from the inlet to the discharge end of the screw press (See Figure 10.2.31).

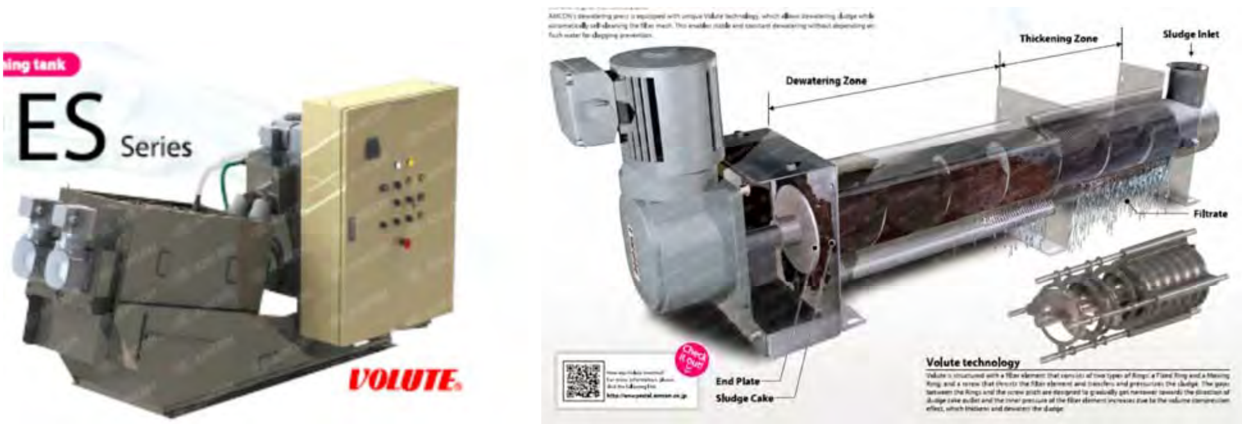


Source: http://www.hydrofluxindustrial.com.au/wp-content/uploads/2013/08/screw-press.jpg

Figure 10.2.31 Typical Image of Screw Press

【Volute Dewatering Press】

Solid is separated directly from liquid by a filter element that consists of two (2) types of rings. Fixed rings, moving rings and a screw thrust, squeeze, transfer and press the filter element and the sludge (See Figure 10.2.32).



Source: AMCON INC. catalogue

Figure 10.2.32 Typical Image of Volute Dewatering Press

Table 10.2.38 shows the comparison of dewatering equipment. Centrifuge is the most suitable option for thickening as it has most compact footprint, capital expense and experience.

Table 10.2.38 Comparison of Dewatering Equipment

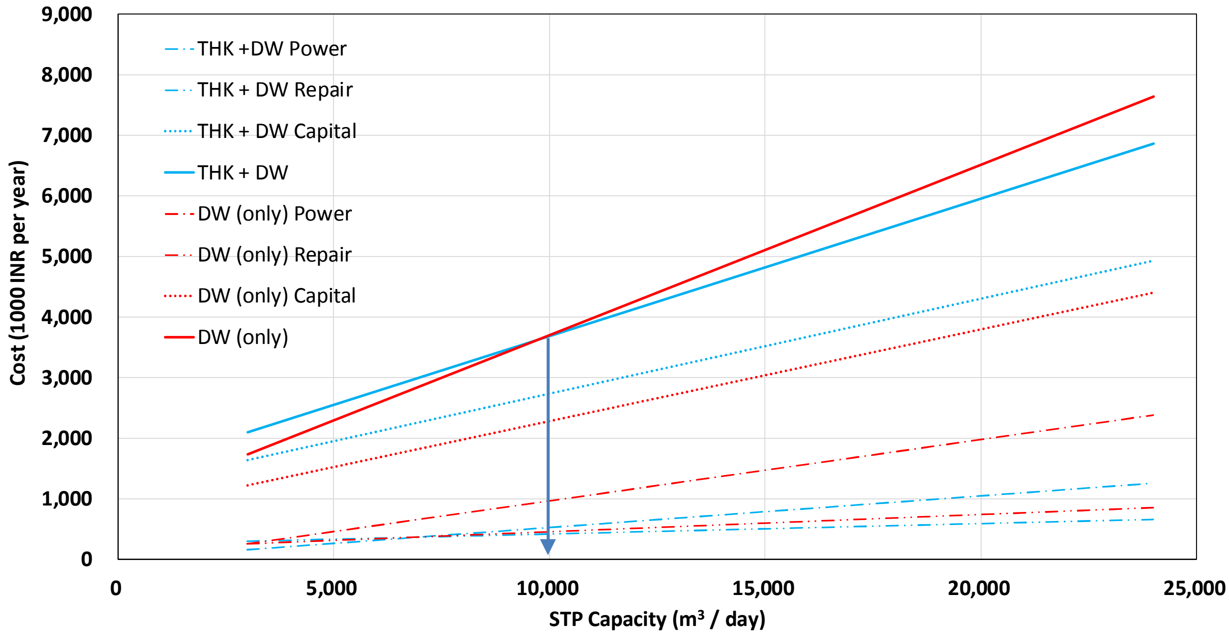
Items	Centrifuge	Belt Press	Screw Press	Volute Dewatering Press (without gravity thickener)
Performance	4	4	4	4
Dewatered Cake Solid	18 - 20 %	18 - 20 %	18 - 20 %	18 - 20 %
Solids recovery rate	95 %	95 %	95 %	95 %
Capital expense	5	4	3	3
Footprint	Moderate	Large	Moderate	Moderate
Civil/ Building	Moderate	High	Moderate	Moderate
M&E	Moderate	Moderate	Moderate	High
Operational expense	4	4	5	5
Chemicals	Moderate	Moderate	Moderate	Moderate
Electrical Power	High	Moderate	Low	Low
Wash water	Moderate	High	Moderate	Low
Repair	High	Moderate	Moderate	Moderate
Easiness of maintenance	4	3	4	5
Required Skill for operation	Moderate	High	Moderate	Low
Noise level	High	Moderate	Moderate	Low
Odour problem	Low	Serious	Moderate	Moderate
Track Record in India	5	4	3	3
Total Score (Evaluation)	**22**	**19**	**19**	**20**

Legend: 5: Excellent, 4: Good, 3: Fair, 2: Poor, 1: Bad, 0: N/A (Not Applicable)
Source: JICA Survey Team

Figure 10.2.33 shows an economical study on necessity of gravity thickener. As a result of the study, gravity thickener plus centrifuge dewatering is recommended for the STP with more than or equal to 10 MLD. For the STPs with less than 10 MLD, direct dewatering without thickening process such as “Volute Dewatering Press” is recommended.

Also, there is a lot of experiences in Japan for direct-dewatering (without thickener) called volute Dewatering Press in case of STP with a capacity of less than 10 MLD. It will reduce the mechanical equipment and maintenance work for sludge treatment.

Rotary drum is not considered as it has issue with cloth media clogging and replacement, requiring equipment downtime.



Note: THK=Gravity Thickener), DW =Centrifuge Dewatering Process, DW (only) = Centrifuge Dewatering Process only (Without Thickener)

Source: JICA Survey Team

Figure 10.2.33 Economical Study on Necessity of Gravity Thickener

e) Sludge Digestion

Sludge digester is applied only for the STP with capacity more than 50 MLD. Therefore, sludge digester is not considered for 110 Villages sewerage project. However, centralized treatment may be considered in the future because some of STPs are located closely.

f) Sludge Disposal

Presently, dried or dewatered sludge is utilized as organic fertilizer. However, demand by farmers has been reducing considerably in the urban area. As sludge disposal process in urban area of Japan, dewatered sludge is incinerated to reduce the volume for reduction to landfill or re-use as cement mixing materials. However, proposed STPs are located outside of the city nearby farmland, thus reuse as fertilizer seems to be realistic. Also, the sludge is safe to use as fertilizer, since industrial wastewater is not accepted into the sewerage systems.

Under BWSSP Phase 2 assisted by JICA, K & C Valley STP (60 MLD) has power generation facility, whereas Kengeri STP has gas production facility, but there is no power generation capability. The other plants are provided with sludge drying beds.

For existing plants, BWSSB has entrusted the responsibility for disposal of the sludge generated at the STPs to the O & M contractors. O & M contractors dispose the treated sludge by generally selling it (as manure) to farmers at a nominal price / free, with the farmer arranging for transportation of digested sludge. Where there is no demand on sludge from farmers, the O&M contractors may have to arrange the sludge for landfill.

In newly tendered STP projects, the Design Build Operate (DBO) contractors need to maintain the plant for a period of 7 to 10 years. During this phase, BWSSB considers lead charges for disposal of treated sludge assuming 5 km distance for transportation. Contractors shall identify the proper landfill site/s and get approval from BWSSB before starting the operation. If the demand on sludge from farmers is not confirmed, the DBO contractors may have to arrange the sludge for landfill.

The screenings collected at the inlet screens have to be disposed at landfill site. The contractor has to arrange for such disposal as well.

7) Sludge Treatment Method for Planned STPs

Sludge Treatment method for planned STPs are summarized in Table 10.2.39. Extended aeration with enhanced nutrient removal followed by chlorination disinfection shall be applied for sewage treatment method.

Table 10.2.39 Treatment Method for Planned STPs

Zone	Name	Average Flow (MLD)	Treatment Method		Sludge Disposal
			Sewage	Sludge	
Bytrayanapura	Jakkur	7.0	EA + CHL	(TH) + DW	Fertilizer for farmland
	Yelahankakere	6.0	ditto	ditto	ditto
	Doddabettahalli	7.0	ditto	ditto	ditto
	Bilishivalli	17.0	ditto	TH + DW	ditto
Mahadevpura	Varthur	15.0	ditto	TH + DW	ditto
Bommanahalli	Pillaganahalli	4.0	ditto	(TH) + DW	ditto
	Talaghattapura	5.0	ditto	ditto	ditto
R.R. Nagar	Somapura	8.0	ditto	ditto	ditto
	Hemigepura	13.0	ditto	TH + DW	ditto
Dasarahalli	Nagasandra*	9.0	ditto	(TH) + DW	ditto
	Karivobanahalli	10.0	ditto	TH + DW	ditto
	Herohalli	3.0	ditto	(TH) + DW	ditto
	Hosahalli	6.0	ditto	ditto	ditto
	Chikkabanavara-2	4.0	ditto	ditto	ditto

Note: EA: Extended Aeration Process, CHL: Chlorination, TH: Thickener, ( ): Possibility of Cancel, DW: Mechanical Dewatering
Nagasandra* STP is an existing STP which will be diverted the sewage flow from Daddabidarakallu area.
Source: JICA Survey Team

10.2.6 ISPS

(1) Required ISPSs in Application of the Study Results in the DPR

ISPSs (Intermediate Sewage Pumping Station) are planned at three (3) sites in the DPR. The requirements of ISPSs were further studied based on the hydraulic calculation of sewer lines in the preliminary design. In this sub-section, a total of seven (7) ISPSs are planned including three (3) ISPSs in the DPR and four (4) ISPSs planned instead of STPs which are included in the DPR, through above mentioned study on sewerage systems. The locations of the seven (7) pumping stations are shown in Figure 10.2.34.

Table 10.2.40 shows planned ISPSs. The size of the three (3) ISPSs (Naganathapura, Hagadur and Daddabidarakallu ISPSs) is large with about 13 MLD or 24 MLD in 2049 to transfer collected sewage in respective service areas.

Table 10.2.40 Design Sewage Flow for Planned ISPSs

Zone	ISPS		Design Flow (MLD)	
	Name	Revised from DPR	2034	2049
Bytrayanapura	Bellahalli	Design Flow	0.9	1.5
Mahadevpura	Hagadur	Changed from STP	15.0	24.0
Bommanahalli	Naganathapura	Changed from STP	9.0	13.0
R.R. Nagar	Arehalli 1	Design Flow	1.1	1.7
	Hemigepura	Changed from STP	1.6	2.4
Dasarahalli	Herohalli	Design Flow	0.5	0.7
	Daddabidarakallu	Changed from STP	8.1	12.8

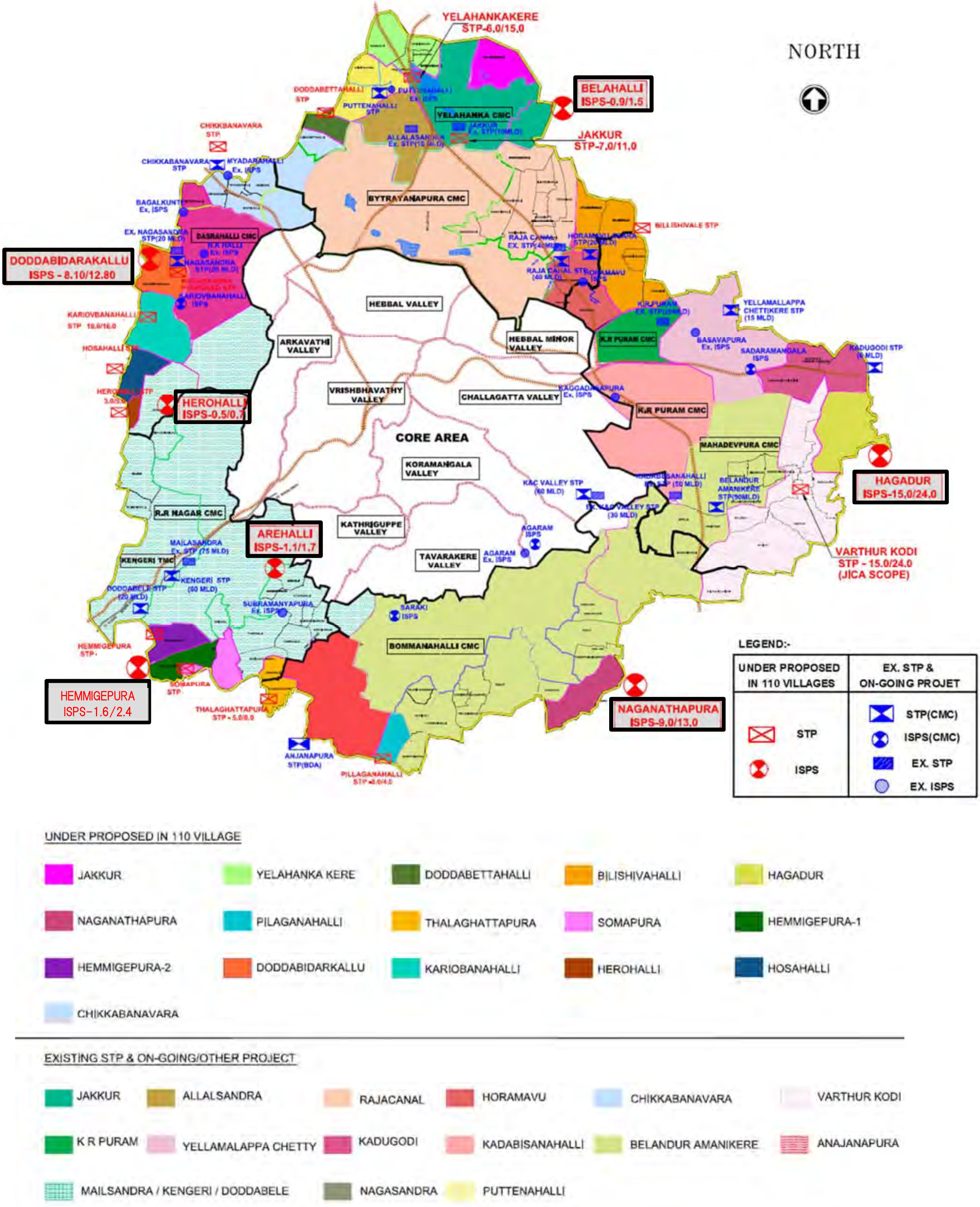
Note: This design flow shows daily average flow.
Source: JICA Survey Team

The pump capacity required shall be determined considering a peak factor. The peak factor shall be adjusted depending on population size as shown in CPHEEO standard (see Table 10.2.41).

Table 10.2.41 Peak Factor for Contributory population

Contributory population	Peak factor
UP to 20,000	3.00
Above 20,001 to 50,000	2.50
Above 50,001 to 750,000	2.25
Above 750,001	2.00

Source: CPHEEO 1993



Source: JICA Survey Team

Figure 10.2.34 Location of ISPSs

(2) Application of Different Types of ISPSs

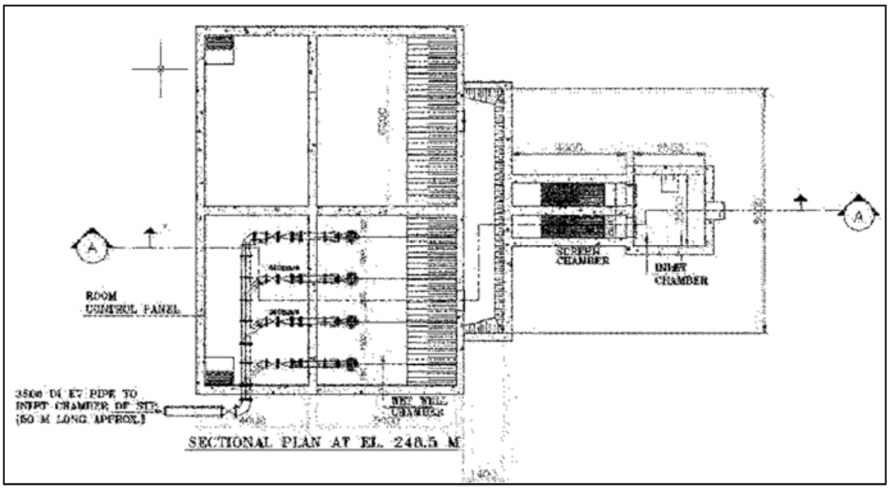
Different types of pumping stations are adopted depending on inflow sewage volume, sewage quality including impurities. These types are as follows:

- Type 1: standard Pumping Station provided with a series of facilities; screen, grid chamber and pump well covered by Pump room
- Type 2: Basically same as Type 1, but grid chamber is omitted.
- Type 3: Manhole type pumping station (submergible pump)

In Bengaluru, existing pumping stations use Type 2 or Type 3. For example, the biggest pumping station with a design capacity of 65 MLD in Agaram located in the Core area adopted Type 2. Photo 10.2.22 shows existing manhole type pumping station.

Photo 10.2.22 Manhole Type Pumping Station (presently not being operated)

Type 2 pumping station is recommended as a standard facility in India (see Figure 10.2.35). The two types of ISPSs shall be employed in the preliminary design; type 2 for a larger size and type 3 for small size pumping stations.



Source: Indian Guideline

Figure 10.2.35 Plan of Standard Pumping Station in India

(3) Plan of ISPSs

Of the planned ISPSs, a manhole type ISPS was planned for Herohalli in the DPR. However, this type of pump station is not recommendable in Bengaluru as shown in Photo 10.22 (not functioning). Although it is advantageous in the area where available land is limited, without proper O&M of facilities it is easy to become non-functioning (No space for the installation of generator set is also one of the issues for stable operation.).

Table 10.2.42 shows the planned land area in the existing/on-going project. Required land areas for the five pumping stations to accommodate generator set and electrical panel room for ISPS are estimated as shown in Table 10.2.43.

Table 10.2.42 Land Area for Existing/On-going ISPSs

Name	Capacity	Dimensions	Land requirement (ha)
Sarakki ISPS	18 MLD	W x L = 30 m x 40 m	0.12 ha
Chikkabanavara TSPS	5 MLD	W x L = 10 m x 15 m	0.02 ha

Source: JICA Survey Team

It was confirmed that required land areas for planned ISPSs will be ensured, thus, Type 2 ISPS shall be adopted for all ISPSs.

Table 10.2.43 Land Area for Planned ISPSs

Zone	ISPS Name	Flow in 2049 (MLD)	Required land area（ha）	Available public land area（ha）
Bytrayanapura	Bellahalli	1.5	0.01	0.4
Mahadevpura	Hagadur	24.0	0.20	0.5
Bommanahalli	Naganathapura	13.0	0.10	0.2
R.R Nagar	Arehalli 1	1.7	0.01	0.1
	Hemigepura	2.4	0.10	0.2
Dasarahalli	Herohalli	0.7	0.01	0.1
	Doddabidarakallu	12.8	0.10	0.2

Source: JICA Survey Team

Chapter 11 The Projects to be Implemented by Indian Side

11.1 General

Three major projects are proposed by BWSSB to improve/expand water supply and sewerage services in the BBMP area. These projects are categorized into two groups from realistic view point considering current development for the realization of the planned projects including local fund availability.

Nevertheless, all projects for water supply and sewerage services, which are categorized into JICA Survey project and Indian side undertaking project, need to function timely and properly in the overall BBMP area. In this connection, facility plans for the additional two component works; required facilities to establish permanent distribution systems for 110 Villages in line with Stage V water supply and Branch Feeding Pipes for water sharing to Core/ULBs were prepared on a preliminary basis in this Chapter.
The following projects are proposed to be undertaken by Indian side to complete overall needs.

1) 110 Villages Water Supply Project:
 a) Urgent need: Feeder pipes between existing GLRs and pumping facilities which are connected to main distribution pipes for each village water supply. Distribution pipe networks by village and Booster pump units are also required.
 b) Permanent need: Feeder pipes between planned GLRs in Stage V and OHTs, OHTs and pumping facilities
2) Stage V related Project:
 a) Conveyance Pipeline
 b) Branch Feeding Pipes to share water from Stage V Project to Core/ULB area
3) 110 Villages Sewerage Project (lateral sewers and house connections)
4) UFW Reduction Project

Firstly review results are summarized with recommendations on the above mentioned projects prepared in the concerned DPRs considering updated information on the projects.

11.2 110 Villages Water Supply Project and UFW Reduction Project for Core Area

BWSSB will implement 110 Villages Water Supply Project and UFW Reduction Project for the remaining area in the Core area, not taken up in Stage IV Phase 2, with financial assistance from GoK (66%), GBWASP (Greater Bengaluru Water Supply Project) and BCC (Beneficiary Capital Contribution) funds. This on-going water supply (110 Villages distribution facilities) is temporary countermeasures using water to be saved through UFW Reduction Project and some to be shared through existing five GLRs constructed for Stage I to Stage IV Phase 2 services.
In September 2016, original DPRs for the both projects were revised. Then, a combined report for the two projects was submitted to GoK for its approval. The combined DPR was approved by GoK through its order dated September 2016. Table 11.2.1 summarizes cost requirements for the two projects.

Table 11.2.1 Cost for 110 Villages Water Supply & UFW Reduction Project - Approved by GoK

S/N	Particulars	Grand Total (Million INR)
1	110 Villages Water Supply Project	
A	Providing water supply including feeder mains connected to existing GLRs and distribution systems, etc.	13,146
B	Providing online booster pump, construction of pump house, treated water sump tank and generator room with office, etc.	1,919
2	**UFW Reduction Project**	
A	Distribution improvement and UFW reduction component (East, North and South-East, Core area of Bengaluru). (tentative costs as a component, but not finalized by BWSSB)	3,795
	Total Cost of the project	**18,860**

Source: BWSSB and JICA Survey Team

11.2.1 Review Results on Original DPR and On-going Project for 110 Villages Water Supply

The distribution networks from GLRs for 110 Villages (existing and newly constructed GLRs) are planned in the DPR. Likewise, OHTs of 137 units were planned to connect to the GLRs in the DPR, however, all OHTs are cancelled for the on-going project, applying the pump direct distribution method, as a temporary water supply. The bidding was commenced in November 25, 2016. This arrangement was made to meet urgent needs in 110 Villages compromising an intermittent water supply under limited water available before completion of Stage V Project. The following are relevant information on the on-going temporary water supply project.

(1) Outline of Urgent 110 Villages Water Supply Project and UFW Reduction Project

1) Scope of Work

BWSSB commenced a bidding for the construction of the facilities as shown below.

a) Main pipelines with diameters ranging from 762 mm to 1,829 mm, which are made of Mild Steel with a total length of 205 km

b) Distribution pipeline networks with diameters ranging from 100 mm to 600 mm, which are made of Ductile Iron with a total length of 2,979 km

c) Inline booster pump, construction of pump houses, pure water sump and Diesel Generator (DG) room, office, etc.

2) Detailed Cost Requirements

The planned detail Cost for 110 Villages Water Supply Project is given in Table 11.2.2.

Table 11.2.2 Planned Cost for 110 Villages Water Supply

S/N	Particulars	Grand Total (Million INR)
A	Providing water supply, Feeder mains and distribution system etc. complete	10,151
B	Providing online booster pump, construction of pump houses, pure water sump and DG room with office etc.	1,505
	Sub-total water component	**11,656**
	Physical Contingency @3%	350
	Administrative Charges @0.5%	57
	Land Acquisition	204
	Sub-total 1	**611**
	Total (A + B)	**12,267**
	Other Additional Costs	0
	Price Escalation at 6% / annum of the total project costs for 3 years	2,098
	Construction workers welfare cess @1% of the total project costs	117
	Work contract tax @ 4% of the total project costs	466
	Consultancy fee for DPR preparation (Reimbursement) on water supply component at 0.5%	58
	Project Management Consultancy and Materials Inspection Charges at 0.5%	58
	Sub-total 2	**2,797**
	Miscellaneous and Rounding off	0.00
	Grand Total	**15,064**

Source: BWSSB

The following cost is not considered in the above cost estimates.

- Environmental Compliance Costs
- Rehabilitation and Resettlement costs
- Detailed Survey and Investigation
- Shifting Utilities
- Other statutory compliances beyond that already considered as contract tax, labour cess etc.

3) Implementation Schedule

According to the DPR, the project needs to be completed by March 2020.

- 300 days for award of contract
- Up to March 2020 – Construction

4) Tendering Process

BWSSB conducted tenders inviting pre-qualified bidders for construction of distribution facilities covering 5 zones. The scope of work includes operation and maintenance for 12 months. The tender details are shown in Table 11.2.3.

Table 11.2.3 Tenders invited for 110 Villages Water Supply

Zone name	Tendering Date From - To	Last Date of Tender Submission	Period of Completion (Including monsoon period)	Amount put to tender in Million INR
Bommanahalli	25/11/2016 - 23/01/2017	24/01/2017	24 months	2,321
Bytrayanapura	25/11/2016 - 23/01/2017	24/01/2017	24 months	1,549
Dasarahalli	25/11/2016 - 23/01/2017	24/01/2017	24 months	1,190
Mahadevapura	25/11/2016 - 23/01/2017	24/01/2017	24 months	2,669
R.R. Nagar	25/11/2016 - 23/01/2017	24/01/2017	24 months	782
Total				**8,511**

The following items are not included in the tender.

- House connections / meter installation are not considered as they are included in house connection fee paid by the consumers
- Further the following items do not seem to be considered in the scope of work
  ⇒ Booster pump installation
  ⇒ Bulk flow meter and remote controlled valves
  ⇒ OHT Tanks

The project was commenced in June/2017.

(2) Review Results of Original DPR

Planned water supply systems in the DPR are reviewed and summarized with recommendations as follows:

1) System Configuration

a) Review on the route and capacity of pipelines from GLRs to OHTs is required as the locations of GLRs were changed from original DPR.

b) The DPR planned to supply water through 137 OHTs controlling water pressure and flow to each service area to meet the water demand. The planning concept is reasonable and recommendable when Stage V Project will be achieved with sufficient water supply to achieve permanent systems.

c) Stage V Project is planned to meet the water demand for 110 Villages in the target year 2049 and surplus water amount in the intermediate years can be shared to Core and ULB areas. The manner of transmission arrangements for the sharing water to Core and ULB areas is included in this Chapter.

d) Present water supply services in Core and YKBs is an intermittent base (6 to 8 hours every other day). However, planned water supply amount meets the demand for 110 Villages upon completion of Stage V Project. Thus, it is recommended to supply water on a 24/7 base.

e) In order to control flow rate, pressure and pipe condition, it is recommended to introduce blocked distribution system complied with bulk flow meter and valves. SCADA system is recommended to monitor each condition to detect water leakage and to increase tariff collection. District Metered areas should be introduced at the onset for better management of water supply system.

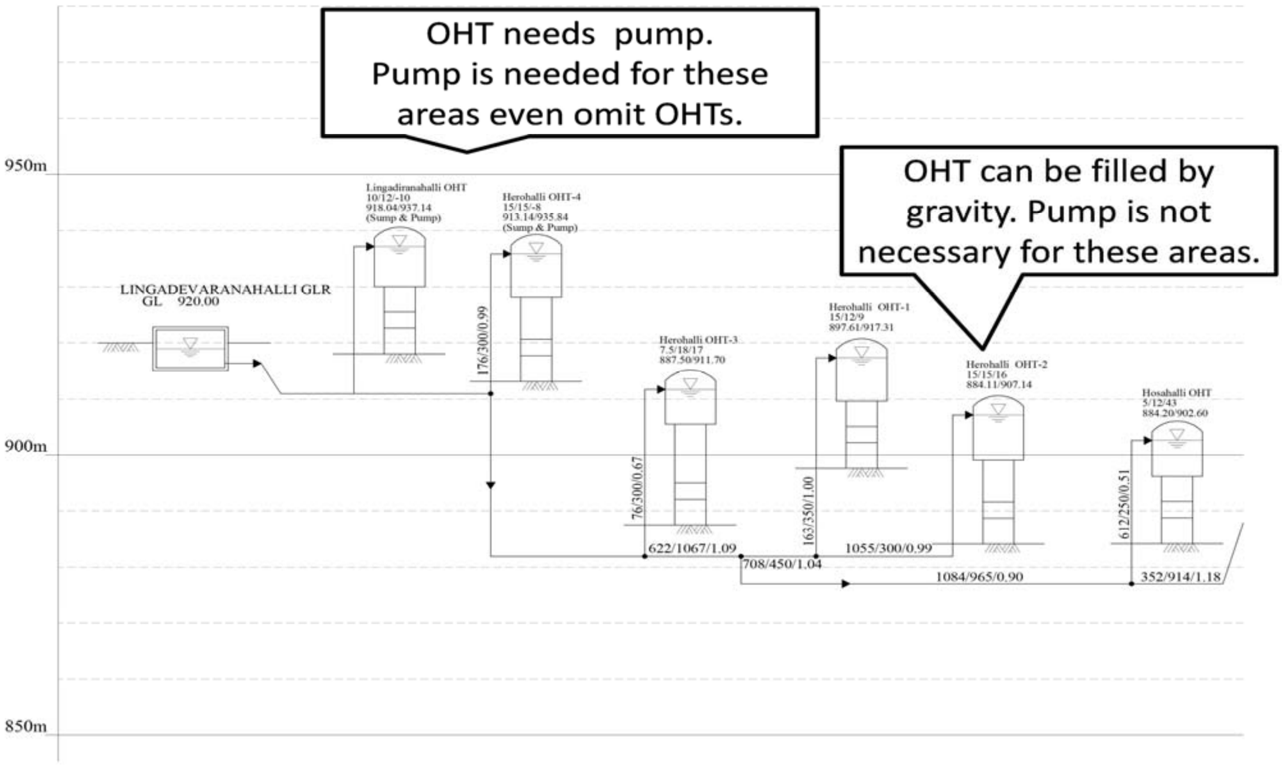
a) BWSSB may also introduce efficient methods for billing in 110 Villages

2) OHT Tank

a) Advantageous Function of OHT

Over Head Tank (OHT) is applied in the original DPR prepared in 2013 (refer to Figure 11.2.1). Their advantageous functions are as follows:

- Distribution of water by gravity maintaining adequate water pressure (even during night time)
- Required daily demand is sent timely from WTP to manage the fluctuation of water demand through the day in the respective service areas. The capacity of the OHT is determined to accommodate required amount for hourly maximum water need.
- There are some disadvantages in application of pump direct distribution system; A continuous pumping through the day need additional energy. Flow adjustment at the pump unit is difficult excepting adjustment by number of pump units. Pumping with high water pressure (to meet hourly demand) causes leakage problem.
- Water supply is not affected at least for short time electricity cut.



Source: JICA Survey Team

Figure 11.2.1 Typical Distribution Arrangements

b) Problems Caused by Pumping System without Application of OHT

Following problems may happen by a pump direct system without application of OHT.

- Water supply to ensure 24/7 may not be achieved, artificially controlled through intermittent water supply (even water source is sufficient to meet demand).
- Construction cost is required for OHT, but O&M cost for a mump direct method is much more expensive in use of pumping through the day for hourly maximum water demand. There are some OHTs which are not used presently in Bengaluru. This is because of the shortage of supply amount against required demand.
- In case that distribution from GLR to service area is ensured by gravity:

⇒ No big influence without OHT

⇒ The connection pipeline between GLR and service area shall have the capacity for hourly maximum flow.

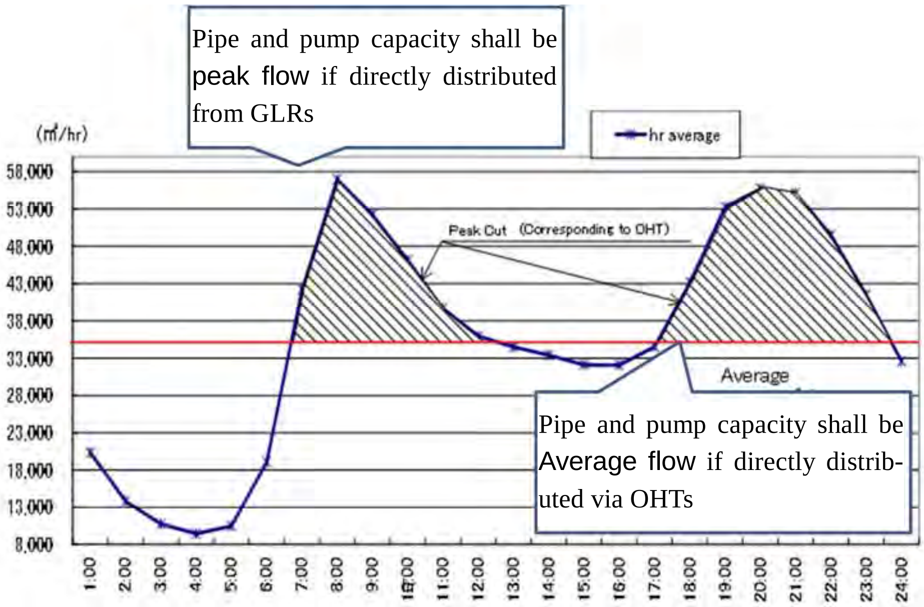
⇒ There is a possibility that water pressure at lower areas becomes very high.

- In case of the application of Booster Pump:

⇒ Continuous operation of the pump unit may be required.

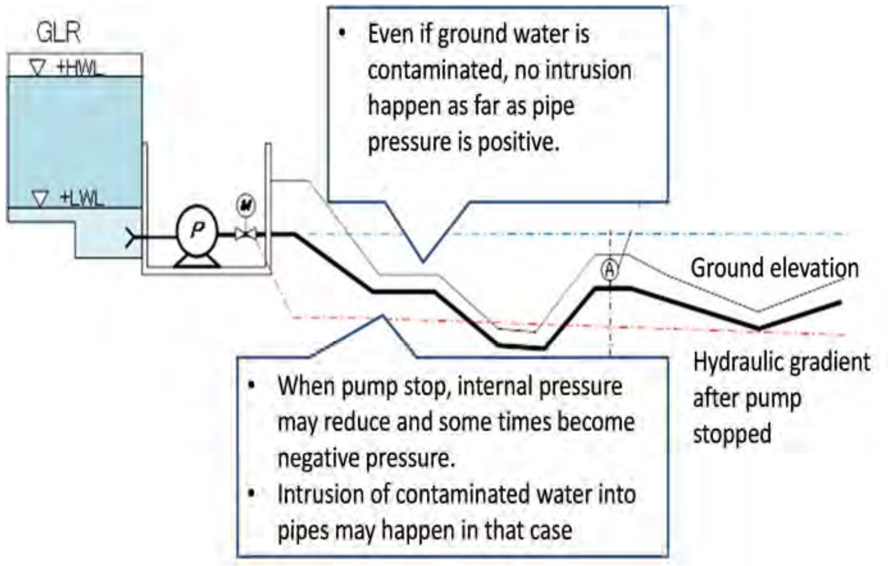
⇒ The required capacities of Pipelines and pump units located downstream of GLR shall be hourly maximum demand as shown in Figure 11.2.2

⇒ Intrusion of contaminated water into pipes may happen, when pump operation is stopped as shown in Figure 11.2.3.



Source: JICA Survey Team

Figure 11.2.2 Comparison of Capacity of Pipe and Pump via OHTs and Direct from GLRs



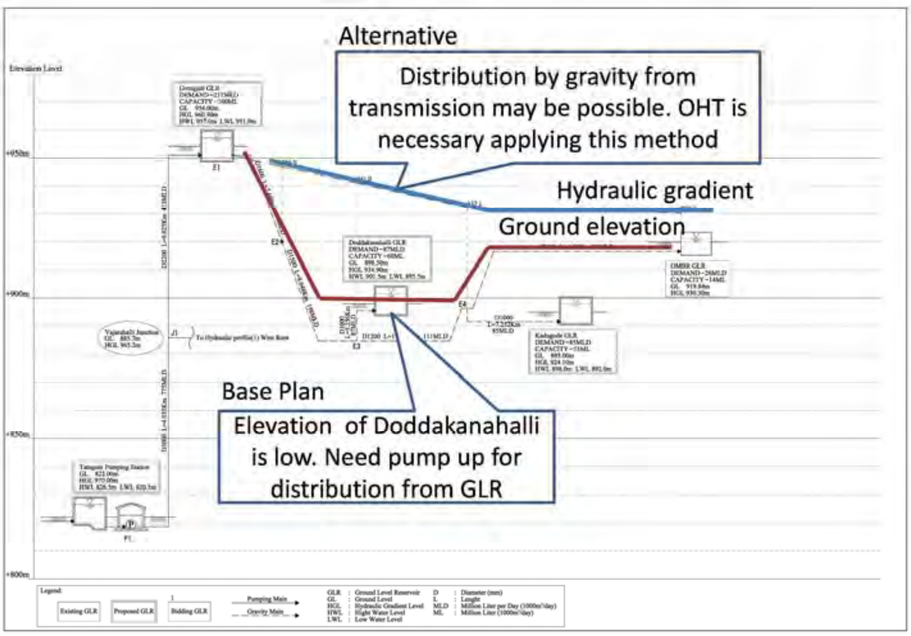
Source: JICA Survey Team

Figure 11.2.3 Negative Impact when Pump Operation Stopped

c) Specific Conditions for 110 Villages Water Supply

- High lift up pump unit is required for many distribution systems to fill water in the OHTs
- Especially in West Route

⇒ Ground elevation at Doddakanahalli GLR is low. Pumps are needed for distribution from GLR, however, to distribute from transmission main directly, gravity flow may be possible because hydraulic gradient is much higher than the GL of service area, as shown in Figure 11.2.4. In case to apply this method, OHT is necessary to equalize peak flow.



Source: JICA Survey Team

Figure 11.2.4 Alternative for Doddakanahalli Distribution

d) Recommendations to Install OHTs

- It is necessary to install OHT for the control of water pressure and flow rate to ensure 24/7 water supply.
- In case of the provision of OHT, there is no need to consider hourly maximum flow for the pipeline from GLR to OHT and pump units.
- Continuous pumping is required in the service area without OHT to prevent from intrusion of muddy water.
- In the DPR for 110 Villages water supply, OHTs are planned. It is necessary to review the requirements after the study to control distribution system/s providing DMAs.
- In the tenders floated by BWSSB for water supply, components of booster/ pumping systems have not been included. BWSSB may evaluate the provision of OHTs for 110 Villages. During detailed engineering stage, BWSSB may optimize the number of OHTs/ Booster pumps required along with consequent changes to water supply network designs in the DPR.

3) Water Pipe Materials

a) It is designed to install DI pipes for transmission pipe from GLR to OHT and for distribution main with the diameter above 100 mm in DPR. It is well known that DI pipes are tough and durable, but recently PE (Polyethylene) pipes are installed in other projects, as PE pipes are also durable and economical. Therefore, it is worth studying on selection of DI pipes or PE pipes. Although a butt joint is applied widely because the material cost is low, an electro fusion joint is applied in some cases to ensure the performance of leak free, referring to “24/7 Water Supply is achievable, September 2010, Field Note, The Water and Sanitation Program (www.wsp.org) The Karnataka Urban Water Sector Improvement Project”.

b) There may exist various piped water supply using groundwater and/or treated effluent. It will be easy to avoid improper pipe connection, if colored pipe materials are employed based on their function.

4) Operation and Management

a) The master plan for the rehabilitation/replacement of water supply facilities such as WTP, PS, GLR and pipeline network is required, as most of the facilities in Stage I were constructed in 1974 and aged.

b) The water supply systems were constructed by stages in respective service areas. It is easy to control supply amount to meet demand by each system, but mutual accommodation of water supply between neighboring systems is difficult, since distribution network is made of tree systems with dead end. In view of risk management, arrangements to connect city transmission pipelines in different stages is recommended. Under this arrangement, a Gridiron system, Circular or ring system or Radial system with installation of SCADA system is recommended to monitor and control the water quantity, pressure and other operation indices.

c) It is necessary to promote the reuse of treated sewage and using rainwater and groundwater, since it is difficult to further develop Cauvery river as water source. In this connection, it is necessary to collect information constantly on the viability and safety of groundwater in use of a water monitoring system. At the same time, it is also necessary to collect tariff or license fee properly for using groundwater.

(3) Recommendations for the Permanent Water Supply System for 110 Villages

BWSSB started to construct water distribution facilities for 110 Villages in advance of Stage V Project. However, these facilities are not enough to achieve planned water supply for the 110 Villages with reference to planned Stage V Project as follows:

- The distribution systems planned for the on-going project are to be operated using water from existing GLRs. But, the water provided by Stage V Project shall be distributed through Planned GLRs for Stage V purpose.
- On-going project cannot ensure sufficient water supply for the 110 Villages, since available water from existing water supply is limited. However, upon completion of Stage V Project, sufficient water will be provided allowing for 24/7 services. Sufficient water supply shall be ensured to meet daily fluctuation of water demand in provision of OHTs, as required.

Therefore, countermeasures as shown in the next sub-section are recommended to achieve permanent water distribution systems for 110 Villages.

11.2.2 Permanent Distribution Facilities for 110 Villages Water Supply

The plan of required distribution facilities for 110 Villages, upon completion of Stage V Project was prepared for the establishment of permanent distribution systems. There are three major component facilities to be constructed: (1) feeder pipes between GLRs and OHTs, (2) Pumping facilities and OHTs and (3) distribution pipe networks after OHTs. Among the requirements, (3) distribution pipe networks will be completed in earlier stage as a major part of on-going project. Thus, upon completion of Stage V Project, the works for item (1) and (2) shall be integrated to form permanent water supply systems for 110 Villages. In this connection plan and design of required facilities were studied on a preliminary basis.

(1) Design Criteria for Facility Planning

Table 11.2.4 summarizes design criteria for planning water distribution facilities.

Table 11.2.4 Design Criteria for Distribution Facilities

Item	Criteria
Design Period	Design period of 30 years
Per capita water consumption	150 lpcd excluding losses
Distribution system pattern	A grid pattern, where the different mains are interconnected keeping dead ends to a minimum.

Item	Criteria
Zoning	Distribution system shall ensure equalization of supply of water throughout the area. The neighboring zones may be interconnected. The difference in pressure between different areas of the same zone or same system does not exceed 3 to 5 m.
Peak factor	For population less than 50,000 peak factor is 3.0.
Residential water pressure	The following minimum residual pressure at ferrule points. • Single story building - 7m. • Two story building - 12m. Distribution system is designed for minimum residual pressure of 12 m.
Minimum pipe size	Minimum pipe sizes of 100 mm for towns with population up to 50,000 and 150 mm for those above 50,000. For dead ends less than 100 mm.
Pipe Material	DCIP is used for the pipes with diameter equal to or less than 700 mm in dia., while MS is planned to use for larger diameter pipes than 700 mm in dia.

Source: JICA Survey Team

(2) Scope of Work

The scope of work is shown in Table 11.2.5. Distribution networks after OHTs are not included as these works are to be undertaken by BWSSB through on-going water supply project for five (5) administrative zones. The consultant and contractors were selected in May, 2017.

Table 11.2.5 Scope of Work for Distribution Facilities in 110 Villages

Component Work; Required Facilities/Equipment	Quantities
Feeder pipes between GLRs and OHTs	DI Pipe: Dia 150 mm ～ 700 mm: 149.7 km MS Pipe: Dia 800 mm ～ 1,750 mm: 49.7 km
OHTs	135 Units
Pumps	61 Units
Monitoring equipment for SCADA system	To be included in Stage V Project

Source: JICA Survey Team

(3) Facility Plan

Facility plans for (1) feeder pipes between GLRs and OHTs, and (2) Pumping facilities and OHTs are presented by GLR service area by administrative zone, as a result of hydraulic calculation.

1) Feeder Pipes between GLRs and OHTs

All proposed lands for OHTs in the existing DPR are existing facility site and/or public sites (park etc.) and the routes from GLRs to OHTs are selected considering road width, traffic, existing pipes, existing cables etc. Locations of OHTs are shown by zone in Figure 11.2.5 and Figure 11.2.15. The water supply network by GLR is shown in Table 11.2.6 and Table 11.2.7.

Table 11.2.6 Length of Feeder Main by Diameter and GLR Service Area (1/2)

Bommanahalli Zone

Pipe Diameter (mm)	Pipe Length (m)
Gottigere GLR Service Area	
150	0
200	7,132
250	7,258
300	5,021
350	1,966
400	2,343
450	2,255
500	2,002
600	3,613
700	2,262
800	0
900	2,231
1,000	3,951
1,050	0
1,100	3,952
1,150	0
1,200	5,779
1,250	0
1,350	3,169
1,750	1,026
Sub-Total of DI Pipe	33,851
Sub-Total of MS Pipe	20,107
Total	53,958

Bommanahalli Zone

Pipe Diameter (mm)	Pipe Length (m)
Doddakanahalli GLR Service Area	
150	0
200	2,331
250	4,850
300	1,428
350	1,436
400	8,760
450	0
500	1,616
600	6,790
700	0
800	2,229
900	5,425
1,000	1,424
1,050	0
1,100	4,899
1,150	0
1,200	0
1,250	0
1,350	0
1,750	0
Sub-Total of DI Pipe	27,210
Sub-Total of MS Pipe	13,977
Total	41,187

Bytrayanapura Zone

Pipe Diameter (mm)	Pipe Length (m)
Chokkanahalli GLR Service Area	
150	105
200	5,051
250	5,346
300	2,979
350	446
400	4,395
450	417
500	8,654
600	0
700	3,253
800	1,323
900	2,728
1,000	565
1,050	0
1,100	0
1,150	0
1,200	1,054
1,250	0
1,350	398
1,750	0
Sub-Total of DI Pipe	30,645
Sub-Total of MS Pipe	6,067
Total	36,712

Bytrayanapura Zone

Pipe Diameter (mm)	Pipe Length (m)
GKVK GLR Service Area	
150	0
200	0
250	0
300	1,657
350	90
400	413
450	0
500	74
600	341
700	0
800	0
900	0
1,000	0
1,050	0
1,100	0
1,150	0
1,200	0
1,250	0
1,350	0
1,750	0
Sub-Total of DI Pipe	2,575
Sub-Total of MS Pipe	0
Total	2,575

Bytrayanapura Zone

Pipe Diameter (mm)	Pipe Length (m)
Vasudevapura GLR Service Area	
150	0
200	1,884
250	874
300	2,083
350	0
400	0
450	952
500	484
600	159
700	0
800	0
900	0
1,000	0
1,050	0
1,100	0
1,150	0
1,200	0
1,250	0
1,350	0
1,750	0
Sub-Total of DI Pipe	6,436
Sub-Total of MS Pipe	0
Total	6,436

Source: JICA Survey Team

Table 11.2.7 Length of Feeder Main by Diameter and GLR Service Area (2/2)

Dasarahalli Zone

Pipe Diameter (mm)	Pipe Length (m)
Hegganahalli-2 GLR Service Area	
150	0
200	0
250	612
300	1,498
350	199
400	799
450	1,383
500	352
600	1,084
700	0
800	1,245
900	1,779
1,000	0
1,050	0
1,100	0
1,150	0
1,200	0
1,250	0
1,350	0
1,750	0
Sub-Total of DI Pipe	5,927
Sub-Total of MS Pipe	3,024
Total	8,951

Dasarahalli Zone

Pipe Diameter (mm)	Pipe Length (m)
Lingaderanahalli GLR Service Area	
150	0
200	0
250	2,558
300	565
350	1,410
400	925
450	406
500	1,625
600	2,465
700	730
800	351
900	0
1,000	0
1,050	0
1,100	0
1,150	0
1,200	0
1,250	0
1,350	0
1,750	0
Sub-Total of DI Pipe	10,684
Sub-Total of MS Pipe	351
Total	11,035

Dasarahalli Zone

Pipe Diameter (mm)	Pipe Length (m)
Singapura GLR Service Area	
150	841
200	1,153
250	1,256
300	0
350	94
400	656
450	1,514
500	0
600	627
700	1,586
800	4,838
900	0
1,000	0
1,050	0
1,100	0
1,150	0
1,200	0
1,250	0
1,350	0
1,750	0
Sub-Total of DI Pipe	7,727
Sub-Total of MS Pipe	4,838
Total	12,565

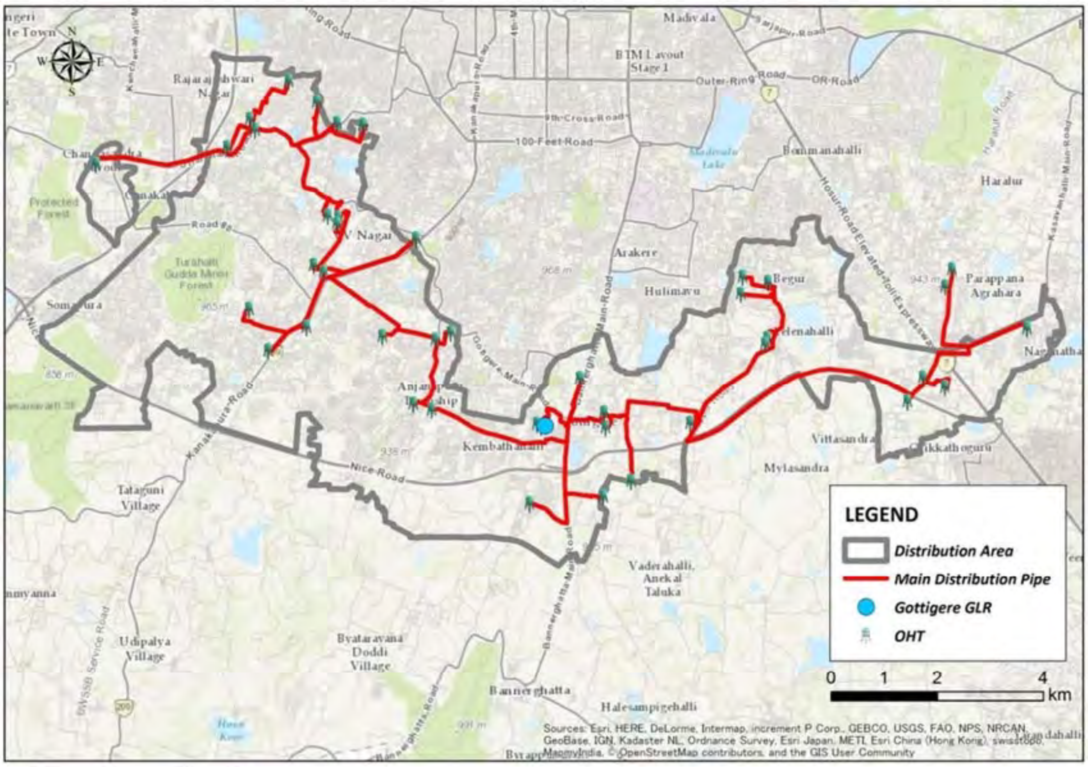
Mahadevpura Zone

Pipe Diameter (mm)	Pipe Length (m)
Kadugodi GLR Service Area	
150	0
200	447
250	372
300	572
350	1,897
400	2,176
450	693
500	2,077
600	6,956
700	0
800	769
900	0
1,000	582
1,050	0
1,100	0
1,150	0
1,200	0
1,250	0
1,350	0
1,750	0
Sub-Total of DI Pipe	15,190
Sub-Total of MS Pipe	1,351
Total	16,540

Mahadevpura Zone

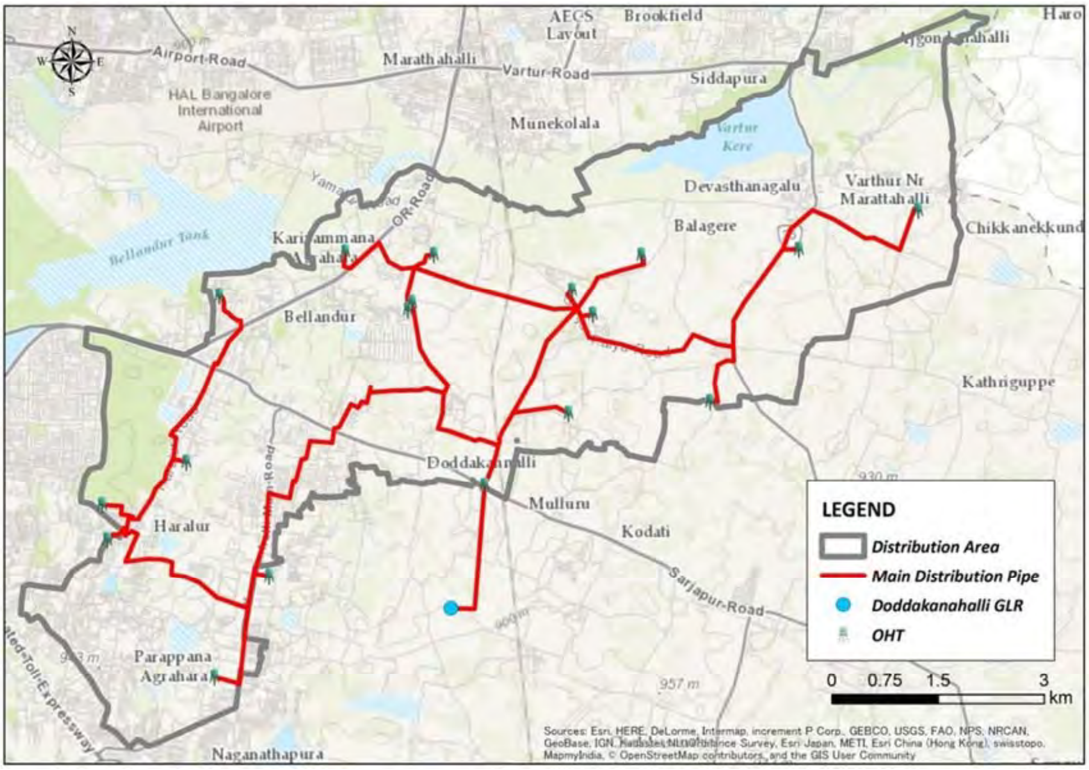
Pipe Diameter (mm)	Pipe Length (m)
OMBR GLR Service Area	
150	0
200	507
250	755
300	1,291
350	1,693
400	0
450	981
500	0
600	4,228
700	0
800	0
900	0
1,000	0
1,050	0
1,100	0
1,150	0
1,200	0
1,250	0
1,350	0
1,750	0
Sub-Total of DI Pipe	9,455
Sub-Total of MS Pipe	0
Total	9,455

Source: JICA Survey Team



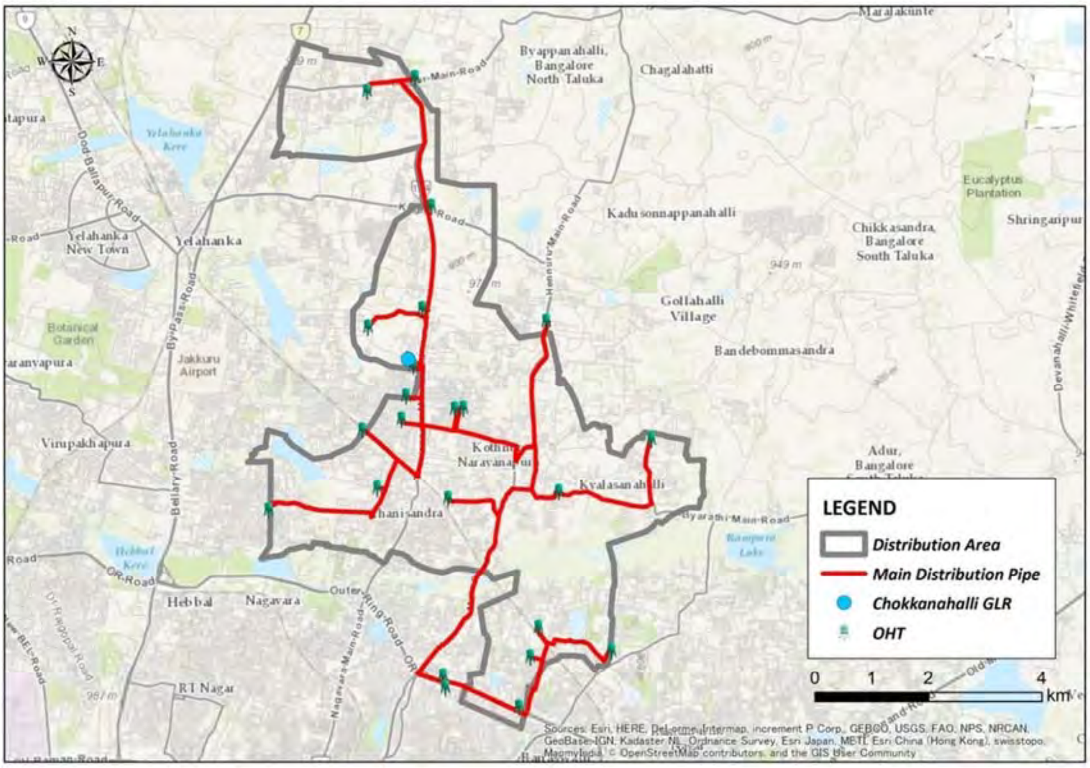
Source: JICA Survey Team

Figure 11.2.5 OHTs' Location in Bommanahalli Zone (Gottigere GLR)



Source: JICA Survey Team

Figure 11.2.6 OHTs' Location in Bommanahalli Zone (Doddakanahalli GLR)

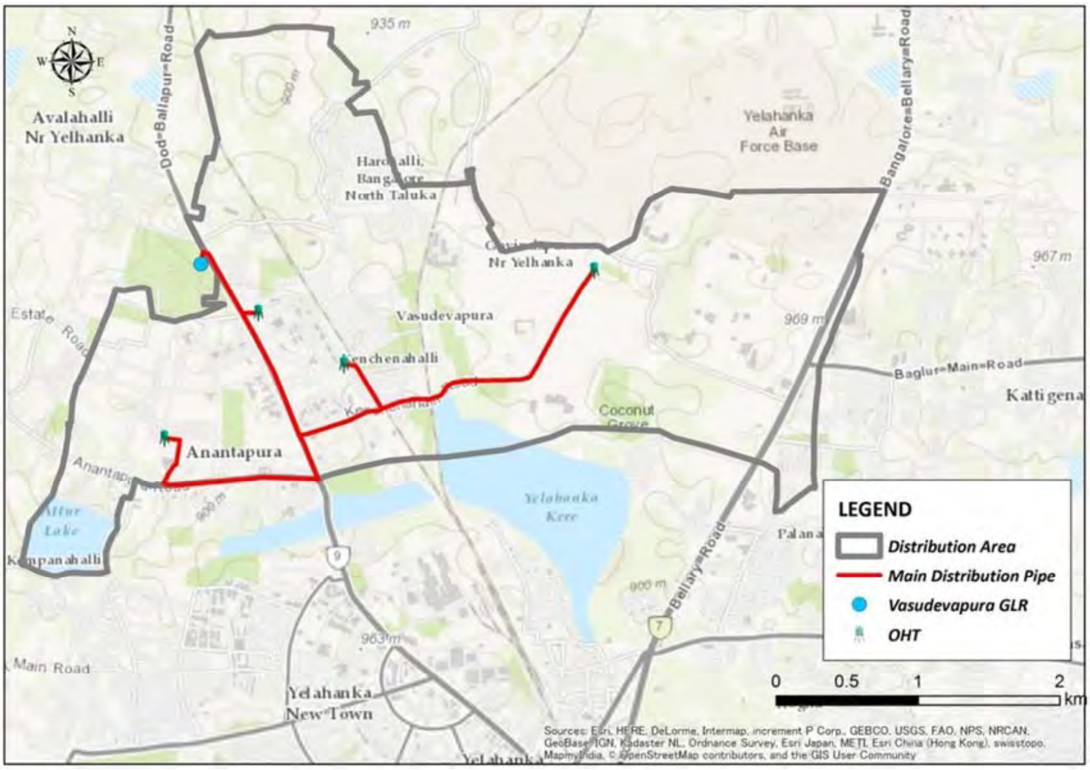


Source: JICA Survey Team

Figure 11.2.7 OHTs' Location in Bytrayanapura Zone (Chokkanahalli GLR)

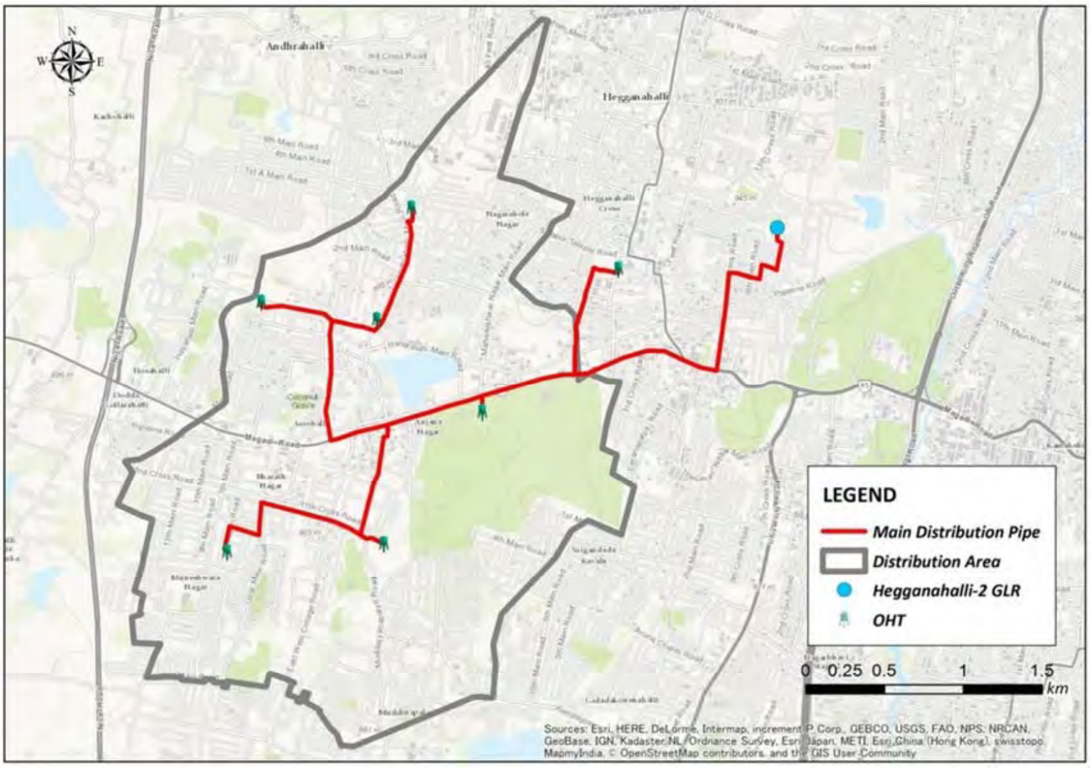
Source: JICA Survey Team

Figure 11.2.8 OHTs' Location in Bytrayanapura Zone (GKVK GLR)



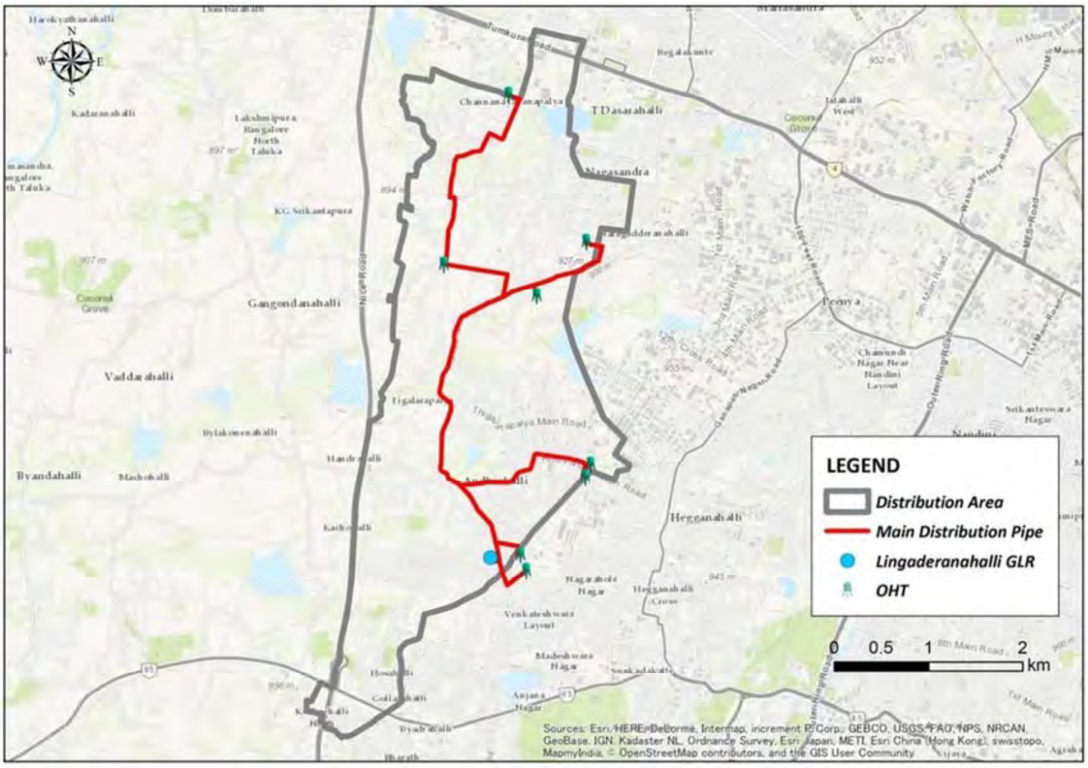
Source: JICA Survey Team

Figure 11.2.9 OHTs' Location in Bytrayanapura Zone (Vasudevapura GLR)



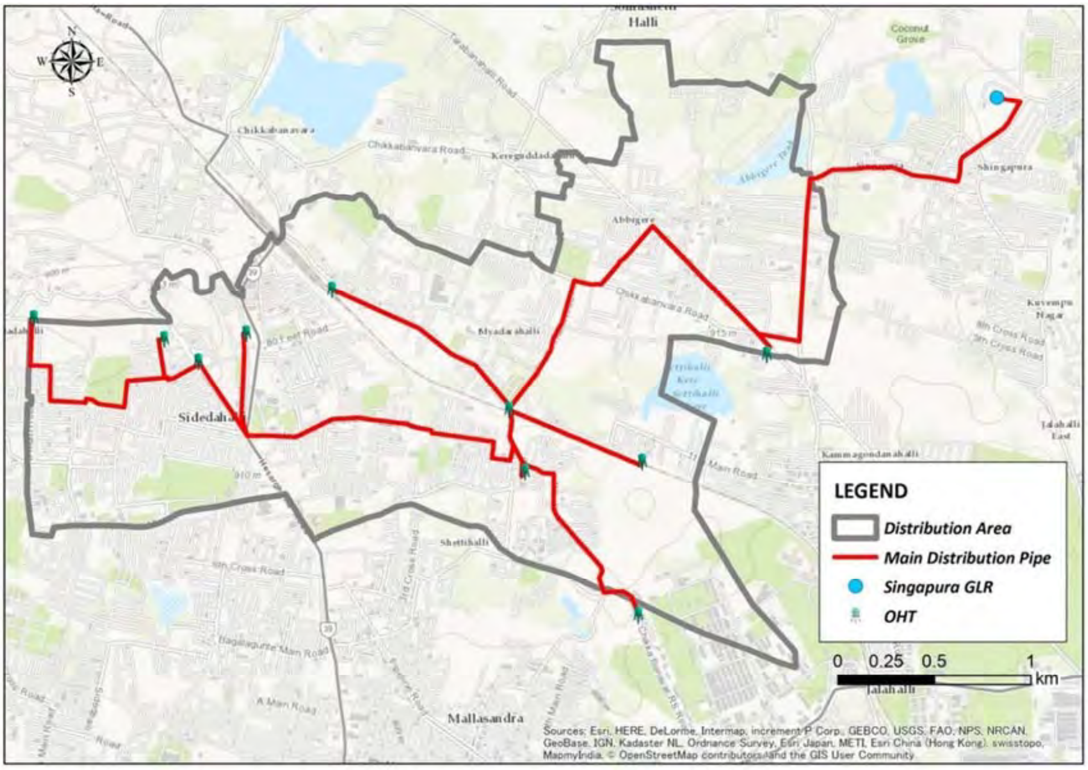
Source: JICA Survey Team

Figure 11.2.10 OHTs' Location in Dasarahalli Zone (Hegganahalli-2 GLR)



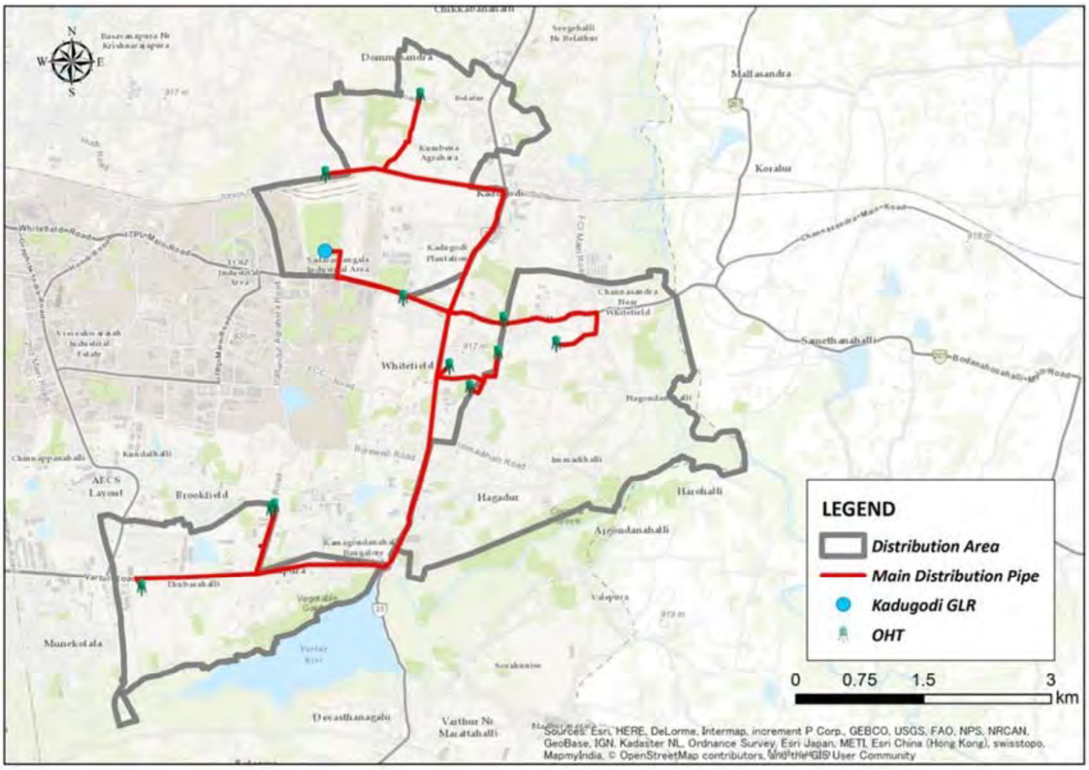
Source: JICA Survey Team

Figure 11.2.11 OHTs' Location in Dasarahalli Zone (Lingaderanahalli GLR)



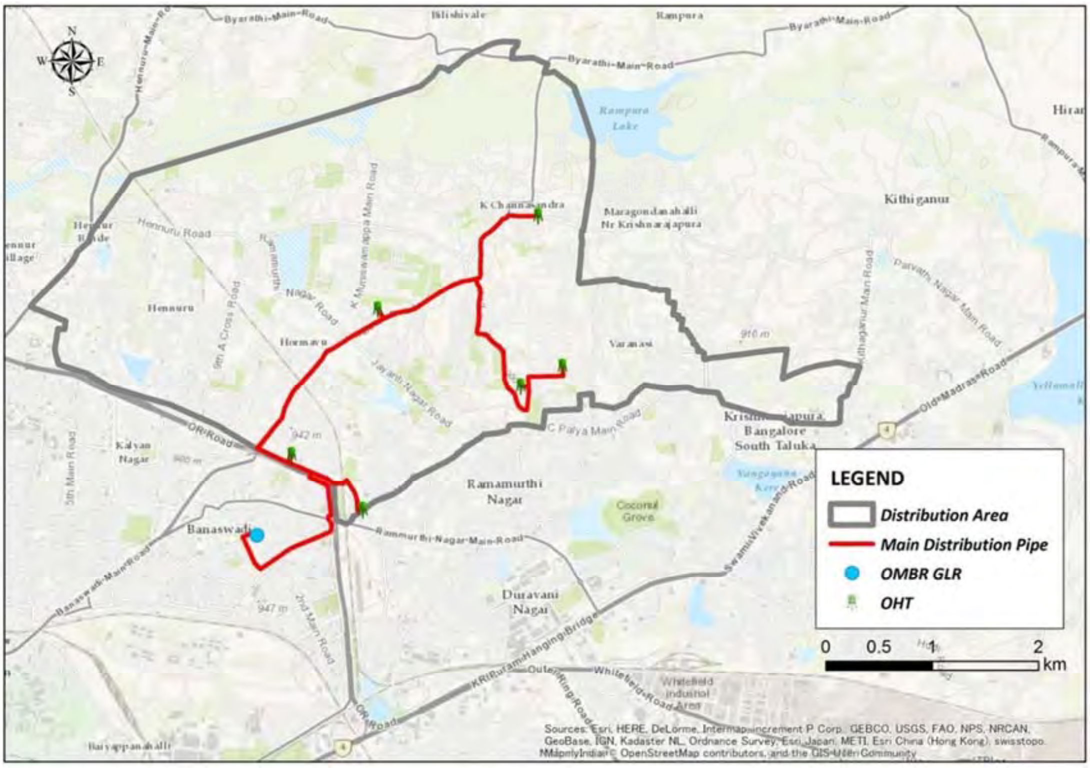
Source: JICA Survey Team

Figure 11.2.12 OHTs' Location in Dasarahalli Zone (Singapura GLR)



Source: JICA Survey Team

Figure 11.2.13 OHTs' Location in Mahadevpura Zone (Kadugodi GLR)



Source: JICA Survey Team

Figure 11.2.14 OHTs' Location in Mahadevpura Zone (OMBR GLR)

2) OHTs and Pumping Facilities

Detailed information on OHTs and needs of booster pump units is presented by GLR by zone. For R.R. Nagar zone, only required OHTs are studied. Table 11.2.8 to Table 11.2.18 show the information related to OHTs and Pump facilities covering five zones.

a) Bytrayanapura Zone

There are 30 OHTs under three (3) GLRs in Bytrayanapura zone and their specifications are shown in Table 11.2.8 to Table 11.2.10.

Table 11.2.8 OHTs' Specifications under Chokkanahalli GLR

GLRs and OHTs in Byatrayanapura Zone		Population in 2049 (People)	Demand in 2049 (m^3/day)	OHT				
				Capacity (m^3)	Detention Time (hr)	GL (m)	LWL (m)	Booster Pump
Chokkanahalli (Proposed GLR)								
1	Bellhalli Tank	11,305	1,990	500	6.03	930.50	924.30	Required
2	Billishivahalli Tank	14,357	2,527	500	4.75	909.83	903.63	-
3	Byarathi Tank	27,004	4,753	1,000	5.05	935.20	928.10	Required
4	Chalakere Tank-1	34,787	6,122	1,500	5.88	920.60	912.90	Required
5	Chalakere Tank-2	32,408	5,704	1,500	6.31	922.61	914.91	Required
6	Chalakere-3	65,477	11,524	2,500	5.21	923.13	915.43	Required
7	Chokkanhalli Tank	9,881	1,739	350	4.83	939.60	933.30	Required
8	Dasarahaslli Tank	55,740	9,810	2,000	4.89	936.28	928.58	Required
9	Geddalahalli	30,151	5,306	1,000	4.52	918.00	910.30	-
10	Horamavu Agara Tank-1	24,103	4,242	1,000	5.66	919.53	912.43	Required
11	Horamavu Agara Tank-2	23,597	4,153	750	4.33	918.56	912.06	Required
12	Horamavu Agara Tank-3	19,269	3,391	750	5.31	914.15	907.65	Required
13	Kattigenhalli Tank-1	40,335	7,099	1,500	5.07	938.56	930.86	Required
14	Kattigenhalli Tank-2	38,262	6,734	1,500	5.35	934.90	927.20	Required
15	Kothanur Narayanpura & Kothanur	61,002	10,736	2,000	4.47	923.80	916.10	-
16	Kyalasanhalli Tank	21,703	3,820	750	4.71	913.18	906.68	-
17	N Nagenhalli Tank	7,511	1,322	2,000	36.31	919.27	913.17	-
18	Rachenahalli Tank-1	13,368	2,353	500	5.1	934.31	928.11	Required
19	Rachenhalli Tank-2	22,848	4,021	750	4.48	926.60	920.10	Required
20	Thanisandra Tank-1	45,184	7,952	1,500	4.53	941.69	933.99	Required
21	Thanisandra Tank-2	74,791	13,163	2,500	4.56	930.51	922.81	Required
22	ThanisandraTank-3	38,118	6,709	1,500	5.37	917.40	909.70	-
23	Thirumnehalli Tank	4,858	855	150	4.21	932.46	927.21	Required
	Sub-Total	**716,059**	**126,025**	**28,000**	-	-	-	-

Source: JICA Survey Team

Table 11.2.9 OHTs' Specifications under GKVK GLR

GLRs and OHTs in Byatrayanapura Zone		Population in 2049 (People)	Demand in 2049 (m^3/day)	OHT				
				Capacity (m^3)	Detention Time (hr)	GL (m)	LWL (m)	Booster Pump
GKVK (Existing GLR)								
1	Chikka Bettahalli-1	33,087	5,823	1,500	6.18	935.08	950.08	-
2	Chikka Bettahalli-2	35,751	6,292	1,500	5.72	928.63	940.63	-
3	Dodda Bettahalli	47,095	8,289	1,500	4.34	929.20	944.20	-
Sub-Total		**115,933**	**20,404**	**4,500**	**-**	**-**	**-**	**-**

Source: JICA Survey Team

Table 11.2.10 OHTs' Specifications under Vasudevapura GLR

GLRs and OHTs in Byatrayanapura Zone		Population in 2049 (People)	Demand in 2049 (m^3/day)	OHT				
				Capacity (m^3)	Detention Time (hr)	GL (m)	LWL (m)	Booster Pump
Vasudevapura (Proposed GLR)								
1	Anantha Pura	27,276	4,800	1,000	5.00	941.68	934.58	Required
2	Herohalli	36,944	6,502	1,500	5.54	941.00	933.30	Required
3	Kenchnehalli	18,800	3,309	1,500	10.88	922.78	922.13	Required
4	Govindapura, Vasudvapu	14,393	2,533	500	4.74	941.30	935.10	Required
Sub-Total		**97,413**	**17,144**	**4,500**	**-**	**-**	**-**	**-**

Source: JICA Survey Team

b) Bommanahalli Zone

There are 60 OHTs under two (2) GLRs in Bommanahalli zone and their specifications are shown in Table 11.2.11 to Table 11.2.12.

Table 11.2.11 OHTs' Specifications under Doddakannahalli GLR

GLRs and OHTs in Bommanahalli Zone		Population in 2049 (People)	Demand in 2049 (m^3/day)	OHT				
				Capacity (m^3)	Detention Time (hr)	GL (m)	LWL (m)	Booster Pump
Doddakannahalli (Proposed GLR)								
1	Ambalipura, Kaikondnahalli 1 & Kasavanahalli 1	48,545	10,000	2,000	4.80	882.69	894.69	-
2	Balagere	14,945	2,582	500	4.65	872.17	884.17	-
3	Bellandur	65,861	11,381	2,000	4.22	885.36	900.36	-
4	Bhoganahalli	10,665	1,843	350	4.56	889.48	904.48	-
5	Chikkabelandur	26,309	4,546	1,000	5.28	889.48	904.48	-
6	Devarabisahalli	30,015	5,187	1,000	4.63	887.80	899.80	-
7	Doddakannalli	53,678	9,276	2,000	5.17	907.20	919.20	-
8	Gunjur-1	16,591	2,867	750	6.28	883.29	898.29	-
9	Gunjur-2	19,704	3,405	750	5.29	880.76	895.75	-
10	Haralur-1	5,714	987	200	4.86	904.70	916.70	Required
11	Haralur-2	16,442	2,839	750	6.34	907.20	919.20	Required
12	Kaikondanahalli-2, Kasavanahalli-2 & Junnasandra	24,144	4,172	1,000	5.75	905.38	917.38	Required
13	Kayammana Agrahara	13,475	2,328	500	5.15	883.29	898.29	-
14	Panathur-1	28,955	5,003	1,000	4.80	882.35	894.35	-
15	Panathur-2 & Kadabisanahalli	9,195	1,589	300	4.53	880.13	892.13	-
16	Parappana Agrahara	46,795	8,086	1,500	4.45	919.50	934.50	Required
17	Sorahunise & Varhtur	62,363	10,776	2,000	4.45	884.80	899.80	-
18	Varthur Part	12,657	7,862	1,500	4.58	882.69	894.69	-
	Sub-Total	**506,052**	**94,729**	**19,100**	**-**	**-**	**-**	**-**

Source: JICA Survey Team

Table 11.2.12 OHTs' Specifications under Gottigere GLR

GLRs and OHTs in Bommanahalli Zone		Population in 2049 (People)	Demand in 2049 (m^3/day)	OHT				
				Capacity (m^3)	Detention Time (hr)	GL (m)	LWL (m)	Booster Pump
Gottigere (Proposed GLR)								
1	Alahalli-2	35,292	6,211	1,500	5.80	919.70	937.70	Required
2	Alahalli-1	37,329	6,450	1,500	5.58	925.85	937.85	Required
3	Anajanapura	22,558	3,970	750	4.53	907.05	922.05	-
4	Arehalli-1	13,616	2,353	500	5.10	878.53	890.53	-
5	Arehalli-2	15,232	2,632	500	4.56	870.92	882.92	-
6	Bartenagrhar	67,053	11,587	2,500	5.18	927.60	942.60	-
7	Basapura	8,280	1,431	300	5.03	924.87	939.87	Required
8	Basavanapura	26,978	4,662	1,000	5.15	934.75	949.75	-
9	Begur-1	55,504	9,591	2,000	5.00	897.14	909.14	-
10	Begur-2	28,291	4,889	1,000	4.91	922.91	931.91	-
11	Begur-3	9,102	1,573	300	4.58	917.92	929.92	-
12	Begur-4	12,149	2,099	750	8.58	913.16	925.16	-
13	Begur-5	33,624	5,810	1,500	6.20	912.70	924.70	-
14	Chikkatoguru	7,607	1,314	250	4.57	926.33	944.33	Required
15	Doddakalasandra	22,431	3,876	750	4.64	904.11	916.32	-
16	Ganakallu	28,834	4,983	1,000	4.82	829.33	841.33	-
17	Gollahalli	26,996	4,665	1,000	5.14	914.32	932.32	-
18	Gottigere Pilaganahalli	32,682	5,647	1,500	6.38	941.12	953.12	Required
19	Gottigere-1	16,404	2,835	750	6.35	948.20	960.20	-
20	Gottigere-2	9,850	1,702	350	4.94	924.40	936.50	Required
21	Gottigere-3, Pillaganahalli-1 & Kembathalli	26,662	4,607	1,000	5.21	946.50	958.50	Required
22	Gubbulalu & Turhalli	30,136	5,208	1,000	4.61	886.51	901.51	-
23	Hosahalli Tank	14,379	2,485	500	4.83	902.00	914.00	-
24	Kalenagarahar	20,321	3,511	750	5.13	920.15	932.15	-
25	Kammanahall-1	9,185	1,587	300	4.54	925.96	937.96	-
26	Kammanahall-2	33,862	5,960	1,500	6.04	928.35	943.35	Required
27	Kudlu Tank-1	62,508	10,801	2,000	4.44	922.26	937.26	Required
28	Kudlu Tank-2	74,491	12,872	2,500	4.66	921.74	933.74	-
29	Naganathapura	35,015	6,051	1,500	5.95	917.90	935.90	Required
30	Raghuvenhalli	7,570	1,308	250	4.59	890.00	905.11	-
31	Talaghattapura	43,565	7,667	1,500	4.70	891.20	906.20	-
32	Tippasandra	4,955	856	200	5.61	898.52	913.52	-
33	Uttarahalli-1	10,010	1,730	350	4.86	880.70	892.70	-
34	Uttarahalli-2	6,279	1,085	200	4.42	876.17	888.17	-
35	Uttarahalli-3	43,604	7,535	1,500	4.78	879.83	891.83	-
36	Uttarahalli-4	45,791	7,913	1,500	4.55	874.51	886.51	-
37	Vaddarpalya	7,247	1,252	250	4.79	881.71	893.71	-
38	Vajarahalli	26,572	4,592	1,000	5.23	887.82	905.82	-
39	Vasanthapura-1	38,450	6,644	1,500	5.42	905.14	911.14	-
40	Vasanthapura-2	66,110	11,424	2,500	5.25	915.72	924.72	-
41	Vasanthapura-3	15,088	2,607	500	4.60	883.98	895.98	-
42	Yelinhalli & Chandrashekapura	8,485	1,466	300	4.91	926.60	941.60	Required
	Sub-Total	**1,140,097**	**197,441**	**42,300**	-	-	-	-

Source: JICA Survey Team

c) Dasarahalli Zone

There are 25 OHTs under three (3) GLRs in Dasarahalli zone and their specifications are shown in Table 11.2.13 to Table 11.2.15.

Table 11.2.13 OHTs' Specifications under Hegganahalli-2 GLR

GLRs and OHTs in Dasarahalli Zone		Population in 2049 (People)	Demand in 2049 (m^3/day)	OHT				
				Capacity (m^3)	Detention Time (hr)	GL (m)	LWL (m)	Booster Pump
Hegganahalli-2 (Existing GLR)								
1	Herohalli-1	47,085	8,287	1,500	4.34	897.61	906.61	
2	Herohalli-2	34,211	6,021	1,500	5.98	884.11	899.11	
3	Herohalli-3	23,099	4,065	750	4.43	887.50	905.50	
4	Herohalli-4	34,510	6,074	1,500	5.93	913.14	928.14	Reruired
5	Herohalli-5	42,923	7,554	1,500	4.77	892.40	910.40	
6	Herohalli-6	58,882	10,363	2,000	4.63	913.50	931.50	Reruired
7	Hosahalli	12,386	2,180	500	5.50	884.20	896.20	
	Sub-Total	**253,096**	**44,544**	**9,250**	**-**	**-**	**-**	**-**

Source: JICA Survey Team

Table 11.2.14 OHTs' Specifications under Lingaderanahalli GLR

GLRs and OHTs in Dasarahalli Zone		Population in 2049 (People)	Demand in 2049 (m^3/day)	OHT				
				Capacity (m^3)	Detention Time (hr)	GL (m)	LWL (m)	Booster Pump
Lingaderanahalli (Proposed GLR)								
1	Doddabidarkallu-1	48,020	8,451	2,000	5.68	903.75	915.75	Reruired
2	Doddabidarkallu-2	15,117	2,661	500	4.51	879.09	897.01	Reruired
3	Doddabidarkallu-3	34,037	5,990	1,500	6.01	887.44	902.50	Reruired
4	Handrahalli-1	7,691	1,354	500	8.86	913.61	925.61	Reruired
5	Handrahalli-2	40,883	7,195	1,500	5.00	917.43	929.43	Reruired
6	Kariobanhalli-1	60,774	10,696	1,500	3.37	912.45	921.45	Reruired
7	Kariobanhalli-2	36,377	6,402	2,000	7.50	892.58	904.58	Reruired
8	Lingaderanahalli	24,285	4,274	1,000	5.62	918.04	930.04	Reruired
	Sub-Total	**267,184**	**47,023.00**	**10,500**	**-**	**-**	**-**	**-**

Source: JICA Survey Team

Table 11.2.15 OHTs' Specifications under Singapura GLR

GLRs and OHTs in Dasarahalli Zone		Population in 2049 (People)	Demand in 2049 (m^3/day)	OHT				
				Capacity (m^3)	Detention Time (hr)	GL (m)	LWL (m)	Booster Pump
Singapura (Proposed GLR)								
1	Abbigere	34,748	6,116	1,500	5.89	901.04	913.04	
2	Chikkasandra-1	30,857	5,431	1,000	4.42	898.70	911.70	
3	Chikkasandra-2	7,745	1,363	250	4.40	877.21	892.21	
4	Myadrahalli	6,548	1,152	250	5.21	886.50	898.50	
5	Shettihalli-1	3,581	630	150	5.71	896.89	911.89	
6	Shettihalli-2	11,855	2,086	350	4.03	898.52	910.92	Reruired
7	Shettihalli-3	12,612	2,220	500	5.41	910.46	919.46	
8	Shiddedahalli-1	37,118	6,533	1,500	5.51	910.15	922.15	Reruired
9	Shiddedahalli-2	45,180	7,952	1,500	4.53	897.29	909.29	
10	Shiddedahalli-3	38,825	6,833	1,500	5.27	897.84	909.84	
	Sub-Total	**229,069**	**40,316**	**8,500**	-	-	-	-

Source: JICA Survey Team

d) Mahadevapura Zone

There are 17 OHTs under two (2) GLRs in Mahadevpura zone and their specifications are shown in Table 11.2.16 to Table 11.2.17.

Table 11.2.16 OHTs' Specifications under Kadugodi GLR

GLRs and OHTs in Mahadevpura Zone		Population in 2049 (People)	Demand in 2049 (m^3/day)	OHT				
				Capacity (m^3)	Detention Time (hr)	GL (m)	LWL (m)	Booster Pump
Kadugodi (Proposed GLR)								
1	Belthur	47,449	8,351	1,500	4.31	859.80	877.80	-
2	Channasandra-1	40,205	7,076	1,500	5.09	887.30	896.30	Required
3	Channasandra-2	52,324	9,209	2,000	5.21	873.35	885.35	-
4	Hagadhur-1	64,243	11,307	2,000	4.25	899.27	908.27	Required
5	Hagadhur-2	18,739	3,298	1,000	7.28	899.00	911.00	Required
6	Kadagodi Plantation	48,582	8,550	2,000	5.61	891.70	906.70	Required
7	Kumbenagrahar	63,977	11,260	2,500	5.33	883.13	892.13	Required
8	Nagagondahalli	11,084	1,951	350	4.31	892.34	901.34	Required
9	Ramagondanahalli	23,435	4,124	750	4.36	879.24	894.24	Required
10	Siddapura	12,566	2,212	500	5.42	879.24	891.24	Required
11	Tubarahalli	97,097	17,089	750	1.05	883.41	895.41	-
	Sub-Total	**479,701**	**84,427**	**14,850**	-	-	-	-

Source: JICA Survey Team

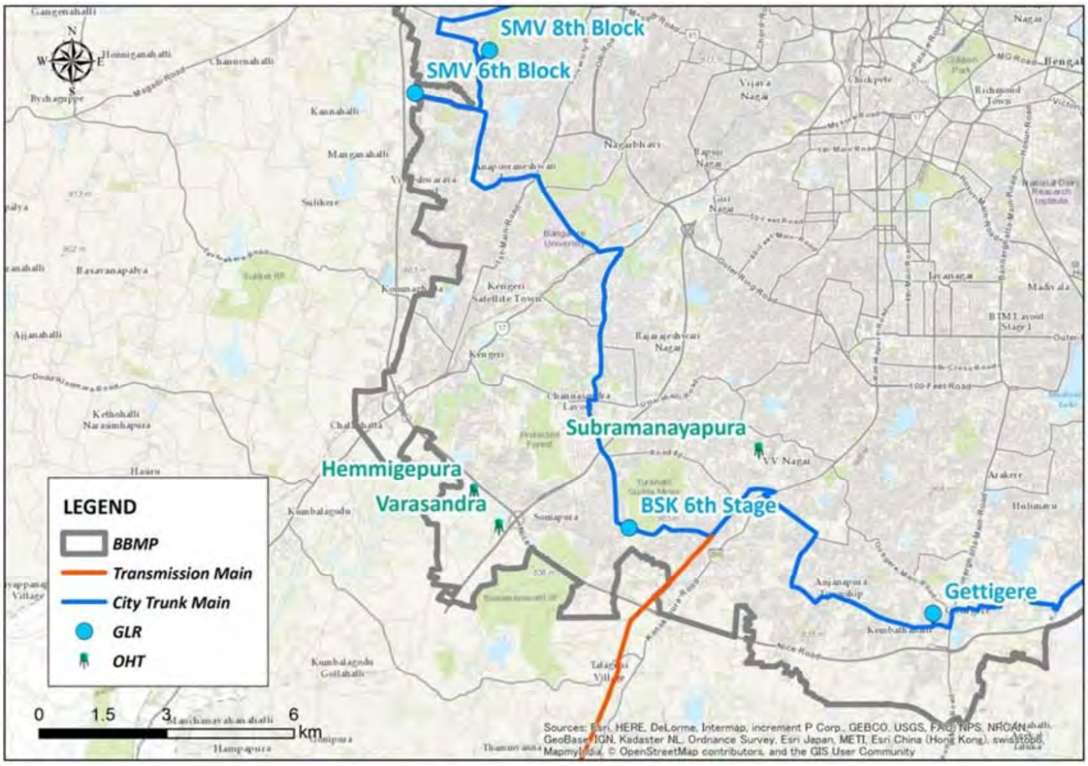
Table 11.2.17 OHTs' Specifications under OMBR GLR

GLRs and OHTs in Mahadevpura Zone		Population in 2049 (People)	Demand in 2049 (m^3/day)	OHT				
				Capacity (m^3)	Detention Time (hr)	GL (m)	LWL (m)	Booster Pump
OMBR (Existing GLR)								
1	Horamavu Tank-1	24,519	4,315	1,000	5.56	909.55	927.55	Required
2	Horamavu Tank-2	15,820	2,784	500	4.31	916.19	931.19	Required
3	K Channasanra Tank	30,203	5,316	1,000	4.51	889.67	901.67	-
4	Kalkere Tank-2	33,300	5,861	1,500	6.14	903.57	921.57	Required
5	Kalkeri Tank-1	31,960	5,625	1,500	6.40	900.05	918.05	Required
6	Varnashi Tank	12,657	2,228	500	5.39	893.00	911.00	Required
Sub-Total		**148,459**	**26,129**	**6,000**	**-**	**-**	**-**	**-**

Source: JICA Survey Team

e) R.R. Nagar Zone

There are only three (3) OHTs under BSK 6th GLR in R.R. Nagar zone. Most of the service area in this zone falls on the BDA's development area and the feeder mains have been installed by BDA already. The locations of OHTs are shown in Figure 11.2.15 and their specifications are shown in Table 11.2.18.



Source: JICA Survey Team

Figure 11.2.15 OHTs' Location in R.R. Nagar Zone (GLRs under BDA)

Table 11.2.18 OHTs' Specifications under BSK 6th GLR

GLRs and OHTs in Zone RR Nagar		Population in 2049 (People)	Demand in 2049 (m^3/day)	OHT				
				Capacity (m^3)	Detention Time (hr)	GL (m)	LWL (m)	Booster Pump
BSK 6th (Existing GLR)								
1	Hemmeigepura Part	19,198	3,379	7,500	53.27	802.70	814.70	-
2	Subramanyapura	48,634	8,560	2,000	5.61	882.00	894.00	-
3	Varasandra	5,549	977	200	4.91	813.52	825.52	-
Sub-Total		**73,380**	**12,916**	**9,700**	-	-	-	-

Source: JICA Survey Team

(4) Construction Cost

1) General Conditions

The construction cost is calculated in application of the following manner.

- Straight Pipe: Based on the unit price on Schedule of Rates (BWSSB, 2016 - 2017)
- Fittings: 15% of straight pipelines' cost
- Valves: 15% of straight pipelines' cost
- OHT: Average OHT cost is assumed at 20 Million INR/unit referring to the study results in the DPR
- Indirect cost: 30% to direct cost for Price Escalation, Physical Contingency and other cost required

2) Feeder Pipes and OHT Cost

The direct cost for feeder pipes and OHTs are summarized in Table 11.2.19.

Table 11.2.19 Direct Cost for Feeder Pipes and OHTs

S/N	Name of GLR	Proposed/ Existing	Direct Cost (INR)		
			Pipe	Pipe Accessory & Valves	OHT
1	Gottigere	Proposed	665,979,547	199,793,864	840,000,000
2	Doddakanahalli	Proposed	450,738,285	135,221,485	360,000,000
3	Kadugodi	Proposed	152,024,317	45,607,295	220,000,000
4	Chokkanahalli	Proposed	314,473,715	94,342,114	460,000,000
5	Vasudevapura	Proposed	28,711,108	8,613,332	80,000,000
6	Singapura	Proposed	134,029,816	40,208,944	200,000,000
7	Lingaderanahalli	Proposed	84,031,021	25,209,306	160,000,000
8	Hegganahalli-2	Existing	92,211,173	27,663,351	140,000,000
9	OMBR	Existing	71,785,124	21,535,537	120,000,000
10	GKVK	Existing	14,192,002	4,257,600	60,000,000
11	3 GLRs under BDA	Existing	0	0	60,000,000
		Sub-Total	**2,008,176,108**	**602,452,828**	**2,700,000,000**
			Total Direct Cost	**5,311,000,000 (INR)**	

Source: JICA Survey Team

3) Pump Facility Cost

The cost for pump facilities at the required OHTs are summarized by zone as shown in Table 11.2.20.

Table 11.2.20 Cost for Pump Facilities

Zone	Pump Cost (Million INR)
Bytrayanapura	45.5
Bommanahalli	96.6
Dasarahalli	74.0
Mahadevpura	98.0
R.R. Nagar	0
Total	314.1

Source: JICA Survey Team

4) Total Construction Cost

The total construction cost for establishment of permanent water distribution facilities from outlet pies of GLRs to OHTs is estimated at 4,985.5 Million INR as shown in Table 11.2.21.

Table 11.2.21 Total Construction Cost for Establishment of Permanent Distribution Facilities

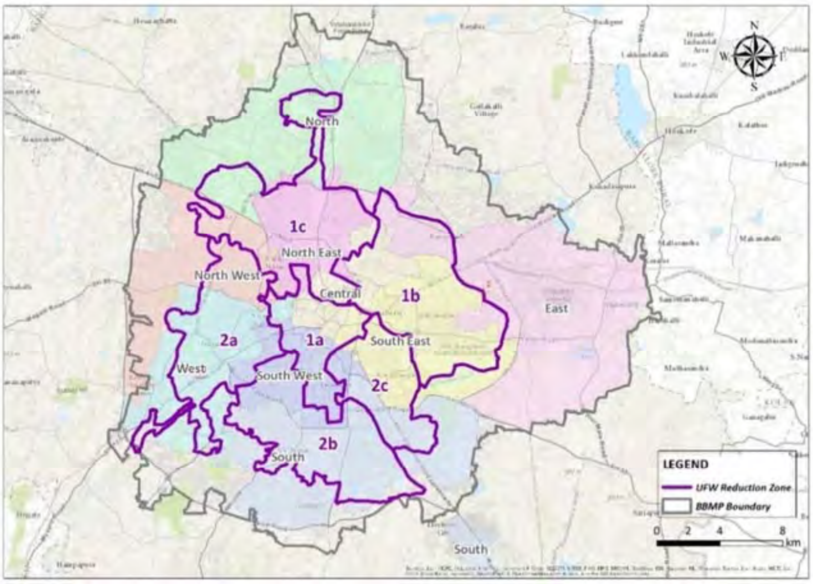
Item	Direct Cost (Million INR)	Project Cost (Million INR)
Feeder Pipes	2,610.6	3,393.8
OHT	2,700.0	3,510.0
Pump	314.1	408.3
Total	5,624.7	7,312.1

Note: Price Escalation, Physical Contingency and other cost is considered as 30%.
Source: JICA Survey Team

11.2.3 UFW Reduction and Distribution Network Improvement Project

BWSSB commenced UWF Reduction Project in 2013. In the three sub-project areas, the construction work for South area was completed under D2b Contract by the end of September 2016. The two other contracts for Central and West parts of Bengaluru city under Contract D1a and D2a will be completed by June 2017. Upon completion of the required construction work, O&M works would be implemented by the same contractor for 5 years.

BWSSB determined to implement UFW Reduction Project in the East, North, and South East areas in the Core area of Bengaluru city (see location of project area in Figure 11.2.16). The DPR for the UFW Reduction Project was prepared in 2007, then updated with the new Schedule of Rates in 2016. The revised DPR proposed the need of 3,790 Million INR. The GoK made an allocation of 3,790 Million INR for UFW Reduction Project and Distribution Network Improvement Project (GoK No. FD 561 EXP-9/2016 dated 23/9/2016). However, after about five months, Assistant Chief Engineer (ACE) for UFW prepared revised scope of work for the UFW Reduction Project with a plan for financial arrangement, then Technical Committee has been under study for finalization as of beginning of March 2017. The following is the Draft Scope of Work.



Source: JICA Survey Team

Figure 11.2.16 Project Area for UFW Reduction and Distribution Improvement

(1) Draft Scope of Work

UFW Reduction Project shall be achieved in provision of two kinds of facilities: (1) Transmission pipelines and GLRs to be financed by solo BWSSB as maintenance work, and (2) Distribution Systems assisted by GoK and partially financed by BWSSB.

1) UFW Reduction Project and Distribution Network Improvement Strategy for Distribution Systems

The scope of work UFW Reduction Project for Distribution System has two major components as stated below. The Asset Management component needs to be undertaken before UFW Reduction component.

- Asset Management and preparation of hydraulic models:
  - ⇒ To develop an asset database for water supply system by conducting asset survey, prepare a hydraulic model and a systematic improvement plan based on hydraulic model.
- UFW Reduction and Distribution Improvement Component:
  - ⇒ Understand the components of UFW in Bengaluru city using surveyed data and implement a UFW reduction strategy in selected areas in Bengaluru city (including maintenance period). These are further divided into 2 parts, a) Design & Construction and b) Maintenance period**.**

a) Asset Management and Water Network Hydraulic Models:

i. Detailed survey

- Water distribution network
- Topographical surveys

- Pumping data
- Pipe and GLR condition
- Customer information

ii. Development of GIS database

iii. Demand Analysis

iv. Flow and Pressure Measurement

v. Development of Hydraulic Model

- DMA Formation
- Preparation of Hydraulic Model in (in Water Gems) to replicate the current trunk main system and operation from GLR onwards up to distribution level, Network Modelling for planning of operational improvement and finalizing laying of mains for network strengthening and Calibration of the Model based on measured flow and pressure in the system
- Post Model Analysis including Analysis of Supply vs Demand gaps and anomalies, baselining of current level of losses under DMAs and overall Water Distribution System and Update water balance

vi. Preparation of Systematic Improvement Plan for distribution network

- Development of minimum replacement program
- Identification and proposal of network augmentation in the distribution zone

b) UFW Reduction and Distribution Improvement Component

i. Design and Construction

- Leakage detection by Helium gas method along with any other conventional methods, and their repair
- Laying of additional mains for strengthening of networks
- Replacement of consumer service connections
- Replacement of defective and aged water meters
- Procure and install Bulk flow meters to measure the incoming and outgoing water
- Monitoring of UFW levels
- Repair damaged pipes

ii. Operation and Maintenance

The activity includes the following. O&M Contract: - Maintenance Period - (5 years)

- Leak Repair & Pipe Maintenance
- Laying and replacement of pipe for cracks, bursts and wherever realignment is needed.
- UFW Monitoring and Control
- Replacement of defective Meters
- Replacement of damaged, leaky house service connections
- Collection of water samples, testing and rectifying the contamination cases
- Determination of UFW for all DMA on monthly basis and submitting the UFW report
- Determination of Cost-Benefit Analysis and submitting the final report
- Active Leakage Management – Implement multiple leakage detection methodologies and ascertain the efficiency of each methodology on parameters of speed of detection, pinpointing leaks and number of

leaks in Urban Bengaluru environment.

The main object of this project is to reduce leakage by replacing distribution pipes made of C.I. pipes. Table 11.2.22 summarizes proposed replacement of C.I. pipes by contract division.

Table 11.2.22 Existing Pipe Details and Proposed Replacement

Name of contract / Division to be covered	Project Area (km^2)	Nos. of existing Connections	Length of existing pipe lines (km)				Proposed replacement of C.I. pipes	
			Total	DI	C.I Pipe with lead joints	75 mm / PVC	Length (km)	% to total C.I pipeline
D1c – North	19	46,500	559	401	155	3	60	39%
D1b – East	38	84,800	732	502	229	1	108	47%
D2c – South-East	22	56,100	540	256	270	14	130	48%
Total	**79**	**187,000**	**1,841**	**903**	**654**	**18**	**298**	**45%**

Source: JICA Survey Team

2) Leakage Reduction Strategy for Transmission Pipelines and GLRs

This component strategically deals with Master Balancing Reservoirs and GLRs with all interconnecting transmission mains. This work will be managed by BWSSB. The work procedures for this component are outlined below.

a) Detailed survey on water transmission pipelines and GLRs including BWSSB's water assets and mapping of all the assets surveyed through GIS.

i. Topographical Surveys: Walk through as well as detailed surveys for entire water distribution network from MBR to GLRs using equipment such as GPR (Ground Penetrating Radar) and Metal Detectors etc.

- From MBR to Ground Level Reservoirs (GLRs), (Macro)
- Properties such as size, material, age, depth, alignment, leakage history will be recorded for all the above assets and interconnecting pipelines from available data.
- All the infrastructure will be located using GPS

ii. Condition Surveys

- Condition assessment of all over-ground assets such as GLRs, pumping stations and recording the observations in asset database along with necessary photos.
- Condition assessment of underground trunk mains such as pipes and associated appurtenances and recording the observations in GIS database including necessary evidence.

iii. GIS Mapping

- Development of asset databases after considering BWSSB's existing GIS
  - ⇒ GLRs
  - ⇒ Transmission mains
  - ⇒ Appurtenances such as different types of valves, inverted syphons, crossings etc.

⇒ Mapping on GIS, correction with BWSSB on alignment and interconnections. Tracing with EPL/GPR at important and strategic points as necessary.

iv. Flow measurement: Assessment of trunk mains, GLRs, pumping stations (Bulk Supply Infrastructure) currently in operation to distribute the water in the network under each command area (ex: Service Station).

- Flow Measurement at inlet/ outlet/s of every GLR/ OHT or drop test to check water level drop per hour during non-supply time
- Flow Measurement at strategic points on the Trunk Main, if required

b) Development of Hydraulic Model for Transmission Mains and GLRs

i. Develop computer hydraulic model (in Water Gems) to replicate the current trunk main system and operation up to GLR level

ii. Monitor the current flows in the trunk mains for period of up to 7 days continues to ensure understanding of the present scenario

iii. Calibrate the Model based on measured flow and pressure in the system

iv. Analyze Supply Vs Demand gaps and anomalies

v. Integrate Stage V and existing CWSS stages

c) Make Bottleneck analysis for Transmission Mains and GLRs: Analysis of Bottlenecks/ Shortcomings / Condition Assessment in the Bulk Supply Infrastructure for even Distribution of Water in Current Scenario

i. Determine the operations on trunk mains

ii. Identify existing bottlenecks in pumping, reservoir capacity, power backup, trunk main (age, capacity, pipe strength, joints), alignment, interdependencies

iii. Conceptual solutions to the observed problems such as leakages in transmission mains or its appurtenances, leakages in GLRs, etc.

d) Prepare the Asset Management Report and GIS Databases

i. Develop asset databases after considering BWSSB's existing GIS databases and suggesting necessary improvements to BWSSB. Development the GIS database with due consideration of earlier available GIS and reconciliation of the differences

ii. Create mapping on GIS, correction with BWSSB on alignment and interconnections. Tracing with EPL/GPR at important and strategic points as necessary.

e) Preparation of DPR based on Transmission and GLRs UFW Reduction Study

i. Classify GLRs according to priority based on percentage leakage

ii. Determine methodology of reducing leakages including repairs / replacement and present in conceptual note to BWSSB

iii. Determine alternate sources of supply for affected households from nearby GLRs

iv. Based on BWSSB approvals to various conceptual solutions, undertake detailed engineering for repairs / replacement including detailed calculations, drawings and Bill of Quantities

v. Prepare public awareness campaign

vi. Prepare DPR for Overall Components

3) Direct and Indirect Cost for Planned UFW Reduction Project

The rates of BWSSB SR 2016-17 and PWD SR 2015-16 are adopted for the cost estimates. The direct cost will be 3,289 Million INR as shown in Table 11.2.23. Indirect cost is also shown in Table 11.2.24.

Table 11.2.23 Division-wised Direct Cost for Distribution System

S/N	Name of Contract / Division	Design Million INR	Construction Million INR	O&M Million INR	Total Cost Million INR
1	Contract D1b East	89.46	866.89	265.54	1,222
2	Contract D1c North	45.27	592.97	227.55	866
3	Contract D2c South-East	52.25	903.17	245.49	1,201
Total cost		**186.98**	**2,363.03**	**738.58**	**3,289**

Source: JICA Survey Team

Table 11.2.24 Project Cost for UFW Reduction Project

S/N	Description	Total amount in Million INR		
		Design & Construction	O & M	Total
I	Construction Cost (project D1b, D1c & D2c)	2,550	739	3,289
	Provisional sum and Physical contingency @ 3% of Bill-I	76	22	98
	Administrative charges @ 0.5%	13	3	16
	Price escalation @ 6 % of Bill-I and II per annum for 3 years Construction worker's welfare cess @ 1% of Total project cost Work contract tax @ 4% of Total project cost Consultancy charges for DPR preparation @ 0.5% of Project cost	475	138	613
	PMC and Third party inspection of materials	80	-	80
	Total	3,194	902	4,096
II	Construction of two story 30 ML GLR and strengthening repairs to existing 9 ML & 14 ML GLRs at CJF	-	-	450
	Advertisement, Misc. & rounding off	-	-	4
Total Cost		**-**	**-**	**4,550**

Source: JICA Survey Team

GoK approved only 3,795 Million INR for UFW Reduction Project, as mentioned above. Therefore, the cost beyond 3,795 Million INR needs to be managed by BWSSB or scope of work may be reduced. Under this condition, BWSSB may adopt an alternative measure such as Public Private Partnership mode. This may involve initial investments by the concessionaires with a revenue sharing from the water saved by UFW reduction and/or annuity payment.

(2) Schedule

The design and construction period is expected to be about 3 years. The operation and maintenance contract period is planned to be 5 years after completion of the design and construction period.

(3) Present Status including Tendering Process

The tendering process for the UFW reduction had not yet commenced as of the beginning of March 2017, because the scope of work prepared in the DPR was under revision.

(4) Technical Recommendations on the Revised Plan

- The following issues on UFW countermeasures are found and the improvement is required.
  - ⇒ Present UFW target of the performance contract is 16%, it is very difficult to achieve.
  - ⇒ The information on existing pipelines is insufficient to estimate the repair /replace work quantity.
  - ⇒ It may be necessary to consider extension of working period at narrow road and low workability locations.
  - ⇒ The present UFW project have faced substantial obstruction/ interference from parties such as BBMP/Traffic Police / BESCOM/ Local governing bodies etc.
- It is difficult to detect water leaks as the water supply service is neither 24/7 nor has proper pressure.
- The scope could include asset surveys, valve condition / location surveys, location and sample condition assessment of existing pipe surveys and house to house surveys
- Additionally include flow measurement for more accurate calibration of the network model
- Reduce the reliance on asset replacement strategy alone and promoting other strategies for UFW reduction by using financial incentives
- Explore other business and financial models for funding and undertaking UFW reduction

(5) Recommendation for BWSSB

- Strengthen organization and develop capacity aiming at NRW reduction is recommended. One of the best benefits is financial gains from increased water sales and reduced water production, including postponement of costly capacity expansion. The reduction of commercial losses, while politically and socially challenging, can also improve relations with the public, since some consumers may be reluctant to pay their water bills knowing that there are many other services without being billed or being under-billed.
- Create teams in working level (Assistant Executive Engineers with Contractors' Senior Engineers) at each or a couple of District Metered Areas (DMAs). The team lead by Assistant Executive Engineer (AEE) and assisted by the Contractor's team shall have the specific Key Performance Indices (KPIs) to implement the operation strategy co-developed with BWSSB for the DMAs/ Service Station/Command Area under his jurisdiction and achieve targeted outcomes within predefined timelines for daily supply, pressure improvements, leakage and NRW control, streamlining of operation eliminating all intermediate valve operations.

11.3 110 Villages Sewerage Project (Lateral & House Connections)

BWSSB has experiences on the construction of lateral sewer/ house connections through Phase 2 Project for ULB areas by GBWASP/BCC (Beneficiary Capital Contribution) funds. A similar concept will be used by BWSSB for the implementation of the sewerage project for 110 Villages.

The revised DPR does not include the facilities in the upstream of the sewerage system including lateral sewers and house connections, since the scope of work is limited to the major sewerage facilities which are considered for JICA Survey Project. Therefore, required cost for the facilities to be undertaken by BWSSB is referred to the original DPR.

(1) Scope of Work

The scope of work for lateral sewers and house connections (HC) is shown in Table 11.3.1 and Table 11.3.2, respectively.

Table 11.3.1 Scope of Work for Lateral Sewers

Zone	Length of lateral Sewers(m)		Total (m)
	ϕ 200mm	ϕ 230mm	
Bytrayanapura	367,871	11,291	379,162
Mahadevpura	360,595	6,884	367,479
Bommanahalli	764,249	9,253	773,502
R.R. Nagar	239,829	3,494	243,323
Dasarahalli	486,851	6,282	493,133
Total	**2,219,395**	**37,204**	**2,256,599**

Source: JICA Survey Team

Table 11.3.2 Nos. of Households

Area (Zone)	Nos. of households		
	2019	2034	2049
Bytrayanapura	28,600	49,500	78,500
Mahadevpura	26,500	46,000	72,800
Bommanahalli	33,500	58,000	92,000
R.R. Nagar	12,900	22,500	35,400
Dasarahalli	22,800	39,500	62,500
Total	**124,300**	**215,500**	**341,200**

Source: JICA Survey Team

(2) Schedule and Cost Estimates

As of the beginning of March 2017, no updates for the construction of sewerage facilities concerned in the DPR had been made. Required cost for the two components is summarized in Table 11.3.3, as presented the difference between the original DPR (all facilities) and revised DPR (STP and trunk sewer).

Table 11.3.3 Required Cost for Lateral Sewers and House Connections

Unit: Million INR

Item	Lateral & HC (2)-(1)	Reference	
		STP & TS (1)Revised DPR	Total Cost (2)Original DPR
1.Sewer	5,780	2,537	8,317
2.STP	**0**	2,580	1,618
3.ISPS	**0**	72	72
4.DI pipe	**0**	24	24
5.Drainage	**0**	10	10
6.House Connection	916	**0**	916
7.Cleaning Machine	301	**0**	301
8.Road Restoration	2,513	536	3,049
Sub-total (Direct cost)	9,510	5,759	14,307
Indirect cost	3,011	2,028	5,039
Total	**12,521**	7,787	19,346

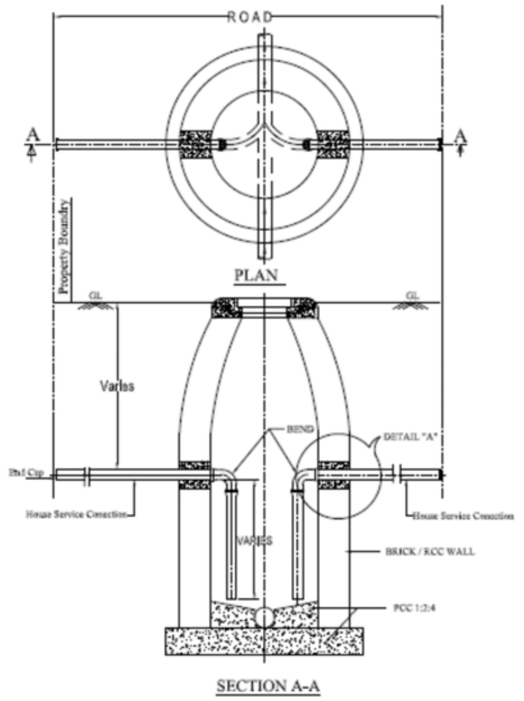
Source: DPR and JICA Survey Team

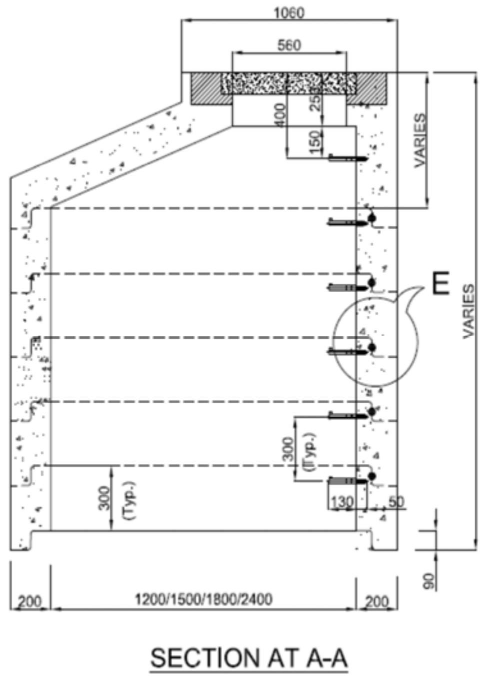
(3) Procurement and Budgetary Cost

The construction work for lateral sewers could be sub-divided into 5 packages similar to water supply packages. However, house connections may be undertaken by BWSSB licensed plumbers. With regard to construction cost of house connections, in case of local funded project implemented by BWSSB, required cost is shouldered by house owners. This arrangement will be adopted for the Project, thus, budgetary cost is 11,605 Million INR excluding the cost for house connections.

(4) Typical method for the Construction of House Connections

Figure 11.3.1 and Figure 11.3.2 show the standard facilities for house connections. Some house connection pipes are connected to the manhole and some pipes are connected directly to sewers. Photo 11.1 shows the actual construction site for the installation of lateral sewers and house connections.

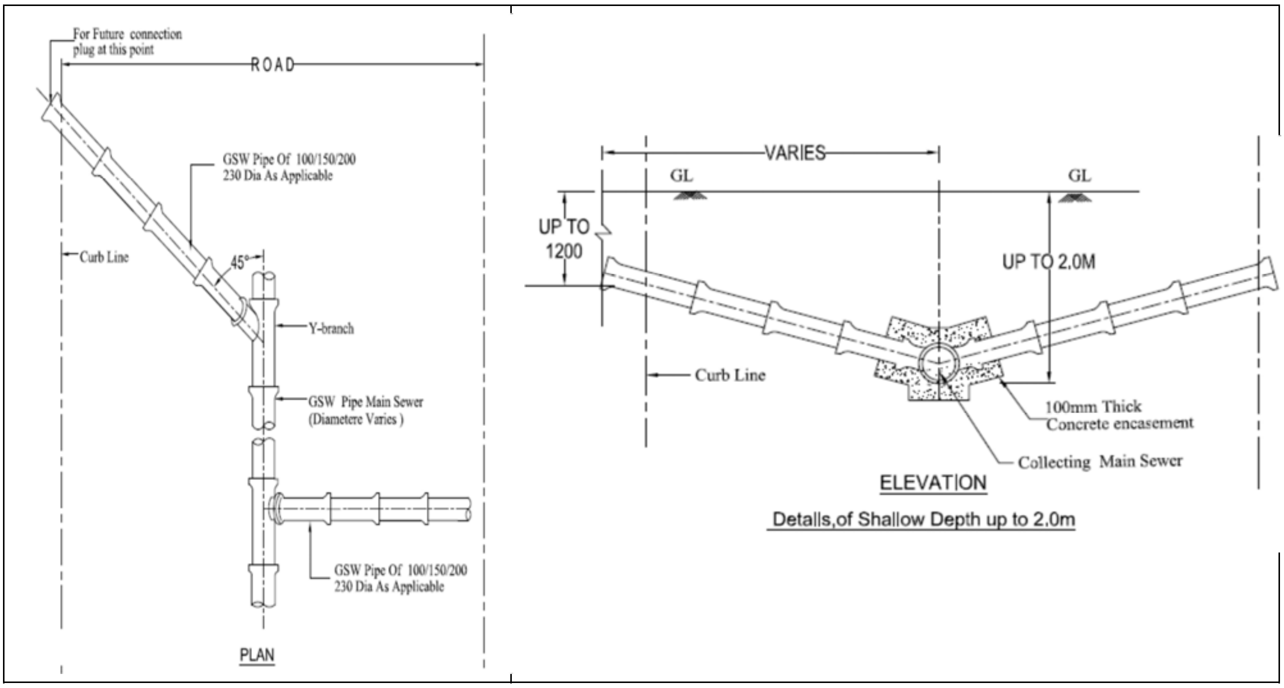




Typical House Connection	Precast Concrete Manhole

Source: CPHEEO Manual

Figure 11.3.1 Standard Drawing of Connection Manholes



Source: CPHEEO Manual

Figure 11.3.2 Typical House Connection to Connect Directly to Lateral Sewer


Laterals and House Connection Pipe Installation


Brick Manhole for Lateral Sewers

Photo 11.1 Actual Construction Site of Lateral Sewers and House Connections

(5) Technical Recommendations

The recommendations on 110 Villages Sewerage Project are mentioned below.

1) Water Pollution and Connection to STP

i. In some areas, lateral sewers and house connections were already installed and collected sewage is directly discharged into nearby water bodies. These sewers shall be connected immediately to public sewers upon completion of STP. In this regard, the outlet points should be recorded clearly.

ii. Sometimes connections are not properly arranged, such as connection to storm water drainage. Thus, BWSSB shall conduct inspection on the completed connection work.

iii. Some illegal connection/discharge from industry or enterprise may be done. BWSSB shall request the report on effluent quality to the customers, and also BWSSB shall conduct inspections on effluent quality. If the wastewater does not meet the regulation, instruct them to stop the discharge. Periodical inspection to the industry /enterprise is also effective.

iv. Sewage treatment facilities are required for those buildings with more than 1,000 m^2 floor. It is necessary to monitor such sewage treatment facilities to confirm the status on the treatment.

v. Connection point to invert level, diameter and sewage flow of existing sewers shall be carefully investigated before starting the design of lateral sewer/house connections. The information shall be reflected in the newly planned sewer network or main sewer design.

vi. Construction of public toilet shall be considered. There are about 500 numbers of public toilet in the BBMP area (Source: http://bbmp.gov.in/toilets) including 110 Villages as shown in Photo 11.2. However, some public toilets are not maintained properly and/or people are still not willing to pay for the toilet. Therefore, it is recommended to construct free and well-maintained public toilet. There are many construction works going on in 110 Villages and no toilet is available for the labour of the construction. BWSSB together with BDA shall force the contractor to install temporary/permanent public toilets for them to prevent the pollution.

Pay & Use Public Toilet in Bengaluru 1

Pay & Use Public Toilet in Bengaluru 2

Public Toilet Not Being Maintained

People are Still NOT Using Public Toilet

Photo 11.2 Actual Conditions on the Existing Public Toilet in BBMP Area

2) Technical Aspects

i. Commonly manholes are made of brick even under heavy traffic roads. Traffic load has to be carefully considered in case of the design/construction of manholes under the road

ii. RWH facility is not only used for direct use of rain water, but also effective for groundwater conservation and flood prevention. And also water reuse is recommended. But lack of experience causes miss-connection of the pipes. To prevent from these miss-connection of sewers and rainwater pipe, proper construction supervision applying different color marked pipes by function are recommended.

iii. Public sewer will be constructed up to the boundary of public and private land. Study shall be made for the construction of junction box to connect to house connections.

3) Implementation

i. Many projects are implemented in parallel. Asphalt cutting and excavation are conducted for water supply project, then after that again cut the road for sewerage project. Coordination with road department is recommended to adjust the construction timing and to confirm the future development plan. Also, sewers and water pipe including house connections can be installed at the same time

ii. Proper use of water supply and sewer systems is necessary. Some people do not know how to connect to water supply and sewerage systems. Education and/or enlightenment activity has to start as soon as possible for the smooth implementation of the project

iii. Safety measures are not considered properly at the construction sites at present. Safety measures such as H_2S gas prevention (fresh air supply) or temporary support for excavation shall be properly conducted.

iv. To secure the construction quality high, the establishment of a registration system to local contractor is recommended. The system shall be composed as follows; at first, train a technician of local contractor, issue license to graduated technician, then the license becomes one of the requirements to offer the specified works.

4) Operation and Management

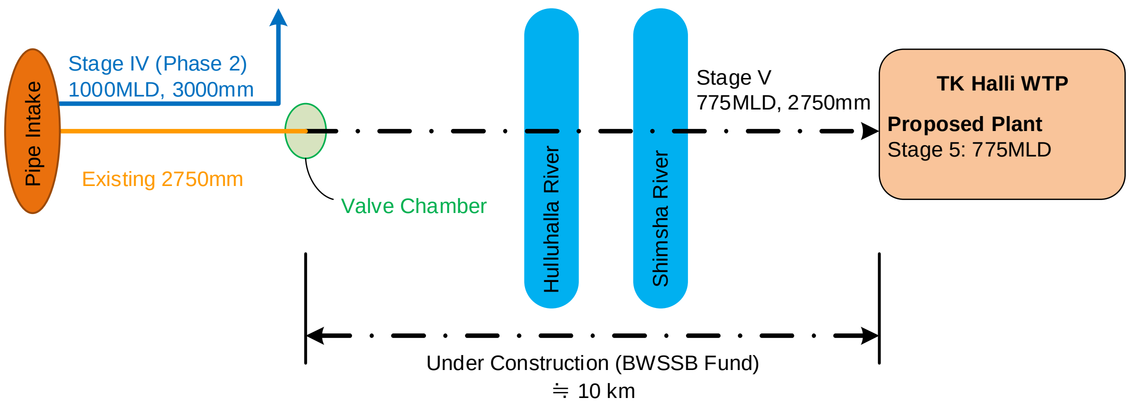
i. A total of about 50 STPs exists and/or is planned in BBMP area including 15 STPs proposed in this study. Therefore, automatic operation and remote control system shall be applied for effective and efficient operation to keep stable effluent quality at all STPs.

ii. In Bengaluru, sewage inflow quality (concentrations) is on a comparatively high level, since the water supply amount is limited comparing with per capita load discharged. There is a possibility that inflow sewage concentrations would become much higher as a result of the promotion of water saving in the future. Thus, the design of STPs shall be carefully made considering the issues.

11.4 Conveyance and Transmission Facilities Related to Stage V Project

11.4.1 Conveyance Pipeline from Valve Chamber to TK Halli WTP

The water conveyance pipeline for CWSS Stage V will be completed from the pipe intake near SBR to TK Halli via the valve chamber located near NBR. The work for the section from the valve chamber to TK Halli was commenced by BWSSB using local fund at the beginning of year 2017. While, existing facilities from pipe intake near SBR to the valve chamber are utilized. Figure 11.4.1shows schematic diagram on the planned conveyance pipelines for Stage V Project from Cauvery River to TK Halli WTP compound.



Source: JICA Survey Team

Figure 11.4.1 Schematic Diagram of Conveyance Pipeline for CWSS Stage V

(1) Conveyance Facilities

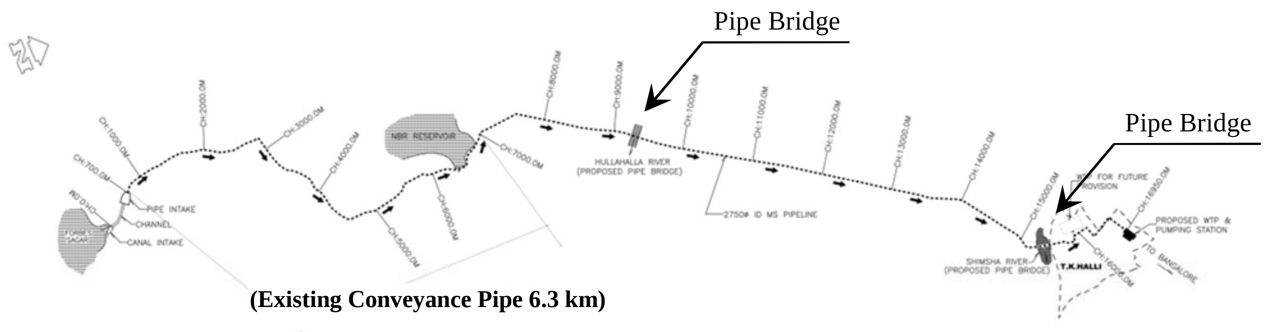
The water conveyance pipeline crosses the rivers two (2) times (Hullahalla and Shimsha rivers) in the section undertaken by local fund of BWSSB. The existing river crossings for Stages I and II are made of RC-T-beam and Stage IV, Phase 1 & 2 are of RCC bridges. A similar RCC bridge is planned for the crossing of conveyance pipeline of Stage V. The conveyance pipeline after passing the Hulluhalla River Bridge shall be encased with concrete based on the experience on higher soil overburden (6 to 7 m) for a length of about 300 m. The length of river crossings is shown in Table 11.4.1.

Table 11.4.1 Length of River Crossing

Rivers and Chainage	Crossing Length	Type of Crossing
Hulluhalla River @ chainage - 9.3 km (Chainage 0 km starting from SBR)	108 m	Stages I & II: RC T-beam, Stage IV Phase 1 & 2: RCC Bridge, Stage V Pipeline: RCC Bridge
Simsha River @ chainage - 15.5 km (Chainage 0 km starting from SBR)	300 m	

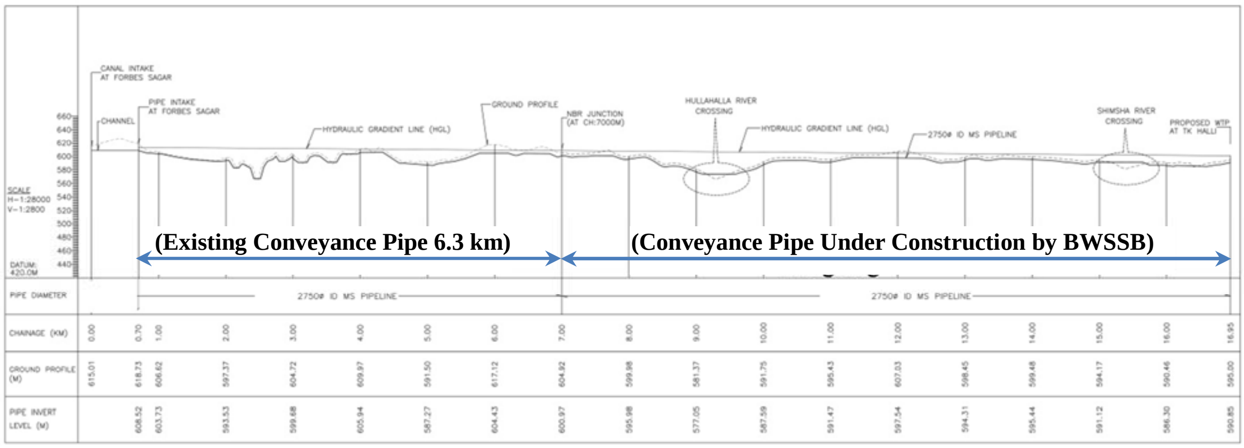
Source: JICA Survey Team

It was confirmed through hydraulic calculation that planned flow of 775 MLD can be conveyed by gravity using planned MS pipe with a diameter of 2,750 mm. The plan and profile of the conveyance pipeline for Stage V is shown in Figure 11.4.2 and Figure 11.4.3.



Source: JICA Survey Team

Figure 11.4.2 Plan of Conveyance Pipeline



Source: JICA Survey Team

Figure 11.4.3 Profile of Conveyance Pipeline

(2) Scope of work

This scope include the construction of conveyance from Valve Chamber to TK Halli WTP because existing conveyance can be used from Pipe intake to NBR.

The scope of work for the project component is as follows:

1) Procurement of material, fabrication of pipes and specials, and pipe laying including jointing and testing the pipeline from NBR to TK Halli WTP.

a) Supplying MS pipe with a diameter of 2,750 mm (clear internal diameter after lining) fabricated using Mild Steel Plates / HR Coils.

b) Laying, jointing and testing the fabricated 2,750 mm diameter pipeline for the length of about 10 km. The new pipeline is to be laid parallel to existing BWSSB pipelines. The majority of pipe laying section is proposed to arrange underground. The exposed portion is to be supported by saddles on ground and by ring girders on pipe bridges. In some sections the pipeline laid underground needs concrete encasement at the places of higher soil overburden, stream crossings and road crossings.

c) External coating of 30 mm thick plastering/ epoxy painting and in-situ internal cement mortar lining of 14 mm thick.

d) Fabrication, laying and jointing of pipe specials.

e) Procurement and erection of valves.

f) Construction of pipe saddle supports, thrust blocks, and anchor blocks.

g) Construction of valve chambers.

h) Construction of two (2) pipe bridges across Hulluhalla and Shimsha rivers.

(3) Schedule

The required period for the completion of the project is planned as 24 months according to the contract document.

(4) Cost requirement

BWSSB has issued a letter of acceptance to the proposed cost to the contractor (M/s Sai Sudhir.) on 30th Jan 2017. The contract price for the conveyance main from NBR to TK Halli is 1,676 Million INR. The project cost estimated in the DPR was 1,760 Million INR including price and physical contingency.

11.4.2 Transmission pipeline to Share water from Stage V to Core and ULB Area in the Medium Term (Branch Feeding Pipes)

(1) Required Countermeasures to Share Transmitted Water from Stage V Project to Core and ULB Areas in the Medium Term (Branch Feeding Pipes)

1) Water Balance in Core and ULB Areas

The water balance in Core and ULB areas in medium term is shown in Table 11.4.2. It is clear that water shortage is significant in Core area. The saving water from the reduction of UFW will supplement supply amount year by year. Never the less, water shortage in Core area from 2024 to 2034 is constant. While additional water requirement for ULBs is much less than that of Core area.

Table 11.4.2 Water Balance in Core and ULB Areas

Unit: MLD

Area	2024				2034			
	Supply	Demand	Available Groundwater	shortage	Supply	Demand	Available Groundwater	Shortage
	A	B	C	A-B+C	A	B	C	A-B+C
Core	540	1,187	300	- 347	540	1,201	300	- 361
ULBs	770	673	100	197	770	903	100	-33

* Minus mark indicates water shortage amount

Source: JICA Survey Team (Chapter. 6)

2) Available Water Amount for Diversion from Stage V Project to Core/ULB Areas

Water balance in 110 Villages for target years between water demand and planned supply amount (by Stage V Project) is presented in Table 10.1.1, Chapter 10. After delivery of planned water to the 110 Villages to cater for water demand by only river water (without using groundwater), 425 MLD to 275 MLD (if groundwater is used, 525 MLD to 375 MLD is available) may be supplied for Core and ULB areas from the year 2024 to 2034 (refer to calculation bases below). During this decade, the water amount available to share to Core/ULBs will be decreased gradually in proportion to the increase of demand in 110 Villages.

- 2024: Cauvery River Source 775 - Demand 350 * = 425 MLD (If groundwater is used, 525 MLD is available.)
- 2034: Cauvery River Source 775 - Demand 500 * = 275 MLD (If groundwater is used 375 MLD is available)

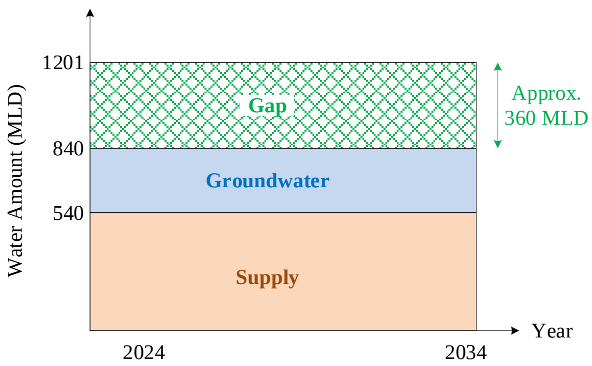
Note: * Refer to Table 10.1.1 (Demand and Supply)

3) Required Countermeasures to Share Water through Stage V Project to Core and ULB Areas

For the full use of available water from Stage V Project in the entire BBMP area, the manner of delivery of the water to Core (The service is provided by Stage I to III.) and ULB (The service is provided by Stage IV.) areas was studied. This study was not included in the relevant existing DPRs, because no sharing of the water to Core/ULBs was out of scope.

In the water sharing, the water to ULBs will be managed through existing Stage IV GLRs (OMBR, GKVK and Hegganahalli-2 GLRs), thus there is no need of additional measures for the ULBs. The scope of work to share water to Core area through Stage I to III GLRs was studied.

About 360 MLD is in short in Core area in the next 10 years as shown in Figure 11.4.4. The following alternative study was made.



Source: JICA Survey Team

Figure 11.4.4 Water Balance in Core Area

a) To Divert Water Transmitted by Stage V to Clear Water Reservoir of Stage I to III at Tataguni PS Compound.

This method is to share water transmitted by Stage V project at the compound of Tataguni Pump Station (PS) in use of stand-by pump units installed in the Stage I to III with comparatively cheaper cost. Presently, a total of 540 MLD is transmitted to Core area by pump facilities of Stage I to Stage III. Each one of stand-by pump for respective stages may be used for sending additional water from Stage V to each service area of the three (3) stages as shown in Table 11.4.3.

Table 11.4.3 Present Pump Unites Installed for Stage I to III and Planned Pump Units for Water Sharing at Tataguni Pump Station Compound

Item	Stage I		Stage II		Stage III	
	Present	Planned	Present	Planned	Present	Planned
Operating pump unit	3	4	3	4	5	6
Stand-by Pump unit	2	1	2	1	3	2
Pump capacity	1,890 m^3/h x 160m		1,890 m^3/h x 160m		2,250 m^3/h x 170m	
Motor output	1,250 kW		1,250 kW		1,525 kW	

Source: JICA Survey Team

However, there are some issues and problems in the application of the above mentioned method as follows:

i. Limited volume for transmitting water: In assumption of the operation of each one unit of stand-by pump for the three (3) stages, 145 MLD (1,890 + 1,890 + 2,250 m^3/h) may be sent, however, it seems to be difficult to ensure the amount from realistic view points, due to the increase of pressure losses at the pump outlet and utilization of existing old facilities.

ii. Need of the increasing power reception capacity

iii. Increase of power consumption affected by the increase of water pressure losses in transmission pipeline

iv. Additional countermeasures, aside from the countermeasure at Tataguni PS compound, are required to cater for the required volume to be shared for Core/ULBs

Because of some problems in the above case, the following method is recommended.

b) Expansion of City Trunk Main to existing GLRs of Stage I, II and III in Core area (installation of Branch Feeding Pipes)

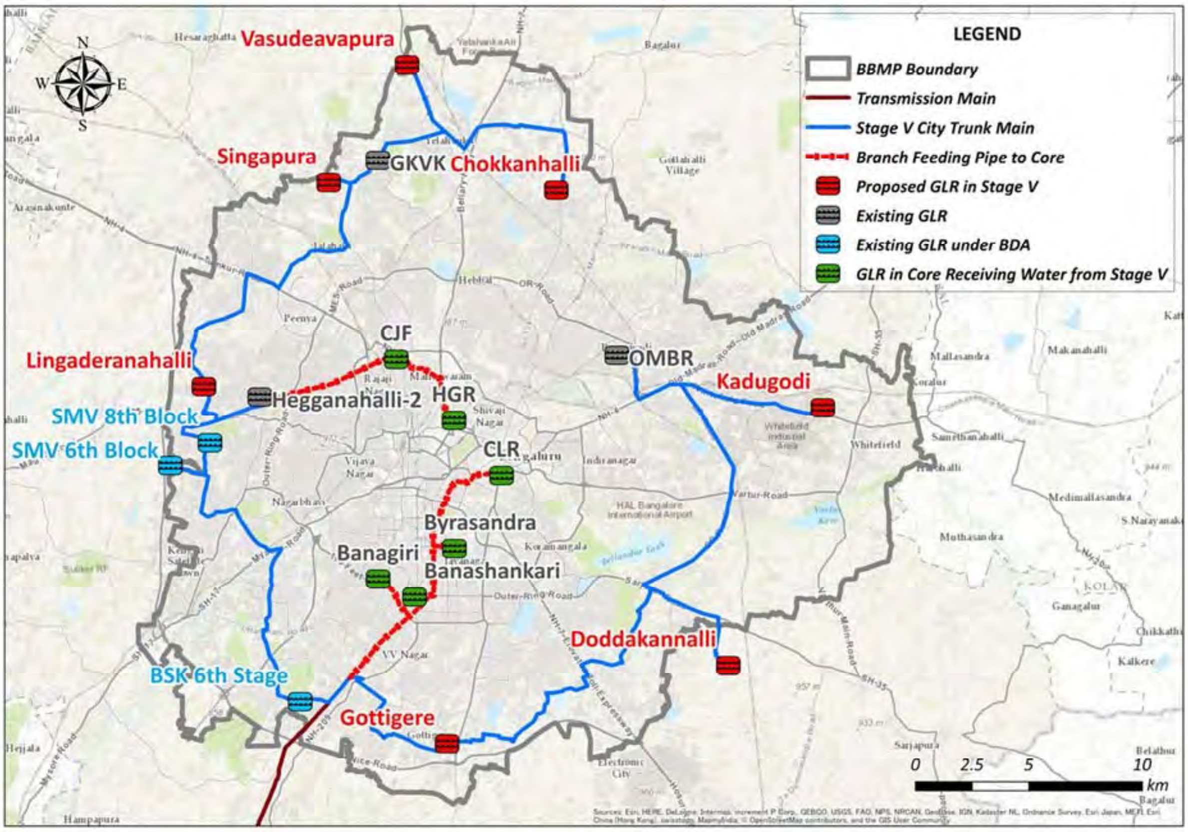
A total of 360 MLD water to share to Core area is divided into the three stages in proportion to respective transmitted water volume (Stage I; 25%, stage II; 25% and Stage III 50%). The water volume to be shared to each stage is set at each 90 MLD for Stage I and Stage II, and 180 MLD for Stage III. Then existing GLRs by stage were selected in consideration of larger capacity for effective distribution of water to each stage service area; a total of six GLRs broken down into one, three and two units for Stage I, Stage II and Stage III, respectively. The water volume to be shared by selected GLRs by stage is calculated in proportion to currently distributed water volume. Table 11.4.4 shows receiving water volume by GLR by stage. The detention time of the GLR is considered to ensure more than six (6) hours.

Figure 11.4.5 presents Branch Feeder Pipes expanding from Stage V City Trunk Mains. There are two (2) major expansion pipelines to reach selected GLRs. One is planned to expand from Hegganahalli-2 GLR to HGR GLR. Another is expanded from Vajarahalli junction to CLR GLR.

Table 11.4.4 Existing GLRs by Stage for Augmentation of Water Supply to Core Area

Stage	GLR	Receiving Water Volume					Detention Time (hour)
	Name	Capacity ML:(A)	Present MLD	Planned			(A)/(B)x24
				% (Stage)	% (GLR)	Volume MLD: (B)	
Stage I	CLR	27.0	49	25	100	90	7.2
Stage II	Banagiri	18.0	23	25	31	28	15.4
	Banashankari	22.5	34		46	41	More than 12
	Byarasandra	25.2	17		23	21	More than 12
	Sub-total	65.7	74		100	90	-
Stage III	CJF	166.6	66	50	47	85	More than 12
	HGR	58.5	75		53	95	More than 12
	Sub-total	225.1	141		100	180	-
	Total	317.8	264	100	-	360	-

Source: JICA Survey Team



Source: JICA Survey Team

Figure 11.4.5 Branch Feeding Pipes from Stage V City Trunk Main

(2) Scope of Work

According to the water balance study, the water transmitted by Stage V Project can be shared to fill in the shortage in the Core and ULB areas until 2034. The scope of work shown below is used to come up with approximate cost required.

Table 11.4.5 Scope of Work to Share Water of Stage V to Core/ULBs

Component Work; Required Facilities/Equipment	Quantities
Branch Feeding Pipes (Vajarahalli junction and Hegganahalli-2 GLR) to Existing GLRs of Stage I, II and III in Core Area	DI Pipe: Dia 600 mm ～ 700 mm: 3.1 km MS Pipe: Dia 1000 mm ～ 1400 mm: 25.8 km
Pump Station (to be installed after Hegganahalli-2 GLR)	One pump station (Head 20 m: 6 units)
Flow Meters to be installed at the inlet of existing GLRs	Dia 350 mm: 1 unit Dia 400 mm: 1 unit Dia 500 mm: 1 unit Dia 700 mm: 3 units
Monitoring equipment for SCADA system	Water gauges for SCADA: 6 units

Source: JICA Survey Team

(3) Design Capacity of Transmission Facilities

Table 11.4.6 shows existing GLRs to be used with related information.

Table 11.4.6 Existing GLRs to be Used by Stage with Related Information

Stage	GLR Name	Capacity (ML)	Receiving Water Amount (MLD)	Flow Meter Diameter (mm)
Stage I	CLR	27.0	105	700
	Sub-Total	27.0	105	-
Stage II	Banagiri	18.0	33	400
	Banashankari	22.5	48	500
	Byarasandra	25.2	24	350
	Sub-Total	65.7	105	-
Stage III	CJF	166.6	98	700
	HGR	58.5	112	700
	Sub-Total	225.1	210	-

Source: JICA Survey Team

(4) Schedule

The construction work shall be completed before the completion of Stage V Project by 2023 from 2021 within 2 and a half year period.

(5) Cost Estimation

1) General Conditions

The construction cost is calculated by the following manners.

- Straight Pipe: Based on the unit price on Schedule of Rates (BWSSB, 2016 - 2017)
- Fittings: Considered as 15% of straight pipelines' cost
- Valves and Water Gauges: Considered as 20% of straight pipelines' cost
- Price Escalation, Physical Contingency and other cost is considered as 30%.

2) Pipeline Cost

Table 11.4.7 summarizes required cost.

Table 11.4.7 Cost for Pipelines and Accessories

Pipe Location			Delivery Water Amount		Pipe				Cost	
					Diameter	Material	Velocity	Length	Straight Pipe	Accessory & Valves
			(MLD)	(m^3/day)	(mm)		(m/sec)	(m)	(INR)	(INR)
Vajarahalli	~	Jayanagar	210	210,000	1,400	MS	1.58	3,800	108,547,000	37,991,450
Jayanagar	~	Banagiri GLR	33	33,000	600	DCIP	1.35	2,500	27,860,000	9,751,000
Jayanagar	~	Adarsh Residency	177	177,000	1,400	MS	1.33	1,000	28,565,000	9,997,750
Adarsh Residency	~	Banashankari GLR	48	48,000	700	DCIP	1.44	600	8,560,200	2,996,070
Adarsh Residency	~	South End Point	129	129,000	1,100	MS	1.57	2,700	59,907,600	20,967,660
South End Point	~	Byarasandra GLR	24	24,000	1,000	MS	0.35	1,100	22,270,600	7,794,710
South End Point	~	CLR GLR	105	105,000	1,000	MS	1.55	5,700	115,402,200	40,390,770
Hegganahalli-2	~	CJF GLR	210	210,000	1,400	MS	1.58	6,900	197,098,500	68,984,475
CFJ GLR	~	HGR GLR	112	112,000	1,100	MS	1.36	4,600	102,064,800	35,722,680
						Direct Cost for Pipeline			670,275,900	234,596,565
										904,872,465

Source: JICA Survey Team

3) Pump Facility Cost

As mentioned above, additional pumps are required after Hegganahalli-2 GLR for sending 98 MLD to CJF GLR and 102 MLD to HGR GLR.

Considering the cost effective performance, the following specifications and conditions are recommended.

- Type of Pump: Horizontal shaft double suction volute pump with single stage impeller
- Capacity of Pump: 2,200 m^3/h
- Number of Pump Units: Four (4) Operating + Two (2) Stand-by

The unit cost of the pump which meets conditions above is about 93.5 Million JPY (55 Million INR). Thus the total cost of pump is 561 Million JPY (330 Million INR).

4) Flow Meter Cost

To monitor the water flow to each receiving GLR in Core area, flow meters are required. The velocity in the inlet pipes of GLRs are assumed around 3.0 m/sec and the diameters of flow meters are summarized in Table 11.4.8.

Table 11.4.8 Flow Meter Diameter and Cost by GLR

Stage	GLR Name	Capacity (ML)	Receiving Water Amount (MLD)	Flow Meter Diameter (mm)	Estimated Cost (INR)
Stage I	CLR	27.0	105	700	1,200,000
	Sub-Total	27.0	105	-	1,200,000
Stage II	Banagiri	18.0	33	400	600,000
	Banashankari	22.5	48	500	840,000
	Byarasandra	25.2	24	350	540,000
	Sub-Total	65.7	105	-	1,980,000
Stage III	CJF	166.6	98	700	1,200,000
	HGR	58.5	112	700	1,200,000
	Sub-Total	225.1	210	-	2,400,000
				Total	5,580,000

Source: JICA Survey Team

5) Total Construction Cost

The total construction cost for sharing Stage V water (360 MLD) to Core area is estimated at 1,612.5 Million INR including indirect cost as shown in Table 11.4.9.

Table 11.4.9 Total Construction Cost for Sharing Water to Core Area

Item	Direct Cost (Million INR)	Total Construction Cost (Million INR)
Pipeline and Accessories	904.8	1176.2
Pump	330.0	429.0
Flow Meter	5.6	7.3
Total	1,240.4	1,612.5

Note: Price Escalation, Physical Contingency and other cost is considered as 30%.

Source: JICA Survey Team