REPUBLIC OF INDIA

BANGALORE WATER SUPPLY AND SEWERAGE BOARD

BENGALURU WATER SUPPLY AND SEWERAGE PROJECT (PHASE 3)

IN

THE STATE OF KARNATAKA, INDIA

FINAL REPORT

(Main Report)

NOVEMBER 2017

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

NJS CONSULTANTS CO., LTD. (NJS)

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1 USD = 112 Yen
1 INR = 1.74 Yen
(As of June 2017)

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ABBREVIATIONS

Item	Description
AER	Aero Engine Reservoir
APL	Above Property Line
ASI	Archaeological Survey of India
ASP	Activated Sludge Process
Aus AID	Australian Agency for International Development
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
AWWA	American Water Works Association
BBMP	Bruhat Bengaluru Mahanagara Palike
BCA	Bengaluru Core Area
BCC	Bengaluru City Corporation
BCC	Beneficiary Capital Contribution
BCCI-K	Bengaluru Climate Change Initiative Karnataka
BDA	Bengaluru Development Authority
BESCOM	Bengaluru Electricity Supply Company Limited
BMP	Bengaluru Mahanagara Palike
BMRDA	Bengaluru Metropolitan Region Development Authority
BOD	Biochemical Oxygen Demand
BOQ	Bill of Quantities
BPL	Below Poverty Line
BWSSB	Bangalore Water Supply and Sewerage Board
BWSSP	Bengaluru Water Supply and Sewerage Project
C/s	Cross section
CADA	Command Area Development Authority
CBO	Community Based Organization
CCTV	Closed-Circuit Television
CDP	City Development Plan
CDS	Community Development Society
CESCO	Chamudeshwari Electricity Supply Corporation Limited
CGS	Cogeneration System
CGWB	Central Ground Water Board
CI	Cast Iron
CJF	Crown Jewel Filter
CMC	City Municipal Council

Item	Description
CNNL	Cauvery Neeravari Nigam Limited
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
CPHEEO	Central Public Health & Environmental Engineering Organization
CRR	Core Ring Road
CRU	Climate Research Unit
CTM	City Trunk Mains
CW	Clear Water
CWRs	Clear Water Reservoirs
CWSS	Cauvery Water Supply Scheme
DAF	Dissolved Air Flotation
DBU	Designated Base Use
DG	Diesel Generator
DI	Ductile Iron
Dia	Diameter
DMA	District Meter Area
DMG	Department of Mining and Geology
DO	Dissolved Oxygen
DPR	Detail Project Report
EA	Extended Aeration
EAC	Expert Appraisal Committee
EBIT	Exchange before Interest and Taxes
EC	Electric Conductivity
EC	Environmental Clearance
EIA	Environmental Impact Assessment
EIUPS	Environmental Improvement of Urban Poor Slum
EMP	Environmental Management Plan
EN	European Norm
ENVIS	Environmental Information System
EPA	Environment Protection Agency
FAR	Floor Area Ratio
FGD	Focus Group Discussion
GAP	Ganga Action Plan
GBWASP	Greater Bengaluru Water Supply Project
GESCOM	Gulbarga Electricity Supply Company Limited

Item	Description
GFT	Gravity Feeder Tank
GI	Galvanized Iron
GIS	Geographic Information System
GLR	Ground Level Reservoir
GO	Government Order
GoI	Government of India
GoK	Government of Karnataka
GP	Gram Panchayat
GPRS	General Packet Radio Service
GRP	Glass-Fiber Reinforced Plastic
GSWP	Glazed Stoneware Pipe
H Valley	Hebbal Valley
H_2S	Hydrogen Sulfide
Ha	Hectare
HDD	Horizontal Directional Drilling
HDPE	High Density Polyethylene
HESCOM	Hubli Electricity Supply Company Limited
HGR	High Ground Reservoir
HMI	Human Machine Interface
HOT	Hand Operated Overhead Traveling
HP	Horse Power
HRCSL	Hukkeri Rural Electricity Cooperative Society Ltd
HRD	Human Resources Development
HRT	Hydraulic Retention Time
HV	High Voltage
HWL	High Water Level
Hz	Hertz
ICB	International Competitive Association
ICB	International Competitive Bidding
IFC	International Finance Cooperation (World Bank)
IMD	India Meteorological Department
INR	Indian Rupee
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producer
IRR	Inner Ring Road

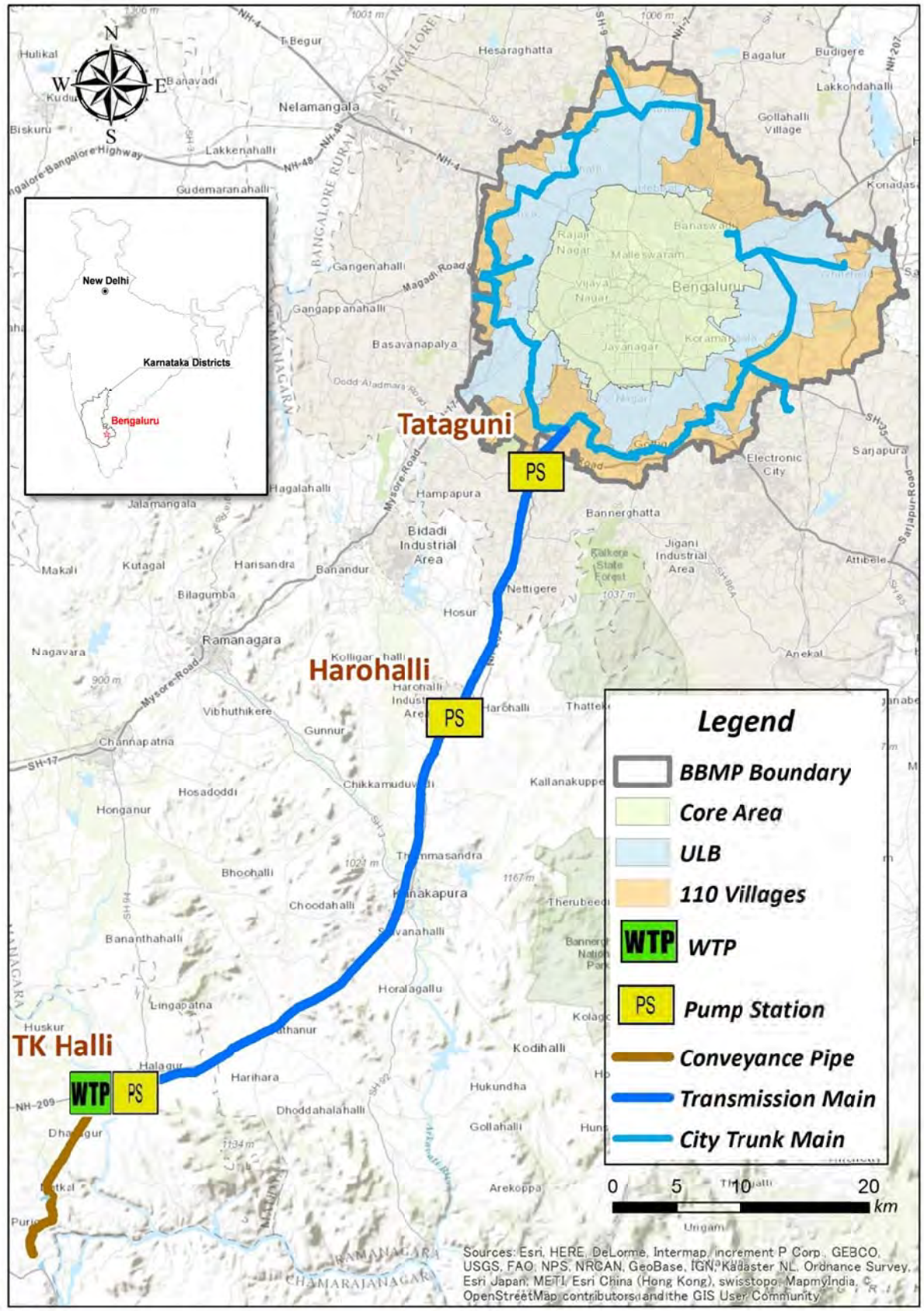
Item	Description
IRWD Act	Interstate River Water Disputes Act
IS	Indian Standards
ISPS	Intermediate Sewage Pump Station
ISS	Indian Standard Specification
ITS	Intelligent Transport Systems
IWWA	Indian Water Works association
JICA	Japan International Cooperation Agency
JIS	Japan Industrial Standards
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
K & C Valley	Koramangala & Challaghatta Valley
KEB	Karnataka Electricity Board
KIADB	Karnataka Industrial Areas Development Board
KL	Kilo Liter
KLCDA	Karnataka Lake Conservation and Development Authority
km	Kilo Meters
KMH	Kumarswamy Layout Reservoir
KMRP	Karnataka Municipal Reforms Project
KPCL	Karnataka Power Corporation Limited
KPTCL	Karnataka Power Transmission Corporation Limited
KSPCB	Karnataka State Pollution Control Board
KUIDFC	Karnataka Urban Infrastructure Development and Finance Cooperation
KUWS&DB	Karnataka Urban Water Supply & Drainage Board
kV	Kilo Volts
kW	Kilo Watt
KWhr	Kilo Watt hour
LAA	Land Acquisition Act
LCB	Local Competitive Bidding
LCC	Local Control Centers
LCC	Life Cycle Cost
Lpcd	Liters per capita per day
Lpm	Liters per minute
LS	Longitudinal Section
LV	Low Voltage
LWL	Low Water Level
M&E	Monitoring and Evaluation

Item	Description
M/P	Master Plan
MBR	Machelibetta Reservoir
MBR	Membrane Bioreactor
MCC	Master Control Center
MESCOM	Mangalore Electricity Supply Company Limited
Mgd	Million gallons per day
MHs	Manholes
MLD	Million Liters per Day
MLR	Mixed Liquor Recycle
MLSS	Mixed Liquor Suspended Solid
MLVSS	Mixed Liquor Volatile Suspended Solid
MoEF	Ministry of Environment and Forests
MR	Meter Reader
MS	Mild Steel
MSL	Mean Sea Level
MSW	Municipal Solid Waste
MTBM	Micro-Tunneling Boring Machine
MVA	Mega Volt Ampere
MW	Mega Watt
MWC	Meters of water column
NAAQS	National Ambient Air Quality Standards
NBR	Netkal balancing reservoir
NCE	Natural Clean Energy
NGRBA	National Ganga River Basin Authority
NHAI	National Highways Authority of India
NHS	N-Hydroxysuccinimide
NRCP	National River Conservation Plan
NRW	Non-Revenue Water
NTU	Nephelometric Turbidity Unit
NUSP	National Urban Sanitation Policy
NWP	National Water Policy
O&M	Operation and Maintenance
ODA	Official Development Assistance
OHT	Over Head Tank
ORR	Outer Ring Road

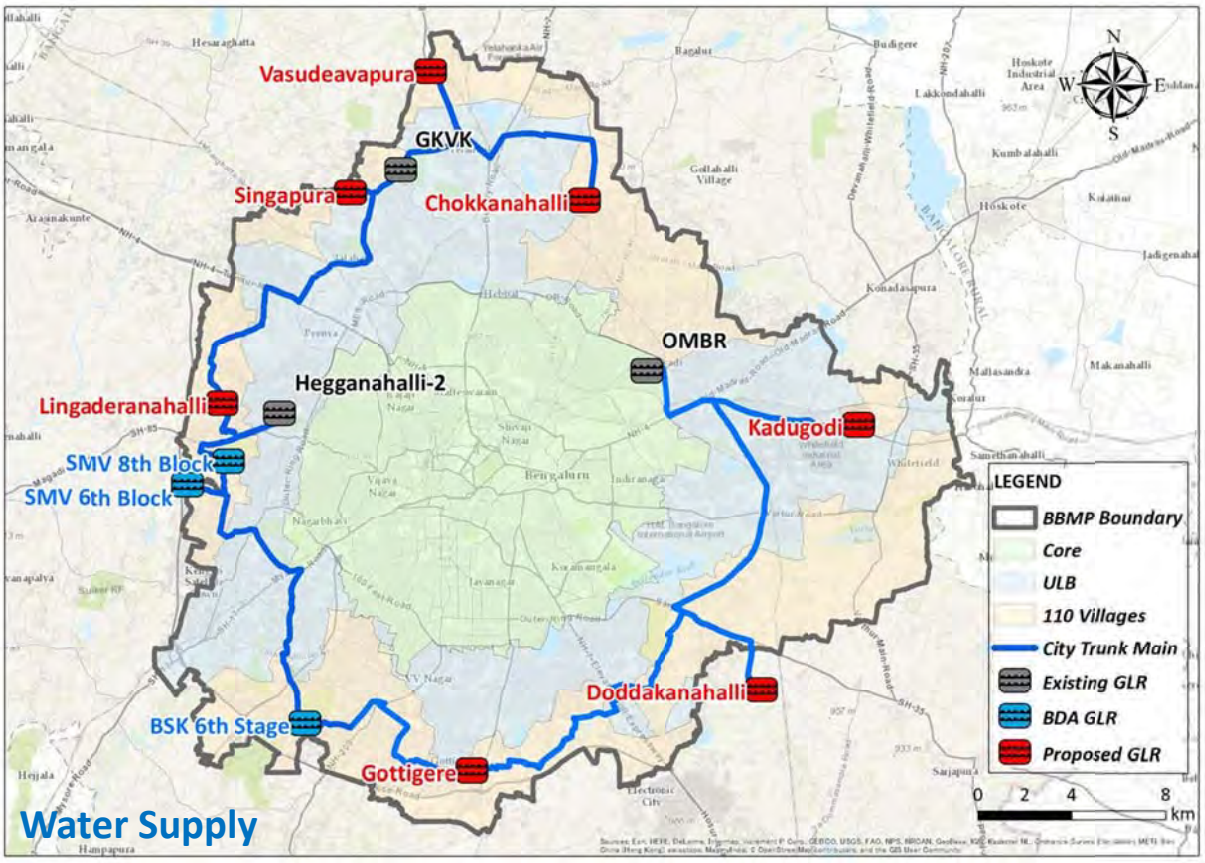
Item	Description
OST	One-way Surge Tank (OST)
P&M	Planning and Monitoring
PAC	Polyalminium Chloride
PAC	Public Affaire Centre
PAFs	Project Affected Farmers
PAT	Profit After Tax
PCB	Pollution Control Board
PCKL	Power Company of Karnataka Limited
PCU	Passenger Car Unit
PDR	Preliminary Design Report
PE	Polyethylene
PE	Project Engineer
PHI	Public Health Institute
PIU	Project Implementing Unit
PLC	Programmable Logic Controllers
PM	Project Manager
PMC	Project Management Consultants
PPR	Polypropylene
PQ	Pre-Qualification
PS	Pumping Station
PSC	Prestressed Concrete
R&R	Rehabilitation and Resettlement
RAP	Resettlement Action Plan
RAS	Return Activated Sludge
RCC	Reinforced Cement Concrete
RCPs	Reinforced Concrete Pipes
RFCTLARR Act	Right to Fair Compensation and Transparency in Land Acquisition , Rehabilitation and Resettlement Act
RO	Reverse Osmosis
RoU	Right of Use
rpm	Rotation per minute
RPM	Respirable Particulate Matter
RRS	Rehabilitation and Resettlement Scheme
RW	Revenue Water
RWA’s	Residential Welfare Associations

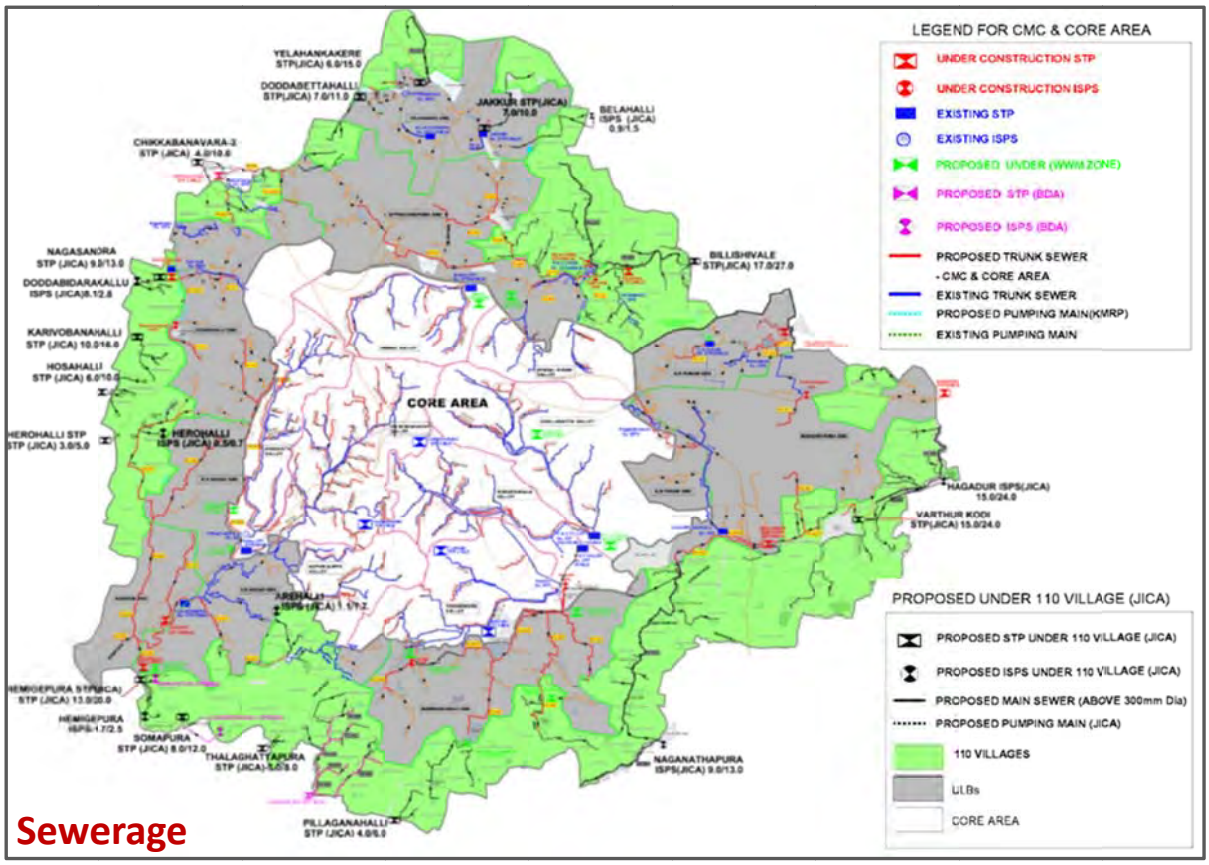
Item	Description
SBR	Shiva Balancing Reservoir
SBR	Sequencing Batch Reactor
SCADA	Supervisory Control and Data Acquisition
SCC	Subsidiary Control Centers
SEAC	State Level Expert Appraisal Committee
SHG's	Self Help Groups
SIA	Social Impact Assessment
SOI	Survey of India
SPCB	State Pollution Control Board
SPM	Suspended Particulate Matter
SRT	Sludge Retention Time
SS	Suspended Solids
STP	Sewage treatment Plant
SW Pipe	Stoneware Pipe
SWD	Storm Water Drains
SWD	Side Water Depth
TF	Trickling Filter
TK Halli	Thorekadanahalli
TMC	Town Municipal Council
TOR	Terms of Reference
TSPS	Terminal Sewage Pumping Station
TSS	Total Suspended Solids
TTP	Tertiary Treatment Plants
UASB	Upflow Anaerobic Sludge Blanket
UDD	Urban Development Department
UFW	Unaccounted For Water
ULB	Urban Local Body
UNDP	United Nations Development Programme
UPS	Urban Poor Strategy
USEPA	United States Environment Protection Agency
V Valley	Vrishabavathi Valley
VFD	Variable Frequency Drive
WAS	Waste Activated Sludge
WB	World Bank
WS	Water Supply

Item	Description
WTP	Water Treatment Plant



LOCATION MAP - 1





LOCATION MAP -2

REPUBLIC OF INDIA

BANGALORE WATER SUPPLY AND SEWERAGE BOARD (BWSSB)

BENGALURU WATER SUPPLY AND SEWERAGE PROJECT (PHASE 3)

IN

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FINAL REPORT

(Executive Summary)

NOVEMBER 2017

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

NJS CONSULTANTS CO., LTD. (NJS)

EXECUTIVE SUMMARY

1 Introduction

The field work in Bengaluru, India for Preparatory Survey on "Bengaluru Water Supply and Sewerage Project (Phase 3)'' had been conducted intermittently six (6) times from June, 2016 to August, 2017. Based on the findings and discussions with Bengaluru Water Supply and Sewerage Board (BWSSB), Final Report was prepared by the beginning of November, 2017.

This preparatory survey report covers existing conditions on water supply and sewerage sectors in the Bruhat Bengaluru Mahanagara Palike (BBMP) area. Feasibility study results on the water balance in the BBMP area with priority projects are presented before establishment of the scope of work for JICA Survey Project. Then, preliminary design of facilities for the JICA Survey Project is presented, followed by operation and maintenance (O&M) of the facilities, Environmental and Social Considerations, Implementation Plan, Financial and Economic Considerations and Organizational and Institutional Improvement. Updated information and some preliminary studies on the projects to be financed by local funds are also incorporated to come up with overall requirements for the proposed all project components.

The objective of the Project is to provide residents in BBMP area with safe and stable water supply, and sewerage services to meet increasing water demand and the need of environmental improvement and to contribute to the promotion of industry. The location of the survey area is presented in the location map, which covers the jurisdiction of the BWSSB including Core area, eight (8) ULBs (Urban Local Bodies) and 110 villages, and pipeline routes from the water intake at the Cauvery River to the entrance of BBMP.

The main objective of the Preparatory Survey is to prepare required information for feasibility evaluation of the proposed projects, as a Japanese Government ODA loan project. Among others, such information includes the outline of the project, project cost estimates, economic and financial viability of the project, project implementation schedule, manner of procurement and construction, organization of project implementation, O&M arrangements, and social and environmental considerations. The prepared report and additional components suggested in the Preparatory Survey would be considered as addendum to the DPRs for the project.

Target years for the Project are established according to the recommendations stated in the Revised Manual by the Central Public Health Environmental Engineering Organization (CPHEEO), in application of the planning base year 2019. The outline of the proposed work is summarized in Table 1.1.

Table 1.1 Outline of the Proposed Work

Proposed Work	Outline	Major Facilities (based on DPR)
Conveyance & Transmission lines from the Cauvery River to BBMP	A total of about 80 km pipeline and WTP for 775 MLD	- Conveyance line: 10 km - WTP: (775 MLD)

Proposed Work	Outline	Major Facilities (based on DPR)
and Water Treatment Plant (WTP)		- Transmission Line: about 70 km
Improvement of distribution system (UFW countermeasures)	The work for 3 zones of a total of 6 zones in Core area has been implemented. The work will be done for remaining 3 zones.	- Replacement of old distribution pipes - Provision of sector inlet chamber, DMA, etc.
Construction of water supply and sewerage facilities for 110 villages	There is no water supply and sewerage facilities in the 110 villages. Therefore construction of required facilities.	- Water Supply: Distribution networks- 2,979 km, Distribution mains- 205 km, OHT- 137 units, House connections- 106,000 HHs - Sewerage: STP* (a total of 129 MLD), main sewers- 338 km, Lateral sewers- 2,243 km, House connections- 106,000 HHs
Consulting Service	D/D, Assistance for bidding, Construction Supervision, Strengthening of capacity Building and community Development	

Source: JICA Survey Team, *STP: Sewage Treatment Plant

The Preparatory Survey covers basic survey on water supply and sewerage sector in the survey area, review of the existing DPRs, implementation issues, organizational structure, project impacts and environmental and social considerations.

2 General Description of the Project Area

BBMP is located in the South Deccan Plateau and the topography of the city is characterized by a series of valleys radiating from a ridge of high elevation to the North, which inclines gradually towards the South. The mean annual temperature is 24°C, which ranges from 13°C in winter to 36°C in summer. The average annual rainfall is about 900 mm and it concentrates between July and September.

The future scenario of the climate change for the mid-term (2021 to 2050) projections resulted in the meteorological change of the increase of temperature and rainfall in the project area. However, the future runoff of the Cauvery River basin was projected to slightly increase comparing with the past baseline data. Therefore, no major impact by climate change will be considered in the project implementation.

The river flow runs from north to south-east as well as to south-west along the natural gradient of the land. During monsoon, surplus water drains from upstream to the downstream lakes collecting sewage discharged in the basin. Inflow of physical and chemical pollutants causes water pollution in the water bodies. The groundwater source exists in shallow aquifer system within one hundred feet from the land surface and deep aquifer. In the areas where water supply by BWSSB is not provided, many apartment complexes and commercial/industrial establishments have been extracting large quantity of groundwater from deep aquifers.

The following is the major legal framework in relation to the water and sanitation sector.

- Water Prevention and Control of Pollution Act, 1974 and its Amendments
- Water (Prevention and Control of Pollution) Cess Act, 1977 including Rules
- The Environment (Protection) Act, 1986, 2004 (amended)
- Karnataka Groundwater (Regulation and Control of Development and Management) Act, 2011
- The RFCTLARR (Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement) Act 2013 as Laws and Regulation relating to Land Acquisition

BBMP is currently composed of one Core area (245.0 km^2), eight (8) ULBs (330 km^2) and 110 villages (225 km^2). BBMP is ranked third spot in terms of most populous city of India. In terms of income among the major States across the country, Karnataka ranked 5th in the years of 2014 and 2015.

3 Existing Water Supply and On-going/Planned Water Supply Projects

(1) Present Water Supply

A major water source at present for the water supply in the BWSSB service area is the Cauvery River. Through four stages of Cauvery Water Supply Scheme (CWSS), water has been conveyed from the river to TK Halli WTP and pumped up to the BBMP area in three stages; TK Halli WTP, Harohalli and Tataguni pump stations. A maximum of 1,460 MLD is supplied to the BBMP area for about 5.8 Million people as of 2016. There are 84 Ground Level Reservoirs (GLRs) at 51 sites and 52 Over Head Tanks (OHTs) to receive water from TK Halli WTP and then distribute by gravity system.

(2) Existing Water Supply Facilities

Raw water from the Cauvery River flows into Shiva Balancing Reservoir (SBR) through the canal, then into Netkal Balancing Reservoir (NBR). The water right (maximum intake amount) for the water supply at present is 1,460 MLD (see Table 3.1). The raw water is conveyed by MS (Mild Steel) pipelines to TK Halli WTP by gravity system.

Table 3.1 Outline of Existing TK Halli WTPs

No.	CWSS Stage, Phase	Water Source (MLD)	WTP Capacity (MLD)	Year of Commissioning
1	Stage I	155	135	1974
2	Stage II	155	135	1982
3	Stage III	315	270	1992
4	Stage IV, Phase 1	315	270	2002
5	Stage IV, Phase 2	520	500	2012
Total		**1,460**	**1,310**	

Source: BWSSB

Raw water received from SBR and NBR is treated at TK Halli WTPs constructed at different stages of CWSS. The overall capacity of existing WTPs commissioned at different stages is 1,310 MLD (with

some margin). Clariflocculator is adopted from Stage I to Stage III, while for Stage IV, Pulsator is used in Phase 1 and Dissolved Air Flotation (DAF) in Phase 2.

In all stages of CWSS, treated water is sent in three (3) stages at TK Halli, Harohalli and Tataguni, and transmitted to GLRs in BBMP by parallel transmission pipelines. The water pumped up from Tataguni pump station is not directly supplied to the service areas, instead stored at GLRs. From GLRs, water is transmitted to small service areas directly or via OHTs by gravity or pumping. The water from Tataguni through Stage I to III is pumped up to South End Circle of the city and from there it is transmitted to GLRs. O&M work including billing and collection work is practiced by division unit. A total of 9 divisions are further divided into 31 sub-divisions. Service station placed in each sub-division is in charge of O&M, billing and collection of water charges. Inflow water volume to each sub-division is measured and controlled by using bulk meters with valves.

(3) On-going Water Supply Project

The Master Plan (M/P) for water supply and sewerage development in the BBMP commenced in July, 2015 to complete in August, 2016. A part of draft report on the M/P was submitted to BWSSB at the beginning of the year 2017. It was confirmed in advance during JICA survey in the year 2016 that basic conditions/assumptions for the planning of water supply and sewerage development/improvement are on the same line between on-going M/P and this survey. Through Stage IV Phase 2 project, BWSSB has taken up Unaccounted For Water (UFW) reduction and distribution system improvement work in the three (3) zones of Core area. After three years since the commencement of the work for three (3) contract packages, the achievement on UFW savings was found to be less than expected due to the delay of District Meter Area (DMA) installation.

(4) Existing SCADA System

Existing Supervisory Control And Data Acquisition (SCADA) systems were initially introduced to the Stage III and expanded to cover the water supply and sewerage networks during Stage IV Phase 1 & Phase 2, while Stage I and Stage II systems have remained without SCADA systems and no control and automation whatsoever. During Stage IV Phase 1 & Phase 2, the SCADA system was introduced to control and monitor the water treatment and distribution system along with the sewerage system. The centralized SCADA system was established at Shimsha Bhavan of BWSSB for monitoring and control major facilities.

4 Existing Sewerage facilities and On-going/ Planned Sewerage Projects

Existing sewerage facilities and on-going sewerage projects in the BBMP area were investigated. Sewerage services have been expanding from Core area to ULB area. But there is no sewerage projects in 110 villages at present. Under these situations, present service coverage is about 60%, while about 14% of people use unsanitary toilets.

The Core area is served by seven (7) sewerage systems according to drainage areas formed by the val-

leys and part of five (5) ULBs is also served. Currently 14 STPs have been operating in the Core area, majority of which adopt secondary treatment method, but tertiary treated water is used by some large-size consumers.

Table 4.1 Outline of Existing STPs

STP Name		Area	Project	Capacity (MLD)	Treatment Method
1	K&C Valley	Core Area	Before Stage IV	218	Activated Sludge Process (ASP)
	K&C Valley	Core Area	Stage IV, phase 1	30	Extended Aeration (EA)
2	V(Vrishabhavathi) Valley	Core Area	Before Stage IV	180	Trickling Filter (TF) Tertiary Plant (A Part)
3	Hebbal	Core Area	Before Stage IV	60	ASP
4	Raja Canal	Core Area	Stage IV, phase 1	40	EA
5	Madivara	Core Area	Before Stage IV	4	Upflow Anaerobic Sludge Blanket (UASB)+ Oxidation Pond (OP) +Constructed wetlands
6	Cubbon Park	Core Area	Before Stage IV	1.5	Membrane Bio-Reactor (MBR) Tertiary Plant
7	Labaugh	Core Area	Before Stage IV	1.5	EA
8	Kempbudhi (Iti Colony)	Core Area	Before Stage IV	1	EA
9	Mailasandra	R.R. Nagar CMC Dasarahalli CMC	Stage IV, phase 1	75	EA
10	Kadabesanahalli	Mahadevpura CMC K.R. Purum CMC	Stage IV, phase 1	50	EA
11	Nagasandra	Dasarahalli CMC	Stage IV, phase 1	20	EA
12	K.R. Purum	K.R. Purum CMC	Stage IV, phase 1	20	UASB
13	Yelahanka (Allasandara)	Yelahanka CMC	Stage IV, phase 1	10	ASP + Filtration（Sand Filter） Tertiary Plant
14	Jakkur	Yelahanka CMC	Stage IV, phase 1	10	UASB+EA

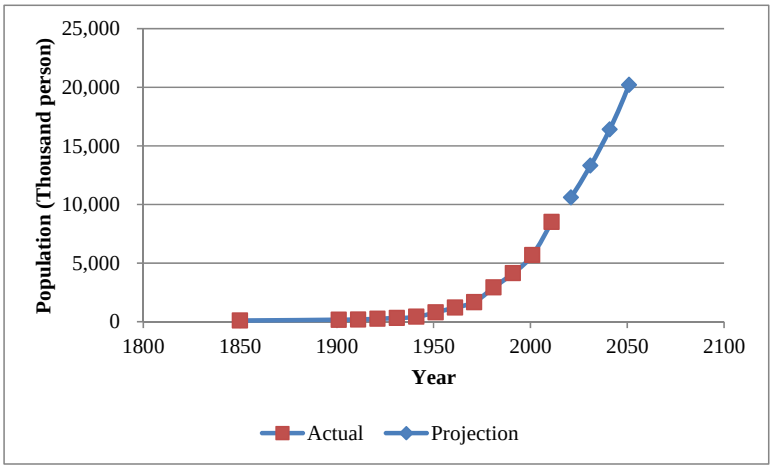
Source: BWSSB

The part of draft sewerage M/P was submitted at the beginning of year 2017. Unit sewage generation rate was a little bit different between the M/P study and this Survey, though both plans use a same methodology. The final figure was decided through discussions with BWSSB referring to National guideline, CPHEEO.

5 Water Demand Projection for the Three Areas by Target Year

(1) Population Projection

The population growth in Bengaluru city in the past is shown in Figure 5.1. From the year 1971 the growth rate was very high. The BBMP was created in 2007 extended from Bengaluru City to surrounding areas including eight (8) ULBs and 110 villages.



Source: JICA Survey Team

Figure 5.1 Population Trend in BBMP

The following assumptions/conditions are considered for the projection of decade population from 2021 to 2051.

- Core Area: The growth rate shall be fixed through the future at 0.78 % per year.
- 110 villages: The population for the next three (3) decades were authorized by concerned agencies.
- ULBs: There are three references on the projection of annual growth rate for ULBs as shown below; 1.3%: (low growth rate), 2.36%: (medium growth rate). Same growth rates from 2011 to 2051 as those adopted for 110 villages (high growth rate)

The high growth rate was adopted for population projection in consideration of the projection result in the M/P for BBMP area in 2051 (projected at about 20,000,000). Table 5.1 shows projected population.

Table 5.1 Projection of Population

Year	Population (person)			
	Core	ULBs	110 Villages	Total
2034	6,482,945	4,809,070	2,819,225	14,111,240
2049	7,284,297	7,620,606	4,452,789	19,357,692

Source: JICA Survey Team

(2) Unit Water Consumption Rate

Presently, water supply services in the BBMP area are provided by BWSSB piped water supply through household tap, public faucet and bulk water supply, ground water and water tanker. Majority of water supply are covered by household tap and bulk water supply (river water use by BWSSB) and ground water supply. Under these conditions, for convenience sake to study water demand in a macrocosmic aspect, an overall average per capita water consumption rate is used. According to the CPHEEO's manual on water supply and treatment published by Ministry of Urban Development, 150 lpcd was adopted for the water consumption as metropolitan and Mega-cities with piped water supply where sewerage systems exist (see Table 5.2).

Table 5.2 Unit Water Consumption Rate (CPHEEO Manual)

No	Class for Cities	Recommended Maximum Water Supply Level
1	Towns provided with piped water supply not without sewerage system	70 lpcd
2	Cities provided with piped water supply where sewerage system is existing / contemplated	135 lpcd
3	Metropolitan and Mega cities provided with piped water supply where sewerage system is existing / contemplated	**150 lpcd** (Applied)

Source: CPHEEO

(3) Water Demand Projection

Water demand by study area in the BBMP was calculated by target year as shown in Table 5.3.

Table 5.3 Water Demand by Study Area in BBMP for Target Years

Item	Unit	2034				2049			
		Core	ULB	*110 V	Total	Core	ULB	*110 V	Total
Population	Person	6,483,000	4,809,000	2,819,000	14,111,000	7,284,000	7,621,000	4,453,000	19,358,000
Service Ratio		75%	88%	80%	80%	77%	92%	87%	86%
Served Population	Person	4,842,200	4,209,800	2,259,000	11,311,000	5,643,200	7,021,800	3,893,000	16,558,000
House Connection	Person	4,613,200	4,052,800	2,259,000	10,925,000	5,643,200	7,021,800	3,893,000	16,558,000
Per Capita	lpcd	150	150	150	150	150	150	150	150
Consumption	MLD	692	608	339	1,639	846	1,053	584	2,483
Slum	Person	229,000	157,000		386,000	0	0		0
Per Capita	lpcd	30	30	30	30	30	30	30	30
Consumption	MLD	7	5	0	12	0	0	0	0
Water Consumption	MLD	699	613	339	1,651	846	1,053	584	2,483
UFW		23%	23%	16%		16%	16%	16%	16%
Water Demand	**MLD**	**908**	**796**	**404**	**2,108**	**1,007**	**1,254**	**695**	**2,956**
Groundwater Consumer	Person	1,640,800	599,200	560,000	2,800,000	1,640,800	599,200	560,000	2,800,000
Per Capita Consumption	lpcd	150	150	150		150	150	150	
Groundwater Consumption	MLD	246	90	84	420	246	90	84	420
Water Loss		16%	16%	16%		16%	16%	16%	
Groundwater Abstraction	MLD	293	107	100	500	293	107	100	500
Total Water Demand	MLD	**1,201**	**903**	**504**	**2,608**	**1,300**	**1,361**	**795**	**3,456**

Note: (Water Consumption) = (Population) x (Unit Water Consumption Rate: 150 lpcd)
(Water Demand) = (Water Consumption) / (1 - UFW)
*110V: 110 Villages

Source: JICA Survey Team

6 Projection of Potential Water Supply Amount by Type of Water Source and Distribution to the three Areas by Target Year

(1) Water Sources Available as of Year 2017

Presently, water supply in the BBMP area is managed by the CWSS using water taken from the Cauvery River. In addition, groundwater withdrawn from deep aquifers is supplementary used for the water supply either by privately or BWSSB owned wells. Other water sources are tertiary treated sewage, saved

water reducing UFW and rainwater. However, the water derived from treated sewage and rainwater can't be mixed with domestic water to be supplied for the public water supply in the BBMP area. Namely, potential water sources for the drinking water supply by BWSSB are limited to surface water, ground-water and saved water from UFW.

(2) Water Allocation

The Gazette notification by the Government of India, Ministry of Water Resources orders water of the Cauvery River be allocated to the three states of Karnataka, Kerala and Tamil Nadu as well as Union territory of Pondicherry for their uses as shown in Table 6.1.

Table 6.1 Water Allocation for Each States

Sr. No.	Description	Quantity
1	The State of Kerala	30 TMC
2	The State of Karnataka	270 TMC
3	The State of Tamil Nadu	419 TMC
4	The Union territory of Pondicherry	7 TMC
	Total	726 TMC

Note: 1 TMC= 77.5 MLD
Source: JICA Survey Team

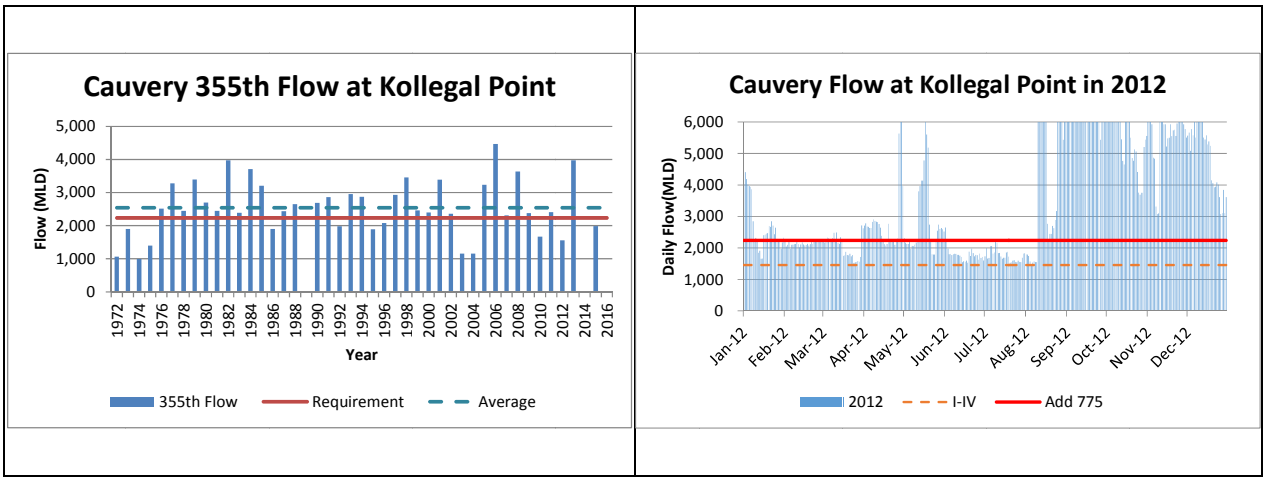
Since its inception in the year 1974, BWSSB has executed several water supply and sewage schemes for the city, including the prestigious CWSS Stages I, II, III & Stage IV Phase 1, Phase 2; 730 MLD for a total of Stage I to III, and additional 730 MLD for Stage IV. The allocation is shown below.

Table 6.2 Allocation for CWSS Stage I to IV

Cauvery Stages	Allocation (MLD)
Stage I, II & III	730
Stage IV Phase 1 & 2	730
Sub-total	1,460
Stage V	775
Total	2,235

Source: JICA Survey Team

Flow data of the Cauvery River is available from 1972 to 2016 and the comparison between Cauvery drought flow and intake requirement is shown in the left figure of Figure 6.1. On the other hand, daily flow in 2012 is shown in right figure of Figure 6.1. Flow was maintained to meet for Stage I to IV requirements, even the year 2012 falls on drought year. The water for BBMP is released/regulated from four (4) reservoirs/dams along the Cauvery River. They are under control by water resource department of GoK.

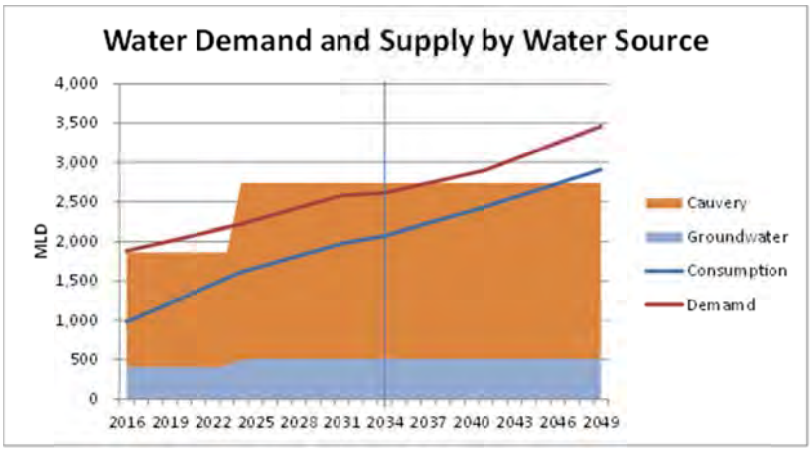


Source: JICA Survey Team

Figure 6.1 Water Flow

(3) Water Balance Study

The water balance study was made in case of high population projection. Figure 6.2 presents water balance in BBMP for the target years. Comparison on water balance between those by BWSSB and JICA Survey result is summarized in Table 6.3.



Source: JICA Survey Team

Figure 6.2 Water Balance in BBMP in Case of High Population Projection

According to JICA Survey, water balance in entire BBMP area will be maintained up to the year 2034 in provision of water supply by Stage V Project. But in the year 2049, supply amount may be short to cater for the required demand in the BBMP area.

Table 6.3 Comparison on Water Balance between those by BWSSB and JICA Survey Result

(MLD)

Year	Study Source	Area	Demand MLD ①	Supply										Balance between ②-①
				Groundwater (a)	Cauvery				Stage V (c)	UFW saving (d)	Tertiary Treated Water (e)	Rainwater Harvesting (f)	Total ② =(a)+(b)+(c)+(d)+(e)+(f)	
					CWSS 1-4 (b)	Current Effective	UFW Saving	UFW						
2022	BWSSB	Core & ULB	2,700	400	1,460				557	250	150	100	2,917	217
		110 Villages	318	100	0				218				318	0
		Total	3,018	500	1,460				775	250	150	100	3,235	217
2024	*JICA Survey*	*Core & ULB*	*1,860*	*400*	*1,460*	*759*	*219*	*482*	*520*				*2,380*	*520*
		110 Villages	*355*	*100*	*0*	*0*	*0*	*0*	*255*				*355*	*0*
		Total	*2,215*	*500*	*1,460*	*759*	*219*	*482*	*775*	*N.A.*	*0*	*0*	*2,735*	*520*
2034	BWSSB	Core & ULB	3,500	400	1,460				470	300	200	150	2,980	-520
		110 Villages	480	100	0				305		50	25	480	0
		Total	3,980	500	1,460				775	300	250	175	3,460	-520
	JICA Survey	*Core & ULB*	*2,104*	*400*	*1,460*	*759*	*365*	*336*	*371*				*2,231*	*127*
		110 Villages	*504*	*100*	*0*	*0*	*0*	*0*	*404*				*504*	*0*
		Total	*2,608*	*500*	*1,460*	*759*	*365*	*336*	*775*	*N.A.*	*0*	*0*	*2,735*	*127*
2049	BWSSB	Core & ULB	6,000	400	1,460				215	350	250	150	2,825	-3,175
		110 Villages	760	100	0				560		50	50	760	0
		Total	6,760	500	1,460				775	350	300	200	3,585	-3,175
	JICA Survey	*Core & ULB*	*2,661*	*400*	*1,460*	*759*	*467*	*234*	*80*				*1,940*	*-721*
		110 Villages	*795*	*100*	*0*	*0*	*0*	*0*	*695*				*795*	*0*
		Total	*3,456*	*500*	*1,460*	*759*	*467*	*234*	*775*	*N.A.*	*0*	*0*	*2,735*	*-721*

Note: N.A.; Not Applicable

Source: JICA Survey Team

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

Sewage volume by area at present and in target years was calculated using projected population and unit sewage generation volume. Per capita sewage generation volume in the future is assumed at 132 lpcd. About 60% of generated sewage is treated at existing STPs at present (as of year 2016). For the year 2034, if planned projects for sewerage development would be completed, almost 90% of the sewage to be generated could be treated. After year 2034, further expansion of STPs will be required to meet additional sewage corresponding to the increasing population. Table 7.1 shows sewage generation in the planning years.

Table 7.1 Sewage Generation in BBMP in the planning years

(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

Table 7.2 presents sewage generation and STP capacities in BBMP area at the year 2016 and 2034. The total STP capacity in the year 2016 is about 57.4% and it will increase up to 97.2% at the year 2034 according to the plan.

Table 7.2 Sewage Generation and STP Capacities

Item	Year 2016			Year 2034		
	Core & ULB	110 Village	Total	Core & ULB	110 Village	Total
Population (Thousand Person)	8,076	1,367	9,443	11,291	2,843	14,134
Sewage Generation (MLD)	1,066	190	1,256	1,490	375	1,866
STP Capacities (MLD)			721 (57.4%)			1,815 (97.2%)

Source: JICA Survey Team

8 water Pollution Status in Public Water Bodies

BBMP is located in the watershed of two (2) principal river basins Arkavati to the west and Pennar to the east. There are three major drainage basins, namely Hebbal (H Valley), Vrishabavathi (V Valley) and Koramangala & Challaghatta (K&C Valley). Due to topographical conditions, the drainage comprises the storm water drains, streams, valleys interspersed with lakes. There are 2,789 lakes in Bengaluru Metropolitan Region and 596 lakes are listed in Bengaluru Development Authority area limits.

The BBMP is responsible for all the storm water drainages in the city. A M/P was prepared for flood protection. The plan is based on the improvement need of the health and sanitation conditions in the surrounding vicinity of the storm water drains and water bodies. In addition, the improvement need of the ground water level is referred to retaining rainwater in the ground. However, there is no water pollution study in the plan. Some studies on the water quality of lakes in BBMP area were conducted. Study results for some lakes are available.

Present water pollution status and sewerage services were analyzed. Generated sewage volume in the present sewerage service area was estimated (100% in Core area and about 50% in 5 ULBs). Generated sewage volume is about 20% larger than the capacity of existing STPs and inflow sewage volume is reported at about 70% of the total capacity of the existing STPs. It seems that about 40% of generated sewage are not collected in the service area. While, in the 110 villages, channels /drainages are playing a role as sewers with a high BOD and SS concentrations, as confirmed by water quality examination results in this survey. It was revealed that BOD of inflow sewage to the STP is more than 200 mg/l and in the public channels 20-40 mg/l.

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.

- To improve the ecology and environment of the lakes
- Aid in increasing the ground water table especially in selected lakes where STPs are constructed
- Facilitate reuse of treated sewage
- Provide better hygienic conditions

9 Project Needs and Implementation Arrangements for Proposed Projects

(1) Project Needs and Expected Benefits

Bengaluru city has expanded rapidly with establishment of job generating industries. The changes in land use 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. Due to limited groundwater source available, effective use of it has 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 overall India. There are a total of 451 Japanese establishments in Karnataka as of October, 2016 (information from JETRO India), which is about three (3) times of that in 2010. There are nine (9) major industrial areas in Bengaluru metropolitan area.

Under current land development in the BBMP area, the industrial areas operated by foreign companies are no more in the Core/ULB areas, located beyond 110 villages areas. The water supply in the 110 villages from where the employees commute to the industrial areas and their surrounding areas where foreign enterprises are located, is presently provided by individual groundwater sources. 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. Specific needs/benefits are as follows:

- Uniform water supply and sewerage services can be provided in the BBMP area.
- In provision of Stage V Project, water demand and supply amount can be balanced up to year 2034, which allows for 24/7 (24 hours 7 days) water supply in the BBMP area.
- Development in 110 villages can be accelerated and mitigation in the Core area is expected.
- Profile of the City with environmental soundness can be enhanced.

(2) Implementation Arrangements for Proposed Projects

BWSSB proposed three major projects as shown below.

- 110 Villages Water Supply and Sewerage Project
- CWSS Stage V Project
- UFW Reduction Project (Majority of UFW is assumed to be caused by leakage based on the experience in the on-going UFW reduction project)

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. Table 9.1 summarizes the reasons of the sorting proposed projects into two groups.

Table 9.1 Planned Population and Water Demand

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.

10 Scope of Work for JICA Survey Projects

(1) CWSS Stage V Project

1) Planned Water Supply Facilities and their Respective Design Flow

This Project is planned to produce 775 MLD using water source of Cauvery River for delivery of the water to 110 villages and Core/ULB areas. For the water demand projection, the following two (2) factors are employed. The planned population and water demand is shown in Table 10.1

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

Table 10.1 Planned Population and Water Demand

No	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
		225.2	1,103,515	1,984,000	2,819,000	4,453,000	354	503	795
Total			**1,100,000**	**1,980,000**	**2,820,000**	**4,450,000**	**350**	**500**	**800**
Water Source									
	Cauvery						**775**	**775**	**775**
	Ground water						**100**	**100**	**100**
	Balance						**521**	**372**	**80**

2) Distribution System

The distribution system for 110 villages water supply was planned in provision of OHTs to maintain required water pressure and adjust the fluctuation of water demand through the day, receiving water from GLRs. Pumping facilities are planned between relevant GLRs and OHTs, as required to ensure required water head for the service area.

3) WTP and transmission

The physical conditions in the planned WTP area at TK Halli are summarized below.

- Location & area: in the TK Halli WTP compound; 15.4 ha
- Current Land Use: Quarters and School are located
- Existing and Design Elevation: +595 m to +586.8 m; Design Elevation: +595 m to +590 m

The treated water quality requirements are specified to meet the CPHEEO as shown in Table 10.2.
Based on the raw water turbidity, the conventional treatment process was adopted and the processes for aeration and pre-chlorination are employed for this project. Chlorination facility (liquid chlorine) is planned to provide safe water to consumers, holding disinfection effect in water distribution pipelines. A centrifuge type of de-watering equipment has been adopted, same as Stage IV Phase 2 project.

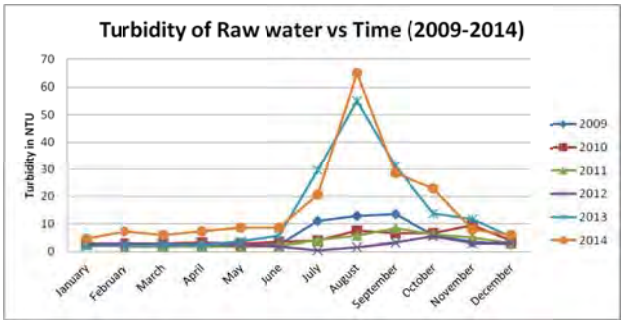


Figure 10.1 Raw Water Turbidity

Table 10.2 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)

The water from Tataguni pumping station is conveyed to 13 GLRs located at eastern and western sides of Bengaluru city through the city trunk mains which have 114 km in a total. The water shall be pumped from Tataguni pumping station to all the GLRs in the western side, while up to the Kadugodi GLR in the eastern side. Six (6) existing GLRs are utilized in this project, thus seven (7) new GLRs are required.

4) Outline of Proposed Facility

The outline of the proposed facility for Stage V is summarized in Table 10.3

Table 10.3 Outline of Proposed facilities for Stage V

Facilities	Details (Specifications)	
Intake Facility	775 MLD	Utilize existing facilities
Conveyance Facility	775 MLD	Utilize existing and under construction facilities Dia. 2,750 mm Gravity flow Length Approx. 6.3 km existing Approx. 10 km under construction
Water Treatment Plant	775 MLD	Adjacent to existing WTP in TK Halli Water Treatment: Rapid sand filtration Disinfection: Liquid Chlorine Sludge Treatment: Centrifuge
Transmission Facilities	775 MLD	Transmission Pipe: Dia. 3,000 mm, Length: Approx. 70 km Pump Station: 3 Nos., Surge tank: 1 No.
City Trunk Main	775 MLD	Length: Approx.114 km (Dia. 500 mm - 3,000 mm) CLR 13 Nos. (New 7 Nos.)

(2) Construction of Major Sewerage Facilities for 110 villages

1) Projection of Population and Sewage Volume

There are five (5) zones in the project area covering 110 villages. Population of component villages and ULBs by zone for base year and the target years are projected using a uniform growth rates to all villages. Sewage volume through the future is estimated by zone using per capita sewage generation rate of 132 lpcd. Sewage volume for the design year (2034) by zone (ULB and 110 villages) is summarized in Table 10.4.

Table 10.4 Projection of Population and Sewage Volume by Zone (ULB and 110 villages)

Zone Name	Population in 2034	Sewage Flow (MLD) in 2034
Bytrayanapura	1,650,931	218
Mahadevpura	1,824,633	241
Bommanahalli	1,535,555	203
R.R. Nagar	1,046,397	138
Dasarahalli	1,570,779	207
Total	7,628,295	1,007

Source: JICA Survey Team

2) Establishment of Sewerage Systems

Following factors are considered for the establishment of sewerage systems.

- Topographic conditions in the study area/planned service area
- Planned location of STP site and land availability
- Merging possibility of the study sewerage system into the neighboring sewerage system

A total of 16 sewerage systems was planned in the DPR, however 14 systems are recommended as a result of the study as shown in Figure 10.2 (Colored zone: Proposed sewer system, Gray zone: Existing/Other Project). A total of seven (7) ISPSs are planned.

3) Design Sewage Inflow and Effluent Volume

Table 10.5 summarizes study results on inflow sewage quality for design of sewerage facilities. Design values to be adopted for concerned indices are decided as shown in the last column of the table by referring to CPHEEO manual, experiences in Bengaluru and plan for Stage IV Phase 2 project.

Table 10.5 Design Sewage Inflow Quality

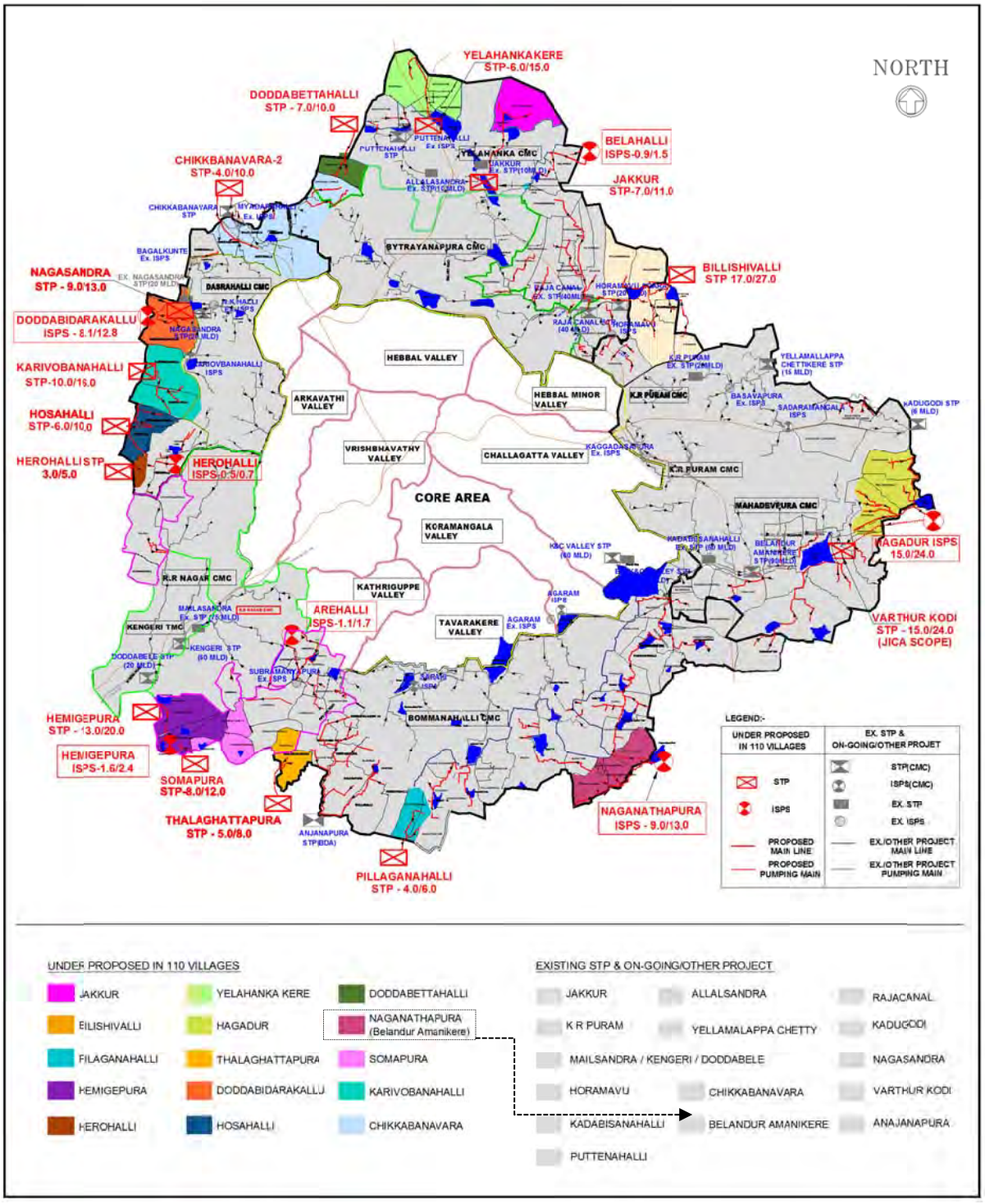
Item	CPHEEO Manual			Existing STP Record	Design Value at Stage IV Phase 2*	Apply in this Study
Unit	lpcd	gpcd	mg/l	mg/l	mg/l	mg/l
BOD	132	45-54	340 - 409	200 - 350	350	350
COD	132	72-103	545 - 777	400 – 800	800	800
TSS	132	70-145	530 - 1098	200 - 450	450	450
T-N	132	6 - 12	45.5 - 90.9	14.4- 45.3	70	70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

*Raja Canal, Source: JICA Survey Team

Effluent quality is decided referring to updated effluent standard in India as shown in Table 10.6.

Table 10.6 Design Sewage Effluent Quality

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

Figure 10.2 Establishment of Sewerage Systems

4) Sewage Treatment Method

Sewage treatment methods were studied considering the experience by BWSSB. Finally, comparative study was made between Extended Aeration (EA) and Sequenced Batch Reactor (SBR). Required removal of T-N and T-P is also considered in application of modified countermeasures in the two methods. As a result of the study, modified EA process was selected because of the advantages in cheaper capital cost and easy O&M. This process was recommended to apply for all planned STPs.

5) Plan of STPs

Application of modified EA process with enhanced nutrient removal followed by chlorination disinfection is recommended for all STPs. For sludge treatment, thickening and mechanical dewatering process shall be adopted. But, in case of the STPs with less than 10 MLD capacity, thickening process may be omitted depending on the types of dewatering machine. Dewatered sludge is utilized as organic fertilizer. The outline of planned STPs is shown in Table 10.7.

Table 10.7 Outline of Planned STPs

Zone	Name	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	Kariobavanahalli	10.0	ditto	ditto	ditto
	Herohalli	3.0	ditto	(TH) + DW	ditto
	Hosahalli	6.0	ditto	ditto	ditto
	Chikkabanavara-2	4.0	ditto	ditto	ditto
	Nagasandra*	9.0	ditto	ditto	ditto

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

6) Plan of Main Sewers and ISPSs

The locations of main sewers and ISPSs are shown in Figure 10.2, Establishment of Sewerage Systems. 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.
And the total length of about 202 km of Main Sewers are planned, which are slightly increased from DPR due to the change of the site for STPs etc.

11 The Project to be Implemented by Indian Side

(1) General

Three major projects are proposed 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 the availability of local funds. Additional two component works to the proposed works were identified and studied to cover overall requirements for the achievement of project purposes. The following projects are proposed to be undertaken by Indian

side to complete overall needs.

1) 110 Villages Water Supply Project including feeder pipes between planned GLRs and OHTs, OHTs and pumping facilities to establish permanent distribution systems, distribution pipe networks and monitoring equipment for SCADA system
2) Stage V related Project including conveyance pipeline and branch feeding pipes to share water from Stage V Project to Core/ULB area
3) 110 Villages Sewerage Project (lateral sewers)
4) UFW Reduction Project (This project will be implemented by BWSSB, aside from the JICA assisted Project)

(2) 110 Villages Water Supply Project and UFW Reduction Project

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

BWSSB will implement the water supply project for 110 villages and UFW Reduction Project for Core areas with financial assistance from GoK and remaining from its own funds. In September 2016, original DPRs for the both projects were revised. Then, a combined report for the two projects was approved by GoK in September 2016.

The standard distribution networks for the villages from GLRs located in the Bengaluru city are planned in the DPR. However, OHTs planned in the DPR were omitted, instead a pumping method has been applied for the bidding commenced in November 25, 2016. It is recommended that the following shall be further studied during the detailed design stage.

- Review on the route and capacity of pipelines from GLRs to OHTs, as the locations of GLR were changed in the DPR for Stage V project from the DPR for 110 villages' water supply and sewerage project.
- To construct 135 OHTs and supply water to each independent service area to achieve normal water supply, controlling water pressure, as proposed in the original DPR.
- Stage V Project will allow for the distribution of surplus water to Core and ULB areas. For the purpose, detailed plan shall be prepared from 2024 to 2034 for effective sharing of available water.
- The current water service in Bengaluru city is intermittent, 6 to 8 hours by alternate day, however, the distribution capacity will fully meet the demand of 110 villages after completing Stage V Project. In addition, the project for the reduction of UFW is on-going/planned in the Core area and the UFW for the new distribution systems in the 110 villages is planned to achieve 16 %. Thus, it is recommended to supply water on 24/7 base.
- In order to control water quantity, pressure and pipe condition, it is recommended to introduce blocked distribution system in provision of bulk flow meter and valves. SCADA system is also recommended to monitor each condition to detect water leakage and to increase tariff collection.

2) Distribution Facilities for 110 Villages Water Supply

For the establishment of permanent distribution systems, there are three major component facilities to be

constructed: (1) feeder pipes between GLRs (planned as the part of Stage V Project) 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, 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.

The scope of work is shown in Table 11.1. Distribution networks after OHTs are not included as these works are to be undertaken by BWSSB through on-going water supply project for five administrative zones. In addition, feeder pipeline works for planned seven (7) GLRs for permanent distribution systems are also excluded (newly construction of 3 GLRs), because these are included in the on-going urgent project. Concretely for feeder pipes, those from three (3) exiting GLRs are same and remaining four feeder pipelines are to be connected to existing pipelines at the points near planned GLRs.

Table 11.1 Scope of Work for Distribution Facilities in 110 Villages

Component Work; Required Facilities/Equipment	Quantities
Feeder pipes between GLRs and OHTs	Diameter: 150 mm - 1,750 mm Length: Approx. 200 km
OHTs	135 Units
Pumps	61 Units
Monitoring equipment for SCADA system	To be included in Stage V Project

Source: JICA Survey Team

3) UFW Reduction Project

BWSSB decided to implement second stage UFW reduction project in the East, North, and South East areas in Core area of Bengaluru. The original DPR, for the UFW reduction, prepared in 2007 was up-dated with the new schedule in 2016. It is recommended that details on DMAs shall be further studied to consider the contract packages for distribution improvement, procurement and installation cost shall include that for replacement of pipes, consumer connections and meters etc.

(3) 110 Villages Sewerage Project (Upstream Facilities Including Lateral Sewers and House Connections)

BWSSB has been implementing construction of laterals/house connections in ULB areas using GBWASP/ beneficiary contribution funds. A similar concept will be used by BWSSB for the implementation of 110 villages sewerage project. The revised DPR does not include items of lateral sewers and house connections. Detailed design of lateral sewer shall be prepared referring to the study results in the original DPR.

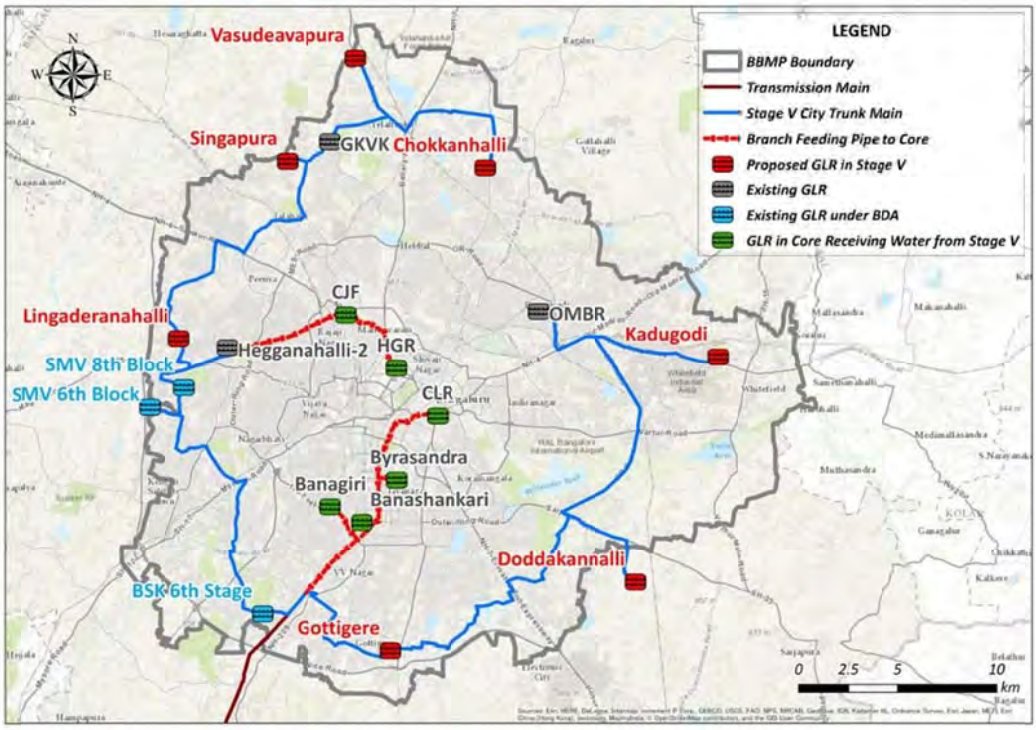
(4) Conveyance and Expansion of City Trunk Mains (Branch Feeding Pipes) related to Stage V Project

1) Conveyance Pipeline from Valve Chamber to TK Halli WTP

The work for the section from the valve chamber to TK Halli was commenced by BWSSB using local fund at the beginning of the year 2017. While, the existing pipeline from pipe intake near SBR to the valve chamber near NBR is utilized. Figure 12.1 shows schematic diagram on the planned conveyance pipeline for Stage V related project from the valve chamber to TK Halli WTP compound.

2) Branch Feeding Pipes to Share Water from Stage V to Core and ULB areas in the Medium Term

Figure 11.1 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.



Source: JICA Survey Team

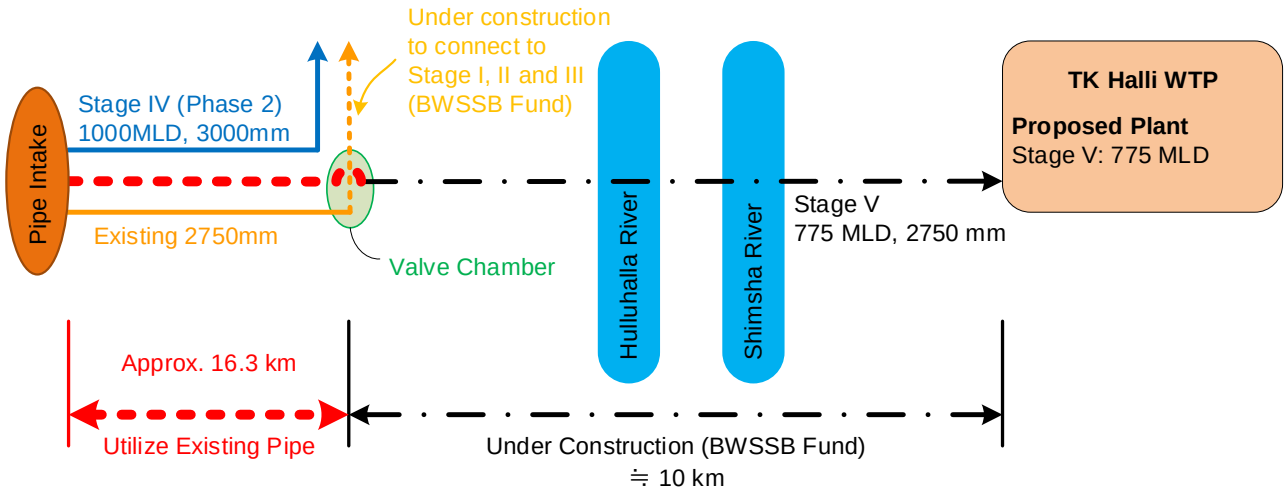
Figure 11.1 Branch Feeding Pipes from Stage V City Trunk Main

12 Preliminary Design of Water Supply and Sewerage Facilities for JICA Survey Project

(1) Water Supply

The proposed WTP with the planned capacity of 775 MLD is designed considering two (2) parallel series of the treatment system from cascade aerator to rapid sand filter for the convenience of operation and maintenance. Wastewater generated as the by-product from sludge treatment is planned to be returned to raw water inflow channel to use inflow water effectively. The sludge treatment units are planned to accept raw water with turbidity 33 NTU.

The proposed land is inclined from north to south, thus facilities are set from north to south and sludge treatment facilities are shifted to southern side. The power receiving facility is decided considering the location of power supply cable. The layout of WTP is shown in Figure 12.2.



Source: JICA Survey Team

Figure 12.1 Schematic Diagram of Conveyance Pipeline for CWSS Stage V

The pump house shall be made of RC (reinforced concrete). 12 pumps (8 Working + 4 Stand-by) are planned in the DPR for each transmission pump station. However, in view of economical and convenient O&M of the facilities, the number of pumps is recommended to be nine (9) units in a total (6 W + 3 S). In the preliminary design, air vessels are chosen as the countermeasure against water hammer.

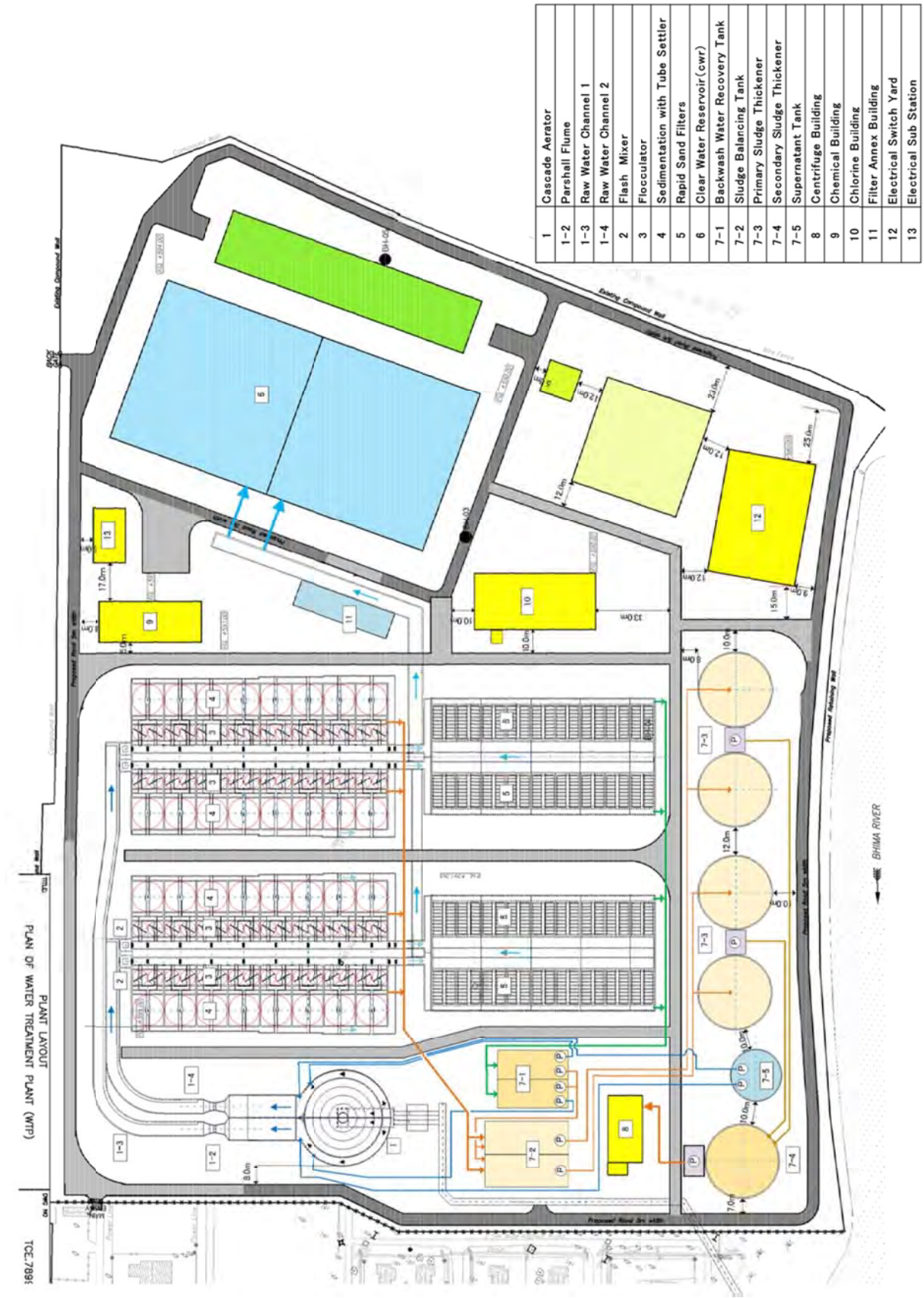
The transmission pipeline starts from TK Halli WTP and ends at Vajarahalli junction in Bengaluru city. The detail specifications on transmission pipeline are summarized in Table 12.1.

Table 12.1 Details of Water Transmission Pipelines

Section	Diameter (mm)	Thickness (mm)
TK Halli to Harohalli	3,000	18
Harohalli to Tataguni	3,000	20/18

Source: JICA Survey Team

All proposed GLRs are planned to be RCC structure. For the proper O&M of facilities, proposed GLRs shall have two (2) series of tanks, except for Lingaderanahalli GLR as its available land is limited. The detention time of proposed GLRs is shown in Table 12.2 and Figure 12.3 presents the alignment of city trunk main and location of GLRs.



Source: JICA Survey Team

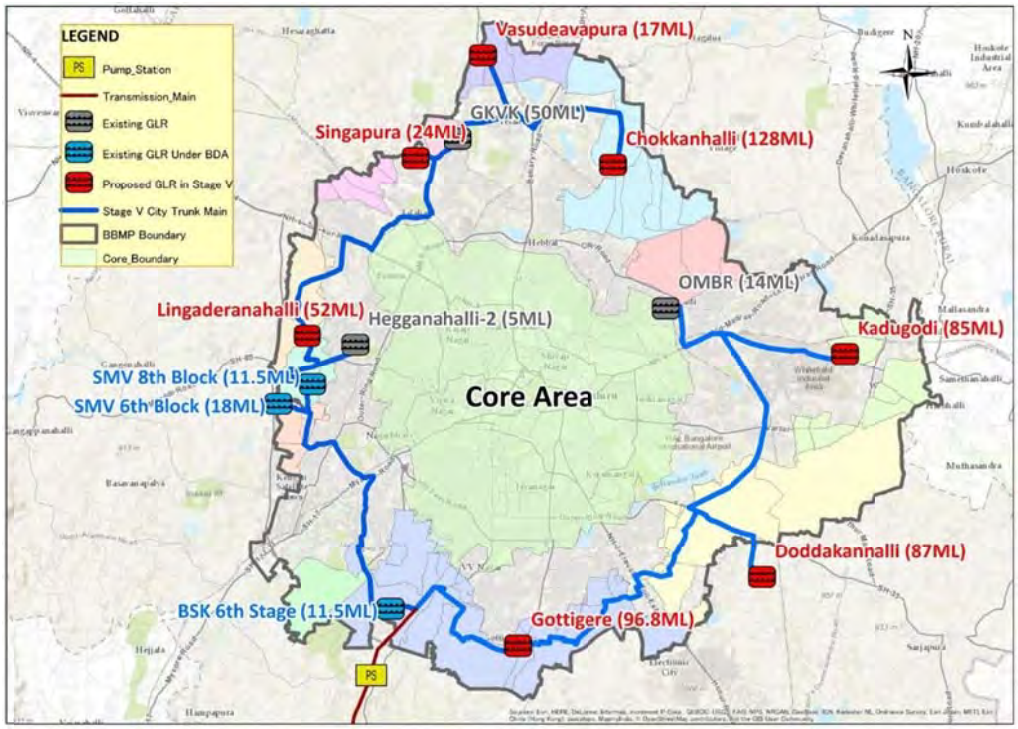
Figure 12.2 Layout of WTP

Table 12.2 Summary of GLR Structure and Detention Time

Name of Proposed GLR	Demand (MLD)	Proposed Dimension (m) Length	Width	Height	No of Tank	Proposed Capacity (m^3)	Detention Time (Hour)
1 Gottigere	198	48 x	48 x	7.0	6	112,896	13.7
2 Doddakanahalli	110	80 x	50 x	6.0	2	48,000	10.5
3 Kadugodi	86	80 x	50 x	6.0	2	48,000	13.4
4 Chokkanahalli	130	90 x	60 x	6.0	2	64,800	12.0
5 Vasudevapura	17	30 x	30 x	6.0	2	10,800	15.2
6 Singapura	41	50 x	40 x	6.0	2	24,000	14.0
7 Lingaderanahalli	47	52 x	38 x	9.0	1	17,784	9.1
Total	**629**					**326,280**	**Ave. 14.3**

Note: Gottigere GLR is in trapezoidal shape

Source: JICA Survey Team



Source: JICA Survey Team

Figure 12.3 Alignment of City Trunk Main and Location of GLRs

(2) 110 Villages Sewerage Project

1) Main Sewers and ISPSs

Planned main sewers by zone are shown in Figure 10.2. Table 12.3 shows daily average and hourly maximum flow for the ISPSs for target years 2034 and 2049.

Table 12.3 Design Flow for ISPSs

Zone	ISPS		Design Flow (MLD)			
	No	Name	2034		2049	
			Daily Average	Hourly Max.	Daily Average	Hourly Max.
Bytrayanapura	A-1	Bellahalli	0.9	2.7	1.5	4.5
Mahadevpura	B-1	Hagadur	15.0	33.8	24.0	54.0
Bommanahalli	C-1	Naganathapura	9.0	20.3	13.0	29.3
R.R. Nagar	D-1	Arehalli 1	1.1	3.3	1.7	5.1
	D-2	Hemigepura	1.6	4.8	2.4	7.2
Dasarahalli	E-1	Herohalli	0.5	1.5	0.7	2.1
	E-2	Doddabidarakallu	8.1	18.2	12.8	28.8

Source: JICA Survey Team

Table 12.4 shows the diameter and velocity of proposed pressure main.

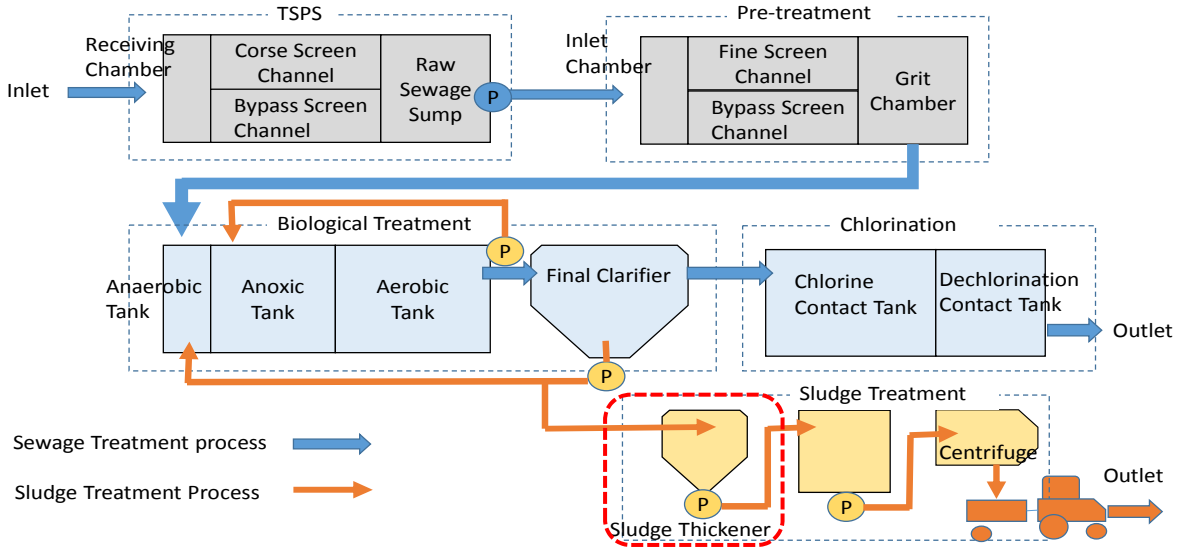
Table 12.4 Diameter and Velocity of Proposed Pressure Main

Zone	ISPS		Diameter	Length	Total Head	$*V_{2034}$	$*V_{2049}$
	No	Name	mm	m	m	m/s	m/s
Bytrayanapura	A-1	Bellahalli	250	1,380	37	0.71	1.06
Mahadevpura	B-1	Hagadur	800	5,300	29	0.78	1.25
Bommanahalli	C-1	Naganathapura	600	3,000	36	0.83	1.20
R.R. Nagar	D-1	Arehalli 1	250	730	24	0.78	1.13
	D-2	Hemigepura	400	1,500	25	0.61	0.90
Dasarahalli	E-1	Herohalli	200	1100 (60m: Trenchless)	15	0.56	0.89
	E-2	Doddabidarakallu	600	2,300	33	0.75	1.20

Note: $*V_{2034}$ is velocity at the year 2034. $*V_{2049}$ is velocity at the year in 2049.
Source: JICA Survey Team

2) STP

Process flow of sewage treatment plant is shown in Figure 12.4. For small size STPs with less than 10 MLD, sludge thickener which is circled by red break line in the flow is omitted, because direct sludge dewatering method is applied to reduce the number of mechanical equipment.



Source: JICA Survey Team

Figure 12.4 Process Flow for STP with a Capacity of More than 10 MLD

13 Operation and Maintenance of Water Supply and Sewerage Facilities

(1) Water Supply

1) O&M Works for CWSS Stage V

Operation and maintenance of water supply facilities include various facilities (e.g. intake, water treatment, distribution, chemical injection, wastewater treatment, other treatment, etc.). It is important to operate all these facilities satisfactorily to achieve the purpose of water supply services.

2) Total Water Supply O&M Cost

O&M cost for Stage V and 110 Villages water supply including revenue collection are summarized as shown in Table 13.1.

Table 13.1 Total O&M Cost for Water Supply (Stage V and 110 Villages Water Supply):

Unit: Thousand INR

Price year			Future Price 2034	Calculation Base
Water Supply				
Overhead	Personnel	Technical	118,818	110 Village DPR
		Revenue	67,798	110 Village DPR
	Sub-total		186,616	
Stage V	Personnel		83,292	WTP, PS Capacity
	Power		4,473,906	Water Production 775 MLD
	Chemicals		117,993	Water Production 775 MLD
	Repairs & maintenance		377,312	0.5 % of Capital Cost
	Sub-total		5,052,503	

Price year				Future Price 2034	Calculation Base
	110 Villages	Personnel	Network	215,633	110 Village DPR
			Pump	63,370	110 Village DPR
			Subtotal	279,003	
		Power		164,759	110 Village DPR
		Chemicals		0	110 Village DPR
		Repairs & maintenance		181,608	110 Village DPR
		Sub-total		625,370	
	Total			**5,864,489**	

Source: JICA Survey Team

(2) Sewerage Facilities

1) General

Sewerage facilities to be operated and maintained include sewers, ISPSs, and STPs. Presently, O&M of existing ISPSs and STPs are undertaken by contractors with minimal involvement of the BWSSB. There is a team for O&M of sewers in BWSSB, then the cleaning, investigations, attends to consumer complaints, replacement and/or repair works are done by BWSSB. However, some of cleaning, investigations, replacement and/or repair works are contracted out to the local contractors.

2) Sewers

Sewers are maintained by two (2) separate divisions based on the size of the sewers.

3) STPs and ISPSs

Currently O&M work for the majority of existing STPs and ISPSs has been undertaken by the Contractors who were awarded the Construction Contract (DBO: Design Built Operation). The contractor usually operates and maintains the STPs and ISPSs for the period of 7 to 10 years.

4) Monitoring by SCADA System

Operators can monitor the ISPSs and STPs at SCADA HMI (Human-Machine Interface) provided in Operator Station to operate and maintain the plant load/equipment properly. The SCADA HMI may give the operators any plant information in a user-friendly manner using graphical diagram and table format.

5) Additional Facilities for Effluent Reuse in STPs

It is recommended to add some effluent supply facility for all STPs to sell the effluent for recovering O&M cost, especially at No.2 Yelahankakere STP which is located next to the power plant and nearby a textile industry.

BWSSB commissioned a study in 2015 for demand assessment and willingness to use tertiary treated sewage from Tavarakere / Nagasandra to Peenya Industrial Area for non-potable purposes. The demand has been assessed at around three (3) MLD with about 38% of the respondents' willingness to consider

using tertiary treated sewage.

6) Water Quality Examination on Inflow and Effluent at STP

During the first two (2) years in the O&M Contract (1 year of Defect Liability Period + 1 year of O&M), the raw sewage pumped to the STP, treated sewage, and disinfected effluent shall be sampled and analyzed at the laboratory (in-house) of the STPs.

7) O&M Cost

Table 13.2 shows O&M cost for the sewage facilities in the year 2034. Annual O&M cost is estimated at about 1,081 Million INR.

Table 13.2 Total O&M Cost of Sewage Facilities at 2034

Item	JICA Survey
	Annual O&M Cost (Million INR/year)
General Staff	63.1
Main Sewers	24.0
Laterals & Others	159.4
ISPSs	40.5
STPs	793.9
Repairs & Miscellaneous	Included in each items above
Total	**1,080.9**

Source: DPR and JICA Survey Team

14 Environmental and Social Consideration

The project sites of the Stage V water supply facilities; WTP and transmission facilities are planned to be constructed at existing BWSSB's land. The city trunk mains and GLRs are planned to be constructed in the existing built-up areas. Most of the facility sites for the 110 Villages Sewerage Project are planned at vacant public lands in the existing built-up areas or along public roads.

The proposed projects do not require EIA in the EC (Environmental Clearance). However, the projects require relevant permissions/clearances with due process from competent authorities, because of its interference with water areas of rivers and nallahs or pubic infrastructures such as roads, railways, power and other utilities.

The Stage V Water Supply Project may cause some adverse impacts on social infrastructures due to their crossing major roads or underground excavation, infectious diseases, occupational health and safety, air pollution (dust), waste, noise, accident and climate change due to electricity consumption by three (3) stage pump operation at its project implementation of construction or operation phase. In addition, the Sewerage Project for 110 Villages will cause some potential adverse impact on social infrastructure due to the same reasons as mentioned above, infectious diseases, occupational health and safety, air pollution (dust), waste, soil contamination, noise, odour, accident and climate change due to pump operation and

sludge disposal at its project implementation of construction or operation phase.

In the Stage V Water Supply project, four (4) GLR sites should be acquired out of the proposed seven (7) GLR sites, while other project sites do not need to be acquired, since these sites are planned within existing BWSSB's facility areas. In the Sewerage Project for 110 villages, nine (9) STP sites and all seven (7) ISPS sites should be acquired among proposed fourteen (14) STPs and seven (7) ISPSs. However, these sites to be acquired are all governmental land owned by GoK, BBMP and BDA, and joint surveys and administrative procedures are currently under way up to their expected final transfer to BWSSB in October, 2017.

For the successful implementation of the project, stakeholders' meeting at different stage is essential. The first meeting in the planning stage was held by BWSSB on August 22, 2017 to provide concerned parties with information on the project and exchange opinions to get understanding and cooperation from them.

15 Implementation Plan and Project Cost

Confidential

16 Financial and Economic Considerations

(1) Financial Capability of BWSSB

Financial capability of the BWSSB at present is negative situation. The BWSSB has been in deficit for several years. Although water revenue has been increasing, operation and maintenance cost, and depreciation cost have increased more rapidly than income. Consequently, only water revenue could not recover O&M cost, depreciation and interest on loans. Liabilities such as loans, grants, and current liabilities from the GoK have gradually increasing, but these cannot be repaid. The reason is that the BWSSB borrowed funds for the projects annually from the GoK but they could not obtain sufficient water revenue.

(2) Present Practice for Water and Sewerage Tariff

Domestic water consumption is 89%, while non-domestic water consumption is 11%. On the other hand, revenue percentage of domestic use is 84% and that of non-domestic use 16%. Therefore, comparing with domestic charge, the unit price per water consumption for non-domestic (hospital, commercial facility, etc.) is set significantly higher than that for domestic, so that it is possible to get more income with less consumption.

The collection rate of water and sewerage charge in the last three (3) years is more than 90%. This higher percentage seems to have brought by a variety of payment methods set by the BWSSB. Especially, use of internet banking and ECS gave a positive impact.

Current water and sewerage tariff per household (4 persons/house) per month is calculated at 432 INR.

Whereas, average monthly income of household in BBMP is 16,610 INR according to Economic Survey of Karnataka in the year 2015. So the ratio of water tariff is 2.6% and this level is lower than that of other developing countries. In conclusion, it is said that there is room for rising up to valid water tariff level.

(3) Calculation of Average Monthly Charge Required per Household in 2034

1) Average Monthly Household Charge Required for the JICA Survey Project

Average monthly charge per household for water supply by the JICA Survey Project arrived at 322 INR (229 Million INR/month/710,770-HH) in 110 villages and 73 INR (206 Million INR /month/2,823,003-HH) in Core/ULB area. On the other hand, average charge per household for sewerage by the JICA Survey Project arrived at 127 INR (90 Million INR/month/710,770-HH in 110 villages) in 110 villages.

2) Average Monthly Household Charge in the Entire BBMP

Average monthly charge per household for water supply in the entire BBMP arrived at 635 INR (2,245 Million INR/month/3,533,773-HH in 110 villages + Core/ULB). On the other hand, average charge per household for sewerage in the entire BBMP arrived at 394 INR (1,060 Million INR/month/2,686,872-HH in 110 villages + Core/ULB). Accordingly, total monthly charge in 2034 will be 1,029 INR.

(4) Recommendations on Progressive Charge Systems

The proposed tariff plan for progressive charge system was studied to recover monthly expenditures for the facilities operated in the entire BBMP. In the proposed tariff plan, the percentage of sewage charge to water charge is set at 50%, referring to the calculated percentage of 47% in the year 2034, as shown in Table 16.1.

Table 16.1 Percentage of Sewerage to Water for O&M Cost in the Entire BBMP

Item	O&M Cost for the Entire BBMP	Amount (Million INR)
a	Water	26,943
b	Sewerage	12,718
Item	**Calculation for Percentage of O&M Cost**	**Proportion**
c	Percentage of sewerage to water (b / a)	47%

Source: JICA Survey Team

1) Proposed Tariff: Average Monthly Charge per Household in the Entire BBMP

For the entire BBMP, a progressive charge system with reference to water consumption was studied (See Table 16.2). It is assumed that that consumer who use water more than 135 lpcd for domestic and 150 lpcd for non-domestic is charged applying heavy rate.

Table 16.2 Proposed Water Tariff for the entire BBMP

Domestic					
Consumption / person	Tariff Slab (KL)	Set Rs/KL	Assumed	Consumption	Rs.in Million
LPCD	Water Consumption		Consumption %	ML/Month	Per/Month
Upto 65 lpcd	0 - 8	7	5%	2,550	18
65 to 135	8 - 16	15	15%	7,650	115
135 to 300	16 - 36	36	25%	12,750	459
Above 300	Above 36	64	26%	13,260	849
Sub - Total			**71%**	**36,210**	
Non Domestic					
Upto 150 lpcd	0 - 18	70	1%	510	36
150 to 400	18 - 48	81	1%	510	41
400 to 600	48 - 72	98	2%	1,020	100
Above 600	Above 72	120	3%	1,530	184
Sub - Total			**7%**	**3,570**	
High Rise		28	8%	4,080	114
Partial ND		32	11%	5,610	180
Industry		98	3%	1,530	150
Total Water Supplied/month			**100%**	**51,000**	**2,245**

Source: JICA Survey Team; Note: The percentage of each Tariff slab (KL: Kilo Litter = m^3) is referred to current records.

In application of the progressive charge in Table 16.2, monthly cost required for O&M of the water supply facilities in the entire BBMP can be recovered. Monthly sewerage charge shall be 50% of the water charge.

(5) Financial Analysis and Economic Analysis

This project's financial internal rate of return (FIRR) in application of the present tariff is calculated at -0.13 %, considering both cost of JICA survey and Indian projects.

For economic analysis, it was confirmed that this project will bring about economic benefit. Concretely, saving of water tanker cost (1,300 INR/month) and bottled water cost (600 INR/month) will bring economic benefit. Moreover, saving of medical cost (250 INR/year) will also contribute to economic benefit. This project's economic internal rate of return (EIRR) is 21.26 %. Therefore, it is concluded that this project would be economically acceptable more than opportunity cost of resource.

17 Institutional Development

BWSSB was established in 1964, as an autonomous body formed by the State legislature, but financial matters are regulated by GoK requiring its approval in case of large capital works either financed by external aide or local aid by Indian Government. The tariff setting also needs GoK approval, as it is a socio-political issue. Nevertheless, since its inception in 1964 as a small organization, it has expanded enormously and had undergone several structural and functional changes, mainly due to changes in area under BMA and service requirements of its population. During initial years, it focused on development of required urban infrastructure with massive investments as compared to its focus on service delivery. Realizing the need for paradigm shift to service delivery from creation of sheer infrastructure, MOUD and GOI identified a number of Service Level Benchmarks (SLBs) to measure the progress on quality of WSS services. These included supply of 135/150 lpcd quality water, 24/7 supply, 20% NRW, 100%

coverage, high revenue billing and recoveries, and a tariff structure to generate revenues enough to at least meet current O&M costs etc. Similar SLBs have also been defined for sewerage services.

Realizing the needs, BWSSB has also slowly shifted towards quality of WSS service delivery. BWSSB as an organization has an existing vision and mandate to provide quality WSS services to the residents (about 8.5 Million in 2011) in 800 km^2 of BBMP area. To discharge the mandate, BWSSB has been functionally re-organized (Sept. 2016) into seven (7) Zones namely Maintenance, Waste Water Management, Projects, Kaveri, MIS+HRD+Design zone besides Administrative and Finance Zones. Most of the senior officials of various zones function from the headquarter located at Cauvery Bhavan, However, engineering zones with involvement in O&M, maintenance, etc. have a large number of field offices (divisional office, sub-divisional office). The field office (Division level) is generally headed by an Executive Engineer, whereas a sub-divisional filed office is headed by an AEE/AE. To undertake various activities, BWSSB has employed 2,200 regular employees (as of 25 Jan 2017) and has also engaged the services of + 2,100 staff on outsourcing basis to support operationalization of various services (mostly non-core services like data entry, dispatch, security, house-keeping, support services etc.).

Based on review and analysis of available documents, reports etc. coupled with discussions with senior officials, a situational analysis of BWSSB was undertaken. The positives include its legal authority, technical expertise, functional organizational structure, rich asset base, high billing, high collection efficiency, current revenues (mainly water tariff) meeting current (mainly O&M) expenditures (recently only) etc., whereas its challenges (areas needing improvements) include its Vision, Strategic and Business Planning, Reduction of UFW and NRW, Duration of Water Supply, Geographical Coverage, Tariff Policy, Decision Making Process and Delegation, financial dependency limiting its autonomy and sustainability, HRM and Personnel Policies and Practices etc. The analysis resulted in identifying external drivers like emerging technologies, public demand for higher SLBs (including need for 24/7 water supply), rising economic activity and immigration of professionals etc., which are putting pressure on BWSSB to improve its services.

The need to provide WSS services of 110 villages (added under BBMP areas) has been considered as an emerging challenge, to be responded by BWSSB. The need to improve inherent limitations and to respond to emerging challenges, BWSSB needs to adopt a number of organizational improvement measures.

From institutional perspective, these should include strategic visioning with focus on service delivery, business planning with self-sustainable management systems, reduction of UFW and NRW (policies and systems for leakage control, volumetric metering and reduction of pubic faucets), sound tariff policy, improved connectivity to WSS services, improved billing and collection system, sound human resource management (including personnel and training) practices, scientific asset records and management system, information management system, organizational restructuring, improved decision making systems etc. The report provides various strategies and an action plan for implementation in short, medium and

long term so as to meet the "TO BE" state of BWSSB. The suggested institutional improvements have been considered necessary to transform BWSSB not only as a self-sustaining organization providing quality WSS services with high SLBs, but also as a competent and capable organization to meet upcoming challenges.

The major stakeholders of BWSSB include Ministry of Urban Development at GOI level and Departments of Urban Development, Water Resources, Finance and Law at GoK level, BBMP and Public at local level besides regulator like Karnataka State Pollution Control Board. For its daily operations, it follows various codes and procedures laid by GoK. It is felt that each one of them would have a distinct role during project financing and implementation. Considering these and by visualizing possible implementation challenges during the period of JICA loan and using past experience of BWSSB and other similar agencies, a Project Management Structure has been suggested.

The suggested Institutional Improvement Strategies, respective Action Plans, proposed Project Implementation Structure and post-implementation Project Management Structure have been presented and discussed with BWSSB officials at various forums.

Chapter 1 Background and Outline of the Project

1.1 Introduction

The field work in Bengaluru, India for Preparatory Survey on Bengaluru Water Supply and Sewerage Project (Phase 3) had been conducted intermittently six (6) times from June, 2016 to August, 2017. Based on the findings and discussions with BWSSB, Final Report was prepared by November, 2017.

This report covers existing conditions on water supply and sewerage services in the study area. Project needs and implementation arrangements for the proposed projects with reference to Japanese ODA loan are presented before establishment of the scope of work for JICA Survey Project. Then, preliminary design of facilities are presented for the JICA Survey Project, followed by O&M of the facilities, Environmental and Social Considerations, Implementation Plan, Financial and Economic Considerations and Organizational and Institutional Improvement. In addition, updated information on the projects to be financed by local funds are also incorporated in Chapter 11 as well as in other related chapters to come up with overall requirements for the management by BWSSB. Preliminary design was also prepared for additional City Trunk Mains to share water of Stage V Project to Core/ULBs, and distribution facilities including feeder pipes between planned GLRs and OHTs, and pumping facilities and OHTs to complete permanent distribution systems for 110 Villages.

1.2 Objectives of the Project and Preparatory Survey

The objective of the Project is to provide residents in BBMP (Bruhat Bengaluru Mahanagara Palike) area with safe and stable water supply, and sewerage facilities to meet increasing water demand. The Project is expected to improve sanitary environment in the subject area and contribute to the promotion of industry. The location of project area is presented in the location map, which covers the jurisdiction of the BWSSB including Core area (Bengaluru city), eight (8) ULBs and 110 Villages, and pipeline routes from water intake to the entrance of BBMP.

The main objective of the Preparatory Survey is to prepare required information for feasibility evaluation of the proposed Project, as a Japanese ODA loan project. Among others, such information includes the outline of the Project, project cost estimates, economic and financial viability of the Project, the Project implementation schedule, manner of procurement and construction, organization of project implementation, operation and maintenance (O&M) arrangements, and social and environmental considerations. The prepared report and additional components suggested in the Preparatory Survey would be considered as addendum to the DPR (Detail Project Report) for the Project.

1.3 Survey Area and Design Year

The water supply services for the Core area (Bengaluru city) commenced from the year 1889 and expanded to ULBs through Cauvery Water Supply Scheme (CWSS) from the year 1974. Upon inclusion of 110 Villages into BBMP in 2007, BWSSB are responsible for the water supply and sewerage services covering entire BBMP. The Preparatory Survey covers current jurisdiction of BWSSB (BBMP area) for

water supply and sewerage services, as shown in Table 1.3.1.

Table 1.3.1 Survey Area and Design Year

Jurisdiction	Composition and Area (km^2)
Core Area (Bengaluru city)	245 km^2
8 ULBs	Yelahanka, K.R. Puram, Mahadevpura, Bommanahalli, R.R. Nagar, Kengeri, Dasarahalli, Bytrayanapura; 330 km^2
110 Villages	225 km^2
Total	800 km^2

Source: JICA Survey Team

The final target year in this study is considered as 2049, same as DPRs. According to the recommendations stated in the revised manual by the CPHEEO (Central Public Health & Environmental Engineering Organization), in application of the planning base year 2019, target years for the Project by design purpose are as follows:

Water Supply

- Design of distribution system: year 2049 (30 years)
- Design of raw water and clear water conveying mains: year 2049 (30 years)
- Design of pumping (pump and mechanics): year 2034 (15 years)
- Design of reservoirs: year 2034 (15 years)
- Design of water treatment unit: year 2034 (15 years)

Sewerage

- Design of sewers: year 2049 (30 years)
- Design of pump stations (pump and mechanics): year 2034 (15 years)
- Design of sewage treatment plant: year 2034 (15 years)

1.3.1 Outline of the Proposed Work

The outline of the proposed work is presented in Table 1.3.2.

Table 1.3.2 Outline of Proposed Work

Proposed Work	Outline	Major Facilities (based on DPR)
Conveyance & Transmission Lines from Cauvery River to BBMP and Water Treatment Plant (WTP)	A total of about 80 km pipeline and WTP for 775 MLD	- Conveyance line: 10 km - WTP: (500 MLD and 275 MLD) - Transmission Line: Approx. 70 km
Improvement of Distribution System (UFW Countermeasures)	The work for 3 zones of a total of 6 zones in Core area has been implemented. The work will be done for remaining 3	- Replacement of old distribution pipes - Provision of sector inlet chamber, DMA, etc.

Proposed Work	Outline	Major Facilities (based on DPR)
	zones.	
Construction of Water Supply and Sewerage Facilities for 110 Villages	There is no water supply and sewerage facilities in the 110 Villages, construction of required facilities.	- Water Supply: Distribution networks 2,979 km, Distribution mains 205 km, OHT 137 units, House connections 106,000 HHs - Sewerage: STP (a total of 129 MLD), Main sewers 338 km, Lateral sewers 2,243 km, House connections 106,000 HHs
Consulting Service	D/D, Assistance for bidding, Construction Supervision, Strengthening of capacity building, community development	

Source: JICA Survey Team

1.4 Scope of Work for the Preparatory Survey

The Preparatory Survey will cover the following items, through basic survey on water supply and sewerage sector in the project area, and review of the DPRs which were already prepared by BWSSB.

(1) Basic Survey on Water Supply and Sewerage in the BBMP Area and the pipeline route from water intake of Cauvery River to the entrance of BBMP

1) Present conditions (natural conditions, socio-economic conditions and trends, environmental conditions)
2) Current water consumption and demand forecast
3) Water resource management
4) Non-revenue water
5) Current sewage generation and forecast
6) Sewage effluent and its influence to living conditions
7) Current water supply and sewerage situations (existing water supply and sewerage facilities) and future development plan
8) Recycle/Reuse of sewage (current facilities, future needs and marketing survey)
9) Water tariff and sewage charge, willingness to pay for water supply and sewerage services
10) Review of Master Plan

(2) Review of Existing DPRs (Modifications may be suggested based on certain justifications.)

1) Scope and design of water supply and sewerage facilities
2) Cost (base cost with foreign and local currency, consulting services, price escalation, physical contingency, interest during construction, front end fee, land acquisition, taxes and duties, administration cost, etc.)

(3) Implementation Issues

1) Procurement plan (contract packages, selection method)

2) Consulting Services (TOR, man-month, selection method)
3) Implementation Schedule (construction of monsoons, technical and financial capacity of BWSSB, assessment of local contractors and their capacities)

(4) Organizational Structure
1) Construction stage (role and function, legal and regulatory framework, budgetary policy, technical and financial capacity, decision making and approval process of each division, measures and action plan to strengthen and streamline the structure)
2) O&M stage (same as above with particular focus on water tariff system)

(5) Project Impacts
1) Quantitative assessment (operation and effect indicators, EIRR< FIRR)
2) Qualitative assessment

(6) Environmental and Social Considerations (review and supplement, if necessary, of the existing reports in accordance with the requirements of JICA's guideline
1) Environmental Impact Assessment (EIA) Report
2) Resettlement Action Plan (RAP) report

(7) Composition of the Report

Considering the above requirements, Draft Final Report was prepared by updating/modifying two (2) interim reports in addition to the technical study results including preliminary design of JICA Survey and recommendations on financial/economic and institutional improvement. The report covers

1. Background and Outline of the Project
2. General Description on the Project Area
3. Existing Water Supply and On-going/Planned Water Supply Projects
4. Existing Sewerage Facilities and On-going/ Planned Sewerage Projects
5. Water Demand Projection for the Three Areas by Target Year
6. Projection of Potential Water Supply Amount by type of Water Source and Distribution to the Three Areas by Target Year
7. Present Sewage Volume in the Three Areas and Projection of Sewage Generation Volume for the Project Area
8. Water Pollution Status in Public Water Bodies
9. Project Needs and selection of JICA Survey Projects
10. Scope of Work for JICA Survey Projects
11. The Projects to be Implemented by BWSSB
12. Preliminary Design of Water Supply and Sewerage Facilities
13. Operation and Maintenance of Water Supply and Sewerage Facilities
14. Environmental and Social Considerations

15. Implementation Plan and Construction Cost Estimates
16. Financial and Economic Considerations
17. Institutional Development

This report also includes Supporting Report and Data Report.

Chapter 2 General Description on the Project Area

2.1 Natural Conditions

2.1.1 Location and Topographic Conditions

Bengaluru is situated in the southeast of Karnataka, at an average elevation of 920 m above mean sea level, and is located at 12.97°N, 77.56°E. Figure 2.1.1 and Figure 2.1.2 presents locations of various areas. The Bengaluru Urban District is divided into four (4) Taluks* as below and shown in Figure 2.1.1.

- North Taluk
- South Taluk
- East Taluk
- Anekal Taluk

*Taluk: It is an area of land with a city or town that serves as its administrative center, with possible additional towns, and usually a number of villages in India.

The Bengaluru North Taluk is a relatively level plateau, while the Bengaluru South Taluk has an uneven landscape with intermingling hills and valleys. Anekal Taluk represents an uneven landscape with intermingling of hills and valleys. The topography of Bengaluru is flat except for a ridge in the middle running NNE-SSW. The highest point in Bengaluru is Doddabettahalli (see Figure 2.1.1) with an elevation of 962 m.

2.1.2 Meteorological Conditions

The city is situated at a fairly high altitude and on account of its elevation Bengaluru is bestowed with salubrious and equable climate throughout the year. The mean annual temperature is 24°C and it ranges from about 13°C in winter to about 36°C in summer. The average annual rainfall is about 900 mm. The following are the outline of seasonal features.

Summer: The season lasts from April to June. The highest temperature during the season rarely exceeds 37°C, making the summers quite mild.

Winter: The season stretches from December to March. The lowest temperature in winter is about 10°C on January. Early morning fog can also be experienced during December and January.

Monsoon: There are two monsoon seasons, which are South Western monsoon from June to September and North Eastern monsoon from November to December.

(1) Temperature

The monthly and annual temperatures (highest, lowest and average) in the BBMP area in the past 41 years from 1976 to 2016 are shown in Table 2.1.1 and Figure 2.1.3. The highest and lowest temperatures are recorded in April and January, respectively.

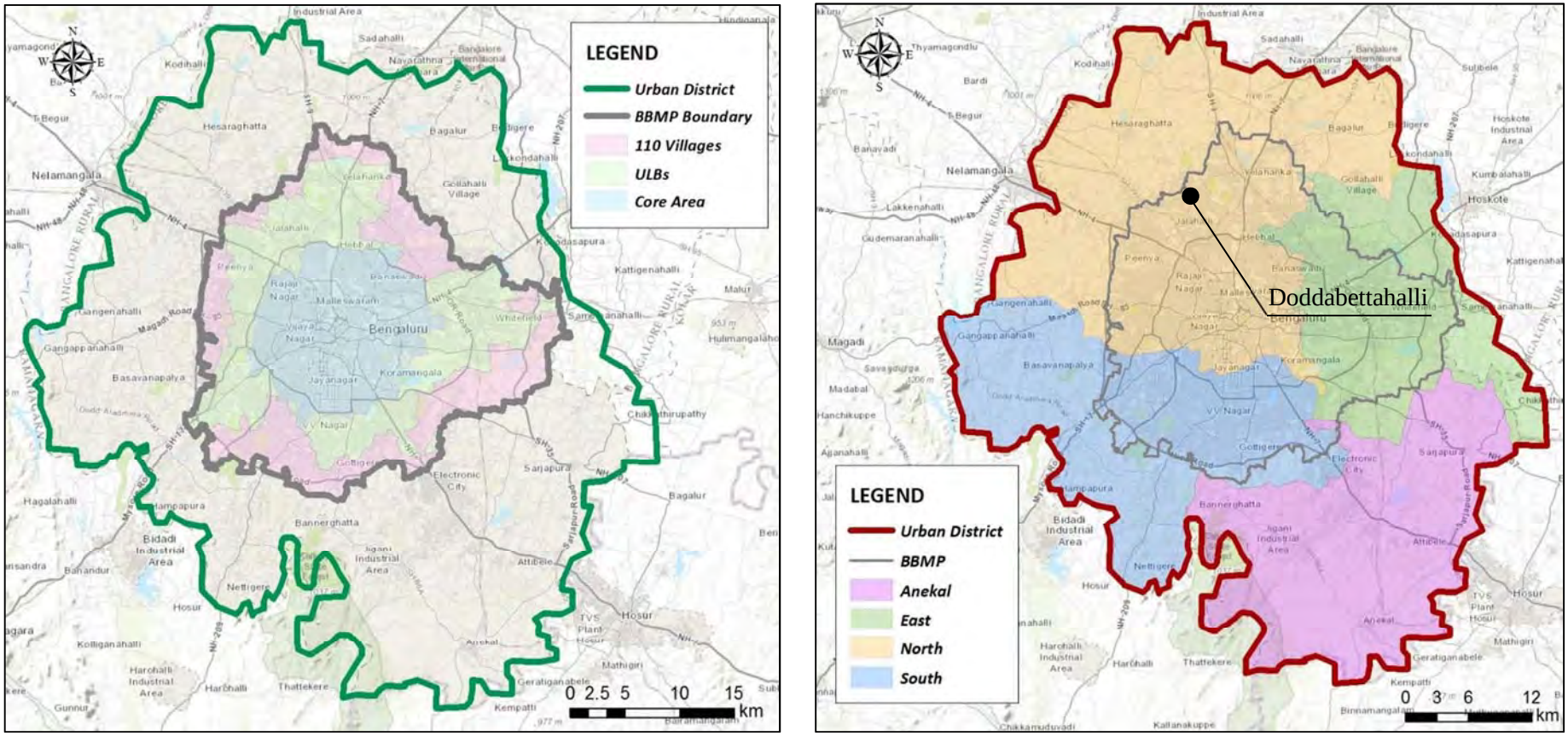
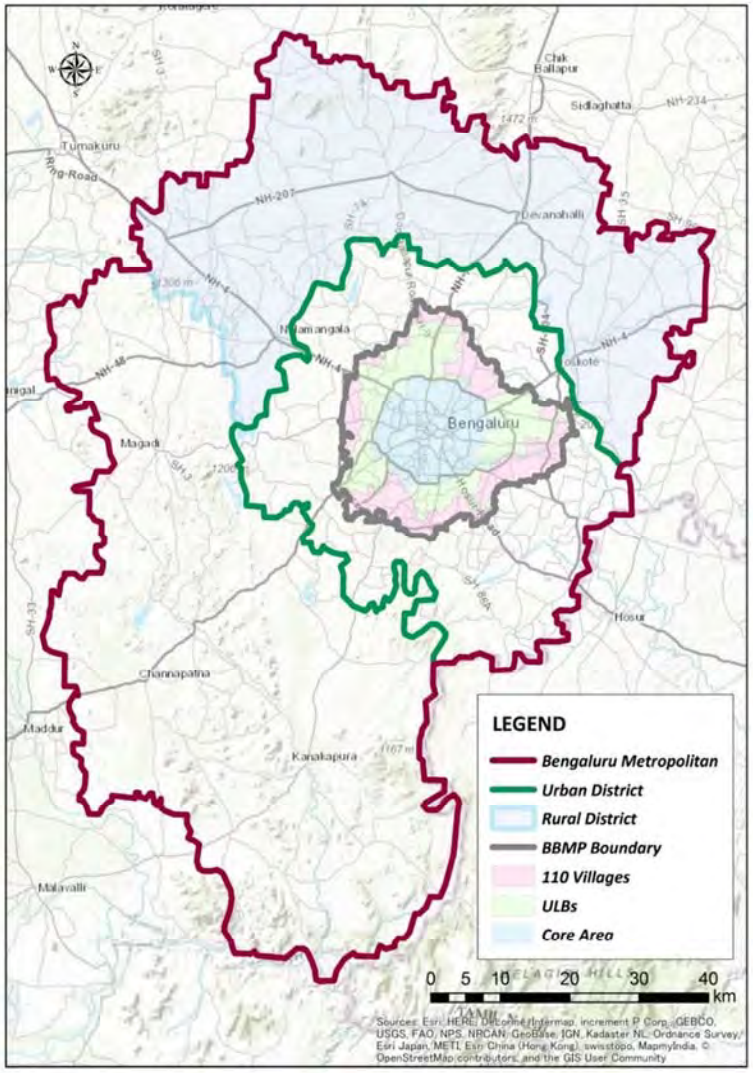


Figure 2.1.1 Locations of Various Areas: Bengaluru Metropolitan Region, Urban District, Rural District, Taluks, BBMP and Administrative Zones in BBMP (1)



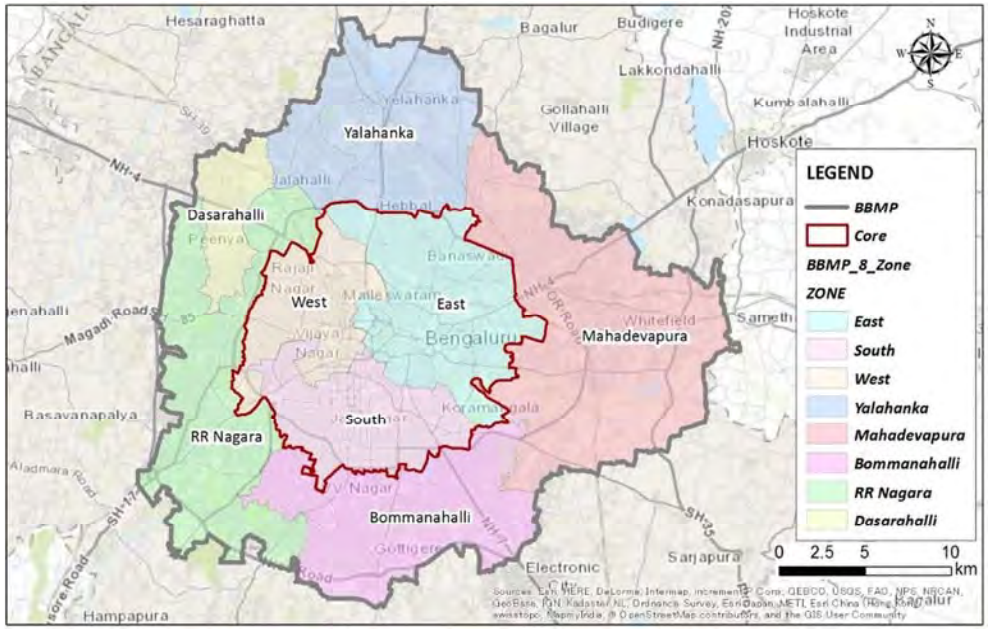
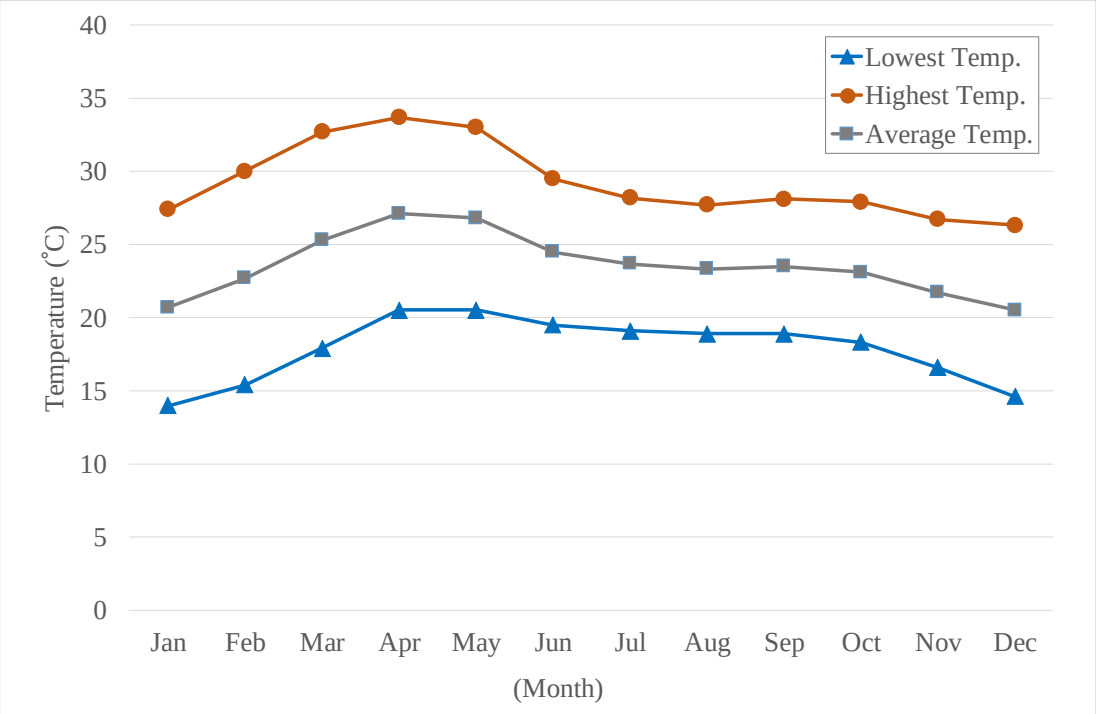


Figure 2.1.2 Locations of Various Areas (2)

Table 2.1.1 Monthly Lowest, Highest and Average, and Annual Average Temperatures in Last 41 Years (1976 - 2016) in BBMP

Trend of Month Average	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Lowest Temp. °C	14.0	15.4	17.9	20.5	20.5	19.5	19.1	18.9	18.9	18.3	16.6	14.6	17.9
Highest Temp. °C	27.4	30.0	32.7	33.7	33.0	29.5	28.2	27.7	28.1	27.9	26.7	26.3	29.3
Ave. Temp. °C	20.7	22.7	25.3	27.1	26.8	24.5	23.7	23.3	23.5	23.1	21.7	20.5	23.6

Source: Website of University of Agricultural Sciences, Bengaluru



Source: Website of University of Agricultural Sciences, Bengaluru

Figure 2.1.3 Monthly Temperatures in Last 41 Years (1976 - 2016) in BBMP

(2) Rainfall

Rainfall records in the BBMP area in the last 54 years (1963-2016) are presented in the Table 2.1.2 and Figure 2.1.4. The maximum rainfall was recorded in the year 1963 with 1,582.4 mm against minimum 556 mm in the year 1972. Annual average rainfall is calculated at about 1000 mm.

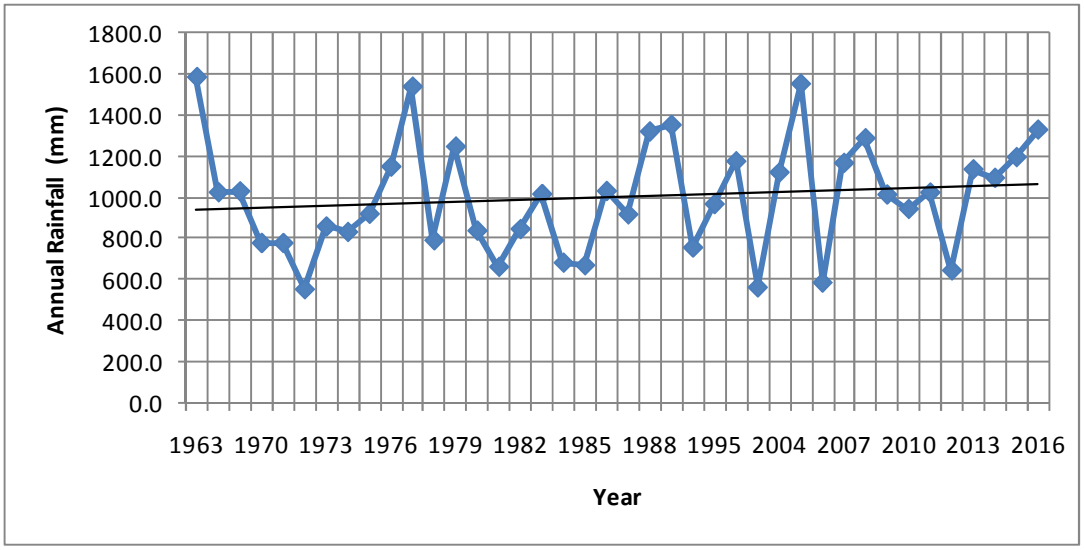
Table 2.1.2 Monthly Rainfall in BBMP from 1963 to 2016

Unit: mm

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1963	12.0	2.0	0.0	111.0	0.0	98.0	8.0	305.0	241.0	198.0	5.0	602.4	1582.4
1964	0.0	0.0	0.0	0.0	80.0	75.0	253.0	71.0	273.0	121.0	152.0	0.0	1025.0
1969	0.0	0.0	0.0	86.6	120.3	44.7	50.6	199.0	81.3	240.6	113.5	93.6	1030.2
1970	0.0	20.4	1.5	19.6	135.0	29.5	87.0	101.1	117.3	230.6	37.5	0.0	779.5
1971	0.0	0.0	0.0	45.6	115.7	0.0	53.4	205.2	233.5	101.0	25.0	0.0	779.4
1972	0.0	0.0	0.0	7.5	48.9	83.0	24.0	87.2	28.5	189.0	15.5	72.4	556.0
1973	0.0	0.0	0.0	7.3	53.3	41.5	65.6	196.0	285.0	172.0	27.0	12.0	859.7
1974	0.0	0.0	0.0	11.0	123.0	18.5	121.0	61.0	387.7	111.0	0.0	0.0	833.2
1975	0.0	7.5	0.0	0.0	63.0	82.5	222.5	132.5	129.5	165.0	103.0	15.0	920.5
1976	0.0	0.0	0.0	157.5	92.0	27.0	122.5	237.5	152.5	126.0	234.5	0.0	1149.5
1977	0.0	0.0	58.0	79.0	240.5	178.1	133.5	191.0	144.0	407.5	105.1	0.0	1536.7
1978	0.0	0.0	0.0	48.0	78.6	62.3	130.0	87.2	213.2	86.5	59.0	28.0	792.8
1979	0.0	44.4	0.0	28.1	93.4	169.2	90.2	72.5	506.5	157.4	84.5	0.0	1246.2
1980	0.0	0.0	26.4	0.0	153.8	33.9	71.3	129.2	308.7	98.1	18.0	0.0	839.4
1981	0.0	0.0	53.0	0.0	89.0	0.0	131.2	102.3	238.1	50.2	0.0	0.0	663.8
1982	0.0	0.0	0.0	0.0	181.6	92.5	60.5	91.7	245.0	158.0	18.0	0.0	847.3
1983	0.0	0.0	0.0	0.0	100.0	207.5	59.0	189.3	283.0	106.5	0.0	71.0	1016.3
1984	0.0	39.0	79.0	40.0	28.6	14.0	140.0	47.0	179.0	116.0	2.0	0.0	684.6
1985	0.0	0.0	22.0	11.0	93.0	82.0	87.0	67.0	144.0	69.0	96.5	0.0	671.5
1986	0.0	0.0	0.0	0.0	103.0	136.0	35.0	99.0	471.0	80.5	90.5	16.6	1031.6
1987	0.0	0.0	28.0	47.8	96.8	137.0	42.0	139.0	105.0	240.5	37.0	45.0	918.1

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1988	0.0	0.0	23.5	82.5	137.0	22.5	281.5	268.2	436.2	8.5	24.5	35.0	1319.4
1991	0.0	0.0	0.0	21.8	181.3	216.2	77.7	112.5	252.5	330.5	158.5	0.0	1351.0
1992	0.0	0.0	0.0	0.4	118.0	132.8	78.0	97.5	130.0	162.0	39.0	0.0	757.7
1995	15.0	0.0	9.0	17.1	135.5	108.9	96.3	246.8	209.7	129.9	0.0	0.0	968.2
1997	0.0	0.0	35.7	53.2	76.5	54.3	14.0	189.4	240.9	268.5	227.5	15.0	1175.0
2003	0.0	3.4	12.0	68.3	0.0	51.3	94.2	108.3	69.0	158.5	0.0	0.0	565.0
2004	18.0	0.0	0.0	52.1	164.1	62.9	283.3	75.0	299.0	140.8	26.4	0.0	1121.6
2005	0.0	7.3	9.2	93.6	146.6	60.7	152.3	213.5	190.7	623.9	46.0	5.8	1549.6
2006	0.0	0.0	72.4	19.0	145.6	129.8	51.8	43.5	52.2	43.4	30.6	0.0	588.3
2007	0.0	0.0	0.0	105.2	121.1	43.0	189.0	256.2	249.6	142.3	29.0	31.4	1166.8
2008	0.0	40.0	55.5	7.0	125.0	97.0	245.4	322.8	130.6	212.6	51.2	0.0	1287.1
2009	0.0	0.0	11.0	52.2	127.8	88.1	17.1	190.3	416.6	30.7	46.6	34.0	1014.4
2010	1.0	0.0	9.0	122.0	72.0	104.0	89.0	116.0	162.0	141.0	128.0	0.0	944.0
2011	0.0	35.0	0.0	126.0	151.0	55.0	76.0	297.0	96.0	142.0	42.0	4.0	1024.0
2012	0.0	0.0	162.0	-	-	308.0	-	-	-	177.0	-	-	647.0
2013	0.0	3.0	0.0	13.0	136.0	196.0	142.0	90.0	354.0	106.0	96.0	0.0	1136.0
2014	0.0	0.0	5.0	0.0	54.0	152.0	77.0	78.0	409.0	300.0	20.0	0.0	1095.0
2015	0.0	0.0	74.0	262.0	156.0	73.0	84.0	94.0	177.0	44.0	228.0	3.0	1195.0
2016	10.0	0.0	46.0	46.0	258.0	280.0	280.0	158.0	80.0	30.0	0.0	140.0	1328.0
Average	1.4	5.1	19.8	47.2	112.7	96.2	110.7	147.9	223.6	160.4	62.0	31.4	999.9

Source: Department of Economics and Statistics, Karnataka



Source: Department of Economics and Statistics, Karnataka

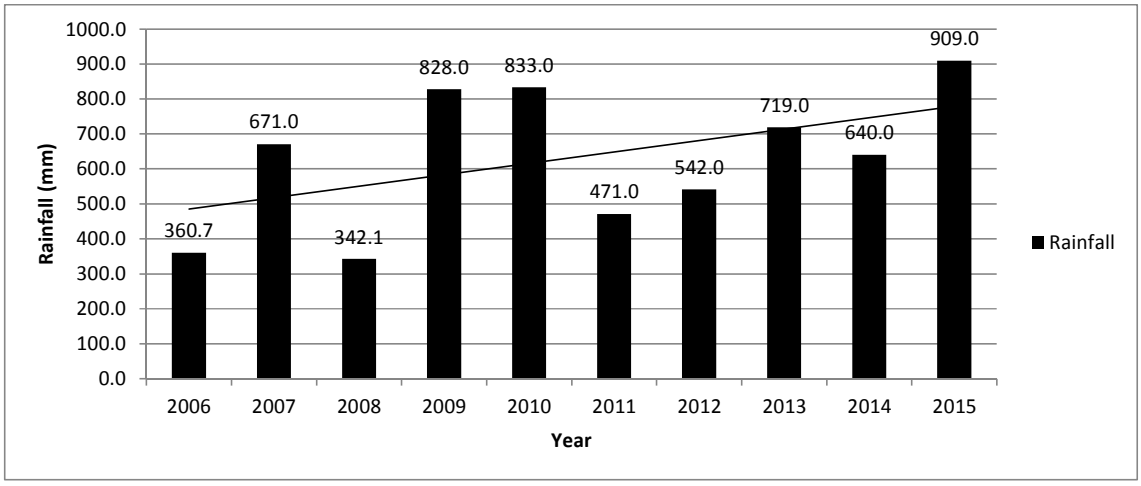
Figure 2.1.4 Annual Rainfall in BBMP from 1963 to 2016

Annual rainfall at the water source area of the proposed project (Malavally: near Thorekadanahalli (TK Halli)) is shown in Table 2.1.3 and Figure 2.1.5. The records show that the rainfall at the water source area is less than that in BBMP area and the rainfall has been gradually increasing in spite of its occasional dry years.

Table 2.1.3 Annual Rainfall at Water Source of Cauvery River in the Last 10 Years

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Average
Rainfall (mm)	360.7	671.0	342.1	828.0	833.0	471.0	542.0	719.0	640.0	909.0	631.6

Note: Monitoring point (Malavally) is near TK Halli



Source: Website of University of Agricultural Sciences, Bengaluru

Figure 2.1.5 Annual Rainfall at Water Source of Cauvery River in the Last 10 Years

(3) Current Status on Climate Change in Project Area

1) Climate Variability

a) Methodology

"Karnataka Climate Change Action Plan", submitted by Bengaluru Climate Change Initiative - Karnataka (BCCI-K) in May 2011 was used for the analysis on climate change.

The current climate variability in Karnataka state was analyzed by using the IMD (Indian Meteorological Department) daily rainfall data for the period of 1971 to 2005 and CRU (Climate Research Unit: The CRU Global Climate Dataset, available through the IPCC - DDC (Intergovernmental Panel on Climate Change - Data Distribution Center), consists of a multi-variate 0.5º latitude by 0.5º longitude resolution mean monthly climatology for global land areas, excluding Antarctica.) data for the temperature for the period of the years of 1901 to 2002.

b) Past Climate Variability in Project Sites

i. Rainfall Variability

Bengaluru is located in the south part of Karnataka State. Its meteorological feature of above South Interior Karnataka was analyzed on the climate variability.

The following results were obtained.

- Most of the South Interior Karnataka districts experience lowest (below five (5) mm / day)* seasonal mean rainfall in a climatological sense.
- The coefficient of variation of rainfall (defined as the inter-annual variability) is higher over South Interior districts (above 55%)** of Karnataka.
- The precipitation trend*** for the period of 100 years in Bengaluru was projected as 7.83 and 7.89 mm/day/100 years for the past 100 years.

The summary of the results is shown in Table 2.1.4. The location of Bengaluru Rural and Urban is presented in Figure 2.1.2.

Table 2.1.4 Past Trend of Rainfall and Precipitation in Bengaluru

District	Mean Rainfall (mm/day)	Standard Deviation (mm/day)	Coefficient of Variation (%)	Precipitation Trend (mm/day/100yr)
Bengaluru Rural	3.9	3.01	77	7.83
Bengaluru Urban	4.09	3.02	74	7.89

Source: Karnataka Climate Change Action Plan, Bengaluru Climate Change Initiative - Karnataka (BCCI-K), May, 2011

ii. Temperature Variability

The district wise variation of the annual mean minimum and maximum temperature averaged for the past 100 years of 1901 to 2002 derived from CRU-TS dataset (CRU-TS dataset is a "Climate Research Unit – Time Series" dataset in monthly basis variation on climate data over the last century which has been developed by the Climate Research Unit at the University of East Anglia, UK) was used for the analysis.

The summary of the results in BBMP area on minimum and maximum temperature is shown in Table 2.1.5 and Table 2.1.6. The temperature of about 19°C and 30°C was obtained for the annual average and annual mean maximum temperature.

* "(below five (5) mm/day) " means an indicator of average daily rainfall at monsoon season (June to September) for the years of 1971 to 2005 at each district of Karnataka state. The results show that the indicator of the south Karnataka covering BBMP is below five (5) mm/day and less than those of other districts in the state.
* * "Districts (above 55 %) of Karnataka" shows that the coefficient of rainfall variation exceeds 55 %". The "coefficient of rainfall variation" means the coefficient of the variation of the daily rainfall during the monsoon season (June to September) of the years of 1971 to 2005, namely, which is equivalent to the value of the standard deviation of the daily rainfall divided by the average value of the daily rainfall during the season at each districts of the state. The figures of the coefficients indicate 77 % and 74 % in Bengaluru rural and Bengaluru urban, respectively, which exceeds 55 % of the state average.
* * * "Precipitation Trend" is a slope of the straight line when the past daily rainfall data at the target area is projected in linear regression into 100 years. The precipitation trend of Bengaluru rural and Bengaluru Urban shows the increased figures of 7.83 mm/day and 7.89 mm/day, respectively.

Table 2.1.5 Annual Mean Lowest Temperature, Coefficient Variation and Seasonal Mean Lowest Temperature for 1901 to 2002 in BBMP

District	Annual Mean Lowest Temperature (˚C)	Coefficient of Variation (%)	Seasonal Mean Lowest Temperature (˚C)			
			Jan. to Feb.	Mar. to May	Jun. to Sep.	Oct. to Dec.
Rural	19.09	11.53	16.14	21.03	20.26	17.55
Urban	19.15	11.29	16.17	20.95	20.38	17.7

Source: "Karnataka Climate Change Action Plan", Bengaluru Climate Change Initiative – Karnataka (BCCI-K), May, 2011

Table 2.1.6 Annual Mean Highest Temperature, Coefficient Variation and Seasonal Mean Highest Temperature for 1901 to 2002 in BBMP

District	Annual Mean Highest Temperature (˚C)	Coefficient of Variation (%)	Seasonal Mean Highest Temperature (˚C)			
			Jan. to Feb.	Mar. to May	Jun. to Sep.	Oct. to Dec.
Rural	30.09	9.34	29.32	34.34	29.19	27.56
Urban	30.08	8.90	29.24	34.11	29.33	27.62

Source: "Karnataka Climate Change Action Plan", Bengaluru Climate Change Initiative – Karnataka (BCCI-K), May, 2011

2) Future Climate Projections in Project Sites

a) Methodology

The data from the HadCM3 (Hadley Centre Coupled Model, version 3) global climate model downscaled by PRECIS model, a regional climate model for downscaling climate projections (see Kumar et al., 2006), was used. The combination of HadCM3 and PRECIS models is known as the HadRM3 (Hadley Centre Regional Model, version 3) model. The pathways for atmospheric greenhouse gases (e.g. CO_2, CH_4, N_2O, CFCs) are prescribed from the mid-term (2021 to 2050) projections.

b) Projected Increase in Average, Minimum and Maximum Temperature

The projected increase of the temperature in BBMP in midterm of 2021 to 2050 compared to those of the baseline for 1961 to 1990 is shown in Table 2.1.7. The increase of the average, minimum and maximum

temperature was 1.96 to 1.97, 2.06 and 1.88 to 1.91°C.

Table 2.1.7 Projected Change in Annual Average, Minimum and Maximum Temperature in BBMP

District	Projected increase of Temperature: Average (˚C)	Projected increase of Temperature: Minimum (˚C)	Projected increase of Temperature: Maximum (˚C)
Bengaluru Rural	1.97	2.06	1.91
Bengaluru Urban	1.96	2.06	1.88

c) Projected Changes of Rainfall

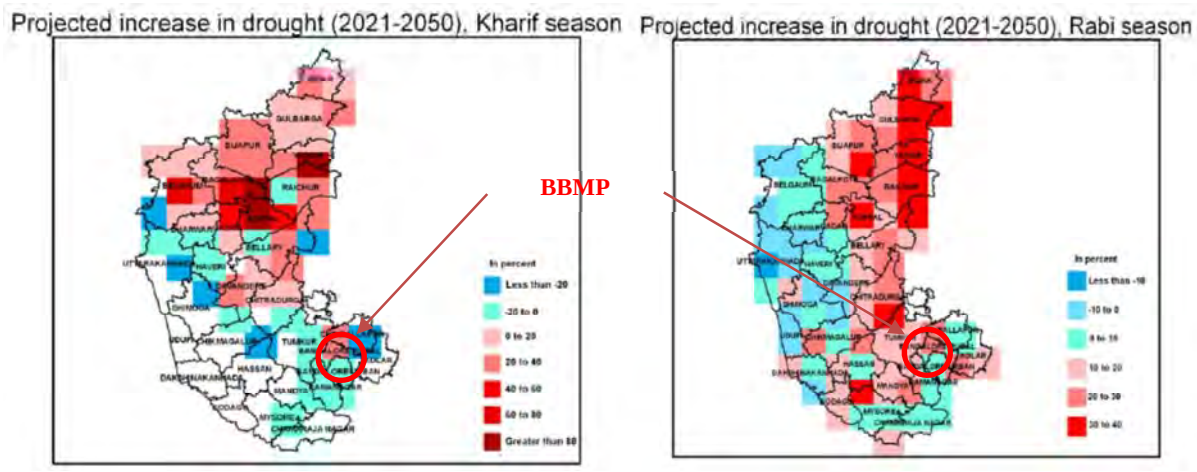
The change in rainfall for BBMP for the year of 2021 to 2050 was projected as 3.56 % increase compared to those of the baseline of 1961 to 1990 as shown in Table 2.1.8.

Table 2.1.8 Projected Change in Annual and Seasonal Rainfall for BBMP

District	Change Projected for Jan. to Feb (%)	Change Projected for Mar. to May (%)	Change Projected for Jun. to Sep (%)	Change Projected for Oct. to Dec. (%)	Change in Annual Mean Projected (%)
Bengaluru Rural	3.05	36.30	-2.31	9.61	3.56
Bengaluru Urban	-15.11	29.92	-2.89	10.14	3.66

d) Projections of Frequency of Droughts

"Severe drought" is defined as a period of absence of rainfall (the rainfall during 40 or more contiguous days is less than 2.5 mm/day). Two major seasons in Karnataka, Kharif (July 2nd week to October 2nd week) and Rabi (September 1st week to February 4th week) were set as a base time for the projection of the future frequency of droughts. The number of incidences of severe droughts are estimated for 2021 to 2050 for each grid point and compared to the baseline, those of the year of 1961 to 1990. The result of the analysis is shown in Figure 2.1.6



Source: "Karnataka Climate Change Action Plan", Bengaluru Climate Change Initiative – Karnataka (BCCI-K), May, 2011

Figure 2.1.6 Projected Increase in Drought Incidences in Future (Blue: Decrease, Red: Increase)

The following results were obtained for the project sites in BBMP and the target Cauvery river catchment.

- In the Kharif season, most of the sites indicates -20 to 0% for the baseline, that is, the incident of drought will be decreased
- In the Rabi season, most of the sites indicates 0 to 10% or 10 to 20% for the baseline, that is, the incident of drought will be slightly increased in the future

3) Potential Impact of Climate Change on Water Resources

a) Methodology

An assessment of the impacts of climate change on water resources can be best handled through modeling of hydrological conditions in river basins under future predicted climate variables. The main components of the hydrological cycle are precipitation, evaporation and transpiration. Changes in climate parameters, solar radiation, wind, temperature, humidity and cloudiness affect evaporation and transpiration. Three variables, namely, precipitation, evapotranspiration and surface runoff were considered. The projection of the impact level for the main catchment area of Cauvery river basin was carried out based on the following global climate model, HadCM3.

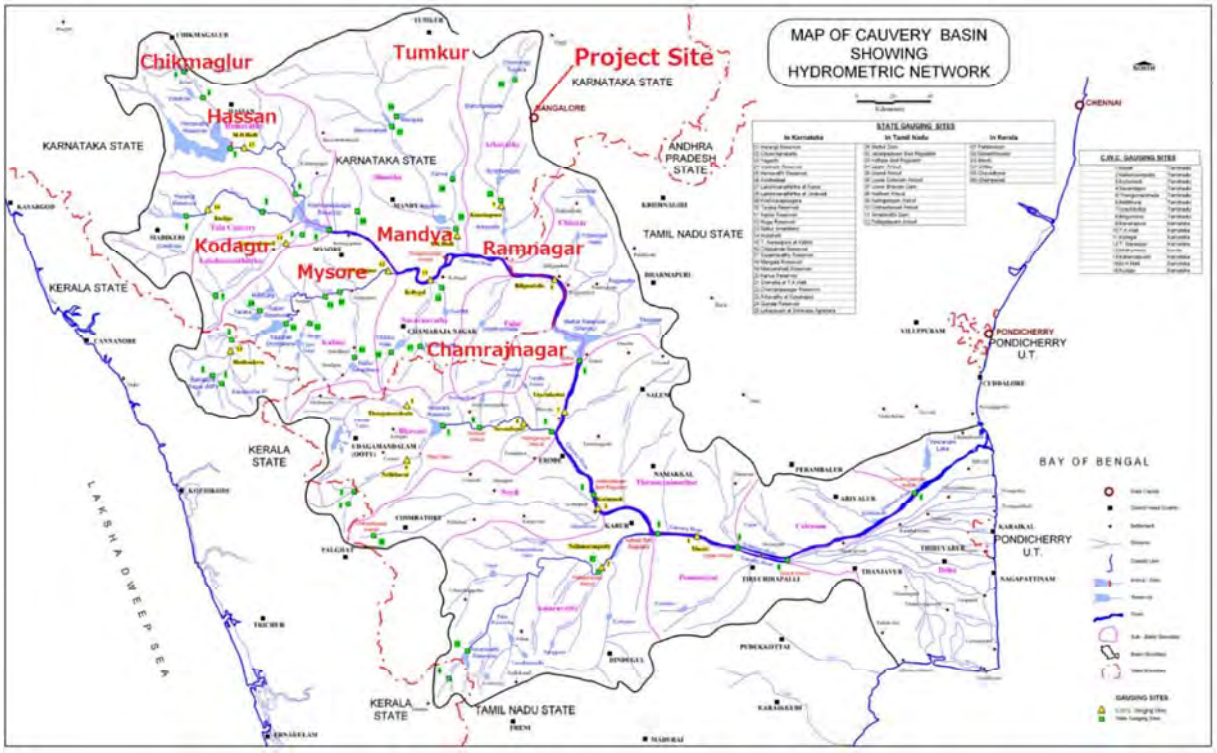
Global Climate Model (HadCM3): The process based, Global Climate Model, HadCM3, is used in this analysis for generating the hydrological scenario for the three variables, precipitation, evapotranspiration and runoff. This model has been used recently for generating climate change projections for various parts of the Indian subcontinent (Rupa Kumar et al., 2006).

b) Analysis Results

i. Precipitation

During the Kharif season, percentage decline in rainfall was projected for all districts in the Cauvery basin (Figure 2.1.7 for Cauvery basin) with up to 20% decline projected for Kodagu and Chikmaglur districts. In the remaining districts of the Cauvery basin, the decline in rainfall ranges from no change to 10%.

For the Rabi or post monsoon season, a decline in rainfall by over 20% was projected for Chamrajnagar. In the case of Ramnagar and Bengaluru Urban districts, a rainfall decline of 20 to 10% was projected. In Mandya and Mysore districts, no change in rainfall to 10% decrease was projected. Rainfall in Hassan, Kodagu, Tumkur and Chikmaglur districts is projected to increase by 10% in the future.



Source: State of Tamir Nadu

Figure 2.1.7 Map of Cauvery Basin

ii. Evapotranspiration

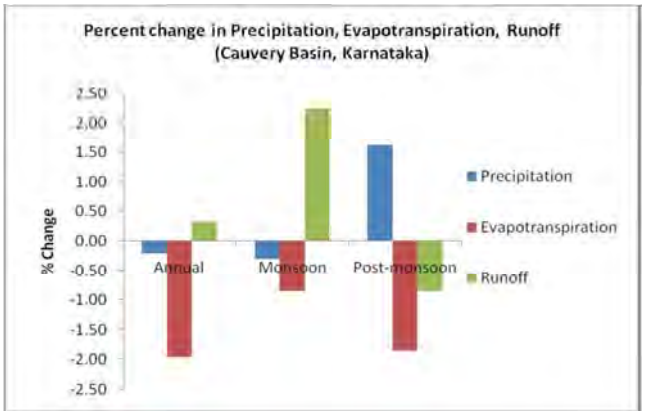
Overall in the Kharif season, evapotranspiration is projected to decrease. Chamarajanagar and Mandya districts were projected to show a decline, whereas Kodagu, Hassan and Chikmaglur were projected to show an increase. The remaining districts were projected to show marginal decrease of zero (0) to five (5) %.

For the Rabi season, only Mysore was projected to show a significant decline in evapotranspiration, and Ramanagar was projected to show maximum increase in the evapotranspiration. Mandya and Tumkur also were projected to show increase, while the remaining districts were projected to show marginal decrease.

iii. Runoff

For both the Kharif and Rabi season, an increase in runoff was identified in the Eastern districts of the basin. For Kharif season, districts like Mandya, Chamaraja Nagar and Ramanagar was projected to show increase in runoff by 50%, whereas districts like Hassan and Mysore represented a decline by 0 to 25 %.

For the Rabi season, Chamaraja Nagar, Mandya, Ramanagar, Bengaluru Urban and Bengaluru Rural were predicted to show an increase in total runoff. Tumkur and Chickmagalur were predicted to show no change to an increase in 25% runoff (See Figure 2.1.8). The reason of runoff increase may be caused by the urbanization in BBMP, although precipitation decrease.



Source: "Karnataka Climate Change Action Plan", Bengaluru Climate Change Initiative – Karnataka (BCCI-K), May, 2011

Figure 2.1.8 Percentage in Precipitation, Evaporation and Runoff in Cauvery Basin

4) Overall Evaluation on Impact of Climate Change on Project Implementation

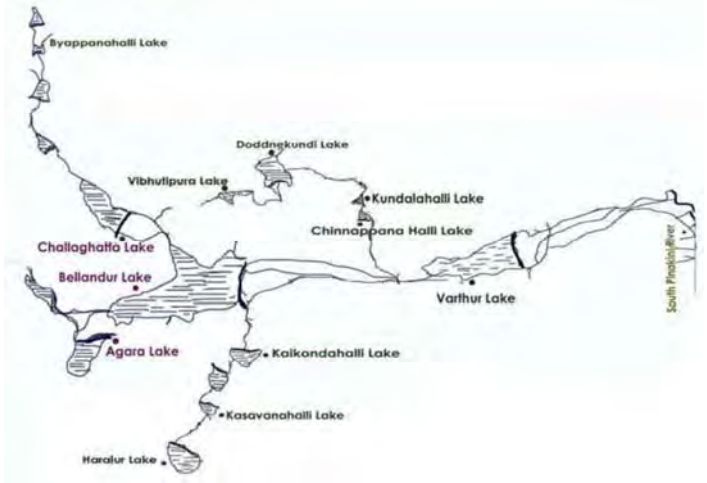
The future scenario of the climate change for the midterm (2021 to 2050) projections resulted in the meteorological change of the increase of temperature and rainfall at the project sites. However, the future runoff of the Cauvery river basin which is the main water source for the proposed project, was projected to slightly increase compared to the past baseline. Therefore, no major impact on climate change will be estimated for the project implementation.

2.1.3 Hydrological and Hydrogeological Conditions

(1) Surface Water

The area is characterized by first and second order streams and only near Bellandur it passes on to third order. The BBMP area has good natural vegetation, garden and lakes. There are three (3) lake series including Varthur Lake Series, Byramangala Lake Series and Yellamallappa Chetty Lake Series, as shown in Figure 2.1.10. The flow of the water runs from north to south-east as well as to south-west along the natural gradient of the land. During monsoon, surplus water drains from upstream lake to the downstream in the chain and this leads to greater pollution with physical and chemical pollutants.

Figure 2.1.9 Location of Lake Series in BBMP



Varthur Lake Series

No.	Name of the Lake	Area (ha)
1	Byappanahalli Lake	3.23
2	Haralur Lake	5.16
3	Kasavanahalli Lake	8.91
4	Kaikondanahalli Lake	27.09
5	Doddanakundi Lake	47.08
6	Vibhuthipura Lake	30.2
7	Kundalahalli Lake	10.48
8	Chinnappanahalli Lake	56.8
9	Varthur Lake 180.40	180.4
10	Bellandur lake 364.00	364

Varthur Lake Series

Byramangala Lake Series

No.	Name of the Lake	Area (ha)
1	Byramangala Lake	350
2	Maragondanahalli Lake	56.8
3	Bheemanakuppe Lake	39.6
4	Kombgatta Lake	15
5	Bovi Basappanakere	27.1
6	Gangondanahalli Lake	15
7	Halekere, Nayandahalli	5.8
8	Doddakere, Hosakerehalli	24.16
9	Mogakere, Uttarahalli	7.1
10	Subramanyapura Lake	11
11	Dorekere, Uttarahalli	11.61

Byramangala Lake Series

Yellamallappa Chetty lake series

No.	Name of the Lake	Area (ha)
1	Bantkondanahalli Lake	42
2	Amanikere, Singanayakanahall	178
3	Yelahanka Doddakere	135.68
4	Kattigenahalli Lake	2.5
5	Kogilu Lake	180
6	Gramadakere, Allalasandra	16.84
7	Jakkur Lake	50
8	Amruthahalli Lake	9.35
9	Rachenahalli Lake	60
10	Kodigehalli Lake	21
11	Chikkamaranahalli Lake	10
12	Kacharakanahalli Lake	22.57
13	Kalkere Lake	75
14	Ramapura Lake	5
15	Basavanapura Lake	56.6
16	Seegehalli Lake	5
17	Yellamallappa Chetty Lake	110

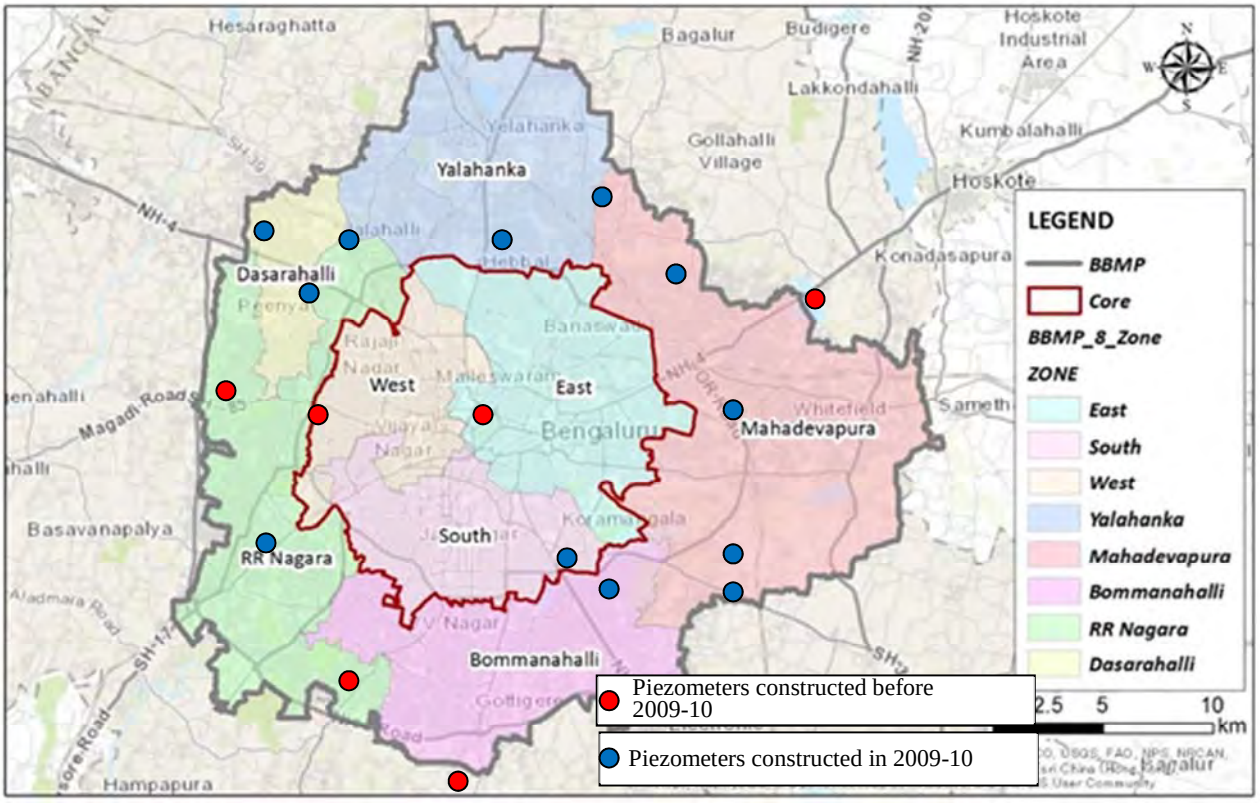
Yellamallappa Chetty lake series

Figure 2.1.10 Lake Series in BBMP

(2) Groundwater

BBMP is situated on a plateau with central ridge running north-east to south-west at an altitude of 962 m to 808 m. The geology and topography of BBMP which are not situated on a river bank or sea coast places have severe constraints on its water regime. Bulk of the groundwater source exists in shallow groundwater system within one hundred feet from the land surface. The groundwater is controlled by hydrogeology and climatological factors. The DMG (Department of Mining and Geology) is monitoring the groundwater levels at 12 wells by piezometer in the BBMP and available data is computerized (Refer to Figure 2.1.11).

In the areas where water supply by BWSSB has not been provided, many apartment complexes and commercial/industrial establishments are extracting large quantity of groundwater from deep wells. This water supply using groundwater is supplementing the piped water supply by the BWSSB to cover entire service area. The average depth of deep wells in the 1980s used to be about 80 to 120 ft (24 – 36 m) and now increased to 600 to 1000 ft (180 - 300 m), according to "Identification of sources for sustainable water supply to BBMP, August 2013, prepared by expert committee". In this report it is mentioned that there are no enough data on groundwater for assessment of total water potential and recommended to conduct scientific groundwater investigation.



Source: Department of Mines and Geology, March 2011

Figure 2.1.11 Groundwater Monitoring Network in BBMP Area

Water source of BWSSB water supply is river water from Cauvery River at present. Groundwater is used privately to supplement the water supply by BWSSB. The Expert Committee studied groundwater. The

quantity of water extracted from deep aquifer is estimated by considering 105,451 deep wells distributed in the six (6) zones and considering 50% of wells are dry up and remaining wells yield almost 1.5 l/sec with pumping of two (2) hours per day (refer to Table 2.1.9). Table 2.1.10 shows aquifer system with characteristics, which is also included in the report prepared by the Expert Committee. Heavy extraction of groundwater has lowered the groundwater table steeply and affected the quality.

Table 2.1.9 Zone Wise Water Supply and Groundwater Withdrawal (as of Year 2013)

Water Supply Zone	River water (MLD)	Nos. of Deep Wells	Groundwater Withdrawal (MLD)
Central	69	7,206	39
North	210	16,126	87
West	185	27,625	149
East	169	9,346	50
South	133	32,593	176
South-east	105	12,555	68
Total	869	105,451	569

After Stage VI Phase II, CWSS with additional 500 MLD, River water supply capacity is 1,460 MLD (Supplied amount is 1369.54 MLD). Source: Geological Society Memoir - 79 - Bengaluru Page 55.

Table 2.1.10 Aquifer System with Characteristics

Aquifer System	Depth (m)	Discharge	Transmissivity	Storability
1. Shallow Zone	< 25	1 - 5 l/s	-	-
2. Moderate Deep Zone	25 - 60	2 - 6 l/s	10/65 m^2/day	
3. Deep Zone	> 60	2 - 6 l/s	20/280 m^2/day	$2.8x10^{-3/8}x4x10^{-4}$

Source: Geological Society Memoir - 79 - Bengaluru Page 55.

The state has enacted the Karnataka Groundwater Act, 2011 (Regulation and Control of Development and Management) and Rule 2012 to regulate the over exploitation of groundwater. Groundwater level behavior is analyzed in Bengaluru Urban District based on monitoring results of groundwater level at the network hydrograph stations (NHS) established by CGWB (Central Ground Water Board). Groundwater quality for the district has been obtained based on hydro chemical data of NHS wells and exploration bore wells. Groundwater in the district shows wide variations in its chemical composition. Both shallow and deep groundwater is alkaline with pH value ranging from 7.8 to 8.5. Total hardness varies from 100 to 600 mg/l. Table 2.1.11 shows groundwater quality based on the examination results in Bengaluru Urban District.

Table 2.1.11 Groundwater Quality Examination Results in Bengaluru Urban District.

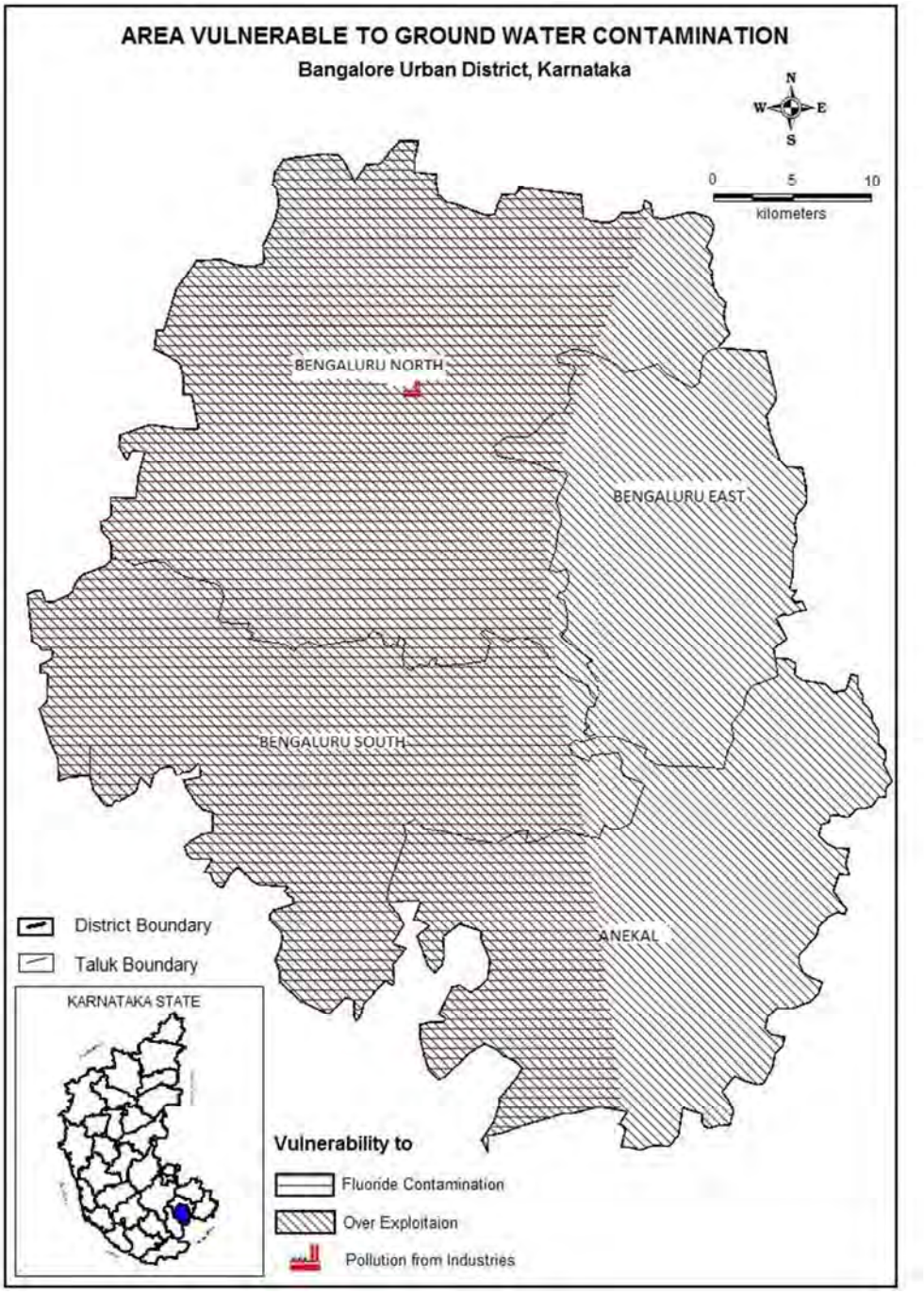
Bengaluru Urban Districts	pH	Total Hardness (mg/l)	EC (μ mhos/cm)	Chloride (mg/l)	Floride (mg/l)
Desirable limit	6.5-8.5	300	-	250	1.0
Permissible Limit	no relaxation	600	600	1000	1.5

Bengaluru Urban Districts	pH	Total Hardness (mg/l)	EC (μ mhos/cm)	Chloride (mg/l)	Floride (mg/l)
Bengaluru North (BN)	7.8-8.5	100-600	500-1000	250-1000 (part of BN)	>1
Bengaluru South (BS)	7.8-8.5	100-600	2000-3000	250-1000 (part of BS)	>1
Bengaluru East (BE)	7.8-8.5	100-600	2000-3000	250-1000 (part of BE)	<1
Anekal	7.8-8.5	100-600	1000-2000	250-1000	<1

Source: Ground Water Information Booklet for Bengaluru Urban District by Central Ground Water Board, 2013.

Major part of the district is having fresh water with EC (Electric Conductivity) ranging from 250 to 2000 micro mhos/cm at 25˚ C. In Bengaluru north and south Taluks, larger part of the Taluks are having fresh groundwater with EC ranging from 500 to 1000 micro mhos /cm at 25˚C. Isolated patch in North East corner of Bengaluru North Taluk and center of Bengaluru South Taluk shows EC in the range of 2000 to 3000 micro mhos /cm at 25˚C. In Anekal Taluk, EC varies from 1000 to 2000 micro mhos /cm at 25˚C except for small part in the center of Anekal Taluk where salinity is more with EC> 2000 micro mhos /cm at 25˚C.

Larger part of Anekal Taluk, isolated patches in the eastern part of Bengaluru north, south-west and eastern part of Bengaluru South Taluk have Chloride in the range of 250 to 1000 mg/l. Major part of the area of Anekal Taluk and in Bengaluru South Taluk, have nitrate content more than the permissible limit of 45mg/l. In Bengaluru North Taluk only small portions in southwestern part and northeastern part, groundwater is affected by high nitrate content. In general groundwater in the district is of Fluoride content is less than one (1) ppm and in localized pockets of Bengaluru South Taluk, fluoride content above one (1) mg/l is reported. The area vulnerable for groundwater contamination by fluoride is prepared by the department and the same is presented in Figure 2.1.12.



Source: Ground water information booklet for Bangalore Urban District, Karnataka

Figure 2.1.12 Area Vulnerable for Groundwater Contamination by Fluoride

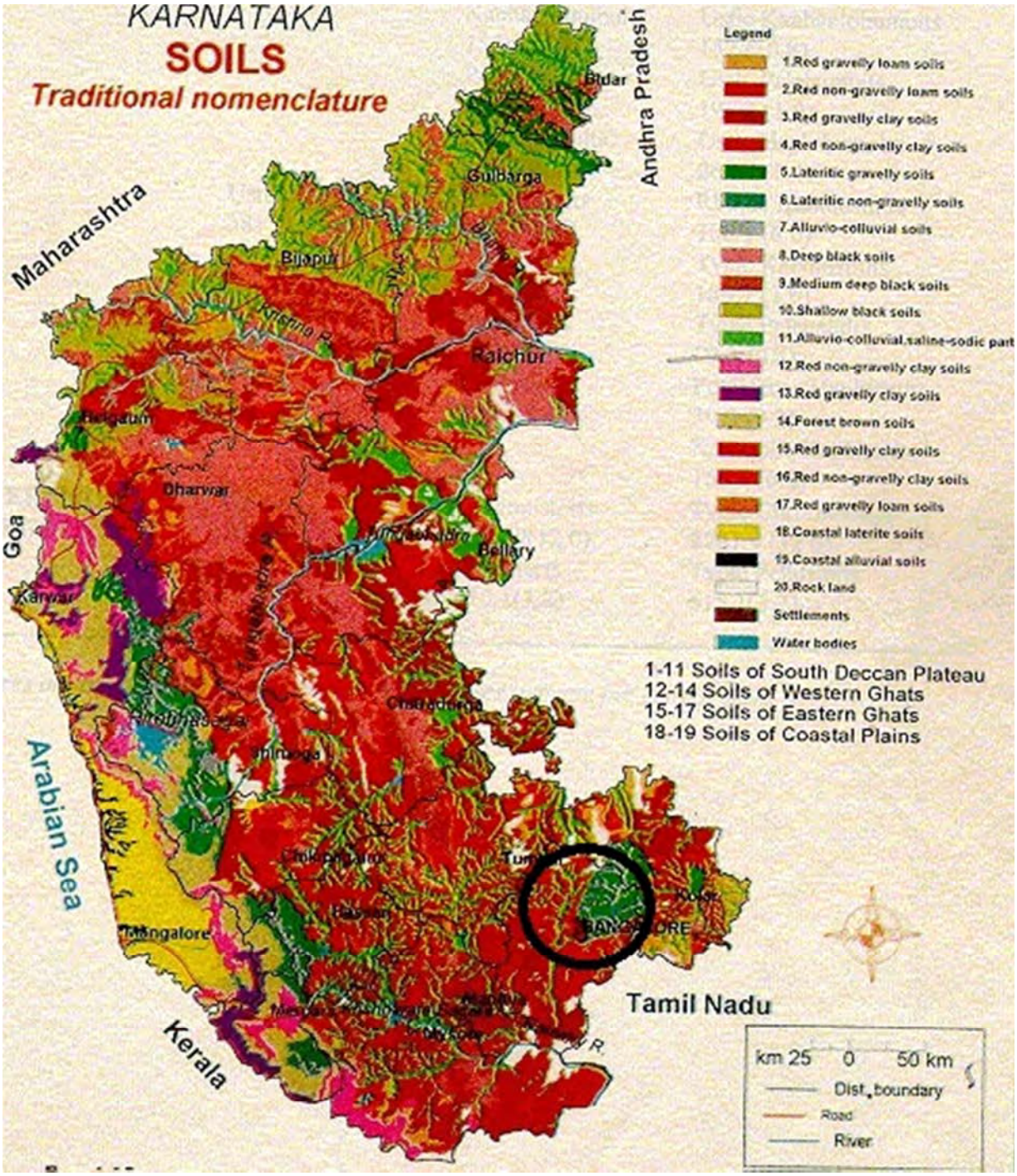
In general, groundwater is no potable in the urban district, though there are some potable areas in Core area. According to the study in "Groundwater Hydrology and Groundwater Quality in and around Bengaluru city" prepared by Department of Mines and Geology in 2011, no potable area is about 30%, potable area is 9% and remaining is alternate area (within permissible limit for drinking though not in desirable limit).

2.1.4 Geological Conditions

Bengaluru Urban distributed mainly with red soil, lateritic soil, Alluvio-Colluvial soil and rock lands. The prevailing rock formation is Granite gneiss, schist, quartzitesphyllites, charnockites, partially with Alluvium and colluvial sediment. Table 2.1.12 shows the description of geographical distribution in BBMP area. Figure 2.1.13 shows Traditional Soil Group of Karnataka.

Table 2.1.12 Geographical Distribution in BBMP Area (Bengaluru Urban District)

Classification Traditional (soil units)	Description	Agro-climatic zones	Geology
Red gravelly loam soils	Shallow welldrained to excessively drained, reddish brown to yellowish brown, gravelly sandy loam to sandy clay loam, moderately to severely eroded.	Hills and ridges, rolling and undulating lands of plateau and eastern ghats	Granite Gneiss, quartzite, schist
Red loam soils	Shallow, excessively drained to well drained, reddish brown to yellowish red, sandy clay loam to sandy loam soils, moderately to severely eroded.	Ridges, rolling, and undulating lands of plateau	Granite Gneiss, quartzite, schist sand-stone
Red gravelly clay soils	Deep to mod, deep and shallow, welldrained to excessively drained, yellowish brown dark red to reddish brown, gravelly sandy loam to sandy clay loam and loamy sand surface soils and gravelly sandy clay to clay subsurface soils, moderately to severely eroded.	Hills and ridges, hill ranges, rolling gently and undulating lands, inter-hill basins of plateau, western ghats, eastern ghats	Granite gneiss, schist, quartzitesphyllites, charnockites
Red clay soils			Granite gneiss schist, sandstone, quartzite
Lateritic gravelly	Deep, welldrained to excessively drained yellowish red to dark reddish brown, gravelly, sand clay loam to sandy clay and clay surface soils and sandy clay to clay subsurface soils moderatley to severely eroded with surface crusting.	Mounds summits and upper slopes of plateau, sloping lands of malnad	Granite gneiss schist, phyllites, basalt
Lateritic soils	Deep welldrained to excessively drained, yellowish red to dark reddish brown, sandy loam to sandy clay and clay surface soils and clay subsoils, moderately to severely eroded with surface crusting.	Gently sloping plains, summits of plateau, steeply sloping lands of Western ghats and malnad	Granite gneiss, phyllites, schist
Non-saline	Deep to shallow, moderately welldrained to imperfectly drained and poorly drained, yellowish brown to strong brown and dark greyish brown nonsaline, clay loam to clay and sandy clay loam surface soils and clay to clay loam and sandy clay loam, sub surface soils.	Valleys, low lands of plateau and malnad	Alluvium and colluvial sediment
Saline and sodic in patches	Deep, moderately well drained to perfectly drained, dark greyish brown to very dark greyish brown and strong brown, clay to sandy clay and clay loam surface soils and clay to loam subsurface soils with salinity and alkalinity in patches.	Valleys, low lands very gently sloping plains of command areas of plateau	Alluvium, Colluvial sediments
Rock lands	Rock land	Hills and ridges rolling lands	granite gneiss quartzite charnockite



Source: NBSS & LUP, RC, Bengaluru / KSDA, http://raitamitra.kar.nic.in/agriprofile/soilclass.htm

Figure 2.1.13 Traditional Soil Group of Karnataka and their Geographic Distribution

Groundwater is normally encountered within six (6) to nine (9) meters in the low-laying parts of the city. However, it may rise to within three meters from ground surface during the rainy season.

2.2 Legislative Conditions

2.2.1 National/State/City Water Policy

(1) National Policy

1) National Water Policy

A first National Water Policy of the Government of India was established in 1987. The national policy for priority principle for water use is as follows:

- Drinking Water
- Irrigation
- Hydro-power
- Navigation
- Industrial and other uses

The National Water Policy (NWP 2002) was subsequently introduced in relation to the rapidly changing scenario in the domain of water to address the emerging issues and provide critical policy inputs. NWP 2002 gave emphasis to ecological and environmental aspects for water allocation as a first time.
The NWP 2012 calls for a common integrated perspective to govern the planning and management of water resources. This perspective considers local, regional and national contexts and environmentally soundness. The guiding principles stated in the NWP 2012 include;

- A principle of equity and social justice must inform the use and allocation of water resources.
- Planning, development, and management of water resources need to be governed by common integrated perspectives considering local, regional and national context, having an environmentally sound basis, keeping in view the human, social and economic needs.
- Safe drinking water and water for sanitation should be considered as preemptive needs, followed by high priority allocation for other basic domestic needs, supporting agriculture for food security and minimum ecosystem needs.
- Given the limits on enhancing utilizable water resources coupled with climate change impacts, meeting the future needs of water will depend more on demand management.
- Water-using activities need to be regulated keeping in mind the local geo-climatic and hydrological situations.

2) National River Conservation Policy

The river conservation programme in the country was initiated with the launching of the Ganga Action Plan (GAP) in 1985. The Ganga Action Plan was expanded to cover other rivers under National River Conservation Plan (NRCP) in the year 1995. NRCP, excluding the GAP-I, GAP-II and National Ganga River Basin Authority (NGRBA) programme presently covers polluted stretches of 40 rivers in 121 towns spread over 18 States.

The NRCP aims at preventing pollution of rivers and improving water quality through construction of Sewage Treatment Plants (STPs) including riverfront development and low cost sanitation and afforestation. Users can access to the information on specific action plans for various rivers, details of sewage

treatment plants, water quality monitoring and implementing agencies.

3) National Urban Sanitation Policy (NUSP)

MoUD (Ministry of Urban Development) introduced a new NUSP in November 2009. The vision for Urban Sanitation in India is: All Indian cities and towns become totally sanitized, healthy and lively and ensure and sustain good public health and environmental outcomes for all their citizens with a special focus on hygienic and affordable sanitation facilities for the urban poor and women.

The NUSP introduced a new benchmarking tool and award scheme aiming to address poor sanitation conditions in India's urban areas. The scheme is aligned to larger goals of the NUSP which seeks to mobilize governments and civil society to transform urban India into community-driven Nirmal Shahar Purashar (Clean Cities Award), or totally sanitized, healthy, and livable cities and towns. The goal of Nirmal Shahar Puraskar is to encourage cities to strive for 100 percent access to sanitation facilities to all cities and 100 percent safe disposal of all city generated waste. The rating and award is based on the premise that improved public health and environmental standards are two outcomes that cities must ensure for urban citizens. In doing so, state governments and urban areas must adopt a holistic, city-wide approach while incorporating processes that help reach outputs pertaining to goals of the NUSP. The rating does not recognize mere inputs, hardware or expenditure incurred in urban sanitation, but assesses how these lead to achievements of intermediate milestones towards the final result of 100 percent safe disposal of wastes from the city on a sustainable basis (delivering public health and environmental outcomes and benefits to citizens).

The issues identified, policy, specific goals, rating and categorization methods on the status on the sanitation at each cities are shown in Table 2.2.1.

Table 2.2.1 Key Sanitation Issues

Key Issue	Facts Identified
Poor awareness	Sanitation has been accorded low priority and there is poor awareness about its inherent linkages with public health.
Social and occupational aspects of sanitation	Despite the appropriate legal framework, progress towards the elimination of manual scavenging has shown limited success, Little or no attention has been paid towards the occupational hazard faced by sanitation workers daily.
Fragmented institutional roles and responsibilities	There are considerable gaps and overlaps in institutional roles and responsibilities at the national, state and city levels.
Lack of an integrated city-wide approach	Sanitation investments are currently planned only in phased manner and do not take into account the full cycle of safe confinement, treatment and safe disposal.
Limited technology choices	Technologies have been focused on limited options that have not been cost-effective, and sustainability of investments has been in question.
Reaching the unserved and poor	Urban poor communities as well other residents of informal settlements have been constrained by lack of space or economic constraints, in obtaining affordable access to safe sanitation.
Lack of demand responsiveness	Sanitation has been provided by public agencies in a supply-driven manner, with little regard for demands and preferences of households as customers of sanitation services.

Source: JICA Survey Team

Policy Goals

The overall policy goal is to transform urban India into community-driven, totally sanitized, healthy and lively cities and towns as shown in Table 2.2.2. Table 2.2.3 and Table 2.2.4 present indicative objective rating chart for sanitation in cities and rating categorization, respectively.

Table 2.2.2 Specific Goal

Specific Goal	Description
Awareness generation and behavior change	• Generating awareness about sanitation and its linkages with public and environmental health amongst communities and institutions • Promoting mechanisms to bring about and sustain behavioral changes aimed at adoption of healthy sanitation practices
Open defecation free cities	All urban dwellers will have access to and use safe and hygienic sanitation facilities and arrangements so that no one defecates in the open. In order to achieve this goal, the following activities shall be undertaken: • Promoting access to households with safe sanitation facilities (including proper disposal arrangements) • Promoting community-planned and managed toilets wherever necessary, for groups of households who have constraints of space, tenure or economic constraints in gaining access to individual facilities • Adequate availability and 100 % upkeep and management of public sanitation facilities in all urban areas, to rid them of open defecation and environmental hazards
Integrated citywide sanitation	Re-orienting institutions and mainstreaming sanitation through: • Mainstream thinking, planning and implementing measures related to sanitation in all sectors and departmental domains as a cross-cutting issue, especially in all urban management endeavors; • Strengthening national, state, city and local institutions (public, private and community) to accord priority to sanitation provision, including planning, implementation and O&M management; • Extending access to proper sanitation facilities for poor communities and other unserved settlements; Sanitary and safe disposal: • Promoting proper functioning of network-based sewerage systems and ensuring connections of households to them wherever possible; • Promoting recycle and reuse of treated waste water for non-potable applications wherever possible will be encouraged. • Promoting proper disposal and treatment of sludge from on-site installations (septic tanks, pit latrines, etc.) • Ensuring that all the human wastes are collected safely confined and disposed of after treatment so as not to cause any hazard to public health or the environment. Proper operation & maintenance of all sanitary installation through: • Promoting proper usage, regular upkeep and maintenance of household, community and public sanitation facilities • Strengthening ULBs to provide or cause to provide, sustainable sanitation services delivery

Source: JICA Survey Team

Table 2.2.3 Indicative Objective Rating Chart for Sanitation in Cities (Draft)

No	Indicators	Points
1	**Output-related**	**50**
A	No open defecation sub-total	16
A-1	Access and use of toilets by urban poor and other un-served households (including slums) - individual and community sanitation facilities	4
A-2	Access and use of toilets for floating and institutional populations - adequate public sanitation facilities	4
A-3	No open defecation visible	4
A-4	Eliminate Manual Scavenging and provide personnel protection equipment to sanitary workers	4
B	Proportion of total human excreta generation that is safely collected (6 points for 100%)	6
C	Proportion of total black waste water generation that is treated and safely disposed off (6 points for 100%)	6
D	Proportion of total grey wastewater generation that is treated and safely disposed off (three (3) points for 100%)	3
E	Proportion of treated wastewater that is recycled and reused for non potable applications	3
F	Proportion of total storm-water and drainage that is efficiently and safely managed (three (3) points for 100%)	3
G	Proportion of total solid waste generation that is regularly collected (four (4) points for 100%)	4
H	Proportion of total solid waste generation that is treated and safely disposed off collected (four (4) points for 100%)	4
I	City wastes cause no adverse impacts on surrounding areas outside city limits (five (5) points for 100%)	5
2	**Process-related**	**30**
A	M&E systems are in place to track incidences of open defecation four (4)	4
B	All sewerage systems in the city are working properly and there is no ex-filtration (Not applicable for cities without sewerage systems) five (5)	5
C	Septage/sludge is regularly cleaned, safely transported and disposed after treatment, from on-site systems in the city (MAXIMUM 10 marks for cities without sewerage systems) five (5)	5
D	Underground and Surface drainage systems are functioning and are well-maintained four (4)	4
E	Solid waste management (collection and treatment) systems are efficient (and are in conformity with the MSW Rules, 2003) five (5)	5
F	There is clear institutional responsibility assigned; and there are documented operational systems in practice for b)/c) to e) above four (4)	4
G	Sanctions for deviance on part of polluters and institutions is clearly laid out and followed in practice three (3)	3
3	**Others**	**20**
A	Improved quality of drinking water in city compared to baseline seven (7)	7
B	Improved water quality in water bodies in and around city compared to baseline seven (7)	7
C	Reduction in water-borne disease incidence amongst city population compared to baseline six (6)	6
	Total	**100**

Source: JICA Survey Team

Table 2.2.4 Ratings and Categorization of Cities as per New NUSP

No	Category	Total Points in Table XX	Recommendation for Improvement
1	Red	Below 33	Cities on the brink of public health and "emergency" and immediate remedial action is necessary
2	Black	Greater than or equal to 34 and below 66	Considerable improvements are necessary
3	Blue	Greater than or equal to 67 and below 90	Recovering but still diseased
4	Green	Greater than or equal to 91 and below 100	Health and clean city

Source: JICA Survey Team

4) CPHEEO Manual

The Central Public Health and Environmental Engineering Organization (CPHEEO) is Technical Wing of the Ministry of Urban Development, Government of India, and deals with the matters related to Urban Water Supply and Sanitation Including Solid Waste Management in the Country.

In collaboration with UNDP, JICA and other international agencies, CPHEEO has prepared and published the following Manuals, which are technical guide books for the help of field engineers:

- Manual on Water Supply & Treatment, Third Edition, Revised-updated, May 1999
- Manual on Sewerage & Sewage Treatment Systems (Part A: Engineering, Part B: Operation and Maintenance, Part C: Management) – 2013

"CPHEEO Manual on water supply and treatment" covers the principles of planning, identification of the water source, development and transmission, water treatment, distribution system, testing and other related administrative aspects and also explains the approach to deal with each problem in detail. Even though it has not been revised for 17 years, it is still the standard guide for water supply treatment engineering.

The CPHEEO manual on Sewerage and Sewage Treatment Systems was updated for the previous manual which was released in 1993. The Manual on Sewerage and Sewage Treatment (second edition) published in 1993 mainly gave thrust to engineering aspects of the sewerage and sewage treatment systems. The updated manual in 2013 put emphasis on O&M and management of sewerage and sewage treatment systems.

The CPHEEO Manual for Water Supply & Treatment recommends the following rate for unit water demand for domestic & non-domestic consumers;

- Towns with piped water supply but without sewerage: 70 lpcd (liter per capita and day)
- Cities provided with piped water supply with existing/contemplated sewerage system: 135 lpcd
- Metropolitan & Mega Cities with piped water supply with existing/contemplated sewerage system: 150 lpcd

Project proponents for implementation of water supply projects shall follow above rate for unit water consumption for planning water supply projects.

(2) State's Water Policy

Karnataka's State Water Policy 2002 aims to achieve:

1) Providing drinking water of 55 lpcd in rural areas, 70 lpcd in towns, 100 lpcd in the city municipal council areas and 135 lpcd in city corporation areas
2) Creating an ultimate irrigation potential of 4,500,000 ha under major, medium and minor irrigation projects facilitating the creation of an additional irrigation potential of 1,600,000 ha
3) Improving the performance of all water resources projects
4) Improving productivity of irrigated agriculture by involving users in irrigation management
5) Harnessing the hydropower potential in the state
6) Providing a legislative, administrative and infrastructure framework to ensure fair and equitable distribution and utilization of water resources

BWSSB has adopted per capita water supply rate of 150 lpcd for the proposed project for metropolitan areas such as BBMP as per the Manual on Water Supply and Treatment of CPHEEO.

Karnataka state also has announced the Urban Drinking Water and Sanitation Policy as shown below:

1) To ensure universal coverage of water and sanitation services that people are willing to pay for
2) To provide such services in a manner that preserves the sustainability of the precious water resources of the State, protects and enhances the commercial and economic sustainability of the operations at the same time
3) To ensure a minimum level of service to all citizens
4) To achieve these objectives, the state would:
    - Continue to formulate policies, set the standards for provision of water services
    - Provide resources for capacity creation, regulate, monitor and evaluate the efficiency of the operations
    - Prepare a demand driven urban water action plan for making capital investments based on the principles of optimal utilization of water, water systems and financial sources
    - Propose a new tariff structure that would help recover O&M expenses, debt servicing, and ensure a reasonable return on capital
    - Encourage private sector participation to achieve the sector goals, promote economic and commercial viability of water sector services, allowing the ULBs the choice of providing the services directly through public bodies or through such appropriate private sector participation arrangements

(3) City's Water Policy

Bengaluru City (BDA) prepared the policy for sanitation and water supply. The following are the summary by sanitation and water supply.

1) Sanitation

The city emphasized combined improvement among sanitation, solid waste and drainage and particularly pronounced in surface and groundwater pollution and unsafe waste disposal with adverse health impacts.

The following are summary of present status by item.

- Sewerage: The problem of sewage, linked with problem of access to potable water is a major concern for the city.
- Solid Waste Disposal: The collection of the waste is carried out regularly by the city, but waste treatment is an issue of concern. New dump sites and landfill sites shall be identified and developed.
- Drainage: The flooding of drains during each monsoon exposes its poor state and their inadequate capacity, and impacts the city's overall infrastructure. To control floods, it is important to remove silt and widen these storm water drains to maintain the chain flow and avoid water from stagnating at one point.

Safe sanitation and solid waste management are key challenges for the city. In this regard, the BBMP authority and BWSSB shall be working towards the following strategic outlook:

- Safe sanitation facilities are accessible by all citizens and municipal waste management covers the entire city.
- Public awareness is increased of safe sanitary practice and of citizen's responsibilities to achieve and maintain hygienic environment.
- Municipal waste management practices conforming to the Municipal Solid waste Management Rules.
- Appropriate options for wastewater recycling and reuse are introduced to supplement water for non-domestic usage.
- Storm water runoff is appropriately collected and discharged into natural drainage channels
- Encroachments are relocated to safe areas thereby ensuring that aspects of health and safety are adequately addressed.

2) Water Supply

Water supply is a key concern when it comes to the problem of the city's infrastructure. There are major disparities regarding access to potable water in the city. The Bengaluru Core area is generally well served, however, the villages have quite limited services and majority of households have recourse to the wells and collective water supply because of absence of water supply systems. It is imperative to improve access to potable water for households and improve the sanitary conditions. Irregular water supply and the need to store it cause problems of hygiene. These risks are high in the poorest residential areas and in the slums. The BWSSB provides water supply and sewerage services in the BBMP area. The following are requirements to be achieved by BWSSB.

- Ensuring that water is accessible to all citizens on a continuous basis, every day,
- Ensuring that the quality and quantity of water available to citizens conforms to the Central Public Health and Environmental Engineering Organization (CPHEEO) standards, and
- Ensuring that full cost of water service shall be achieved using funds for long-term asset strengthening and management.

Significant actions arising from the sector strategic outlook comprises:

a) Medium-term Steps: Undertake leak detection and rectification of the distribution system, energy and water audits to reduce water losses and utilize saved water for distribution across the city.
b) Holistic Planning for Water Services: It is necessary to take an integrated look at sector priorities, options, systems and data. The BWSSB shall lead the introduction of more integrated approach, covering the water demand requirement in the BBMP, and linking system information on the GIS-based city maps for long-term asset management and strengthening.
c) Augmentation and Rehabilitation: A combination of new investments and expansions of existing ones is needed.
d) Public Awareness: Introduction of awareness campaign is a Core element of the way forward, especially to promote water conservation and associated techniques, monitoring rainwater harvesting practices in households.
e) Revenue Enhancement and Cost Recovery: The BWSSB shall undertake measures to index water tariff and undertake a path for progressive movement towards cost recovery. BWSSB shall also have to start to analyze the various components of costs as a base for improvement in cost recovery.

2.2.2 Legal Framework

(1) Legal Framework on Water Use

There is no umbrella framework in India to regulate freshwater. The existing legal framework in India is characterized by the coexistence of a number of different principles, rules and acts which have been adopted over many years.

The following laws and regulations have relations to water right in India;

i. Indian Constitution

Indian Constitution is the supreme law of India. It lays down the framework defining fundamental political principles, establishes the structure, procedures, powers and duties of government institutions and sets out fundamental rights, directive principles and the duties of citizens. The Constitution was adopted by the Constituent Assembly on 26 November 1949 and came into effect on 26 January 1950.
The Constitution provides fundamental regulations relating to water right as per the following articles.

Table 2.2.5 Provisions on Water Right in Indian Constitution

Schedule / Article No.	Provisions
Article 21	A right of access to 'Safe Drinking Water' as a part of' 'Right to Life' under this article
Article 262	The Union (federal) can legislate with regard to the adjudication of inter-state water disputes. Based on this article, a bill on the Interstate River Water Disputes Act was presented.

Schedule / Article No.	Provisions
Article 263	Provisions with respect to an inter State Council which is charged with a duty of: Inquiring into and advising upon disputes which may have arisen between States Investigating and discussing subjects in which some or all of the States Making recommendations upon any such subject and, in particular, recommendations for the better coordination of policy and action with respect to that subject
Schedule 7 (List 1 and 2)	States have an exclusive power to regulate water supplies, irrigation and canals, drainage and embankments, water storage, hydropower and fisheries.
73rd Amendments to the Constitution (1993)	Empowerment of states to endow Panchayats (local government body in rural areas) with such powers and authority to enable them to function as institutions of self-government and goes on to list 'Drinking Water', 'Water Management', 'Irrigation', and 'Watershed Development' as subjects under the jurisdiction of Panchayats.

Source: JICA Survey Team

ii. Interstate River Water Disputes Act (incl. its Amendments)

The Interstate River Water Disputes Act, 1956 (IRWD Act) is an act enacted under Article 262 of the Constitution on linguistic basis to resolve the water disputes that would arise in the use, control and distribution of an interstate river or river valley. This act further has undergone amendments subsequently and its most recent amendment took place in 2002. The IRWD Act can be applicable for the cases whereas the actions of an upstream state to use or control or distribute the water of an interstate river can affect the downstream states as shown in the following water issues:

- Decrease in water availability: When an upstream state contemplates water use, it would block the river flows initially by constructing barrages and tries to store the peak flood waters ultimately by constructing massive water storage reservoirs. In this process the river flow regime is altered drastically converting it ephemeral dry in most of the time except during floods. It also alters the ecology of the river located in downstream states affecting its river ecosystem and aquatic flora & fauna.
- Deterioration in water quality: If the water use is 75% of the total available water in the river, the dissolved salts concentration in the river water will increase. Alteration in river water quality / alkalinity / salinity effects growth of traditionally cultivated crops as they are not best suitable with the enhanced soil alkalinity and or soil salinity.

iii. Common Law

Besides statutory frameworks, a number of common law principles linking access to water and rights over land are still prevailing in India. This includes separate rules for surface and groundwater. With regard to surface water, existing rules still derive from the early common rule of riparian rights. Thus, the basic rule was that riparian owners have a right to use the water of a stream flowing past their land equally with other riparian owners, to have the water come to them undiminished in flow, quantity or quality. In recent times, the riparian right theory has gradually been rejected as the appropriate basis for adjudicating water claims due to the context of the recognition that water is a public property. Common law standards concerning groundwater have subsisted longer. The basic principle was that access to and use of groundwater is a right of the landowner. In other words, it is one of the rights that landowners enjoy over their posses-

sions. The inappropriateness of this legal principle has been rapidly challenged during the second half of the 20th century with new technological options permitting individual owners to appropriate not only water under their land but also the groundwater found under neighbor's lands. However, the rapid lowering of water table in most regions of the country has called in question legal principles giving unrestricted rights to landowners over groundwater. As a result of the rapid expansion of groundwater use, the central government has tried to persuade states to adopt groundwater legislation since the 1970s.

(2) Water Prevention and Control of Pollution Act, 1974 and its Amendments

The Water (Prevention and Control of Pollution) Act and the Environment Protection Act promulgated in 1974 and 1986, respectively deal with the prevention and control of water pollution. The latter is considered as an umbrella act covering all aspects of the environment, under which the central government can take appropriate measures for;

- Protecting and improving the quality of the environment, and
- Preventing, controlling and abating environmental pollution.

The Pollution Control Board (PCB) was established under this act both at the Central Government called as Central Pollution Control Board (CPCB) and also at the State Government level for each state.
The Act vests regulatory authority on the State Pollution Control Board and empowers them to establish and enforce effluent standards for industries and local authorities discharging effluents.
The followings are the important provisions under this Act:

- Provide the State Pollution Control Board (SPCB) any information which is sought for preventing or controlling pollution of water regarding the construction, installations, operation or the treatment and disposal system of an industrial establishments
- Not to discharge, knowingly of any effluent into the stream, sewers or on land of quality which is not conforming to the standards prescribed by SPCB
- Furnish information to SPCB and other designated agencies of any accident or unforeseen event, in which effluents not conforming to the prescribed standards are being discharged or likely to be discharged in to a stream or sewer or on land
- Comply with the directions issued in writing by SPCB, within the specified time.
- Comply with the condition as prescribed in the "Consent to Establish" or "Consent to Operate" for discharge of effluent in to stream or sewers or on land.
- The responsibilities pursuant to this law is as follows;
  - To obtain "Consent to Establish", prior to taking any steps to establish any industry or any treatment and disposal system which is likely to discharge effluents.
  - To obtain "Consent to Operate", prior to commencing operation of any industry or any treatment and disposal system which is likely to discharge effluents.
  - To apply for renewal of the "Consent to Operate": before the expiry of validity period along with the prescribed fee.

(3) Water (Prevention and Control of Pollution) Cess Act, 1977 including Rules

The act provides the levy and collection of a cess on water consumed by persons carrying on certain industries and by local authorities to augment resources for PCB.

As per the provision of Section three (3), all specified industries under the Water (Prevention and Control of Pollution) Cess Act, 1977 are liable to pay cess in the prescribed rate made under the statute. It is provided under Section five (5) that every specified industry or local authority is liable to furnish cess to respective authorities. Also all specified industries and local authorities for the purpose of measuring the quantity of water consumption shall install suitable meters.

To encourage capital investment in pollution control, the Act gives a polluter a 70% rebate of the applicable cess upon installing an effluent treatment plant.

(4) The Environment (Protection) Act, 1986, 2004 (amended)

The Environment (Protection) Act was conceived as an "umbrella legislation" seeking to supplement the existing laws on the control of pollution (the water Act and the Air Act) by enacting a general legislation for environment protection and to fill the gaps in regulation of major environmental hazards.

- Section 3 (1) of the Act (with respect to the power of central government) empowers the Centre to "take all such measures as it deems necessary or expedient for the purpose of protecting and improving the quality of the environment and preventing, controlling and abating environmental pollution".
- It also authorizes the government to make rules on any aspect related to environment protection.
- No industries can discharge any solid, liquid or gaseous substances beyond the permissible limit as laid down by the Central Government on its behalf.
- Comply with the directions issued in writing by the Central Government within a specified time as mentioned in the order.
- Furnish information to the prescribed agencies of any accident or unforeseen event, in which environmental pollutants occurred in excess of the prescribed standards are being discharged, of are likely to be discharged in the environment.

The following is the provisions regarding the responsibilities pursuant to the law;

- Obtain prior "Environmental Clearance" from MoEF (Ministry of Environment and Forests) in case of a new project or for modernization/expansion of the existing project and in respect of projects falling under EIA notification

(5) Karnataka Groundwater (Regulation and Control of Development and Management) Act, 2011

The rising concerns about diminishing groundwater resources prompted the legislation of the Karnataka Groundwater (Regulation and Control of Development and Management) Act, 2011. The act seeks to regulate access and exploitation of groundwater. Permissions are required for operating existing bore wells, drilling new bore wells and drawing water for water− intensive crops in certain notified areas. These can be refused if stipulated conditions are not met. The act also stipulates watershed management, rainwater harvesting and groundwater recharge in 'worthy' areas to be notified.

(6) Laws and Regulation relating to River Minimum Maintenance Flow

The latest National Water Policy (NWP 2002) gives fourth priority to ecology after drinking water, irrigation and hydropower. However, the policy does not say what this priority would mean. The section under Water Quality in the NWP 2002 has some relevant provisions for rivers including maintaining minimum river flow shown as:

- Minimum flow should be ensured in the perennial streams for maintaining ecology and social considerations.

However, the legislation for keeping a minimum river flow has not been established.

(7) Laws and Regulation relating to Land Acquisition

In India, the Land Acquisition Act (LAA) 1894 had served as the basis for all government acquisition of land for public purposes. The first land acquisition law was enacted during the British Raj in 1824, which underwent several modifications and was finally replaced by the LAA, 1894. The GoI (Government of India) in 1947 adopted the LAA 1894. Since then, several amendments have been made due to its weak framework such as lack of clear definition of "Public Purpose", complete absence of a statutory absence of R & R (Rehabilitation and Resettlement) for affected persons and inadequate protection of the interests of the land owners. In addition, various State Governments also amended the Act in order to respond to the local demands, like in the case of Land Acquisition (Amendment and Validation) Act of 1967 by the state of Karnataka. Afterwards, two (2) bills, "The Land Acquisition (Amendment) Bill, 2007" and "The Rehabilitation and Resettlement Bill, 2007" were introduced in Lok Sabha (the lower house of India's Bicameral-Parliament). Through discussions based on these two (2) bills, the Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013 (RFCTLARR Act) was enacted and an ordinance of the amendment of the RFCTLARR act was promulgated.

Key features of the RFCTLARR Act are;

- Social Impact Assessment (SIA) : Whenever a project proponent intends to acquire land for a public purpose, the proponent shall carry out a SIA study.
- Public Purpose: The Act defines the public purpose as 1) the provision of land for strategic purposes relating to naval, military, air force, and armed forces of the Union or any work vital to national security or defense of India or State Policy, 2) infrastructural projects under the Department of Economic Affairs, projects involving agricultural infrastructure, industrial corridors or mining activities, water harvesting and water conservation projects, government aided educational and research institutions, projects for sports, healthcare and tourism etc.
- Affected term: Affected term shall include both the land losers and livelihood losers.
- Rehabilitation and Resettlement: Various R&R package are provided for PAFs (Project Affected Farmers)
- Institutional mechanism for R&R in the form of institutions of Administrator for Rehabilitation and Resettlement, Commissioner for Rehabilitation and Resettlement, Rehabilitation and Resettlement Committee at project level, the Land Acquisition, Rehabilitation & Resettlement Authority at State level and National Monitoring Committee at Central level.
- Compensation: The Act provides the compensation of four times the market price in rural areas and

twice the market price in urban areas. This shall include a solatium of 100 percent of the compensation. Apart from this value of assets attached to the land shall also be part of the compensation package.

- Consent: For land proposed to be acquired in any area for public purpose as part of a public-private partnership project, the prior consent of 70 percent of the affected land owners is required and in case of private company, prior consent of 80 percent of the affected land owners is required.

(8) Classification of Inland Water Bodies

As of now only criteria available for classification of water bodies are as per the "Designated Best Use" (DBU) prescribed by Bureau of Indian Standards and CPCB prepared way back in 1981. The concept sets out of various purposes for which the water body is used and taken as the benchmark and classified as "Designated Best Use". According to these criteria water bodies are divided into five categories as follows:

- Class A: Drinking water source without conventional treatment with chlorination
- Class B: Outdoor bathing
- Class C: Drinking water source with conventional treatment
- Class D: Propagation of wildlife and fisheries
- Class E: Irrigation, industrial cooling and controlled waste disposal

Table 2.2.6 shows above criteria lay down for the parameters of pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD_5), coliform, etc.

Table 2.2.6 Classification of Surface Waters based on Designated Best Use prescribed by Central Pollution Control Board

Designated Best Use	Quality Class	Parameter	Values
Drinking water source without conventional treatment, but after disinfection	A	pH	6.5 to 8.5
		Dissolved oxygen, mg/l	6 or more
		BOD_5 (20 ^oC), mg/l	2 or less
		Total coliform (MPN/100 ml)	50
		Free ammonia, mg/l	NIL
		Electrical conductivity, μmho/cm	NIL
		Sodium adsorption ratio	NIL
		Boron	NIL
Outdoor bathing (organized)	B	pH	6.5 to 8.5
		Dissolved oxygen, mg/l	5 or more
		BOD_5 (20 ^oC), mg/l	3 or less
		Total coliform (MPN/100 ml)	500
		Free ammonia, mg/l	NA
		Electrical conductivity, μmho/cm	NA
		Sodium adsorption ratio	NA
		Boron	NA
Drinking water source after conventional treatment and disinfection	C	pH	6.5 to 8.5
		Dissolved oxygen, mg/l	4 or more
		BOD_5 (20 ^oC), mg/l	3 or less
		Total coliform (MPN/100 ml)	5,000
		Free ammonia, mg/l	NA
		Electrical conductivity, μmho/cm	NA
		Sodium adsorption ratio	NA
		Boron	NA
Propagation of wildlife and fisheries	D	pH	6.5 to 8.5
		Dissolved oxygen, mg/l	4 or more
		BOD_5 (20 ^oC), mg/l	NA
		Total coliform (MPN/100 ml)	NA
		Free ammonia, mg/l	1.2
		Electrical conductivity, μmho/cm	NA
		Sodium adsorption ratio	NA
		Boron	NA
Irrigation, industrial cooling, and	E	pH	6.5 to 8.5
		Dissolved oxygen, mg/l	NA

Designated Best Use	Quality Class	Parameter	Values
controlled waste disposal		BOD_5 (20 ^oC), mg/l	NA
		Total coliform (MPN/100 ml)	NA
		Free ammonia, mg/l	NA
		Electrical conductivity, μmho/cm	2,250
		Sodium adsorption ratio	26
		Boron	2

Source: CPCB

Recently, CPCB has revised the primary quality for class B regarding coliform number as; faecal coliform: < 500 MPN/100ml (Desirable), < 2,500 MPN/100ml (Maximum permissible).
As of now these criteria are followed by various agencies responsible for management and control of water quality in the country including the two ongoing programmes viz. National River Conservation Plan and National Lake Conservation Plan.

In year 2002, CPCB has proposed new criteria for classification of water bodies. The new approach is based on the premise of maintaining and restoring "wholesomeness" of water for the health of ecosystem and environment in general; and protecting the designated organized uses of water by human beings and involving community for water quality management.
The new classification system as shown in Table 2.2.7 proposes three categories or tiers of indicators of water quality depending on the ease or complexity involved in their determination with regard to knowledge, skills, and equipment. Secondly, it classifies water bodies into three broad categories viz.:

Class A: Excellent (long term goal)
Class B: Desirable level of wholesomeness (medium term goal)
Class C: Minimum acceptable level (Short term goal)

Table 2.2.7 Key Indicators of Inland Surface Water Quality under Revised Criteria by CPCB

Indicator	Unit	A-Excellent	B-Desirable	C-Acceptable
DO	(% saturation)	90-110	80-120	60-140
BOD_5	(mg/l)	<2	<5	<8
Faecal Coliform	MPN/100ml	<20	<200	<2,000

Source: CPCB

(9) Treated Wastewater Discharge Standards

The effluent standards are shown in Table 2.2.8. Effluent discharge standards are specified with reference to the type of industry, process or operations and in relation to the receiving environment or water body such as inland surface water, sewers, land or sea.

Table 2.2.8 Effluent Standards for Different Receiving Water Bodies

Indicator	Inland surface water	Public sewers	Land for irrigation	Marine outfall
Suspended Solids(SS) (mg/L)	100	600	200	100
Oil and grease (mg/L)	10	20	10	20
BOD_5 (mg/L)	30	350	100	100

Note: All values are in mg/L and are the maximum permissible levels.

Source: Pollution control acts, rules and notifications issued hereunder, CPCB, September 2001.

The general BOD_5 limit specified for discharge of wastewater from typical industrial sources or domestic sewage is same at 100mg/L. However, the rules specify that the discharge limits can be made stringent if the concerned State Pollution Control authority finds it appropriate depending on the condition of the receiving environment and severity of the discharges from various sources.

(10) Ambient Air Quality Standards

CPCB has notified the National Ambient Air Quality Standards (NAAQS) in Schedule VII of these Rules, which are reproduced in Table 2.2.9.

Table 2.2.9 National Ambient Air Quality Standards

Pollutant	Time	Concentration in ambient air			Method of Measurement
	Average	Industrial	Residential	Sensitive	
SO_2	Annual*	80	60	15	1. Improved West & Gaeke method
	24 hrs**	120	80	30	2. Ultra violet fluorescence
NOx	Annual	80	60	15	1. Jacob & Hochheiser modified (Na-Arsenite) method
	24 hrs	120	80	30	2. Gas phase chemi-luminescence
SPM	Annual	360	140	70	Average flow rate not less than
	24 hrs	500	200	100	1.1 m^3/minute
RPM	Annual	120	60	50	
	24 hrs	150	100	75	
Pb	Annual	1.00	0.75	0.50	AAS method after sampling using
	24 hrs	1.50	1.00	0.75	EPM 2000 or equivalent paper
CO***	8 hrs	5	2	1	Non dispersive infrared spectroscopy
	1 hour	10	4	2	

Note*: Annual arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hourly at uniform intervals.
Note**: 24 hourly / eight (8) hourly values to be met 98% of the time in a year. However, 2% of the time, it may exceed but not on two consecutive days.
Note***: Values in mg/m^3

Source: CPCB

(11) Ambient Noise Standards

The standards for ambient air quality in respect of noise are given in Schedule III under the Noise Pollution (Regulation and Control) Rules, 2000 and amendment 2002 and the values are shown in Table 2.2.10.

Table 2.2.10 Ambient Noise Standard

Area Code	Category of Area	Limits in dB (A)	
		Day time	Night time
A	Industrial	75	70
B	Commercial	65	55
C	Residential	55	45
D	Silence zone	50	40

Note 1: Daytime is reckoned in between six (6) am to 10 p.m.
Note 2: Night time is reckoned in between 10 p.m. to six (6) a.m.
Note 3: Silence zone is defined as areas up to 100 meters around such premises as hospitals, educational institutions and courts. The silence zones are to be declared by the Competent Authority. Use of vehicular horns, loudspeakers and bursting of crackers shall be banned in these zones.
Note 4: Mixed categories of areas should be declared as one of the four above-mentioned categories by the Competent Authority and the corresponding standards shall apply.

Source: CPCB

2.2.3 Relevant Organizations to the Sectors

(1) General

Water supply and sanitation is a State responsibility under the Indian Constitution. States may give the responsibility to municipalities in urban areas called Urban Local Bodies (ULB). At present, states generally carry out planning, design and execute water supply schemes (and often operate them) through their state departments such as BWSSB.

(2) Responsible Agency at Central Government

The responsibility for water supply and sanitation at the central and state level is shared by various Ministries. At the central level three Ministries have responsibilities in the sector: The Ministry of Drinking Water and Sanitation is responsible for rural water supply and sanitation, while the Ministry of Housing and Urban Poverty Alleviation and the Ministry of Urban Development share the responsibility for urban water supply and sanitation. Except for the National Capital Territory of Delhi and other Union Territories, the central Ministries only have an advisory capacity and a limited role in funding.

(3) BWSSB

BWSSB is an autonomous body formed by the State legislature under Bengaluru Water Supply and Sewerage Board Act on 10-09-1964 for Water Supply and Sewage disposal. It is one of the first Water Supply & Sanitation Utilities in India with jurisdiction of entire BBMP Area of 800 km^2, (Bengaluru Core area of 245 km^2, eight (8) Urban Local Bodies of 330 km^2 (seven (7) City Municipal Corporation and one (1) Town Municipal Corporation) and 110 Villages of 225 km^2). The BWSSB's existing facilities and their operation status are described in details in Chapter three (3) and four (4).

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BWSSB has the following mandates:

- Adequate water supply to meet demand; creation of sewerage network and safe discharge of sewage,

- Preparation, implementation of plans and schemes for augmenting water supply and safe discharge of sewage, and
- Levy and collection of water charges

The staff members of BWSSB consist of BWSSB permanent staff and those to be employed through out-sourcing. Table 2.2.11 shows the status of BWSSB permanent staff as of year 2015. A total of 3,501 persons with positions were approved by GoK, however, only 2,157 persons were employed and there are still vacant staff, as shown in the balance column (total of 1,344). In 2016-2017, additional 211 persons were approved by GoK for BWSSB permanent staff and their recruitments will be done in the near future.

Under the above conditions, presently a total of 4,157 persons are employed including 2,000 persons who have already employed through outsourcing (2,157 + 2,000).

Table 2.2.11 Present Number of BWSSB Permanent Staff

Category of Position	Sanctioned Staff Number as per Reorganization	Number of Actual Working Staff	Balance (Vacancy)
Group A (Higher Level)	207	146	61
Group B (Middle Level)	310	190	120
Group C (Lower Level 1)	1,935	1,241	694
Group D (Lower Level 2)	1,049	580	469
Total	3,501	2,157	1,344

Source: BWSSB as of August, 2017

(4) Karnataka State Pollution Control Board (KSPCB)

The Karnataka State Pollution Control Board for Prevention and Control of Water Pollution was constituted by the Government of Karnataka on The Twenty First of September Nineteen Seventy Four (21.9.1974) in pursuance of the Water (Prevention & Control of Pollution) Act, 1974 . The Water Act will provide for the prevention and control of water pollution and maintaining or restoring of wholesomeness of water. After the enactment of the Air (Prevention & Control of Pollution) Act, 1981 the enforcing responsibility was entrusted to the above Board. As such, the Board was later renamed as the Karnataka State Pollution Control Board (KSPCB) in 1985.

KSPCB is enforcing the following acts and rules;

- The Water (Prevention & Control of Pollution) Cess Act, 1977, and as amended from time to time
- The Water (Prevention & Control of Pollution) Cess Rules, 1978
- The following Rules and Notifications framed under Environment (Protection) Act, 1986;
  - Hazardous Waste (Management, Handling and Transboundary Movement) Rules, 2008
  - Environmental Impact Assessment Notification, 2006
  - Bio-Medical Waste (Management & Handling) Rules, 1998, and Amendment Rules, 2000
  - Plastic Waste (Management & Handling) Rules, 2011

- The Noise Pollution (Regulation & Control) Rules, 2000
- Municipal Solid Wastes (Management & Handling) Rules, 2000
- E-waste (Management and Handling) Rules 2011
- Batteries (Management and Handling) Rules, 2001
- The Public Liability Insurance Act, 1991

(5) BBMP

BBMP is one of Municipal Corporation, it is responsible for infrastructural assets of the Greater Bangalore Metropolitan area.

BBMP comprises of Core area with three administrative zones i.e., East, West & Central, and eight (8) ULBs (Urban Local Bodies) consisted of seven (7) CMC (Bytrayanapura, Yelahanka, K.R. Puram, Mahadevpura, Bommanahalli, R.R. Nagar and Dasarahalli) and one (1) TMC i.e., Kengeri, and 110 Villages. The total area of BBMP is 800 km^2. While, Bengaluru Metropolitan Region under the responsibility of Bengaluru Metropolitan Region Development Authority (BMRDA) comprises Bengaluru Urban district, Bengaluru Rural district and Ramanagara District. Since 2007 BMRDA covers an area of 8,005 km^2 (refer to Figure 2.1.2).

(6) Karnataka Lake Conservation and Development Authority (KLCDA)

Karnataka Lake Conservation and Development Authority Act 2014 has been constituted vide Gazette Notification No. SAMVYASHAE 07 SHASANA 2012, Bengaluru dated March 7th, 2015 for Lake Conservation and Development.

The Karnataka Lake Conservation and Development Authority Rules has come into existence on March 5th, 2016.

As per the KLCDA Act 2014, the jurisdiction of authority applies to all the lakes in the Karnataka State located within the limits of all Municipal Corporations and Bengaluru Development Authority or any other water bodies or lakes notified by the Government from time to time.

The functions of KLCDA:

- To exercise regulatory control over all the lakes within its jurisdictions including prevention and removal of encroachment of lake;
- To protect, conserve, reclaim, regenerate and restore lakes to facilitate recharge of depleting groundwater by promoting integrated approach with the assistance of concerned Government departments, local and other authorities;
- To take up environmental impact assessment studies for any or all lakes;
- To take up environmental planning and mapping of lakes and their surrounding areas with the help of geographical information system and prepare database and atlas of lakes and their catchments;
- To prepare a plan for integrated development of lakes;
- To improve and also create habitat (wetlands) for aquatic biodiversity, water birds and aquatic plants for reducing wastewater and non-point sewage impacts;

- To facilitate for impounding storm water drainage system, reduce or remove siltation of lakes by taking up appropriate soil and water conservation measures including afforestation and to augment recharge of groundwater aquifers and revive bore-wells;
- To improve and monitor water quality, conserve lake ecology on a need basis and to protect them against domestic and industrial pollution;
- To utilize or allow to utilize the lakes for the purpose of drinking water, fishing, irrigation, education or tourism or any other purpose as the Authority may determine;
- To encourage participation or communities and voluntary agencies and to launch public awareness programmes for lake conservation, preservation and protection of lakes;
- To advise on any matter that may be referred to it by the Government or any institution ;
- To promote integrated and coordinated applied research on all the relevant issues pertaining to lakes;
- To do such other acts as the Authority may consider necessary, conducive or incidental, directly or indirectly, to achieve the object of this Act.

(7) PHI (Public Health Institute)

PHI (Public Health Institute) is one of the oldest health institutions and conducts sample tests for food and water in its laboratories. Water samples from both Government and Private Institutions are received to examine and analyze bacteriological and chemical parameters. For current project work, 40% of the water samples for monsoon season are analyzed for bacteriological and chemical parameters in PHI laboratory.

2.2.4 Water Quality and Sewage Discharge Standards in India

(1) Drinking Water Standard

The Indian water quality standard for drinking water purpose is shown in Table 2.2.12.

Table 2.2.12 Indian Drinking Water Standard (BIS 10500: 2012)

S/N	Parameters	Unit	Accepta-ble Limit	Permissi-ble Limit	Method	Reference
Physico-Chemical						
1	Turbidity	NTU	1.0	5.0	Nephelometric	IS 3025 (Part-10)
2	pH	-	6.5 – 8.5	6.5 – 8.5	Conductivity Cell Potentiometric	IS 3025 (Part-11)
3	Conductivity (EC)	µhmos/cm	-	600		
4	Total Dissolved Solids	mg/l	500	2,000	Gravimetric	IS 3025 (Part-16)
5	Carbonate (CO_3)	mg/l	-	-	Calc. pH & Alkalinity	EPA manual
6	Bicarbonate (CO_3)	mg/l	-	-		
7	Calcium (Ca)	mg/l	75	200	EDTA Titrimetric	IS 3025 (Part-40)
8	Magnesium	mg/l	30	100	Calc. TH & Ca	IS 3025 (Part-46)
9	Total Hardness (Ca-CO_3)	mg/l	200	600	EDTA Titrimetric	IS 3025 (Part-21)

S/N	Parameters	Unit	Accepta-ble Limit	Permissi-ble Limit	Method	Reference
10	Sodium (Na)	mg/l	-	200*	Flame Emission Pho-tometric	EPA manual
11	Potassium (K)	mg/l	-	10**		EPA manual
12	Sulphate (SO_4^{2-})	mg/l	200	400	Nephelometric	IS 3025 (Part-24)
13	Nitrate (NO_3^-)	mg/l	45	45	UV-Spectrophoto	IS 3025 (Part-34)
14	Phosphorous (P)	mg/l	-	5**/2.2	Ammmonium Hepta Molybdate – spect.	EPA manual
15	Fluoride (F)	mg/l	1.0	1.5	Ion Selective Electrode	IS 3025 (Part-60)
16	Chloride (Cl^-)	mg/l	250	1,000	Argentometric Titra-tion	IS 3025 (Part-32)
17	Free Residual Chlorine (Min)	mg/l	0.2	1	Colorimetric	IS 3025 (Part-26)
Heavy Metals						
1	Iron (Fe)	mg/l	0.3	0.3	AAS/Phenanthroline: Spec.	IS 3025 (Part-53)
2	Lead (Pb)	mg/l	0.1	0.1	AAS	IS 3025 (Part-47)
Bacteriology Analysis						
1	Total Coliforms	MPN/ 100ml	Nil	Nil	Multiple Tube Fer-mentation	IS1622
2	Faecal Coliforms	MPN/ 100ml	Nil	Nil	Elevated Temperature Fermentation	IS1622
Pesticides (Organochlorine)						
1	Benzen Hexa Chloride	µg/l	-	2	Gas Chromatography	USEPA58
2	Aldrin	µg/l	-	0.03	Gas Chromatography	USEPA58
3	Endosulfan-I (α)	µg/l	-	0.04	Gas Chromatography	USEPA58
4	Endosulfan-I (α)	µg/l	-	0.04	Gas Chromatography	USEPA58
5	o.p. (Orthopara)-DDT	µg/l	-	1.0	Gas Chromatography	USEPA58
6	p.p. (para-para) DDT	µg/l	-	1.0	Gas Chromatography	USEPA58

Note:* WHO Guideline **: EU Guideline
Source: JICA Survey Team

(2) Effluent Discharge Standards

Effluent discharge standards are specified with reference to the type of industry, process or operations and in relation to the receiving environment or water body such as inland surface water, sewers, land or sea (refer to Table 2.2.8). In case of discharge from WTP, the standard for inland surface water is applied.

The general BOD limit specified for discharge of wastewater from typical industrial sources or domestic sewage is same at 100mg/L. However, the rules specify that the discharge limits can be made stringent if the concerned State Pollution Control authority finds it appropriate depending on the condition of the receiving environment and severity of the discharges from various sources.

(3) Effluent Standard of Sewage Treatment Plants

As per the directions under section 18 (1) (b) of the Water Prevention and Control of Pollution Act, 1974 regarding treatment and utilization of sewage which was issues from CPCB to KPCB (Karnataka Pollution Control Board) on April 21st, 2015 the following effluent discharge standard as shown in Table 2.2.13 for sewage treatment plants was established.

Table 2.2.13 Effluent Discharge Standards for Sewage Treatment Plant

S/N	Parameters	Unit	Parameters Limit
1	pH	-	6.5 – 9.0
2	BOD_5	mg/l	Not more than 10
3	COD	mg/l	Not more than 50
4	TSS	mg/l	Not more than 20
5	NH_4-N	mg/l	Not more than 5
6	N-total	mg/l	Not more than 10
7	Fecal Coliform	MPN/100ml	Less than 100

Notes 1: These standards shall be applicable for discharge in water resources as well as land disposal. The standards for fecal coliform shall not be applied for use of treated sewage in industrial purposes.

Notes 2: The standards shall be applied for new STPs after the date of the issuance and within 5 years for existing STPs.

Source: CPCB

(4) Reuse of Treated Sewage

As per the notification of No. FEE 316 EPC 2015 dated January 20th , 2016 which was issued by the undersecretary of Forest, Ecology and Environmental Department of Karnataka state, the following directions were made;

- All apartments with more than 50 units shall treat sewage in their own STPs and reuse the treated sewage within its premises
- Planning authorities of BDA (Bangalore Development Authority) and BBMP shall insist for installation of STPs in residential apartments with 50 units and above irrespective of existence of sewer line and treatment of sewage to urban reuse standards and to reuse the same within their premises

To ensure reuse of treated sewage for non-potable purposes, the state government issued the direction in exercise of the powers delegated to the authorities as listed in Table 2.2.14 and Table 2.2.15 shows the activities on installation of new STPs for ensuring treated sewage.

Table 2.2.14 Direction by Karnataka State regarding Reuse of Treated Sewage

S/N	Designation of Authorities	Directions
1	BBMP, BDA, BMRDA, All City Corporations	The authorities in left-hand columns shall approve the plan for construction of buildings and development in respect of activities listed in Table 2.2.11.
2	BWSSB	The authority shall provide water connection to the activities under the direction in Table 2.2.11.

S/N	Designation of Authorities	Directions
3	DMA (Director of Municipal Administration)	The authority shall approve the plan for construction of building and development in respect of activities listed in Table 2.2.11.
4	Karnataka Urban Water Supply and Sewerage Board	The authority shall provide water connection to the activities under the direction in Table 2.2.11.
5	Town Planning Department	The authority shall approve the plan for construction of building and development in respect of activities listed in Table 2.2.11
6	KIADB (Karnataka Industrial Areas Development Board)	The authority shall approve the plan for construction of building and development in respect of activities listed in Table 2.2.11
7	KSPCB (Karnataka State Pollution Control Board)	The authority shall ensure that the activities listed in Table 2.2.11 are also established along with STPs of appropriate capacity and mechanism for reuse of treated water.

Source: Forest Ecology & Environment Secretariat Notification, 19,01,2016, Gazette issued by GoK

Table 2.2.15 List of Activities to Need Installation of STPs for Ensuring Reuse of Treated Water

S/N	Activities
1	All residential group housing projects / apartments with 20 units and above or having a total built up area of 2,000 m^2 including basement
2	Commercial construction projects with total built up area of 2,000 m^2 and above
3	Educational institutions with or without hostel facility having total built up area of 5,000 m^2 and above
4	Townships and area development projects with area an of 10 acres and above

Source: Forest Ecology & Environment Secretariat Notification, 19,01,2016, Gazette issued by GoK

2.3 Socio-Economic Profile

Bengaluru city is fast developing as administrative, industrial, trade and commercial, and educational center. Indian Telephone Industries, Hindustan Machine Tools, Indian Space Research Organization, Hindustan Aeronautics Limited, Aeronautical Development Agency and several internationally reputed Electronics and Computer Software Industries are located in Bengaluru. Many multinational companies have shifted their corporate offices to Bengaluru from other cities in India. Bengaluru essentially has a capital goods industrial base.

2.3.1 Population, Income and Housing

(1) Population

The trend of the population in BBMP is shown in Table 2.3.1. With a total population of over 11.5 Million, BBMP is ranked at number three spot in terms of most populous city of India. As the city represents modern face of developed Indian economy, a large number of people have migrated from other states to BBMP. BBMP has witnessed a huge growth in its population between years 2001 to 2011. From a small figure of the population of 5.1 Million in 2001, its population has grown to 8.5 Million in 2011. One of

the main reasons of the huge growth is the Cosmopolitan nature of the city. Being a major IT hub of South India, the vibrant metropolitan area of BBMP invites people from far and wide. Over the years, it has attracted Millions of people from India and abroad who have settled here permanently due to various reasons.

Table 2.3.1 Trend of Population in BBMP

Year	Total	Core	ULBs	110 Villages
2011	8,494,962	5,422,033	1,969,414	1,103,515
2016	9,495,298	5,636,817	2,440,189	1,418,292
Literacy Rate in BBMP	89%			

Source: 2011- census data; 2016- projected

(2) Income in Karnataka State

In terms of income among the major States across the country, Karnataka ranked 4th for the year 2015-16, while Maharashtra state ranked the top with the figure of 1,792,122 crore INR (17,921 Billion INR). Karnataka's income for the year was 907,839 crore INR (9,078 Billion INR). Table 2.3.2 shows the ranking of per capita income in the Karnataka state on a yearly base. Of the 30 districts in Karnataka, the per capita income of only six (6) districts is above the state's average, 126,976 INR. Bengaluru Urban tops the list of high income districts, followed by two coastal districts of Dakshina Kannada and Udupi. Two Malnad districts Chikkamagaluru and Shivamogga, and Bengaluru Rural are in the fourth, fifth and sixth place, respectively, for the years of 2013 and 2014.

Table 2.3.2 Ranking of Per Capita Income in Karnataka State

Rank	District	Annual Per Capita Income in Rupee
1	Bengaluru Urban	271,387
2	Dakshina Kannada	218,580
3	Udupi	176,479
4	Chikkamagaluru	168,412
5	Shivamogga	127,655
6	Bengaluru Rural	127,264
.....	.....	.....
25	Raichur	73,851
26	Belagavi	72,428
27	Vijayapura	71,482
28	Bidar	70,543
29	Yadgir	69,014
30	Kalaburagi	67,886
	State Average	126,976

Source: Karnataka Economic Survey 2015-16

(3) Housing

The current status on housing condition in BBMP is shown in Table 2.3.3 comparing with those of the average of Karnataka State. The rate of housing ownership for Bengaluru Urban was less than 40 %, while those of the state average and Bengaluru Rural were over 70 %. Four (4) members were dominant as household size in most of the districts although the household size of two (2) or three (3) members was identified only in Bengaluru Urban unlike those of other districts. The trend of nuclear families in connection with urbanization is estimated to be progressing in this area. With regards to the status on the facilities of water distribution and sewerage network in households, in Bengaluru Urban treated tap water is distributed in the households of slightly less than 70 % and the utilization of tube wells was identified in the households of over 15 %. However, in Bengaluru Rural, the development of the distribution facility of treated tap water is identified only in 19.5 % of its household, which is behind those of the state average. The Electric services for Bengaluru Urban is almost 80%, while for Bengaluru Rural less than 70%.

Table 2.3.3 Current Status on Housing Condition

Ownership

District	Ownership Status in %			
	Owned House	Rental House	Others	Total
State Average	74.2	23.0	2.8	100
Bengaluru Urban	38.4	58.7	2.9	100
Bengaluru Rural	73.0	24.7	2.3	100

Number of Rooms

District	Number of Dwelling Rooms in %							
	No Exclusive Room	One Room	Two Rooms	Three Rooms	Four Rooms	Five Rooms	Six Rooms or Above	Total
State Average	13.4	32.8	28.5	14.4	6.6	2.3	2.0	100
Bengaluru Urban	7.0	33.2	31.7	18.4	6.4	1.9	1.4	100
Bengaluru Rural	15.3	38.8	29.6	11.1	3.6	0.9	0.7	100

Household Size

District	Household Size in %							
	One	Two	Three	Four	Five	Six to Eight	Nine or Above	Total
State Average	4.0	9.6	15.4	26.2	18.9	20.7	5.2	100
Bengaluru Urban	4.5	13.2	21.3	29.9	15.6	13.1	2.3	100
Bengaluru Rural	4.3	10.4	16.7	30.0	17.4	17.6	3.7	100

Availability of Drinking Water Facility (%)

Water Source Type	Tap Water			Well			Hand pump	Tube well	Spring	River, Canal	Tank, Pond, Lake	Other Source
	Total	From Treated Source	From Un-treated Source	Total	Covered Well	Un-covered Well						
State Average	66.1	41.2	24.8	9.0	1.0	8.0	5.5	15.9	0.3	0.8	0.9	1.4
Bengaluru Urban	79.1	66.6	12.5	0.8	0.5	0.3	0.5	16.4	0.1	0.1	0.3	2.7
Bengaluru Rural	66.8	19.5	47.3	0.6	0.3	0.3	1.0	28.0	0.0	0.0	0.0	3.4

Source of Lighting (%)

District	Source of Lighting					
	Electricity	Kerosene	Solar Energy	Oil	Other Source	No Lighting
State Average	66.1	41.2	24.8	9.0	1.0	8.0
Bengaluru Urban	79.1	66.6	12.5	0.8	0.5	0.3
Bengaluru Rural	66.8	19.5	47.3	0.6	0.3	0.3

Source: "CENSUS OF INDIA 2011, Housing, Household Amenities and Assets - Karnataka", Directorate of Census Operations, Karnataka

2.3.2 Education

BBMP has one of the best educational institutions in India and the standard of education is considered to be very high compared to many other states in the country. It is for this reason that students graduating from the Universities in Bengaluru are one of the most sought after by the multinationals, Corporates and big industrial houses.

Bengaluru is a hub for education for students from all over India and many parts of the world as well. The Common Entrance Test popularly called the CET for admission into the professional course like Engineering, Medicine, Information Technology is very popular throughout the country that students from every nook and corner of India tries their might to get come out successful seeking admission to the various institutes and colleges of Karnataka in general and Bengaluru in particular. Institutions here have excelled in the deliverance of high-quality education in various disciplines to enable students to be prepared for a highly competitive working environment after graduation.

The following is the list and number of educational facilities;

- Primary schools: 2,772
- High schools: 1,177
- Pre-University schools: 209
- Engineering Colleges: 26
- Medical Colleges (Allopathy) : 9
- Medical Colleges (General): 6
- Dental Colleges: 12
- Law Colleges: 13

- Universities: 4
- Libraries: 170

2.3.3 Culture and Religion

Karnataka presents a rich diversity of linguistic and ethnicities that are native to the state combined with their long histories and contributed immensely to the varied cultural heritage. Apart from Kannadigas, Karnataka is also home to Tuluvas, Kodavas and Konkanis. Minor populations of Tibetan Buddhists and tribals like Soligas, Yeravas, Todas and Siddhis also live in the state.

The population by religion is shown in Table 2.3.4. Hinduism is majority religion in BBMP with 78.87 % followers. Islam is second most popular religion in city of Bengaluru with approximately 13.90 % following it. In Bengaluru city, Christianity is followed by 5.61 %, Jainism by 0.97 %, Sikhism by 0.15 % and Buddhism by 0.15 %. Around 0.01 % stated 'Other Religion', approximately 0.44 % stated 'No Particular Religion'.

Table 2.3.4 Population by Religion

Religion	Total Population (person)	Percentage
Hindu	6,700,092	78.87 %
Muslims	1,181,077	13.90 %
Christian	476,834	5.61 %
Jain	82,197	0.97 %
Not Stated	37,244	0.44 %
Sikh	12,412	0.15 %
Buddhist	5,150	0.06 %
Others	486	0.01 %

Source: BBMP Website (Year 2011 data)

2.3.4 Slums

The survey carried out by KSCB (Karnataka Slum Clearance Board) and their consultants has established that urban poor live in slums and focus on slums and the inmates would basically address the issues relating to urban poor. The CDP (City Development Plan) has taken into account all the slums spread throughout BBMP (broken down into 3 zones of Bengaluru city and 5 zones in combination of ULB and 110 Villages). The total number of slums captured in the survey is 569 as shown in Table 2.3.5 and the number of households that are proposed to be redeveloped under JNNURM scheme is estimated to be 166,066.

Table 2.3.5 Profile of Slums in BBMP

Declared Slums				
No.	**Zone**	**No. Slums**	**Households**	**Population**
1	East	52	20,154	81,025
2	West	69	24,905	102,054
3	South	82	27,946	127,777
4	Yelahanka	2	227	1,112
5	Mahadevpura	8	2,192	13,729

Declared Slums				
No.	**Zone**	**No. Slums**	**Households**	**Population**
6	Bommanahalli	2	849	3,050
7	R.R. Nagar	9	1,839	9,195
8	Dasarahalli	4	2,549	9,807
Total		228	80,661	347,749
1	East	70	11,438	45,711
2	West	27	8,113	35,670
3	South	31	12,882	51,391
4	Yelahanka	11	5,151	22,503
5	Mahadevpura	14	5,518	22,018
6	Bommanahalli	91	18,987	83,705
7	R.R. Nagar	49	16,879	84,395
8	Dasarahalli	48	6,437	25,524
Total		341	85,405	370,917
Grand Total		569	166,066	718,666

Source: BBMP Website (Year 2011 data)

Urban poor communities in BBMP are characterized by:

- Poor sanitation with over 50% of the households without latrine or drainage;
- High illiteracy rates which are three times as high as in non-slum areas;
- Higher infant and child mortality rates than the urban averages;
- A higher proportion of especially disadvantaged groups;
- A low level of utilization of existing services (such as maternal and child health care);
- High initial enrolment in primary education, but a high drop-out rate (20-50%) in particular among the girls

Each of these failures adds to the toll on people already deeply burdened by poverty and constrains the enormous potential for human development that urban life offers. The common issues faced by people are:

- Lack of basic municipal services-water, sanitation, waste collection, storm drainage, street lighting, paved footpaths, roads for emergency access.
- Lack of schools and clinics within reach, safe areas for children to play.
- Lack of community toilets
- Lack of places for the community to meet and socialize.
- As the average age of people in BBMP is increasing, the average age of slum dwellers is decreasing, so the youth suffer most from unhealthful conditions.
- Visible disparities between slums and better-off neighborhoods increase the social tensions in poorer areas.
- Unplanned growth of settlements makes conventional service provision complicated.

2.3.5 Economy in Bengaluru Urban District

Karnataka, India's biotech capital, is home to over 60% of all biotechnology companies in India having a base in BBMP and driving 50% of the total revenues in the national biotechnology sector. It is the destination of choice for global and domestic biotech investments in India. Bengaluru Urban District also generates revenue mainly from IT exports, stamps and registration tax, excise duty, commercial tax and motor vehicle tax.

Karnataka is leading IT hub of the country. Bengaluru Urban District is the 2nd largest technology cluster in the world after Silicon Valley. The district has emerged as IT Start-up Capital of India with more than 30% of national share. There are 33 Billion US$ of IT exports in the year 2014-15 and more than 400 out of Global Fortune. 500 companies outsource their IT services from BBMP. 50% of the world's SEI CMM (Software Engineering Institute - Capability Maturity Model) and Level 5 certified companies locate in the District. There exist almost all leading IT companies of the world, including Infosys, Wipro, Tata Consultancy Services, Oracle, Dell, IBM, Microsoft, Accenture, Cognizant, etc.

2.3.6 Social Services

(1) Electric Power

In Karnataka state, the generation, transmission and supply of the electricity are undertaken by different companies as shown in Table 2.3.6. The state established PCKL (Power Company of Karnataka Ltd.) as a SPV (Special Purpose Vehicle) to promote development of construction of power station utilizing private investment. The installed capacity of the power generation by energy source in Karnataka State is shown in Table 2.3.7. The grid map is shown in Figure 2.3.1.

Table 2.3.6 Implementation Bodies relating to Power Electricity in Karnataka State

Name of Company	Function
Karnataka Power Corporation Limited (KPCL)	Generation
Power Company of Karnataka Limited (PCKL)	Procurement for Power Projects
Karnataka Power Transmission Corporation Limited (KPTCL)	Power Transmission
Bengaluru Electricity Supply Company Limited (BESCOM)	Power Supply
Mangalore Electricity Supply Company Limited (MESCOM)	
Hubli Electricity Supply Company Limited (HESCOM)	
Gulbarga Electricity Supply Company Limited (GESCOM)	
Chamudeshwari Electricity Supply Corporation Limited (CESCO)	
The Hukkeri Rural Electricity Cooperative Society Ltd (HRCSL)	

Source: "Study on Business Base Development in India", METI, 2015

Table 2.3.7 Source-wise Installed Capacity

No.	Energy Source	Capacity in MW as on 31st, 2015
1.	Hydro	3,773
2.	Thermal	2,720
3.	Diesel	108

No.	Energy Source	Capacity in MW as on 31st, 2015
4.	CGS (Cogeneration System)	2,169
5.	NCE (Natural Clean Energy) Source	5,082
6.	IPP (Independent Power Producer)	1,200
Total		15,052

Source: Energy Department of Karnataka State Website

The following are discussions on the electric supply with reference to existing conditions and requirements for the planned project.

1) There is an existing 220/66 kV KPTCL substation within the BWSSB premises, which is currently providing power supply to the existing CWSS Stage I, II, III, IV – Phase 2 & 2. Power supply to proposed Stage V also can be tapped from the existing 220/66 kV substation by adding 1 unit. of 220/66kV, 100 MVA transformer. This substation has provisions for receiving 4 nos. of incoming 220kV lines from Hootagally, Somanahalli, Kollegal-1 & 2 and under this arrangement power supply reliability is maintained in case of any incoming line failure/shutdown/maintenance.

   Power required for CWSS Stage V works at TK Halli is roughly estimated at 16.5MW. Power supply arrangement with respect to the Stage v works has been described to Executive Engineer, KPTCL 220kV substation, TK Halli under letter no. BWSSB/EE(K-3)/AEE (K-3)-2/AE/577/2015-16 dated 30-09-2015.

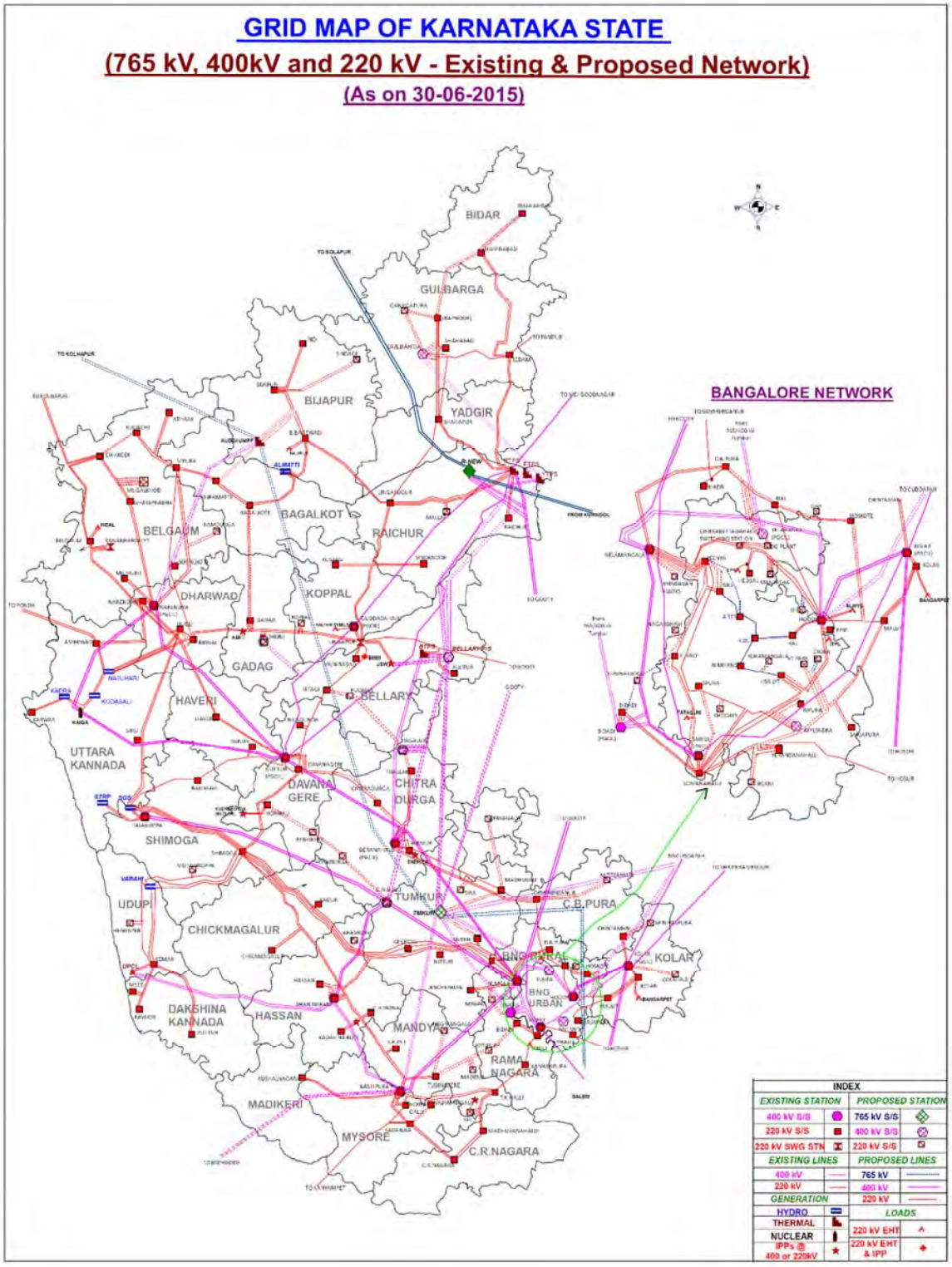
2) There is an existing 220/66kV substation within the Harohalli BWSSB remises. Power supply to the existing Stage I, II, III and IV Phase 1 & Phase 2 have been provided from this substation. 220 kV supply at this substation has been tapped with Loop-in Loop-out arrangement (LILO) at Harohalli from the 220 kV between TK Halli and Somanahalli. This substation has provision for receiving 2 nos. of incoming 220 kV lines from TK Halli and Somanahalli and under this arrangement, power supply reliability is maintained in case of any incoming line failure/shutdown/maintenance.

   Estimated total power required for Stage V works at Harohalli is 17.2 MW. Power supply to proposed Stage V also can be tapped from the existing 220/66kV substation by adding 1 unit. of 220/66kV, 50 MVA transformer. This substation is operated and maintained by BWSSB, thus clearance and permissions from KPTCL is not necessary.

3) There is an existing 220/66kV substation within the Tataguni. BWSSB premises and is currently maintained by BWSSB. Power supply to the existing Stage I, II, III & IV Phase 1 & 2 has been provided from this substation. This substation has provision for receiving 2 nos. of incoming 220kV lines from Peenya and Somanahalli and under this arrangement power supply reliability is maintained in case of any incoming line failure/shutdown/maintenance.

Estimated total power required for CWSS Stage V works at Tataguni is 17.0 MW. Power supply to pro-

posed Stage V also can be provided from the existing 220/66kV substation by adding 1unit. of 220/66kV, 50 MVA transformer. This substation is operated and maintained by BWSSB, thus clearance and permissions from KPTCL is not necessary.



Source: KPTCL

Figure 2.3.1 Grid Map in Karnataka State

(2) Roads, Traffic and Transportation

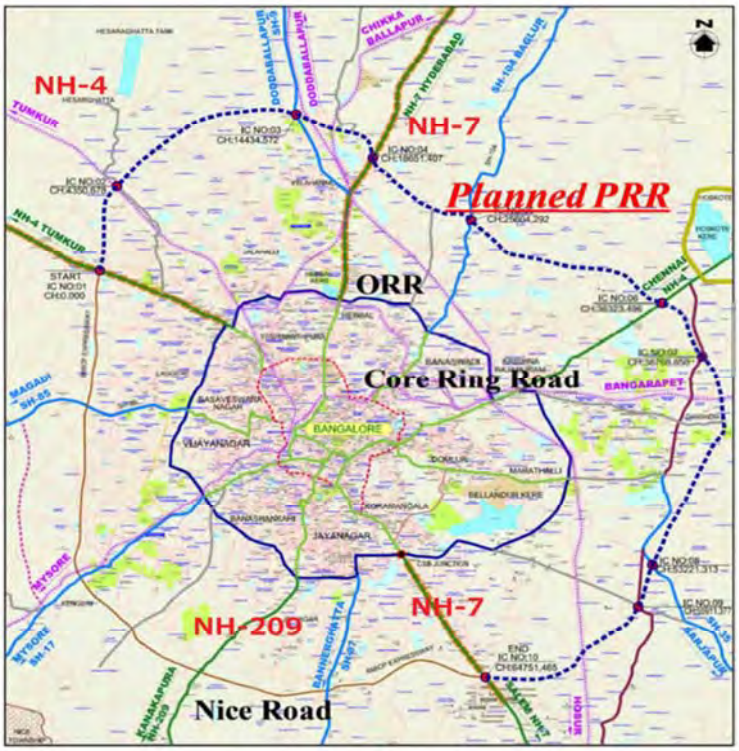
1) Road Network

The total road extension in BBMP area is about 11,000 km which consists of the following radial roads extending from the city center to each direction to rural areas.

- National Highway - 4 (NH-4): It is called as "The Golden Quadrilateral" and runs Mumbai, Bengaluru and Chennai
- National Highway - 7 (NH-7): It runs toward north to Hyderabad and the new air port
- National Highway - 209 (NH-209): It originates Bengaluru city and connects with NH-7 at Din Digul in Tamil Nadu state

In addition, five (5) state roads and IRR (Inner Ring Road) and ORR (Outer Ring Road) run the city center of BBMP area as existing road system. ORR which was constructed in 2002 as bypass highway with its total extension of 65 km to avoid the traffic inflow of heavy vehicles and through traffic into the city center. However, heavy traffic jam has become a daily occurrence even in ORR due to the recent rapid urbanization and the change of the traffic flow after the transfer of the new airport. As new road projects, grade separation projects in major crossings of ORR are currently implemented by BDA, CRR (Core Ring Road) has been proposed by BDA and PRR (Peripheral Ring Road) are currently under planning through utilization of the Japanese ODA loan scheme to mitigate the traffic inflow of above heavy vehicles and through traffic, reduce the traffic flow of ORR.

The road network of Bengaluru metropolitan is shown in Figure 2.3.2.



Source: "The Detailed Planning Survey for the Master Plan Study on the Introduction of Intelligent Transport Systems (ITS) in Bengaluru and Mysore", JICA, 2013

Figure 2.3.2 Road Network of BBMP Area

2) Vehicle Number and Status of Traffic Congestion

The number of registered vehicles is 4.7 Million units as of March 2013. 90% of the total vehicles run through the center of BBMP. About 70% (3.2 Million) of the vehicles is two wheel vehicles. The number of the registered vehicles per day is 3,000 to 4,000 in whole Karnataka state and its increasing rate is estimated at about 10 %.

The status on the traffic congestion in major roads is shown in Table 2.3.8. The rate of V/C (Volume/Capacity) has reached 1.0 in almost all roads with the average speed of 13.5 km/hour. The peak hours are from 9 to 11 am and 5 to 7 pm, when about of 10 percent of the total traffic volume of the 12 hours of daytime is concentrated.

Table 2.3.8 Status on Traffic Congestion in Major Roads

Name of Road	Traffic Volume in 12 Hours		Peak Hour	
	Vehicle No.	PCU	AM	PM
Sankey Road after Cauvery Theater	183,194	185,057	9-10	5-6
Sankey Road near NTI	179,097	182,047	9-10	5-6
Rajajinagar Link Road near Sujatha Theatre	127,741	146,209	10-11	5-6
M. G. Road near Trinity Circle	99,404	109,114	9.45-10.45	6-7
J. C. Road near BBMP Parking Lot	99,821	106,048	10-11	6-7
Ballary Road near Mekhri Intersection Underpass	95,424	100,973	9-11	5-6
K. G. Road near Cauvery Bhavan	69,896	100,455	10.15-11.15	6-7

PCU: Passenger Car Unit

Source: "The Detailed Planning Survey for the Master Plan Study on the Introduction of Intelligent Transport Systems (ITS) in Bengaluru and Mysore", JICA,2013

3) Solid Waste Management

In 2012 BBMP generated 2.1 Million tons of Municipal Solid Waste (195.4 kg/cap/yr). As per the Municipal Solid Waste Management rules 2000, BBMP is responsible for taking the waste management as per the stipulation. For Administrative purpose, BBMP is divided into eight (8) zones, three (3) zones in old area (Core area) and the remaining five (5) zones in new area (adjacent seven (7) CMC's & one (1) TMC).

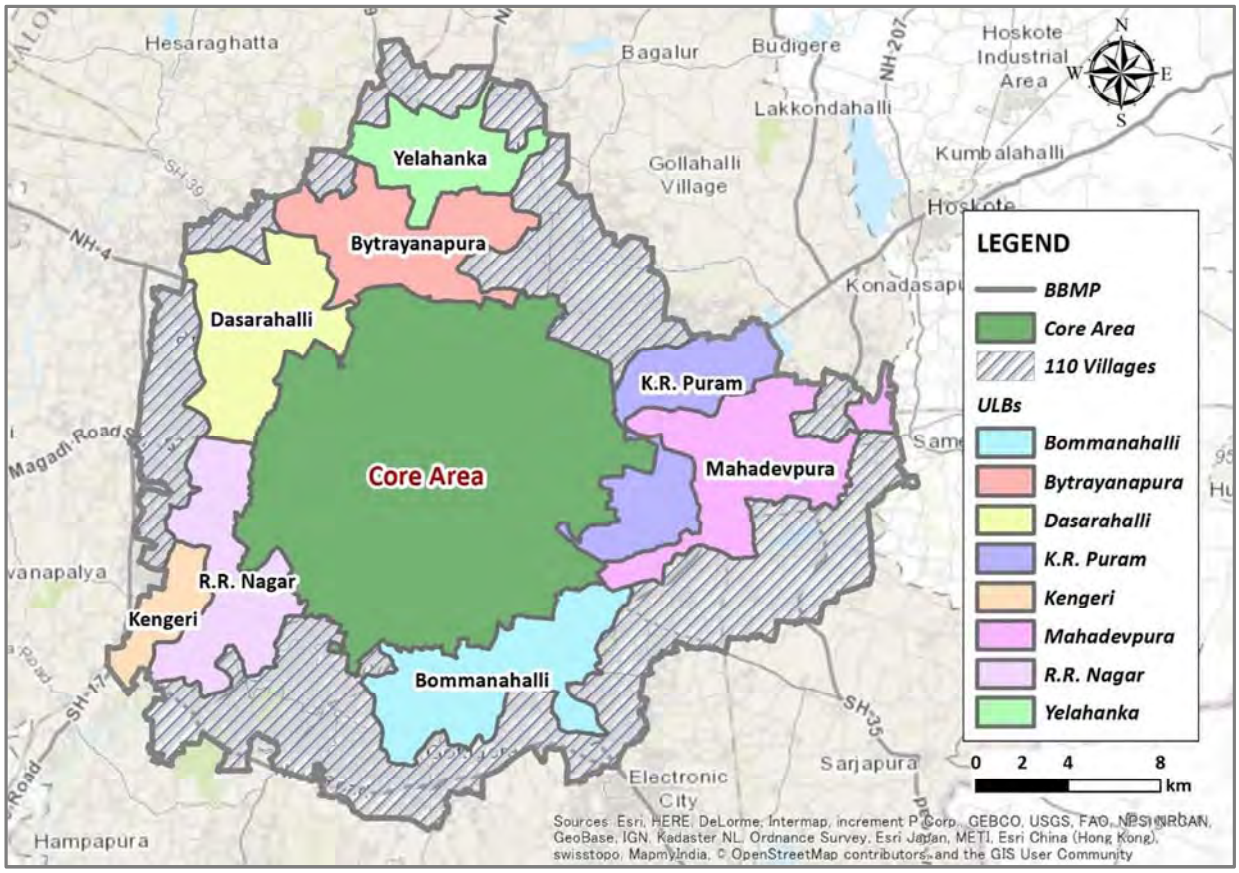
The waste management is summarized below;

- About 70% of the MSW (Municipal Solid waste) activity starting from primary collection to disposal has been outsourced and 30% is managed by BBMP.
- There are about 4,300 Pourakarmikas (Sweepers) of BBMP & 10,000 Pourakarmikas (Sweepers) from contractor who performs door to door collection & sweeping activities.
- In some of the area in the new zones the door to door collection activity is entrusted to Self Help Groups (SHG's). which are basically below poverty women's groups.
- In some of the residential areas the Residential Welfare Associations (RWA's) are involved in Door to Door collection & decentralization of composting the waste Primary Collection (Door to Door collection).

- A primary collection is performed using pushcarts and auto tippers.
- There are around 11,000 pushcarts and 650 auto tippers for Door to Door collection of waste.
- Waste is collected in the unsegregated form as segregation is not practiced at source.
- Secondary collection and transportation: There are about 600 MSW transportation vehicles including Compactors, Tipper Lorries, Dumper placers & Mechanical Sweepers both BBMP and contractors.
- The waste collected from the households is brought to a common point i.e., secondary locations from where the waste is shifted to the treatment sites through compactors & tipper Lorries.
- Segregation at source & the secondary storage is not done hence unsegregated waste reaches the processing plants.
- Street sweeping activity: Street sweeping is performed both manually & mechanically. In some of the highly commercial activity areas sweeping is done at night & in the VIP areas the sweeping is done mechanically.

2.3.7 Administrative Divisions

Figure 2.3.3 shows the existing administrative division with their area size. BBMP is composed of one (1) Core area, eight (8) ULBs and 110 Villages.



Source: JICA Survey Team

Figure 2.3.3 Administrative Map with Area Size of BBMP

2.4 Existing and Future Land Use

2.4.1 Existing Land Use

The City Development Plan (CDP) was prepared by BBMP for the approval from GoK in 2007. Five major zones described blow can be distinguished in the existing land occupation, as indicated in Figure 2.4.1.

- 1st zone: A Core area which consists of the traditional business areas, the administrative center, and the central business district. Basic infrastructure (acceptable road system and water conveyance) in the Core areas is reasonably good, particularly in the south and west part of the city. This zone also has a large distribution of mixed housing /commercial activities.
- 2nd zone: A peri-central area which is located in the surroundings of the Core area and has older, planned residential areas. This area also has reasonably good infrastructure, though its development is more uneven than the Core area.
- 3rd zone: A recently extended area of the city (past five (5)-seven (7) years) flanking both sides of the Outer Ring Road, portions of which are lacking infrastructure facilities.
- 4th zone: A new zone that has developed in the peripheries of the city, with some vacant lots and agricultural lands. During the past few years of rapid growth, legal and illegal land use has come up in the periphery of the city, particularly developed in the south and west. These areas are not systematically developed.
- 5th zone: A green belt and agricultural area in the city's outskirts including small villages. This area is being gradually urbanized.

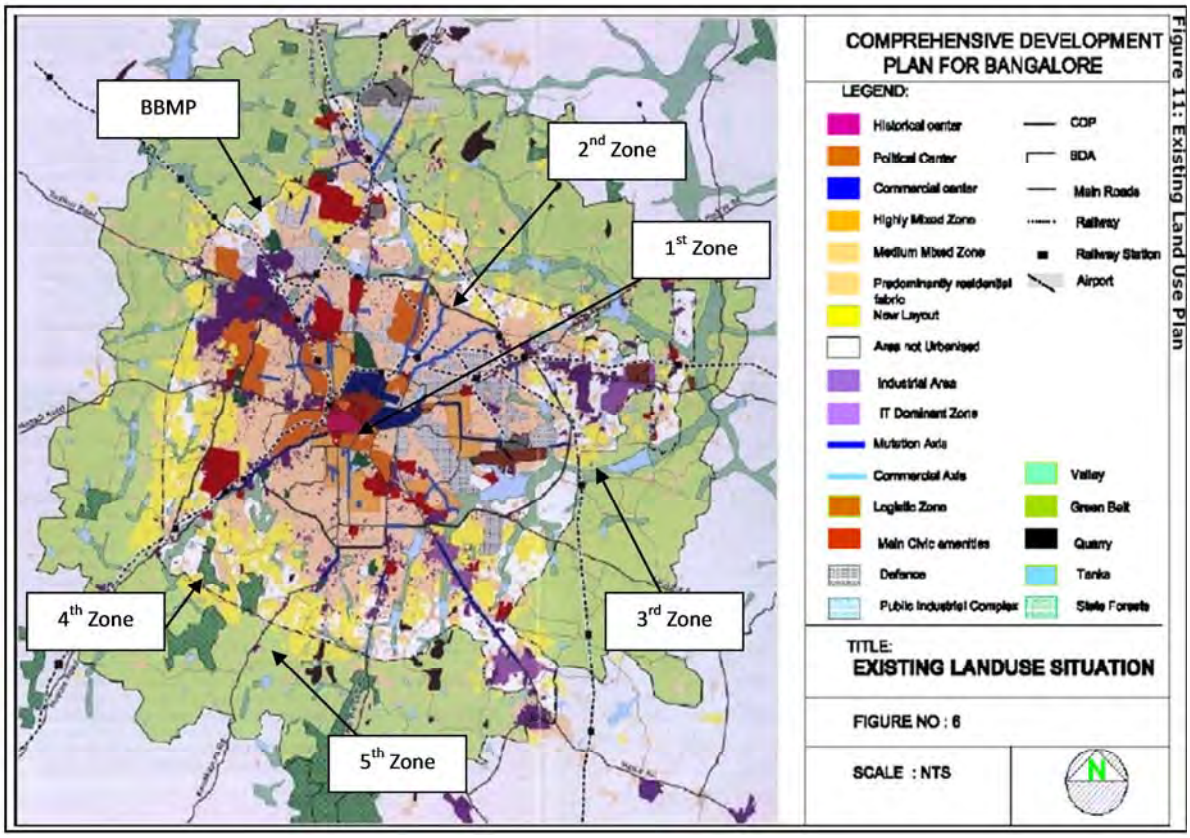
The Core area has been the seat of traditional business and economy (markets and trading), while the peri-central area has been the area of the Public Sector Undertaking (PSU). The new technology industry is concentrated in the east and southeast.

The existing land use pattern in BBMP and its surrounding area is indicated in Table 2.4.1 and Figure 2.4.1.

Table 2.4.1 Existing Land Use Pattern in BBMP and its Surrounding Area

Category	Area in ha	%
Residential	16,042	14.95
Commercial	1,708	1.59
Industrial	5,746	5.36
Park and open spaces	1,635	1.52
Public semi-public area	4,641	4.33
Transportation	9,014	8.40
Public utility	192	0.18
Water area	4,066	3.79
Agricultural land	64,243	59.88
Total	107,287	100

Source: JICA Survey Team



Source: JNNURM Revised City Development Plan

Figure 2.4.1 Existing Land Use Pattern in BBMP and its Surrounding Area

2.4.2 Future Land Use

The Bengaluru Development Authority (BDA) is entrusted with the task of preparing a Comprehensive Development Plan (CDP) as per the KTCP Act. The KTCP Act requires that the CDP be revised every 10 years. Consequently, BDA's mandate is to update the Revised CDP of 1995.

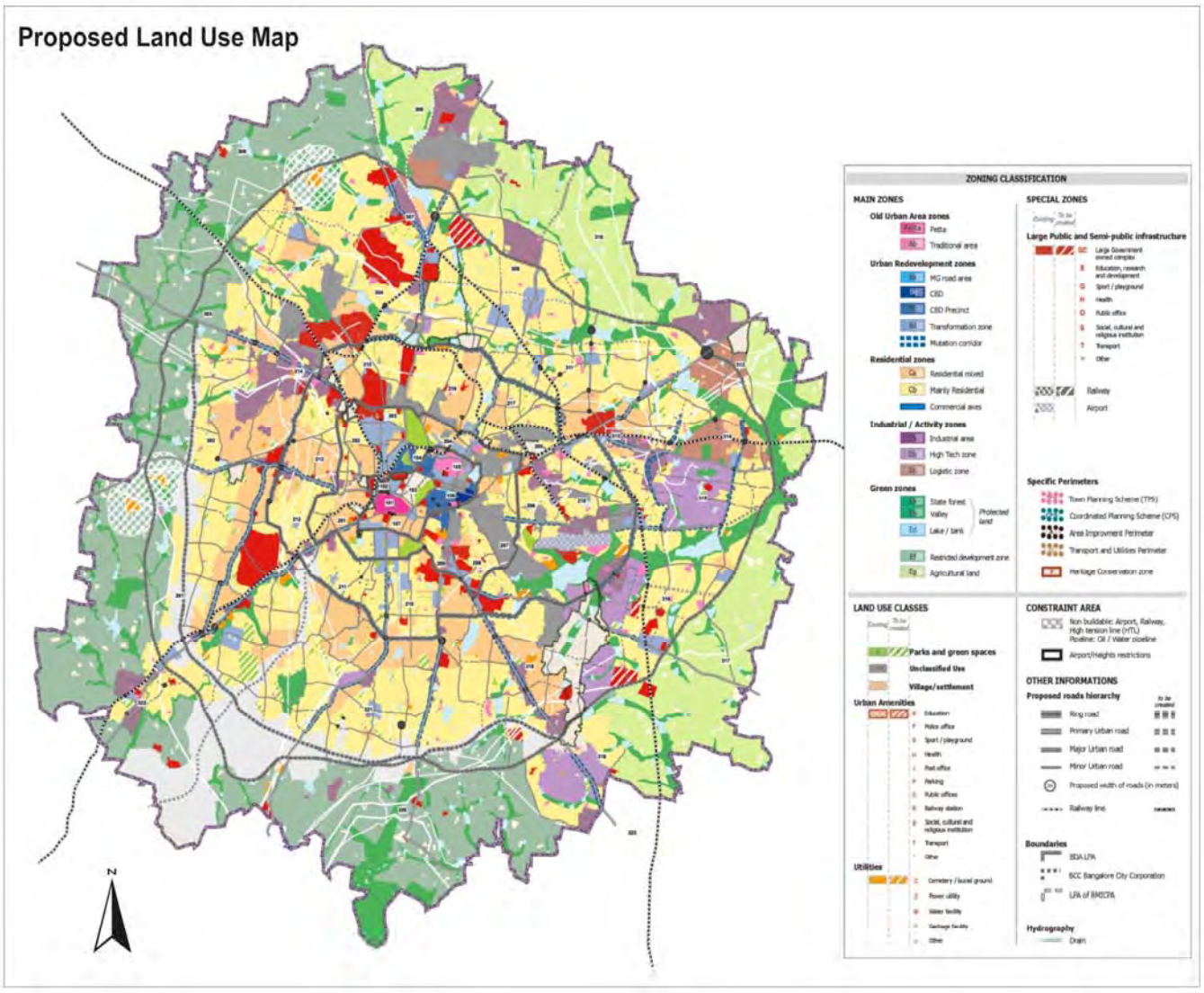
The Draft Master Plan - 2015, prepared under the KTCP Act, covers a Local Planning Area of 1,306 km^2 and consists of 387 villages, seven (7) City Municipal Councils (CMC) and one (1) Town Municipal Council (TMC).

It serves as the foundation for developing strategic plans and local area plans, and finally, designing neighborhood. The Vision 2015 map which was prepared by BDA (Bengaluru Development Authority) defines a framework and general directions to spatially delineate the areas where development is to be focused and promoted. It provides a strategic vision for the city and forms the basis for the Draft Master Plan. The following is the vision;

- Respect the natural environment
- Promote economic efficiency
- Ensure social equity
- Preserve historical heritage
- Ensure efficient and affordable transport systems

- Structure development in relation to a strategic transport network.

Based on the Vision 2015, the proposed land use map as shown in was Figure 2.4.2 prepared.



Source: Draft Master Plan - 2015, Bengaluru Development Authority

Figure 2.4.2 Proposed Land Use Map

Chapter 3 Existing Water Supply and On-going/Planned Water Supply Projects

3.1 Existing and On-going Water Supply

3.1.1 General Conditions on Water Supply in Bruhat Bengaluru Mahanagara Palike

A major water source at present for the water supply in the BWSSB service area is Cauvery River. The served areas cover Core area with blue color and ULBs with grey color in the BBMP area outlined by grey color line, as shown in Figure 3.1.1. Through four stages of CWSS as of March/2017, water has been conveyed from the river to TK Halli (Thorekadanahalli) WTP and pumped up to BBMP area through three (3) staged pumping arrangements at the TK Halli WTP, Harohalli and Tataguni pump stations using 5 sets of large diameter parallel pipelines. Figure 3.1.1 also shows the alignment of main water supply facilities of CWSS within the BBMP which is present jurisdiction of the BWSSB including 110 Villages with light brown color.

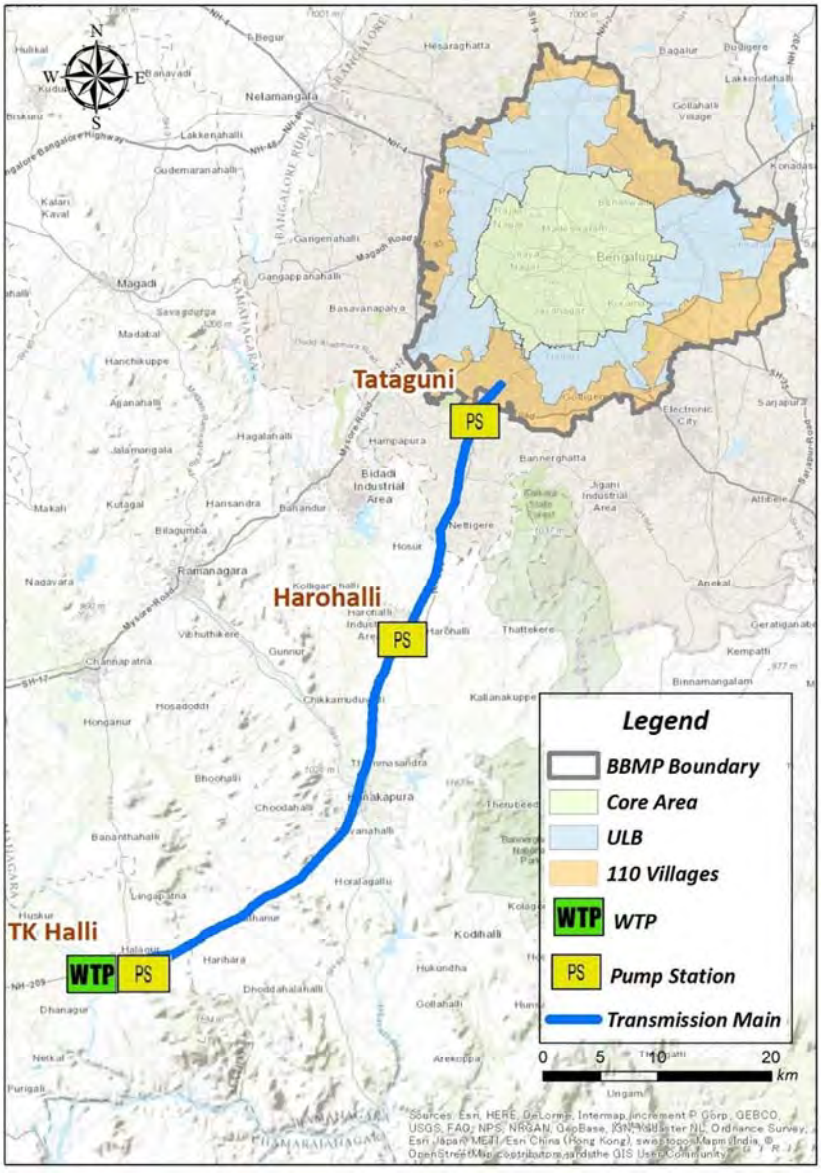


Figure 3.1.1 Location Map of BWSSB Water Supply Facilities

Table 3.1.1 presents the particulars on the increase of design capacity of water supply facilities by stage from 1974 to 2012 (completion year of CWSS Stage IV Phase 2). The capacity of water supply facilities at present is 1,310 MLD in total. Water from TK Halli WTP is distributed to the most part of the Core and ULB areas. Figure 3.1.2 shows the design capacity increase from 1974 to 2016, which is usually used by BWSSB for the presentation of water treatment facilities.

Table 3.1.1 Design Capacity of Water Supply Facilities by Stage

S/N	CWSS Stage, Phase	Design Capacity (MLD)	Year of Commissioning
1	Stage I	135	1974
2	Stage II	135	1982
3	Stage III	270	1992
4	Stage IV, Phase 1	270	2002
5	Stage IV, Phase 2	500	2012
Total		**1,310**	

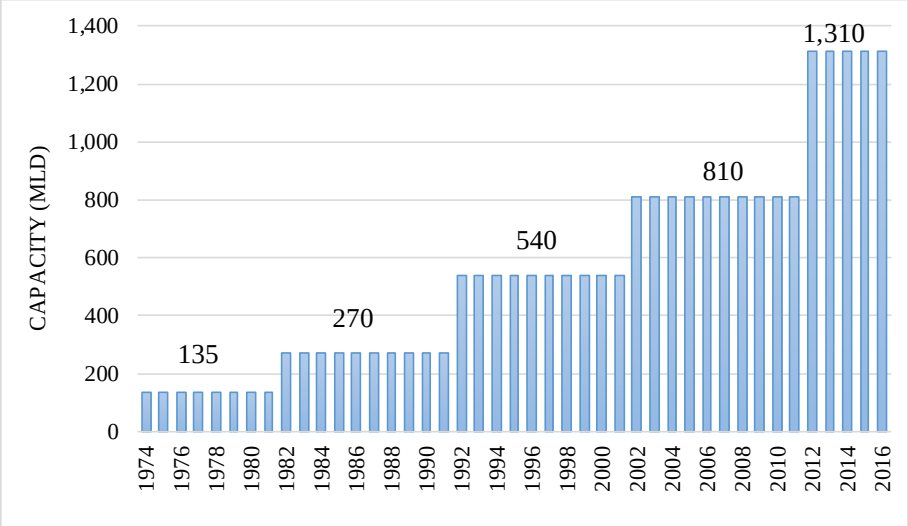


Figure 3.1.2 Increase of Water Supply Capacity to BBMP Area in the Last Half a Century

Figure 3.1.3 presents the overall water supply service area of CWSS Stage I to Stage IV Phase 2 in the BBMP area.

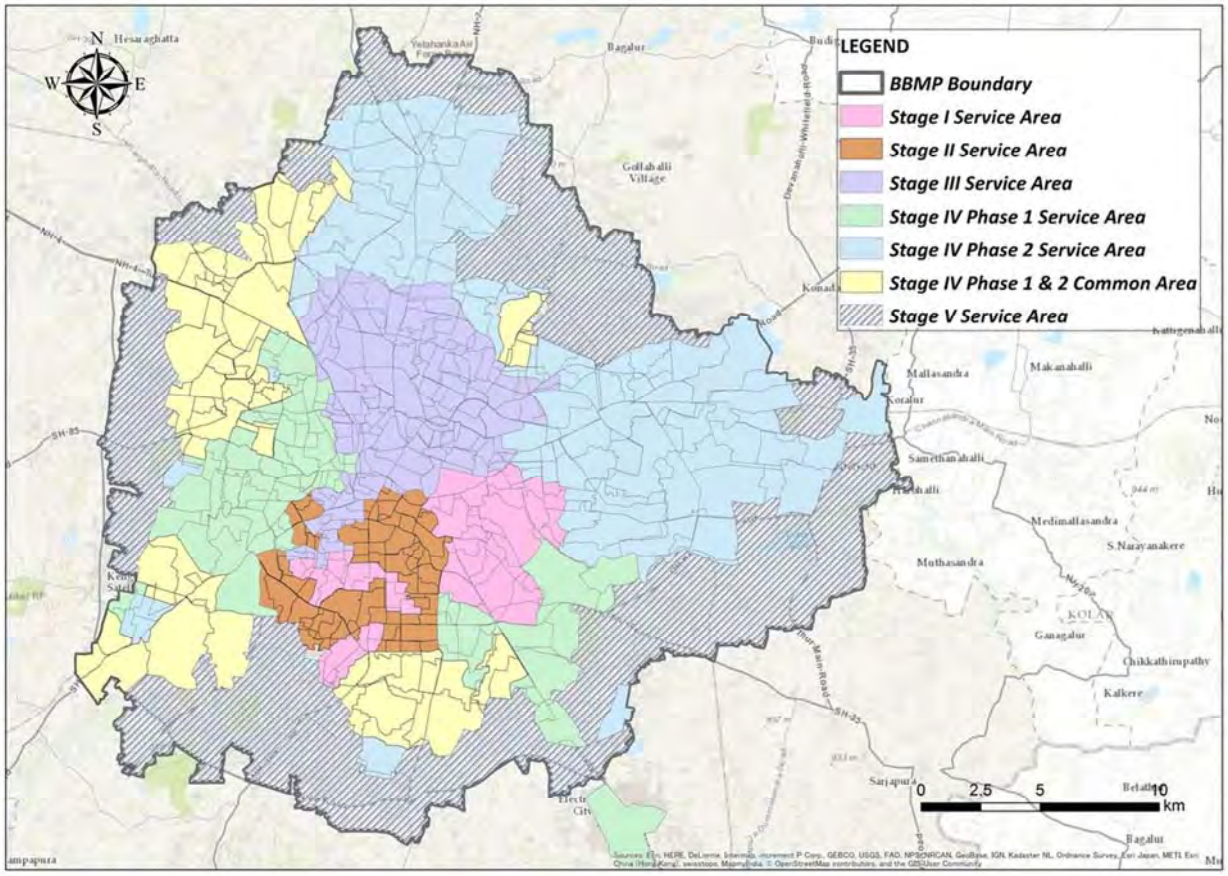


Figure 3.1.3 Overall Water Supply Service Area in the BBMP Area

3.1.2 Population Coverage and Access to Water Services

The salient features of the present water supply system contributed by a series of CWSS through Stage I to Stage IV (Phase 2) is shown in Table 3.1.2. There are 84 GLRs (Ground Level Reservoirs) and 52 OHTs (Over Head Tanks) to receive water from TK Halli WTP and then distribute by gravity system. As shown in Table 3.1.2, The allocated water source amount for the water supply by BWSSB is 1,460 MLD for about 5.8 Million people served for Core and ULB areas (Population in BBMP is about 8.5 Million including 1.1 Million in 110 Villages) through 865,000 house connections.

Table 3.1.2 Salient Features of BWSSB

Item	Figure	Unit
Allocated Water Source Amount from Cauvery River	1,460 *1	MLD
Present Water Supply Amount (Monthly Maximum from June 2015 to May 2016)	1,450 *2	MLD
Present Water Supply Amount (Monthly Average from June 2015 to May 2016)	1,390 *2	MLD
Present Population Served	5,800,000	People

Item	Figure	Unit
Served Area by BWSSB	570	km^2
House Service Connections	865,000	Nos.
Total Length of Water Supply Pipelines	8,746	km
Pipe Diameters' Range	100 to 3000	mm
No. of GLRs	84 GLRs at 51 sites	Nos.
Total Capacity of GLRs	1,064	ML
No. of OHTs	52	Nos.
Total Capacity of OHTs	45.9	ML
No. of Booster Pumping Stations	62	Nos.
No. of Public Faucet	7,477	Nos.
No. of Public Tap	371	Nos.
No. of Water Tanker Lorries	62	Nos.
Quantity of Water Supplied/Month	42,200	ML
Average Cost of Water	28	INR/m^3
Design per Capita Water Consumption (CPHEEO)	150	lpcd
Present per Capita Water Supply	146	lpcd
Present NRW	48	%
Present per Capita Water Consumption	76	lpcd

*1 Allocation to Stage I to III: 730 MLD (734 is rounded)
Allocation to Stage IV Phase 1 and Phase 2: 730 MLD (734 is rounded)
As BWSSB uses 1,460 MLD instead of 1,468 MLD officially, thus JICA Survey Team also use this figure here.
*2 Figures are calculated from the Monthly Details of Water Receipts (Apr/2015 - May/2016)
Source: BWSSB website and JICA Survey Team

3.2 Existing Water Supply Facilities

3.2.1 Intake and Conveyance Facilities

(1) Location of Water Source and Alignment of Conveyance Lines

The water source for all stages of CWSS is river water of Cauvery. River water is transferred to Shiva Balancing Reservoir (SBR) from Shiva Anicut located in the left riverbank of Cauvery River as shown in Figure 3.2.1 (about 120 km far from the center of Bengaluru City) through an open channel. Netkal Balancing Reservoir (NBR) is connected to SBR. The conveyance pipelines with the diameters ranging from 1,750 mm to 3,000 mm are installed from the two (2) reservoirs to TK Halli WTP as shown in Figure 3.2.2.

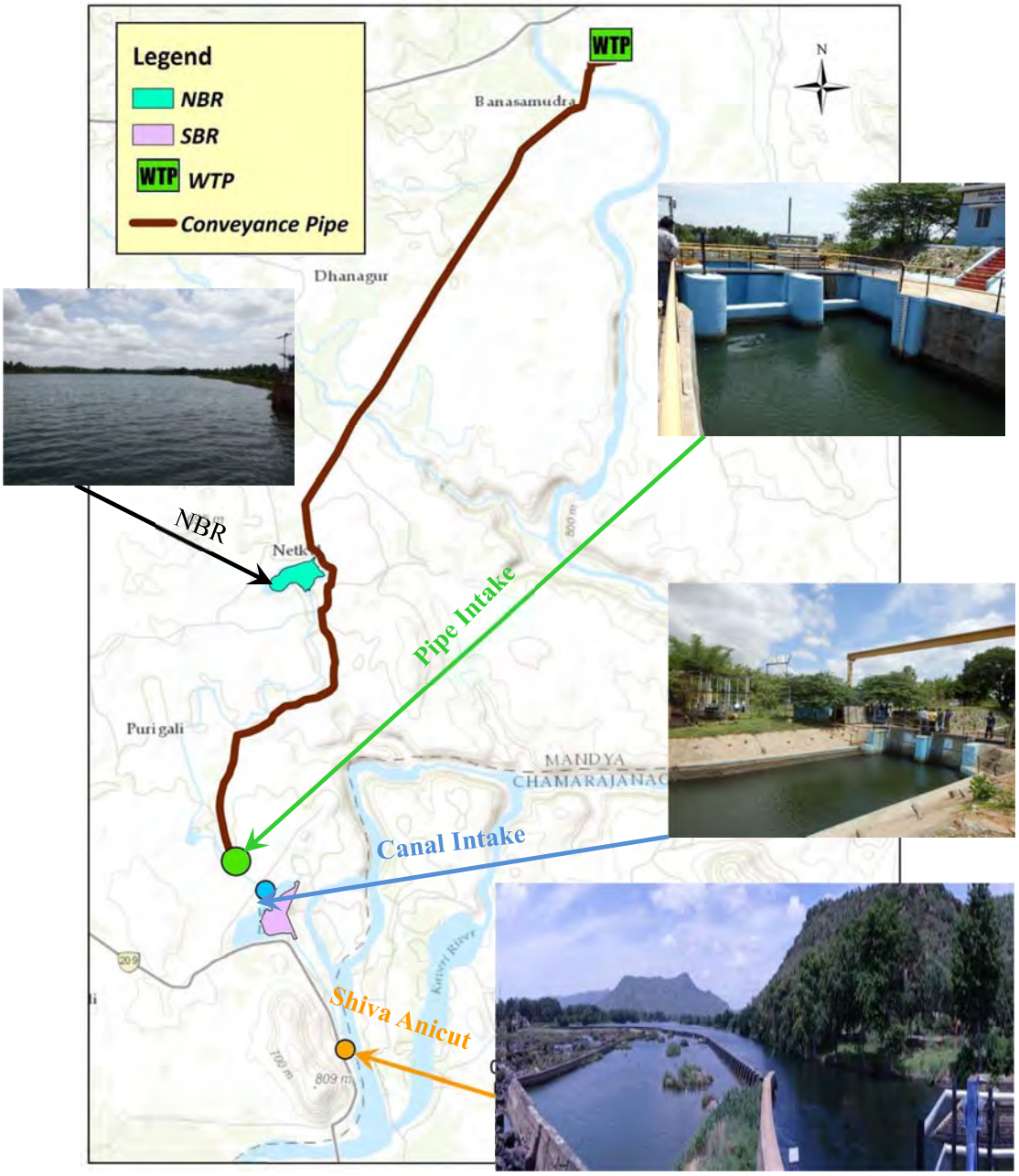


Figure 3.2.1 Location of Intake and Conveyance Facilities

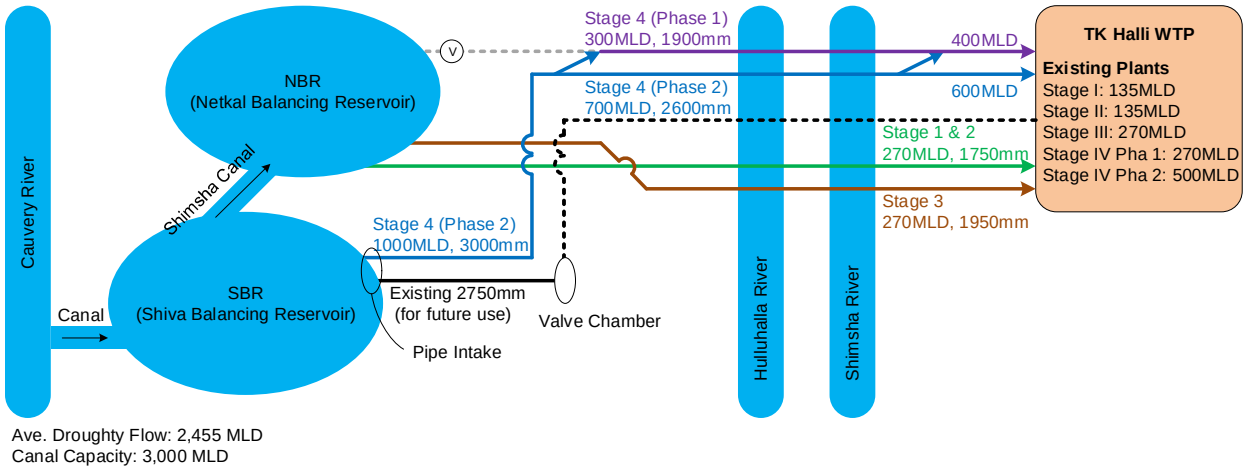


Figure 3.2.2 Schematic View of Water Conveyance in a Series of Projects by CWSS Stage

The raw water is conveyed to the water treatment plant by gravity from pipe intake, which has been constructed in Stage IV. Figure 3.2.3 presents ground elevations of a series of facilities from intake to ground reservoir in the city. Gottigere GLR is located at the mouth of BBMP with the highest elevation, from which the city trunk main for the east route is started see the location of Gottigere GLR in Figure 10.1.1.

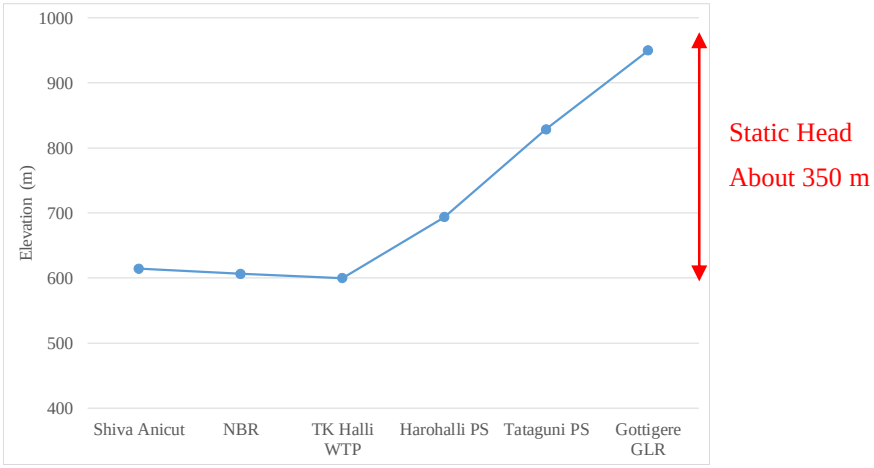


Figure 3.2.3 Ground Levels at Different Locations

(2) Capacity of Conveyance Pipelines

Raw water from Cauvery River flows into SBR through the canal, then into NBR. The water source amount and capacity of WTP in the various stages of the CWSS are summarized in Table 3.2.1. The water source amount as of now based on water right for CWSS allotted from Cauvery River is 1,460 MLD. The capacity of WTPs at TK Halli was designed for the capacity of 1,310 MLD, but it was constructed with some margin, a total of 1,450 MLD (see Table 3.1.2) was recorded as monthly maximum of water supply. Among these figures related to water supply capacity, amount of water source (1,460 MLD) is used for water balance study and for facility design 1,310 MLD is employed as practiced by BWSSB.

Table 3.2.1 Water Source and Capacity of WTP by Stage

S/N	CWSS Stage, Phase	Water Source (MLD)	WTP Capacity (MLD)	Year of Commissioning
1	Stage I	155	135	1974
2	Stage II	155	135	1982
3	Stage III	315	270	1992
4	Stage IV Phase 1	315	270	2002
5	Stage IV Phase 2	520	500	2012
Total		**1,460**	**1,310**	**-**

The raw water is conveyed by MS (Mild Steel) pipelines to TK Halli WTP by gravity. The details of conveyance pipelines for all stages are shown in Table 3.2.2. Intake gates are shown in the photos 3.2.1 and 3.2.2.

Table 3.2.2 Details of Existing Conveyance Pipelines

S/N	CWSS Stage, Phase	Pipeline			Remarks
		Diameter (mm)	Length (km)	Material	
1	Stage I & II	1,750	9.6	MS	Gravity Main from NBR to TK Halli
2	Stage III	1,950	9.6	MS	Gravity Main from NBR to TK Halli
3	Stage IV Phase 1	1,900	9.6	MS	Gravity Main from NBR to TK Halli
4	Stage IV Phase 2	3,000	6.3	MS	Gravity Main from Pipe Intake to NBR
		2,600	9.4	MS	Gravity Main from NBR to TK Halli
5	Additional Raw Water Pipeline*	2,750	16.3	MS	Gravity Main from Pipe Intake to TK Halli

* The pipeline from Pipe Intake to NBR has already been laid for a length of 6.3 km
* DPR for expansion of pipeline from NBR to TK Halli was prepared and presently under the tendering

Photo 3.2.1 Gate for Canal Intake

Photo 3.2.2 Gate for Pipe Intake

3.2.2 Water Treatment Plant

(1) Outline and Capacity

Raw water received from SBR and NBR is treated at TK Halli WTPs constructed at different stages of CWSS before supplying water to BBMP area. Details of existing water treatment works are presented in Table 3.2.3. From the Stage I to Stage III, the contractor was SUEZ, while for Stage IV Phase 1 and 2, Degremont. Degremont has been merged by Suez in 2001 and become a subsidiary of Suez Group. The overall design capacity of existing water treatment plants commissioned at different stages is 1,310 MLD (The total capacity of constructed WTPs is 1,450 MLD based on the instructions by BWSSB to the contractors). BWSSB uses design capacity for discussion of water treatment capacity of constructed facilities from Stage I to Stage IV, though there is a difference between design and constructed figures.

Table 3.2.3 Details of Existing Water Treatment Plants at TK Halli

S/N	WTPs of CWSS	Capacity (MLD)	Year of Commissioning	Contractor	Treatment Process
1	Stage I	135	1974	Suez	Clariflocculator
2	Stage II	135	1982		
3	Stage III	270	1992		
4	Stage IV Phase 1	270	2002	Degremont * (Suez Group)	Pulsator
5	Stage IV Phase 2	500	2012		DAF
Total		**1,310**	-	-	-

*Degremont has been merged by Suez in 2001 and become a subsidiary of Suez Group

(2) Water Treatment Process

1) Coagulation and Sedimentation

Clariflocculator is adopted from Stage I to Stage III, while for Stage IV, Pulsator is used in Phase 1 and DAF (Dissolved Air Flotation) in Phase 2.

a) Clariflocculator

Clariflocculator mechanism is a combination of flocculation (Flocculator) and clarification (Clarifier) in a single basin, which is designed to achieve compact sizing, and construction and cost competitiveness (refer to Figure 3.2.4). It involves two (2) concentric tanks wherein inner tank serves as a flocculation basin and the outer tank serves as a clarifier. These tanks are normally constructed with the range of four (4) meters to a maximum up to seventy meters in diameter and their material could be RCC (Reinforced Cement Concrete) for large size or MS (Mild Steel) for small size.

In the Clariflocculator, the water enters the flocculator, where the flocculating paddles enhance flocculation of the feed solids. As heavy particles settle to the bottom, the liquid flows radially upward in the clarifier zone. The clarified liquid is discharged over a peripheral weir into the peripheral launder. The deposited sludge is raked to the bottom near the central weir from where it is routed to the sludge chamber and discharged.

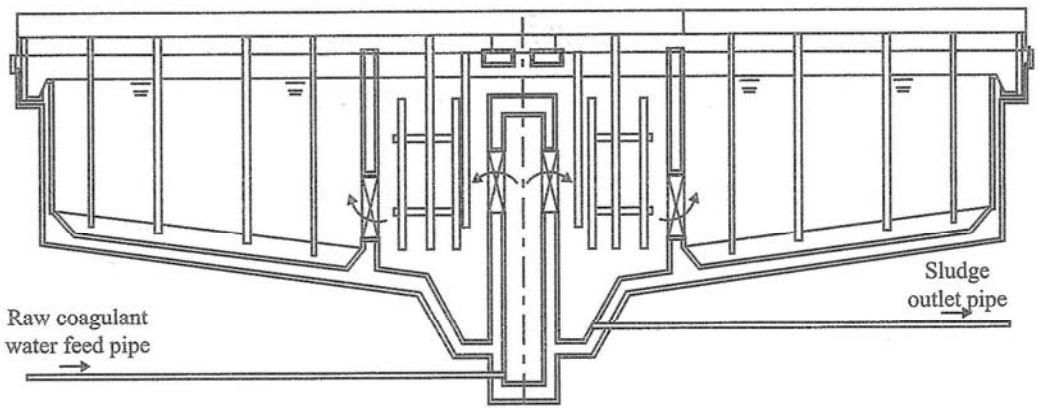


Figure 3.2.4 Section of Clariflocculator

b) Pulsator

The pulsator clarifier is a type of sludge blanket clarifier (refer to Figure 3.2.5) that operates under the principle of an up-flow current through a suspended sludge blanket and it was developed in the early 1950's.

The raw water from the flash mixer is conveyed to the pulsator through the vacuum chamber, where a portion of the incoming water is lifted in the vacuum chamber by applying a vacuum of about 650 mm water gauge using centrifugal fan or vacuum blower. The raised level is released causing increased flow rate through the perforated pipes laid beneath the tank and the water flows upward in parallel streams into the sludge blanket. This creates a pulsating effect in the blanket, which is highly concentrated at the bottom and the concentration decreases progressively to the top. The sludge level is normally two (2) to three (3) m below the water surface.

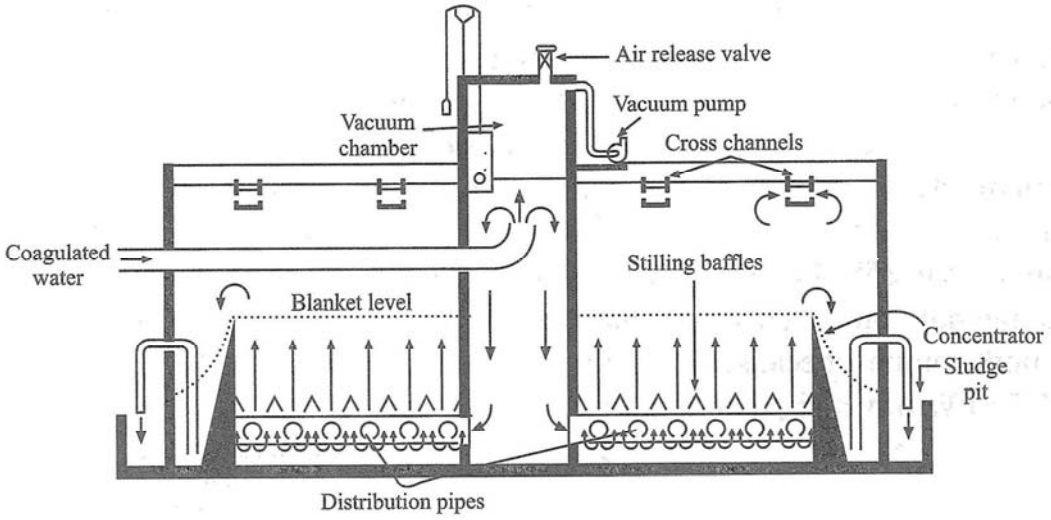


Figure 3.2.5 Water Flow of Pulsator

2) DAF

DAF is a water treatment process that clarifies raw water by separating from suspended solid with dissolving air under pressure in use of the compressor. Upon release of the pressure, microbubbles form in the water and arise up-flow to the surface of the water. At the same time, these microbubbles attach to solids and lift them to the surface, where they can be removed by a surface scraping, skimming mechanism.

In TK Halli WTP (Stage IV Phase 2), the Alum is dosed into the raw water canal and raw water is carried to DAF clarifiers in case the turbidity of it is above 8 NTU. Based on the interview with operators, DAF is used during the rainy season with high turbidity of raw water and the frequency of DAF operation in 2016 was about 20 days. Thus, the suspended substances in raw water are removed in rapid sand filters and it brings high load to filters.

DAF was applied to treat the high turbidity raw water of Cauvery river during the monsoon seasons of CWSS Stage IV Phase 2. However, because the quality of the raw water is relatively high most of the year, a conventional sedimentation process which an O&M cost supposed to be lower than DAF, is recommended in this preliminary design for Stage V.

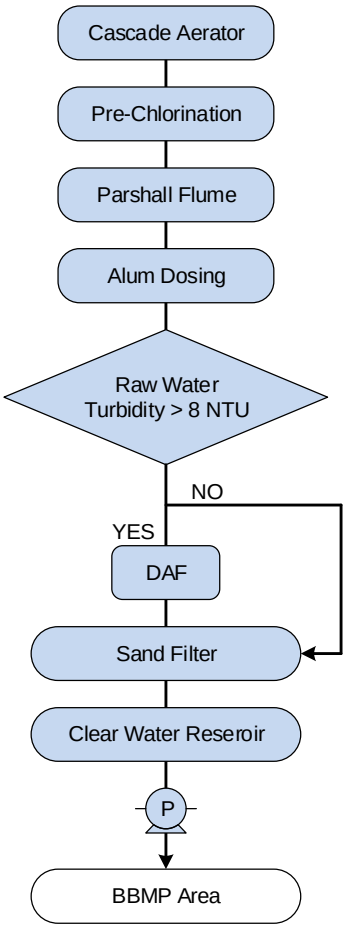


Figure 3.2.6 Treatment Flow of DAF

The treatment process of DAF are summarized in Figure 3.2.6 and water flow of DAF is shown in Figure 3.2.7. Schematic representation of treatment process adopted in CWSS Stage IV Phase 2 is shown in Figure 3.2.8.

Table 3.2.4 shows details of DAF and the following are process descriptions.

i. DAF removes the fine colloidal particles present in water and reduces the turbidity.
ii. After Flash Mixers, coagulated water enters the flocculation zone of DAF where flocculation takes place hydraulically as the water passes through the baffles.
iii. Flocculant/Coagulant Aid is added at the flocculation zone as per the requirement.
A part of the clarified water (DAF outlet) is pumped to a high pressure vessel using high pressure pumps where it is mixed with air at high pressure (5 to 5.5 bar). The mixture of water and air is injected through nozzles to form small air bubbles.
iv. These air bubbles bring up the formed flocs to the surface from where it is removed from time to time as sludge.
v. The clarified water from DAF goes to Sand Filters for filtration.
vi. Sludge from DAF goes to dewatering system where the sludge is separated as cake and the water is recycled back to the inlet.

Table 3.2.4 Details of DAF

Item	Details of DAF	Remark
Number of Basin	10	
Dimension of Basin	L 15.00m x W 14.77m x H 3.90m	
Clarification Rate	27.78$m^3/m^2/hr$	

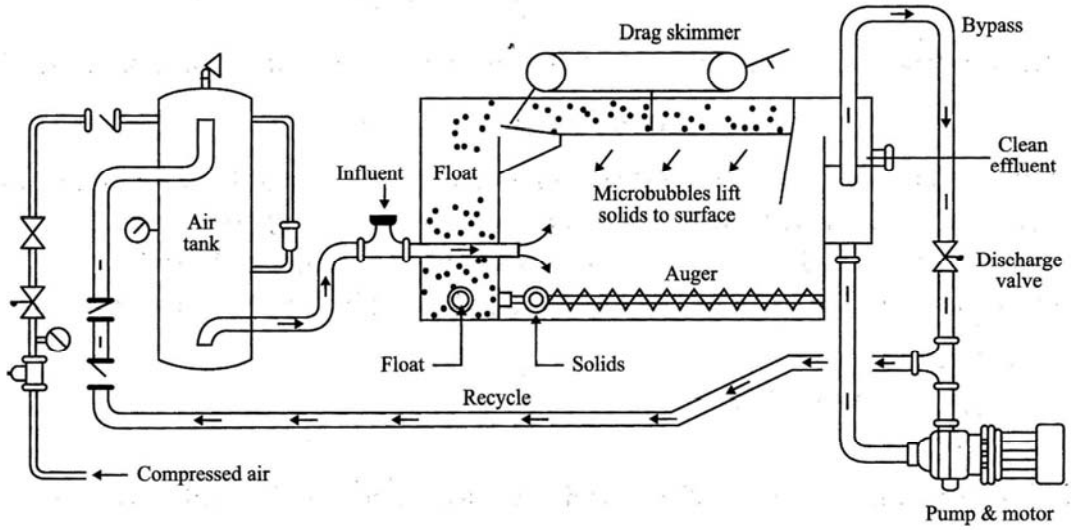


Figure 3.2.7 Water Flow of DAF

3) Sand Filter

Filters of all CWSS stages are single bed type and sands are used as filter media. Table 3.2.5 presents the details of filters. The filter media (sand) is 1.05 m deep and the effective size of the media is 0.9 mm. The filters have false floor with nozzles for uniform distribution and collection of water. Backwash duration is 15 min using air and water.

Table 3.2.5 Details of Filter

Item		Figure of Sand Filter				
		Stage I	Stage II	Stage III	Stage IV Phase 1	Stage IV Phase 2
Number of Unit	(No)	12	12	24	14	24
Dimension of Unit	(m)	12.00 x 9.90	9.47 x 9.74	10.34 x 9.90	16.43 x 9.45	16.43 x 9.45
Filtration Rate	($m^3/m^2/hr$)	6.00	5.13	6.00	7.98	7.98

Source: JICA Survey Team

(3) Situation of Existing WTP

Table 3.2.6 shows inflow rate at the WTP in Stage IV Phase 2 (same as intake flow rate) in the last 7 months (from 2015 to 2016) with a range between 420 MLD and 460 MLD. Table 3.2.7 presents seasonal fluctuation of raw water peak turbidity at the same WTP in the year 2015. The value increases in the summer season up to about 50 - 60 NTU. The turbidity data on the same day available on treated water at WTPs constructed in different stages are shown in Table 3.2.8. The WTPs of Stage IV Phase 1 and 2 se-

cure treated water under 1.0 NTU, even if raw water has high turbidity. However, the older WTPs in Stage I/II/III are affected by raw water quality and treated water quality is insufficient. The major reason of this result is related to design criteria adopted with target turbidity of 5.0 NTU. In order to solve the issue, a new WTP is under construction in TK Halli WTP Complex to replace Stage I and II WTPs.

Table 3.2.6 Inflow Rate at WTP (Stage IV Phase 2, 500 MLD)

Month	Nov. in 2015	Dec.	Jan. in 2016	Feb.	Mar.	Apr.	May
Flow (MLD)	425	423	424	430	437	455	457

Table 3.2.7 Peak Turbidity of Raw Water in 2015 (Stage IV Phase 2)

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.
Turbidity (NTU)	6.85	7.1	5.8	6.1	7.1	33.2
Month	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
Turbidity (NTU)	30.2	32.6	55.23	37.5	33.21	12.2

Table 3.2.8 Seasonal Turbidity of Treated Water Quality at Different Stage WTPs

No	Stage / Phase	Main Treatment Technology	Target Treated Water Quality (NTU)	Low Turbidity (15th Mar. 2016)		High Turbidity (15th July 2016)	
				Raw Water	Treated Water	Raw Water	Treated Water
1	Stage I	Clariflocculator + Filtration	5	4.5	2.6	21	3.1
2	Stage II	Clariflocculator + Filtration	5	4.5	2.5	21	4.5
3	Stage III	Clariflocculator + Filtration	5	4.5	2.6	21	3.3
4	Stage IV Phase 1	Pulsator + Filtration	1	4.0	1.0	25	0.8
5	Stage IV Phase 2	DAF + Filtration	0.5	4.0	1.0	25	0.4

The water quality analysis results in Jun, 2016 at Stage IV Phase 2 WTP is shown in Table 3.2.9. In the data sheet, it is found that pH decreases about 0.6 from raw water to treated water. Treated water quality maintains about 7.7 which meets the drinking water quality standard in India. The maximum and minimum turbidities of treated water are 0.49 and 0.41 NTU as a result of the stable treatment. The chlorine with 2.5 mg/l is added to the treated water. Then, the replenishment chlorination is done at the GLRs in BBMP. Iron and color in the raw water are minimal and meet the standard.

Table 3.2.9 Water Quality Analysis Report (JUN/2016)

BANGALORE WATER SUPPLY & SEWERAGE BOARD

CWSS Stage - IV , Phase - II, 550 MLD W.T.P , T.K.HALLI

DAILY ANALYSIS REPORT JUNE 2016

Date	Raw Water					Treated Water							
	Flow MLD	pH	Turbidity NTU	Res.Cl_2 mg/l	Color	Flow MLD	pH	Turbidity NTU	Res. Cl_2 mg/l	Res.Al mg/l	Iron	Color	Coliform	Fecal Coliform
01-Jun-16	467	8.29	3.91	0.9	<10	465	7.79	0.46	2.5	0.02	0.02	<5	Nil	Nil
02-Jun-16	461	8.23	3.57	1.1	<10	460	7.69	0.46	2.5	0.02	0.03	<5	Nil	Nil
03-Jun-16	471	8.17	3.82	1.0	<10	470	7.64	0.42	2.5	0.02	0.03	<5	Nil	Nil
04-Jun-16	456	8.26	3.53	1.0	<10	455	7.66	0.43	2.5	0.02	0.04	<5	Nil	Nil
05-Jun-16	456	8.24	3.96	1.1	<10	454	7.69	0.44	2.5	0.02	0.05	<5	Nil	Nil
06-Jun-16	460	8.25	3.68	1.2	<10	459	7.64	0.41	2.6	0.02	0.05	<5	Nil	Nil
07-Jun-16	467	8.29	3.31	1.0	<10	466	7.63	0.43	2.5	0.02	0.02	<5	Nil	Nil
08-Jun-16	456	8.26	3.35	1.1	<10	455	7.63	0.47	2.6	0.02	0.05	<5	Nil	Nil
09-Jun-16	451	8.24	3.50	1.0	<10	450	7.62	0.47	2.5	0.02	0.02	<5	Nil	Nil
10-Jun-16	463	8.27	3.28	0.9	<10	461	7.70	0.48	2.6	0.02	0.03	<5	Nil	Nil
11-Jun-16	457	8.24	4.01	0.8	<10	456	7.67	0.48	2.5	0.02	0.03	<5	Nil	Nil
12-Jun-16	451	8.35	3.88	1.1	<10	450	7.75	0.49	2.5	0.02	0.05	<5	Nil	Nil
13-Jun-16	463	8.32	3.19	1.1	<10	461	7.74	0.49	2.5	0.02	0.05	<5	Nil	Nil
14-Jun-16	454	8.28	3.93	1.0	<10	453	7.79	0.49	2.5	0.02	0.06	<5	Nil	Nil
15-Jun-16	465	8.33	3.93	1.0	<10	464	7.77	0.46	2.5	0.02	0.02	<5	Nil	Nil
16-Jun-16	448	8.35	3.65	1.1	<10	447	7.76	0.48	2.5	0.02	0.02	<5	Nil	Nil
17-Jun-16	460	8.36	3.55	1.0	<10	459	7.73	0.48	2.5	0.02	0.03	<5	Nil	Nil
18-Jun-16	459	8.38	3.45	1.0	<10	458	7.76	0.48	2.5	0.02	0.03	<5	Nil	Nil
19-Jun-16	460	8.33	3.88	1.0	<10	459	7.75	0.42	2.5	0.02	0.04	<5	Nil	Nil
20-Jun-16	466	8.33	3.60	0.9	<10	465	7.74	0.43	2.5	0.02	0.05	<5	Nil	Nil
21-Jun-16	460	8.30	3.38	1.0	<10	458	7.75	0.45	2.5	0.02	0.05	<5	Nil	Nil
22-Jun-16	461	8.32	3.96	1.0	<10	460	7.76	0.48	2.5	0.02	0.02	<5	Nil	Nil
23-Jun-16	453	8.32	3.95	1.0	<10	452	7.76	0.47	2.5	0.02	0.05	<5	Nil	Nil
24-Jun-16	463	8.32	3.97	0.9	<10	462	7.75	0.46	2.5	0.02	0.05	<5	Nil	Nil
25-Jun-16	460	8.33	3.55	0.8	<10	459	7.75	0.45	2.5	0.02	0.02	<5	Nil	Nil
26-Jun-16	474	8.30	3.56	1.0	<10	472	7.71	0.44	2.5	0.02	0.03	<5	Nil	Nil
27-Jun-16	456	8.32	3.79	1.0	<10	455	7.72	0.46	2.6	0.02	0.03	<5	Nil	Nil
28-Jun-16	467	8.27	3.68	0.9	<10	465	7.69	0.47	2.5	0.02	0.05	<5	Nil	Nil
29-Jun-16	466	8.27	3.98	1.0	<10	465	7.70	0.48	2.5	0.02	0.05	<5	Nil	Nil
30-Jun-16	444	8.27	3.85	1.1	<10	442	7.68	0.45	2.5	0.02	0.06	<5	Nil	Nil
Average	**460**	**8.29**	**3.69**	**1.0**	**<10**	**459**	**7.71**	**0.46**	**2.5**	**0.02**	**0.04**	**<5**	**Nil**	**Nil**

Source: SUEZ

Figure 3.2.8 shows treatment flow of WTP (Stage IV Phase 2).

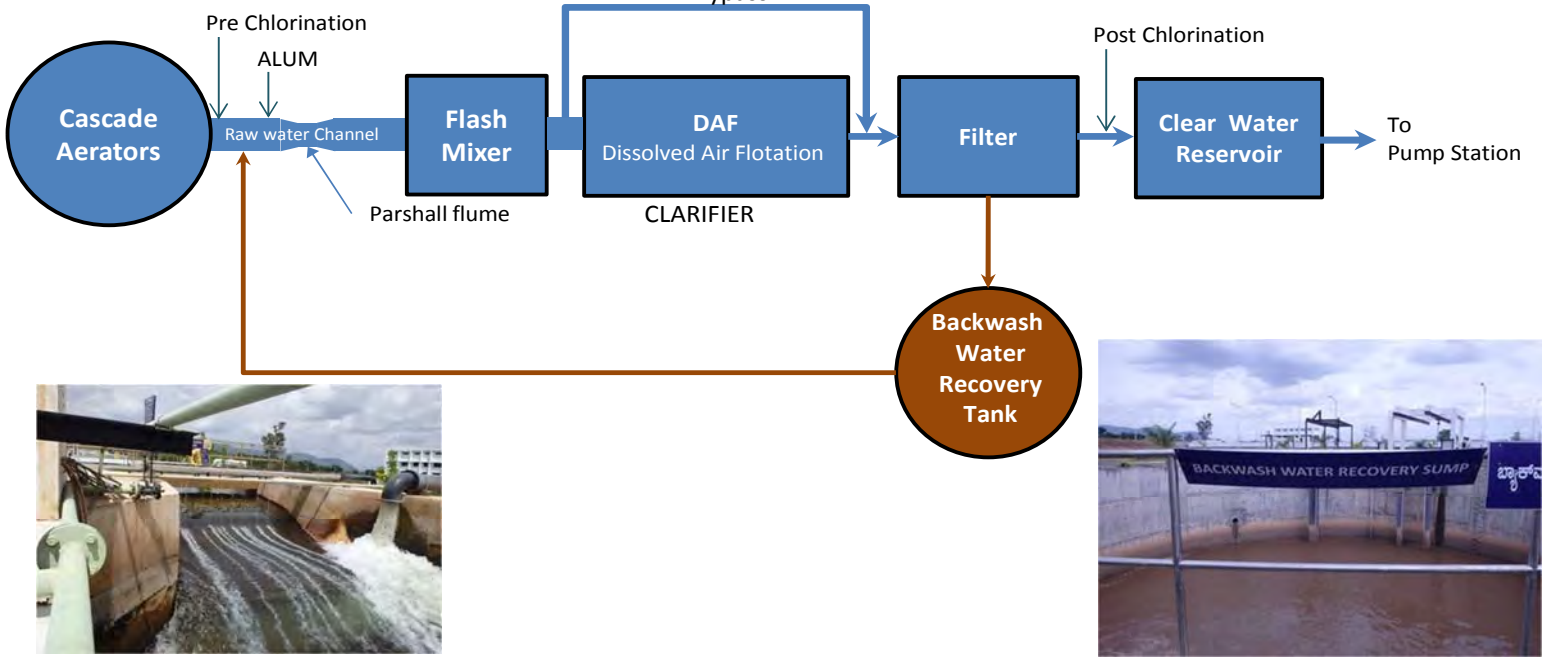


Figure 3.2.8 Treatment Flow at TK Halli WTP (Stage IV, Phase 2)

3.2.3 Water Transmission Facilities

(1) Pump Station

Bengaluru city is located on a highland, which is about 120 km far from and 360 m higher than TK Halli WTP. Hence, treated water must be conveyed and lifted to BBMP area by a pumping system. In all stages of CWSS, treated water is lifted at pump house of TK Halli, Harohalli and Tataguni and transmitted to GLRs in BBMP by parallel transmission pipelines. The elevations at pump stations is given in Table 3.2.10 and Figure 3.2.9 shows the location of pump stations.

Table 3.2.10 Elevations at Pump Stations

S/N	Pump Station	Elevation (m)	Difference of Elevation (m)	Remark
1	TK Halli	600	97	
2	Harohalli	697		
3	Tataguni	825	128	

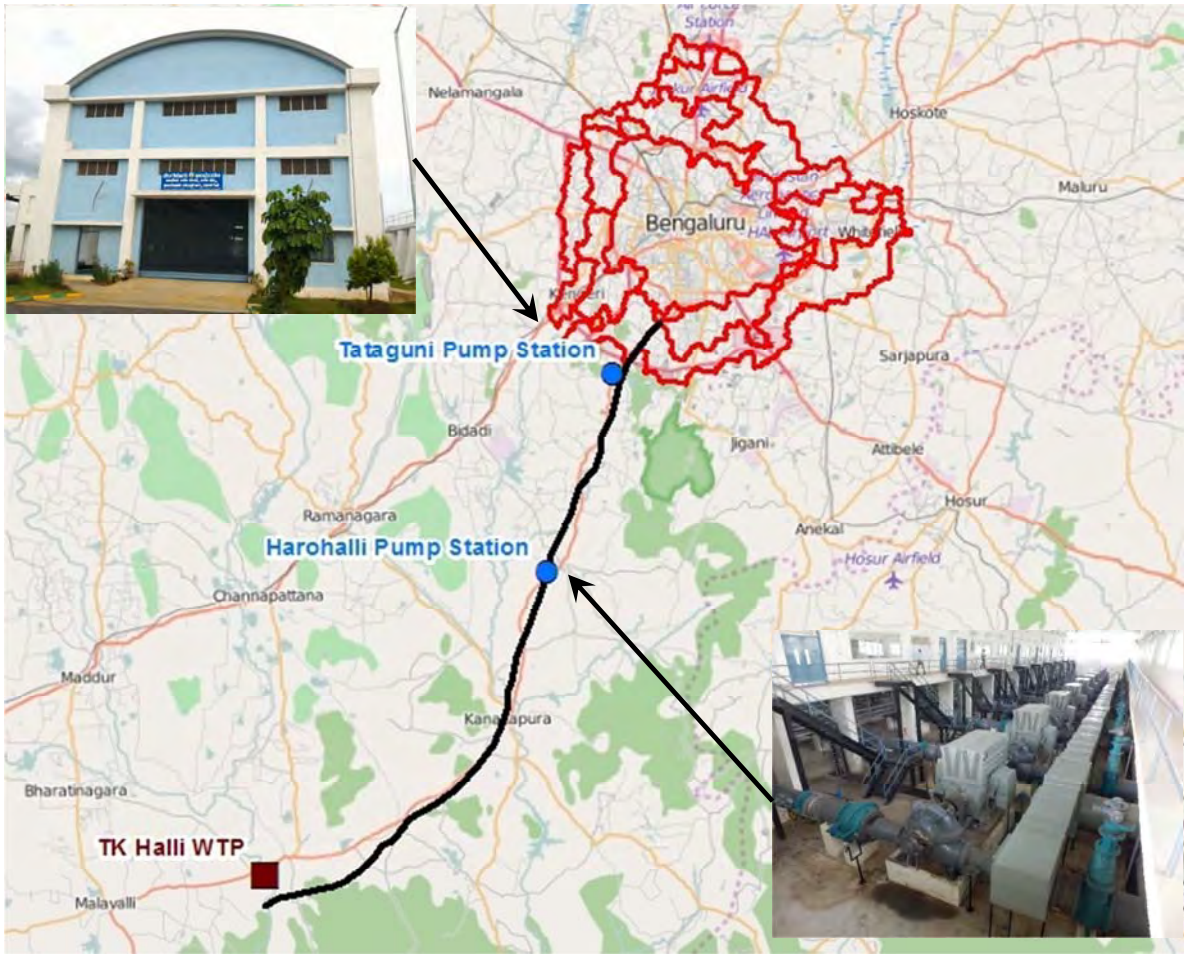


Figure 3.2.9 Location of Transmission Facilities

Photo 3.2.3 TK Halli Pump Station

Photo 3.2.4 Air Chamber at TK Halli WTP

Figure 3.2.10 shows schematic view of transmission facilities. Table 3.2.13 shows details of transmission pump facilities.

(2) Water Hammer Protection Facilities

Air vessels are installed to each existing PS and surge tanks are also constructed to prevent the water hammer damages on pipes and pumps. The specification of air vessels are summarized in Table 3.2.11 and the specification of surge tanks are shown in Table 3.2.12.

Table 3.2.11 Specification of Air Vessels

Stage / Phase of CWSS	Location / Surge Vessel Specification		
	TK Halli PS	Harohalli PS	Tataguni PS
Stage I	Total: 390 Cum (97.5 Cum x 4 Nos.) (Dia: 3 m, Height: 13.8 m, Vertical)	Total: 53 Cum (26.5 Cum x 2 Nos.) (Dia: 3 m, Height: 7.5 m, Vertical)	Total: 161 Cum (80.5 Cum x 2 Nos.) (Dia: 3 m, Height: 11.4 m, Vertical)
Stage II	Total: 390 Cum (97.5 Cum x 4 Nos.) (Dia: 3 m, Height: 13.8 m, Vertical)	Total: 53 Cum (26.5 Cum x 2 Nos.) (Dia: 3 m, Height: 7.5 m, Vertical)	Total: 161 Cum (80.5 Cum x 2 Nos.) (Dia: 3 m, Height: 11.4 m, Vertical)
Stage III	Total: 510 Cum (84.83 Cum x 6 Nos.) (Dia: 3 m, Height: 12.0 m, Inclined)	Total: 113 Cum (56.5 Cum x 2 Nos.) (Dia: 3 m, Height: 8.0 m, Inclined)	Total: 254 Cum (84.66 Cum x 3 Nos.) (Dia: 3 m, Height: 12.0 m, Inclined)
Stage IV Phase 1	Total: 570 Cum (95 Cum x 6 Nos.) (Dia: 3 m, Height: 13.9 m, Inclined)	Total: 240 Cum (85 Cum x 4 Nos.) (Dia: 3 m, Height: 9.7 m, Inclined)	Total: 285 Cum (95 Cum x 3 Nos.) (Dia: 3 m, Height: 13.9 m, Inclined)
Stage IV Phase 2	Total: 791 Cum (98.875 Cum x 8 Nos.) (Dia: 3 m, Height: 14.86 m, Inclined)	Total: 648 Cum (108 Cum x 6 Nos.) (Dia: 3 m, Height: 16.64 m, Inclined)	Total: 721 Cum (103 Cum x 7 Nos.) (Dia: 3 m, Height: 15.26 m, Inclined)

Table 3.2.12 Specification of Surge Tanks

S/N	Stage / Phase of CWSS	Specification of Surge Tank at JG Doddi
1	Stage I	Surge Tank Volume: 622 m^3, (Dia: 6.0 m, Depth: 22.0 m)
2	Stage II	Surge Tank Volume: 628 m^3, (Dia: 10.0 m, Depth: 8.0 m)
3	Stage III	Surge Tank Volume: 722 m^3, (Dia: 12.0 m, Depth: 6.4 m)
4	Stage IV Phase 1	Surge Tank Volume: 973 m^3, (Dia: 17.6 m, Depth: 4.0 m)
5	Stage IV Phase 2	Surge Tank Volume: 1,385 m^3, (Dia: 21.0 m, Depth: 4.0 m)

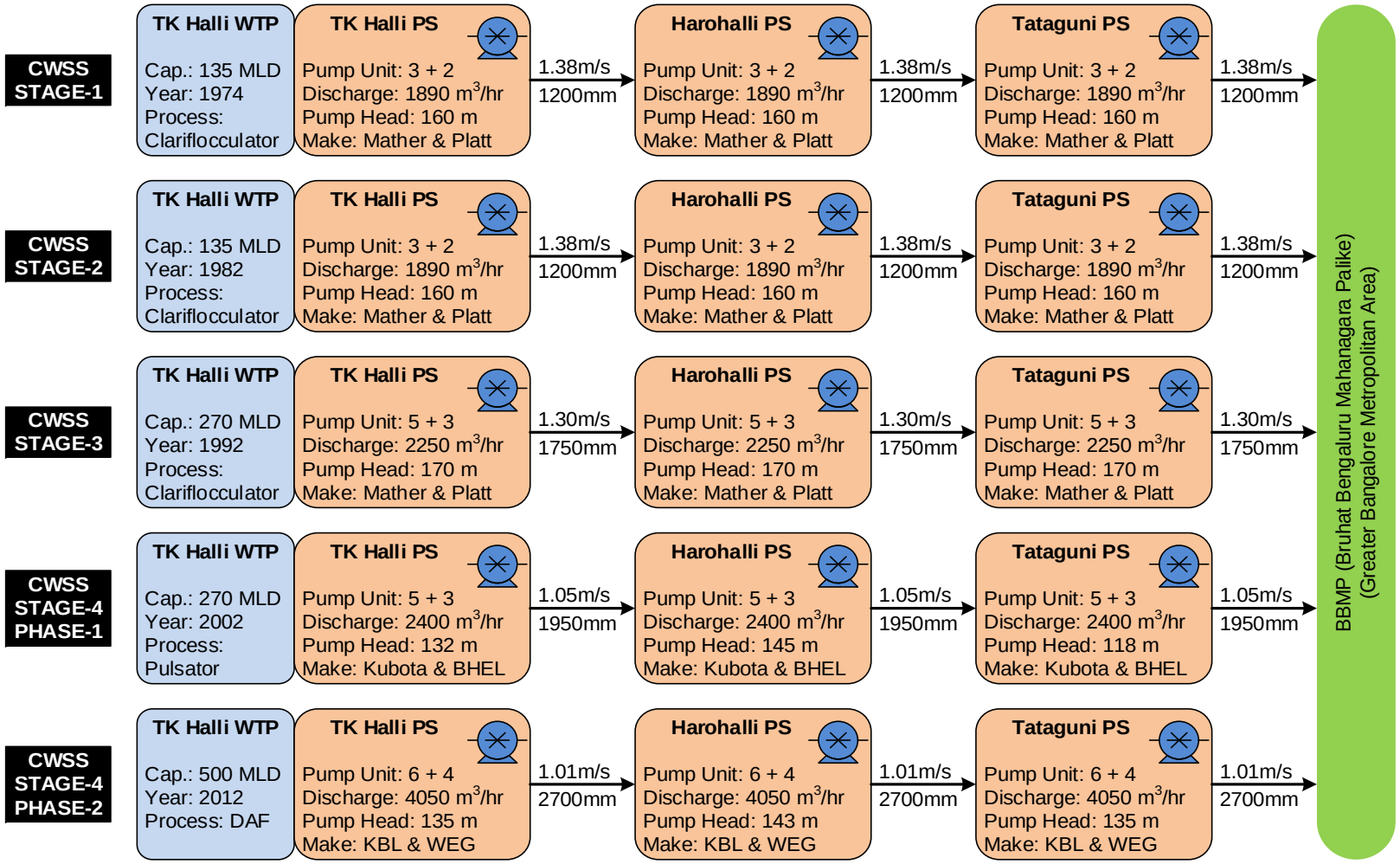


Figure 3.2.10 Schematic View of Transmission Facilities

Table 3.2.13 Details of Transmission Pump Station by Stage

No.	Name of zone	Discharge (m^3/hr)	Head (m)	Motor (kW)	Pump Number			Current Status
					W	SB	Total	
1	**CWSS Stage I**							
	TK Halli	1,890	160	1,250	3	2	5	In service
	Harohalli	1,890	160	1,250	3	2	5	In service
	Tataguni	1,890	160	1,250	3	2	5	In service
2	**CWSS Stage II**							
	TK Halli	1,890	160	1,250	3	2	5	In service
	Harohalli	1,890	160	1,250	3	2	5	In service
	Tataguni	1,890	160	1,250	3	2	5	In service
3	**CWSS Stage III**							
	TK Halli	2,250	170	1,525	5	3	8	In service
	Harohalli	2,250	170	1,525	5	3	8	In service
	Tataguni	2,250	170	1,525	5	3	8	In service
4	**CWSS Stage IV Phase 1**							
	TK Halli	2,400	132	1,440	5	3	8	In service
	Harohalli	2,400	145	1,440	5	3	8	In service
	Tataguni	2,400	118	1,440	5	3	8	In service
5	**CWSS Stage IV Phase 2**							
	TK Halli	4,050	135	2,300	6	4	10	In service
	Harohalli	4,050	143	2,300	6	4	10	In service
	Tataguni	4,050	135	2,300	6	4	10	In service

All pumping facilities installed through four stages of CWSS are properly operated. An operator at Tataguni PS stated that there has not been a chance to use the air chambers installed for the countermeasure against water hammer upon occurring power failure. The SCADA (Supervisory Control and Data Acquisition) system was provided in Stage IV Phase 1 and 2 for monitoring and recording the operation status, as mentioned in sub-section 3.4.

Photo 3.2.5 SCADA in Tataguni PS (Stage IV Phase 2)

(3) Transmission Pipeline

Raw water from Cauvery River is treated at TK Halli WTP and treated water is pumped and conveyed by pipelines to the reservoirs in BBMP. The diameter, length and the material of pipelines by stage are given in Table 3.2.14.

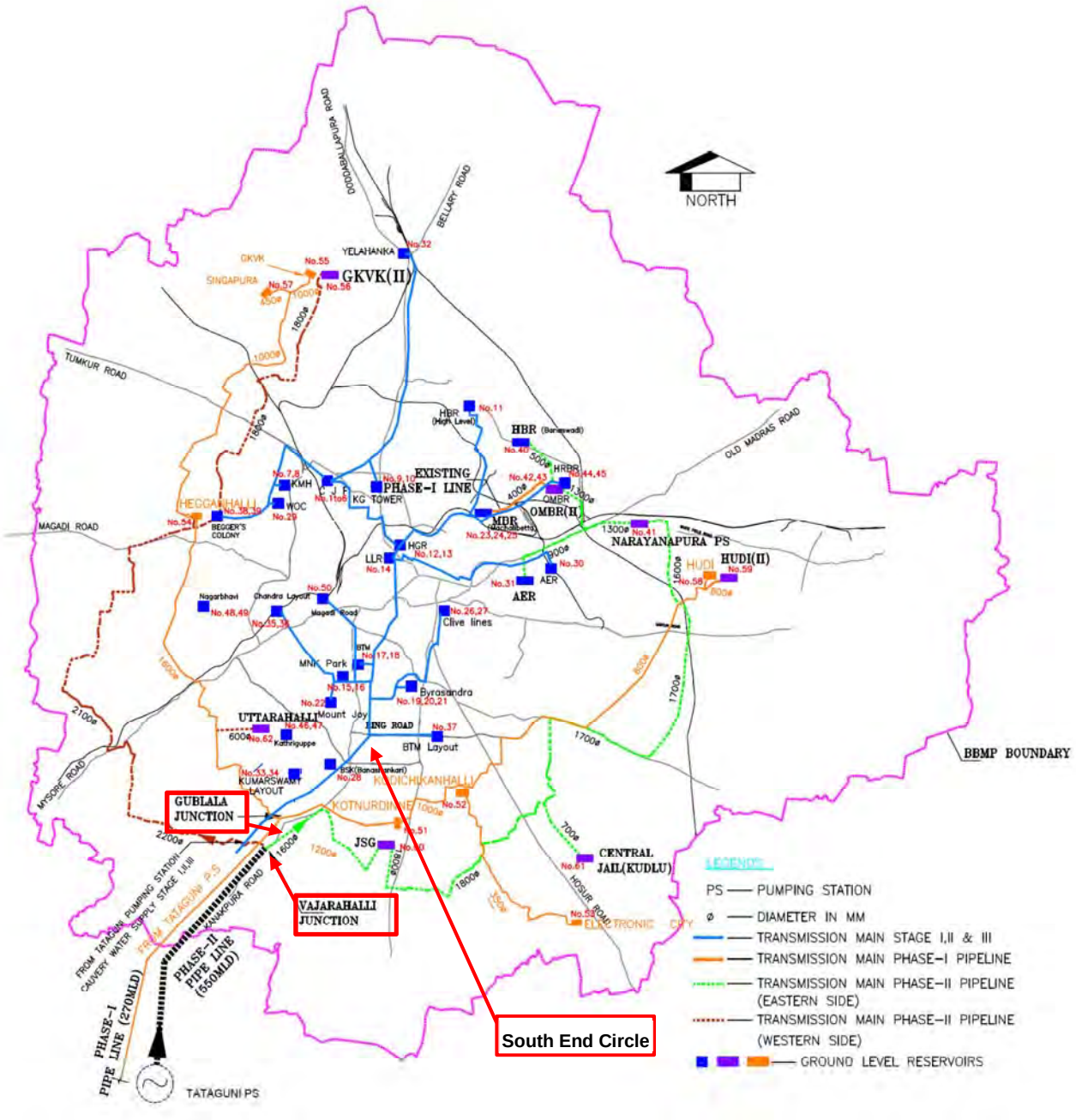


Figure 3.2.11 Location of Transmission and Distribution Facilities in the BBMP

Table 3.2.14 Detail of Existing Treated Water Transmission Pipeline

S/N	CWSS Stage, Phase	Pipeline			Remarks
		Diameter (mm)	Length (km)	Material	
1	Stage I	1,200	78	MS	Rising main from TK Halli to South End Circle
2	Stage II	1,200	78	MS	Rising main from TK Halli to South End Circle
3	Stage III	1,750	78	MS	Rising main from TK Halli to South End Circle
4	Stage IV Phase 1	1,950	70	MS	Rising main from TK Halli to Gublala Junction
5	Stage IV Phase 2	2,700	69	MS	Rising main from TK Halli to Vajarahalli Junction

Note: South End Circle, Gublala and Vajarahalli Junction are described in Figure 3.2.11

3.2.4 Water Distribution Facilities

(1) Service Area

Treated water transmitted from Tataguni pump station is not directly supplied to the service areas, instead stored in GLRs. From GLRs, water is pumped to OHTs for distribution to small service areas. Through Stage I, II and III, water from Tataguni has been pumped to South End Circle of the city and from there it is transmitted to 22 GLRs. Water distribution area by stage is shown in Figure 3.1.3.

(2) Particulars on Water Supply System

The water supply services for the city commenced from the year 1889. Then, the distribution systems have been remodeled, extended and rehabilitated as required. Initially Arkavathi River was the water source and simply treated water was supplied through CJF (Crown Jewel Filter) reservoir for the city. Subsequently, the water treated at TG Halli WTP was also transferred to CJF reservoir. In this regard, CJF reservoir with a storage capacity of about 166 ML was the essential point for water distribution. Additional reservoirs were constructed to supplement increasing needs. The use of water from Cauvery River was started in addition to that of Arkavathi River. However, at present, there is no water supply from Arkavathi River.

Treated water under CWSS Stage I to Stage III was transferred exclusively to Core area through City Trunk Main (Transmission pipeline installed in the city, which is connected to Tataguni Pumping Station). The water under CWSS Stage IV was conveyed mainly to ULB area and partly to Core area. Many OHTs were constructed to receive water from GLRs and average the hourly fluctuation of consumption in the distribution area.

(3) Existing Allocation System of Water Source to Servicing GLR

Under historical expansion of water supply systems in Core area, it is necessary to distribute water effectively through GLRs constructed in different stages. In this connection, areas served by each GLR are identified with served population and supply amount in this study (on-going M/P (Master Plan) also refers to this information).

Future distribution plan shall be prepared for the Core area considering existing GLR conditions/limitations on storage capacities and distribution networks in full use of limited available water. The following are relevant information collected in this study.

Treated water in each stage/phase of CWSS is being transmitted through City Trunk Main to GLRs constructed under corresponding Stage/Phase. After CWSS Stage III, however, part of transmitted treated water is distributed to the GLR constructed in previous stage/phase. Some old reservoirs, like CJF, previously fed by Arkavathi River are now being supplied with the water under CWSS. Schematic water flow to main GLR by stage is shown in Figure 3.2.13.

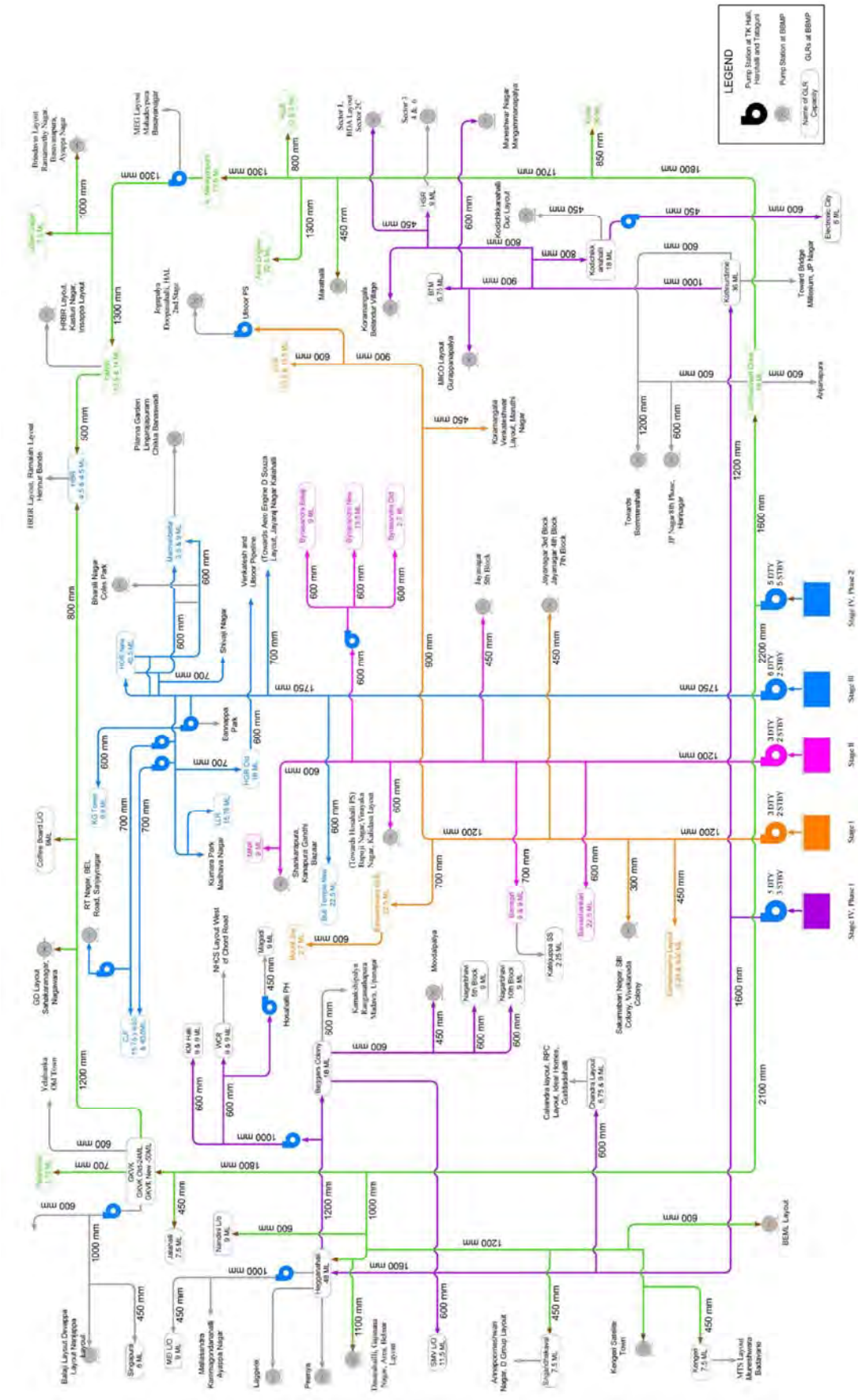


Figure 3.2.12 GLRs and Their Water Source

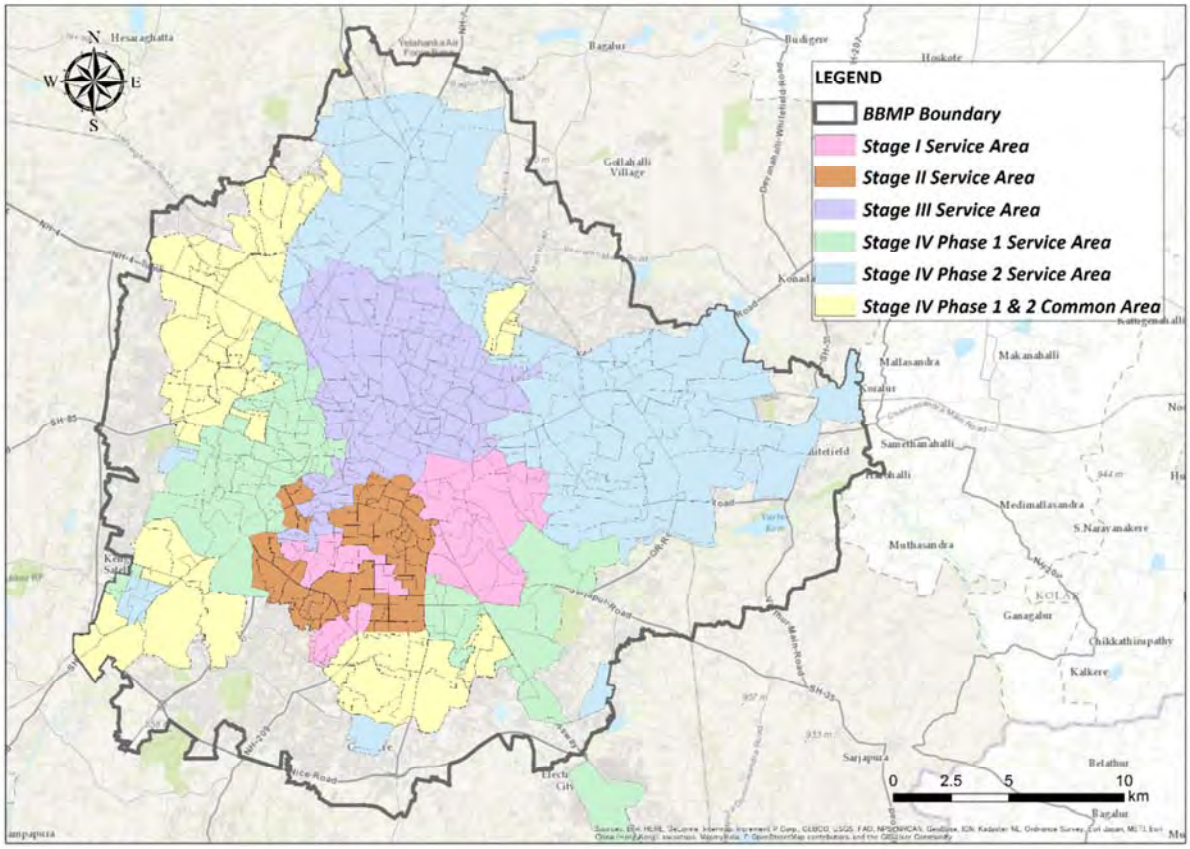


Figure 3.2.13 Coverage by Each Stage

Under Stage II, a pipeline with a diameter of 1,750 mm has been laid from south-end to HGR (High Ground Reservoir: name of reservoir), which enables transfer of Cauvery water to HGR and reservoirs within the area formerly covered by Arkavathi River. Under Stage III, this 1,750 mm has been connected to the 1,750 mm from Tataguni up to South End Circle. This pipeline of 1,750 mm from Tataguni to HGR has become almost a lifeline to transfer Cauvery water to the north and the Arkavathi zone.

Trunk Main (Distribution Main pipe) Length is summarized in Table 3.2.15. The water supply zones are divided by stage-wised pumping station and distribution areas are divided by GLRs. System itself is reasonable but network is expanded as demand increase, some network would be complicated. Moreover, capacity of aged pipes is not sufficient in population increased areas, in this connection, BWSSB started a project "UFW (Unaccounted for Water) reduction and distribution improvement project" in Core area.

Table 3.2.15 Outline of City Trunk Main Pipe

Description	Diameter		Length	Material	Remarks
	(mm)	(inch)	(km)		
a)Cauvery Zone	900	36	6.3	CI	Starting from South End Circle to CLR and reducing to 27" from CLR to Trinity Church (Ulsoor)
b) Arkavathi Zone	675	27	4.2	CI	From CJF to LLR
c) Arkavathi Zone	675	27	3.5	CI	From CJF to HGR
d)Arkavathi Cauvery Zone	600	24	6.2	CI	From LLR to Basaveswara

Description	Diameter		Length	Material	Remarks
	(mm)	(inch)	(km)		
e) Cauvery Zone	750	30	1.6	CI	From South End Circle and bifurcates to 24 inches and 18 inches to Basaveshwara and MNK respectively. Industrial Main from CJF to Veterinary Hospital GLR
f) Cauvery Zone	600	24	7.6	CI	Mount Joy to Kethmaranahalli
g) Arkavathi Zone	375	15	4.6	CI	CJF to HGR
h) Arkavathi Zone	375	15	4.6	CI	CJF to HGR
i) Arkavathi Zone	600	24	7.6	CI	CJF to Machalibetta
j) Arkavathi Zone	600	24	4.6	CI	CJF to Jayamahal
k) Cauvery Zone	375	15	6	CI	LLR to Wilson Garden
l) Cauvery Zone	600	24	1.5	CI	South End Circle to Byrasandra
m) Arkavathi Zone	600	24	3.9	CI	HGR to Ulsoor
n) Cauvery Zone	1,600	64	19.7		Pumping Main from Gublala to Hegganahalli
	1,000	40	15.2		Pumping main from Hegganahalli to GKVK
	450	18	1.2		Pumping main bifurcates from Hegganahalli to GKVK trunk main 1.9km from GKVK to Singapura.
	1,200	48	5.7		Pumping main from Gublala to Kotnurdinne
	1,000	40	6		Gravity main from Kotnurdinne to Kodichikanahalli
	800	32	20.1		Gravity main from Kodichikanahalli to Hudi
	350	14	9.13		Pumping Main from Kodichikanahalli to Electronic City

(4) GLRs and OHTs

Water is supplied to end users through distribution network from GLR (see Table 3.2.13) or Over Head Tank (OHT; see Table 3.2.14). Bengaluru city is on an undulating profile with level difference varying up to 100 m. Due to this, it has become necessary to construct ground level reservoirs (GLRs) where high ground elevations are available to supply water to the surrounding area. Many OHTs are constructed, which are fed from the GLRs with pumping facility. With the completion of Stage IV Phase 2, there are 84 GLRs at 51 sites, capacities ranging from 0.9 ML (Million Litter) to 63 ML and 52 OHTs with capacities ranging from 0.45 ML to 0.9 ML. Details of existing GLRs and OHTs are furnished in Table 3.2.16 and Table 3.2.17.

Out of these GLRs, GLRs at CJF and HGR serve as balancing GLRs as well as service reservoirs which feed the other GLRs and their own command areas. These two (2) GLR are the most important Core reservoirs in BBMP. The total capacity of GLRs is about 1,064.15 ML and that of OHTs is about 45.9 ML.

Total 1,110.05 ML capacity of the GLRs (1,064.15 ML) and OHTs (45.9 ML) is equal to the 18.25 hours (1,110.05 ML / 1,460 MLD x 24 hours) equivalent of actual daily supply volume, which is reported to be 1,460 MLD at present according to BWSSB's information. As a consequence, overall storage/balancing capacity of GLR is enough to correspond to the hourly demand fluctuation of the city. Photo 3.2.6 shows the existing OMBR GLR and neighboring OHT.

Photo 3.2.6 Existing OMBR (1) GLR and Neighboring OHT

Table 3.2.16 Details of Existing GLRs in BBMP

S/N	GLR	Tank	Stage	No. of Tank	Capacity (ML)		Type	Year of Construction	Condition as of Dec 2016
					Each Tank	Total			
1	Beggars Colony								
		Tank 1	-	2	9.00	18.00	RCC	1993	In Service
		Tank 2	-		9.00				In Service
2	Coffee Board Layout		-	1	9.00	9.00		2012	In Service
3	High Level Reservoir		-	1	0.90	0.90		1902	Not in Service
4	Jalahalli		-	1	7.50	7.50		2013	In Service
3	Kattriguppe		-	1	2.30	2.30			Not in Service
5	Kengeri		-	1	4.50	4.50		1996	In Service
6	MEI Layout		-	1	9.00	9.00		2012	In Service
4	Nandini Layout		-	1	9.00	9.00		2013	In Service
7	Srigandhadakaval		-	1	7.50	7.50		2011	In Service
8	Tavarekere	Tank 1	-	2	1.5	3	SSM	1967	Not in Service
		Tank 2	-		1.5		SSM	1967	Not in Service
9	TG Halli	Tank 1	-	3	1.5	4.5	SSM	1933	Not in Service
		Tank 2	-		1.5		SSM	1933	Not in Service
		Tank 3	-		1.5		SSM	1933	Not in Service
10	Visvesvaraya Layout		-	1	11.50	11.50		2014	In Service
11	Clive Lines Reservoir								
		Tank 1	1	2	13.50	27.00	SSM	1974	In Service
		Tank 2	1		13.50		SSM	1984	In Service
12	Koramangala								
		Tank1	1	2	8.00	16.00			Not in Service
		Tank 2	1		8.00				Not in Service
13	Kumaraswamy Layout								
		Tank 1	1	2	2.25	11.25	SSM	1983	Not in Service
		Tank 2	1		9.00			1996	In Service
14	Mount Joy		1	1	2.70	2.70	SSM	1933	In Service
15	Banagiri								
		Tank 1	2	2	9.00	18.00	RCC	1996	In Service
		Tank 2	2		9.00		RCC	1996	In Service
16	Banashankari		2	1	22.50	22.50	SSM	1984	In Service
17	Basaveswara								
		Tank 1	1	2	22.50	45.00	SSM	1974	In Service
		Tank 2	3		22.50		SSM	1984	Not in Service
18	Byrasandra								
		Tank 1	2	3	9.00	25.20	RCC	1993	In Service
		Tank 2	2		2.70		SSM	1964	In Service
		Tank 3	2		13.50		SSM	1974	In Service
19	MNK Park		2	1	9.00	9.00	SSM	1974	In Service

S/N	GLR	Tank	Stage	No. of Tank	Capacity (ML)		Type	Year of Construction	Condition as of Dec 2016
					Each Tank	Total			
20	CJF								
		Tank 1	3	6	15.75	166.50	SSM	1940	In Service
		Tank 2	3		15.75		SSM	1940	In Service
		Tank 3	3		15.75		SSM	1940	Under Repair
		Tank 4	3		15.75		SSM	1940	Under Repair
		Tank 5	3		63.00		SSM	1964	In Service
		Tank 6	3		40.50		SSM	1984	In Service
21	High Grounds Reservoir								
		Tank 1	3	2	18.00	58.50		1898	In Service
		Tank 2	3		40.50		RCC	1993	In Service
22	HRBR								
		Tank 1	3	2	4.50	9.00	RCC	1996	In Service
		Tank 2	3		4.50		RCC	1996	In Service
23	KG Tower								
		Tank 1	3	2	9.00	18.00		1974	In Service
		Tank 2	3		9.00		RCC	1984	In Service
24	Kumar Park		3	1	0.90	0.90			Not in Service
25	Low Level Reservoir								
		Tank 1	3	2	15.75	31.50	SSM	1935	In Service
		Tank 2	3		15.75		SSM	1935	In Service
26	Machalibetta								
		Tank 1	3	3	3.60	13.50	SSM	1962	In Service
		Tank 2	3		0.90		SSM		Under Repair
		Tank 3	3		9.00		RCC	1984	In Service
27	Srirampuram		3	1	0.90	0.90			Not in Service
28	BTM Layout		4-1	1	6.75	6.75	RCC	1993	In Service
29	Chandra Layout								
		Tank 1	4-1	2	6.75	15.75	RCC	1993	In Service
		Tank 2	4-1		9.00		RCC	2001	In Service
30	Electronic City		4-1	1	6.00	6.00	RCC	2002	In Service
31	GKVK								
		Tank 1	4-1	2	24.00	74.00	RCC	2002	In Service
		Tank 2	4-2		50.00		RCC	2012	In Service
32	Hegganahalli								
		Tank 1	-	2	5.00	53.00	RCC		In Service
		Tank 2	4-1		48.00		RCC	2002	In Service
33	HSR Layout		4-1	1	9.00	9.00	RCC	1999	In Service

S/N	GLR	Tank	Stage	No. of Tank	Capacity (ML)		Type	Year of Construction	Condition as of Dec 2016
					Each Tank	Total			
34	Kethamaranahalli								
		Tank 1	-	3	18.00	36.00		1934	Under Repair
		Tank 2	4-1		9.00			1993	In Service
		Tank 3	4-1		9.00			1993	In Service
35	Kodichikkanahalli		4-1	1	18.00	18.00	RCC	2002	In Service
36	Kothnurdinne		4-1	1	36.00	36.00	RCC	2002	In Service
37	Magadi Road		4-1	1	9.00	9.00	RCC	2002	In Service
38	Nagarbavi 1		4-1	1	6.75	6.75	RCC		In Service
39	Nagarbavi 2		4-1	1	9.00	9.00	RCC		In Service
40	West of Chord Road								
		Tank 1	4-1	2	9.00	18.00		1984	In Service
		Tank 2	4-1		9.00				Under Repair
41	Singapura		4-1	1	6.00	6.00	RCC	2002	In Service
42	Hudi								
		Tank 1	4-1	2	9.00	21.00	RCC	2002	In Service
		Tank 2	4-2		12.00		RCC	2013	In Service
43	Aero Engine								
		Tank 1	4-2	2	22.50	45.00	RCC	1984	Not in Service
		Tank 2	4-2		22.50		RCC	1996	In Service
44	Central Jail (Kudle)		4-2	1	30.00	30.00	RCC	2013	In Service
45	Jambu Savari Dinne		4-2	1	18.00	18.00	RCC	2013	In Service
46	Narayanapura		4-2	1	14.00	4.00	RCC	2013	In Service
47	OMBR								
		Tank 1	-	2	13.50	27.50	SSM	N/A	In Service
		Tank 2	4-2		14.00		SSM	2013	In Service
48	Sahakaranagar		4-2	1	5.00	5.00		1990	In Service
49	Uttarahalli		4-2	1	24.00	24.00	RCC	2013	In Service
50	Uttham Sagar		4-2	1	7.50	7.50		2012	In Service
51	Yelahanka		4-2	1	6.75	6.75	RCC	1984	In Service

TOTAL

In Service	**65**	**929.00**
Under Repair	**5**	**59.40**
Not in Service	**14**	**75.75**
Total	**84**	**1,064.15**

Table 3.2.17 Details of OHTs in BBMP

S. No	LOCATION	CAPACITY		YEAR OF COMMIS-SIONING
		ML	MG	
1	Vyalikaval	0.45	0.1	Prior to 1964
2	High Grounds	0.90	0.2	Prior to 1964
3	Kumara Park	0.45	0.1	Prior to 1964
4	Bannnappa Park	0.90	0.2	Prior to 1964
5	Chikkalalbagh	0.90	0.2	Prior to 1964
6	National College	0.90	0.2	Prior to 1964
7	Guttahalli	0.90	0.2	Prior to 1964
8	Chamarajpet	0.90	0.2	Prior to 1964
9	Sirsi Circle	0.90	0.2	1964
10	Jayanagar IV Block	0.90	0.2	1965
11	Jayanagar T Block	0.90	0.2	1975
12	Banashankari II Stage	0.90	0.2	1975
13	Bus Club	0.90	0.2	Prior to 1964
14	Trinity Church(Ulsoor)	0.90	0.2	1963
15	Johnson Market	0.90	0.2	1965
16	Indira Nagar	0.90	0.2	1975
17	L I C Colony	0.90	0.2	1976
18	West of Chord Road II stage	0.90	0.2	1977
19	West of Chord Road III stage	0.90	0.2	1978
20	Austin Town	0.90	0.2	1980
21	Sarakki Phase	0.90	0.2	1978
22	Koramangala	0.90	0.2	1975
23	Ideal Homes Layout	0.90	0.2	1978
24	Jeevan Bheema Nagar	0.90	0.2	1976
25	Magadi Road	0.90	0.2	1984
26	Domlur	0.90	0.2	1984
27	Vijayanagar	0.90	0.2	1984
28	Geddalahalli	0.90	0.2	1986
29	Ananda Nagar	0.90	0.2	1982
30	R T Nagar	0.90	0.2	1984
31	B T M Layout (MICO Layout)	0.90	0.2	1987-88
32	Nandini Layout	0.90	0.2	1987-88
33	R M Vilas Extension	0.90	0.2	1987-88
34	Yelahanka New Township	0.90	0.2	1988-89
35	Pillannna Garden	0.90	0.2	1990-91
36	B S K Third Stage	0.90	0.2	1990-91
37	C J F Malleswaram	0.90	0.2	1990-91
38	Bhashyamnagar Park	0.90	0.2	1990-91
39	Srirampurm	0.90	0.2	1993
40	P E S College B S K - I Stage	0.90	0.2	1992
41	J P Nagar I Stage	0.90	0.2	1993
42	B S K - II Stage	0.90	0.2	1992
43	Coles Park	0.90	0.2	1993
44	Mahalaxmi Layout	0.90	0.2	1993
45	Jayamahal	0.90	0.2	1996
46	H A L - II Stage	0.90	0.2	1996
47	Rajaji Nagar Beauty Spot	0.90	0.2	1996
48	BTM Layout	0.90	0.2	1993
49	Banaswadi (OMBR)	0.90	0.2	1993
50	Banaswadi (HRBR)	0.90	0.2	1994
51	Kengeri Satellite Town	0.90	0.2	1995
52	East of NGEF Layout	0.90	0.2	NA
	TOTAL	**45.90**	**10.2**	

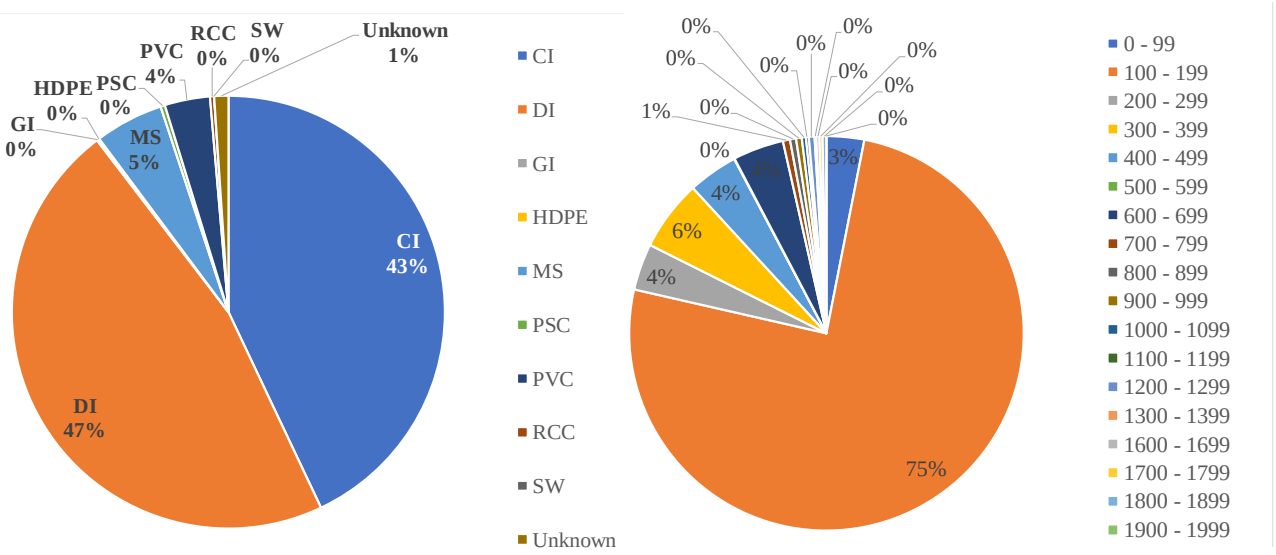
Source: BWSSB Report

(5) Distribution

In terms of pipeline, the matrix of pipe material and diameters extracted from the GIS data received from BWSSB is presented in Table 3.2.18 and the percentage of pipe length in material and diameter is given in Figure 3.2.14.

Table 3.2.18 Breakdown of Existing Distribution Pipe Length by Material

Diameter (mm)	Material										Total
	CI	DI	GI	HDPE	MS	PSC	PVC	RCC	SW	Unknown	
0 - 99	172.13	1.21	14.69	1.61	0.04		92.85			20.44	302.97
100 - 199	2,924.21	4,147.34	0.53	2.66	41.31		237.32	24.71		22.38	7,400.45
200 - 299	203.86	141.72			16.20		1.79	0.68		10.38	374.62
300 - 399	378.86	137.79			36.85			0.85	0.32	12.10	566.76
400 - 499	208.12	89.25			76.91	6.40		3.59		16.60	400.87
500 - 599		4.25			0.08						4.33
600 - 699	260.67	38.79			78.87	24.71				6.38	409.42
700 - 799	17.30	3.85			29.37					5.92	56.43
800 - 899	0.67	3.72			39.83					3.63	47.85
900 - 999	30.50	2.46			11.70					2.18	46.84
1000 - 1099	2.96	0.18			27.91					1.94	32.99
1100 - 1199		1.11			18.71					1.94	21.77
1200 - 1299	5.21	1.50			39.07						45.77
1300 - 1399					12.08						12.08
1600 - 1699					26.88						26.88
1700 - 1799	0.09				24.56						24.65
1800 - 1899	8.67				20.94						29.61
1900 - 1999					0.81						0.81
Grand Total	**4,213.24**	**4,573.17**	**15.22**	**4.27**	**502.10**	**31.12**	**331.96**	**29.82**	**0.32**	**103.88**	**9,805.09**
Percentage (%)	**42.97**	**46.64**	**0.16**	**0.04**	**5.12**	**0.32**	**3.39**	**0.30**	**0.00**	**1.06**	**100.00**



Source: BWSSB GIS Data

Figure 3.2.14 Percentage of Pipe Length in Material and Diameter

It can be seen that the majority of pipe material are CI and DI pipe. There is no any pipeline installation data, but taking both the age and susceptibility to corrosion into consideration, these pipes are certainly

due for replacement. A sustained replacement program will help improve the efficiency and resilience of the distribution system and also reduce NRW.

(6) User Connections

Water is supplied to end users from distribution pipes through connection pipes for domestic, non-domestic and partially non-domestic uses. Non-domestic use includes commercial, industrial, institutional and bulk supply. There exist 908,000 service connections as of 2016 and 865,000 connections are metered.

(7) Sub-divisions for Water Supply Services

O&M work including billing and collection work is practiced by division unit. A total of nine (9) divisions are further divided into 31 sub-divisions as shown in Figure 3.2.15. Also connection by sub-division is shown in Table 3.2.19. Service station placed in each sub-division is in charge of O&M, billing and collection of water tariff work. Inflow water volume to each sub-division is measured and controlled by using bulk meter. The collected data is utilized to estimate UFW ratio.

Table 3.2.19 Sub-division and Connection

Division	Number of Connection per Sub-division				Total
Central Division	C1	C2	C3		
	20,320	14,115	36,652		71,087
North East Division	NE1	NE2	NE3		
	39,302	17,196	40,155		96,653
South East Division	SE1	SE2	SE3		
	41,905	23,730	15,889		81,524
North Division	N-1	N-2	N-3		
	20,346	16,173	38,894		75,413
North West Division	NW1	NW2	NW3		
	37,007	33,195	42,186		112,388
West Division	W-1	W-2	W-3	W-4	
	28,361	28,259	25,957	28,087	110,664
South Division	S-1	S-2	S-3	S-4	
	29,836	36,402	21,227	28,461	115,926
South West Division	SW1	SW2	SW3	SW4	
	35,232	36,629	32,589	35,467	139,917
East Division	East-1	East-2	East-3	East-4	
	36,376	15,533	33,945	18,845	104,699
Total					908,271

Unit: Number of Household

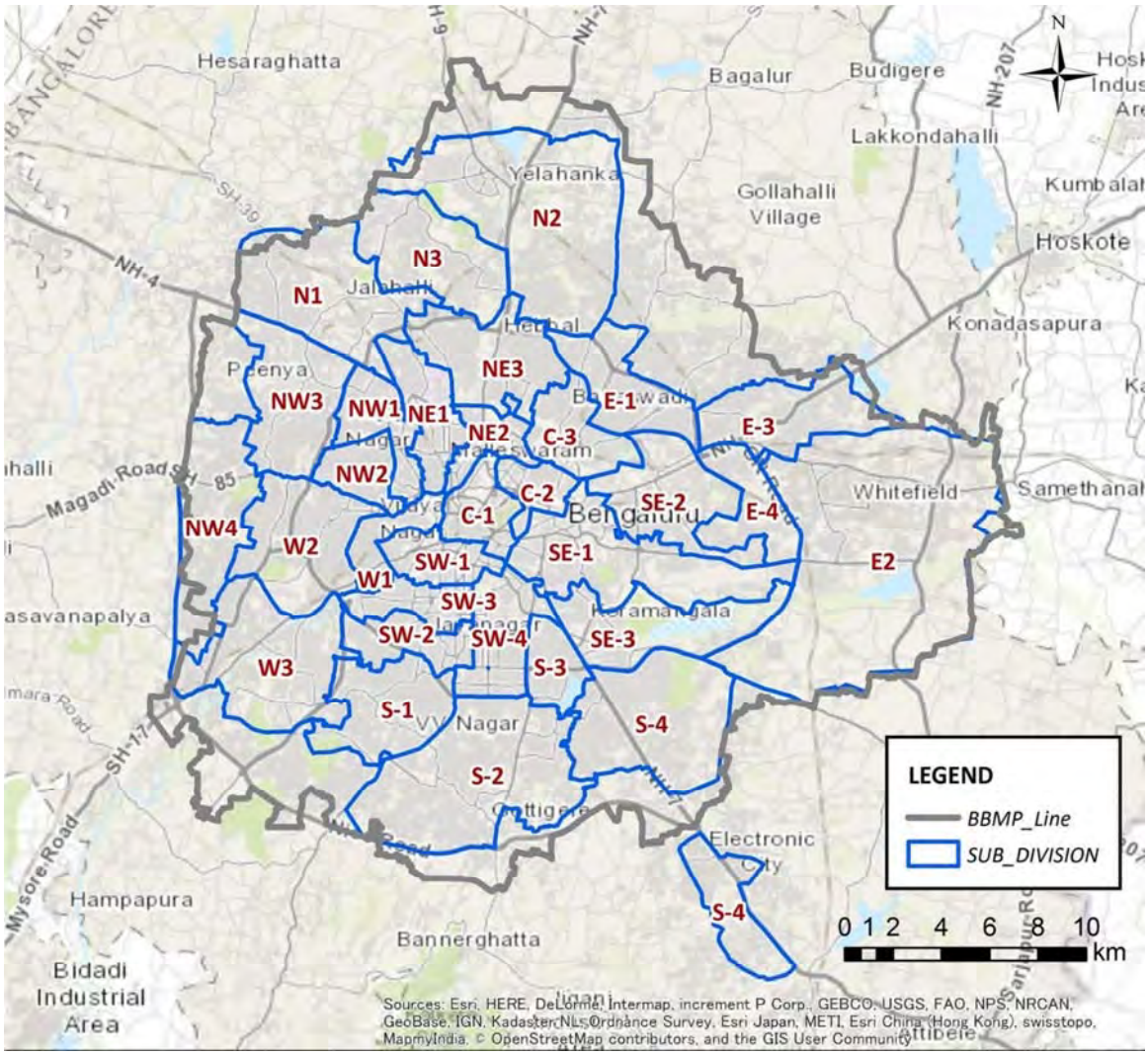


Figure 3.2.15 Location Map of Sub-divisions

(8) Present UFW and NRW (Non-Revenue Water) Conditions

1) Definition of UFW and NRW

Definition of NRW and UFW by IWA is shown in Table 3.2.20. In BWSSB statistics on NRW are available, while data on UFW are not regularly obtained. Present concern by BWSSB is reduction of physical losses in the distribution systems. In this connection BWSSB refers to NRW frequently with reference to on-going UFW reduction project. NRW is discussed to consider all concerned water losses.

Table 3.2.20 Definition of UFW and NRW in IWA

<table>
<tr><td rowspan="4">System Input Volume</td><td rowspan="2">Authorized consumption</td><td>Billed Authorized Consumption</td><td>Billed Metered Consumption (including water exported)
Billed Non-metered Consumption</td><td colspan="2">Revenue Water (RW)</td></tr>
<tr><td>Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption
Unbilled Non-metered Consumption</td><td colspan="2" rowspan="2">Non-Revenue Water (NRW)</td></tr>
<tr><td rowspan="2">Water Losses</td><td>Apparent Losses</td><td>Unauthorized Consumption
Metering Inaccuracies</td><td rowspan="2">Unaccounted For Water (UFW)</td></tr>
<tr><td>Real Losses</td><td>Leakage on Transmission and/or Distribution Mains
Leakage and Overflows at Utility's Storage Tanks
Leakage on Service Connections up to Customer's Meters</td></tr>
</table>

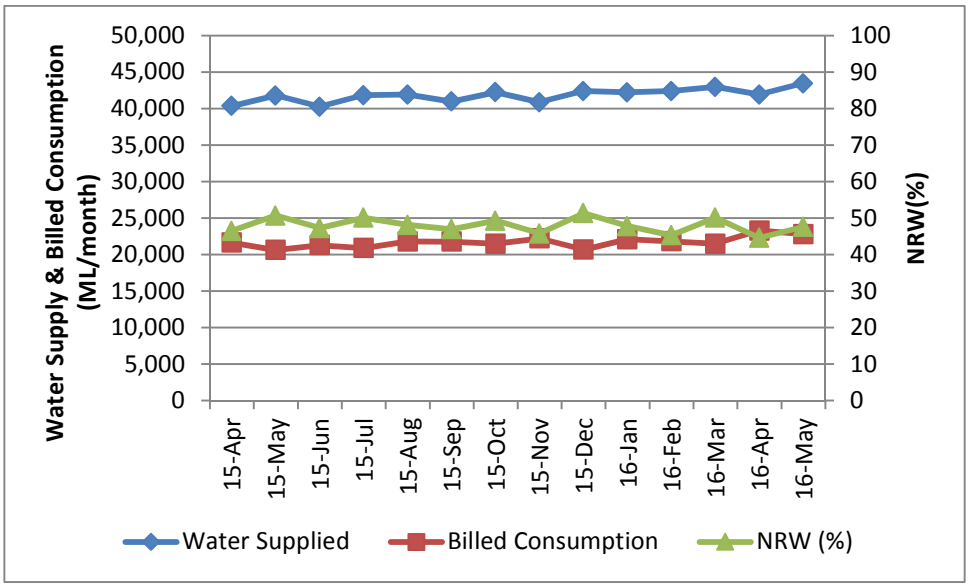
2) Present UFW and NRW Conditions

BWSSB report in May/2016 supplied by BWSSB indicates that an average NRW ratio from April/2015 to May/2016 is 47.9% as shown in Table 3.2.21. Figure 3.2.16 presents billed consumption and NRW percentages.

Table 3.2.21 Water Supply and Consumption

Month/Year	Water Supplied (ML/ month)	Billed Consumption (ML/ month)	NRW (%)
Apr/15	40,358	21,642	46.37
May/15	41,777	20,636	50.60
Jun/15	40,248	21,287	47.11
Jul/15	41,813	20,900	50.02
Aug/15	41,914	21,794	48.00
Sep/15	40,952	21,776	46.83
Oct/15	42,223	21,477	49.13
Nov/15	40,844	22,210	45.62
Dec/15	42,376	20,676	51.21
Jan/16	42,206	22,097	47.64
Feb/16	42,376	21,811	48.53
Mar/16	42,947	21,485	49.97
Apr/16	41,900	23,271	44.46
May/16	43,446	22,786	47.55
Average	41,813 (1,394 MLD)	21,703	48.02
Maximum	43,446 (1,448 MLD)	23,271	51.21
Minimum	40,248 (1,342 MLD)	20,636	44.46

Source: BWSSB



Source: BWSSB

Figure 3.2.16 Trend of Water Supply, Billed Consumption and NRW

From the above information, overall NRW percentage in the BWSSB service area at present is reported at 48%.

3) Sub-division Wise NRW

A sub-division wised NRW is estimated in the Master plan and shown in Table 3.2.22. The estimated NRW is 39 % in RW (Revenue Water) divided by receipt amount, however, 50.6 % is calculated RW divided by supply amount. The difference may come from the loss in transmission and GLRs, or insufficient accuracy of metering because flow meters are installed for each sub-division, but some of them are said malfunctioned.

Table 3.2.22 NRW Estimation by Sub-divisions

Division	Sub-div	Receipt (ML)	Billed (ML)	RW (%)	NRW (%)
Central	C1	1,207	565	46.90%	53.15%
	C2	882	616	69.80%	30.17%
	C3	1,124	618	55.00%	44.99%
North East	NE1	1,421	915	64.40%	35.57%
	NE2	643	457	71.10%	28.93%
	NE3	1,308	726	55.50%	44.48%
North	N1	744	519	69.70%	30.32%
	N2	838	436	52.10%	47.92%
	N3	941	516	54.90%	45.13%
Sub Total (A)		**9,107**	**5,369**	**59.00%**	**41.04%**
North West	NW1	1,477	874	59.20%	40.78%

Division	Sub-div	Receipt (ML)	Billed (ML)	RW (%)	NRW (%)
	NW2	1,168	794	68.00%	32.03%
	NW3	1,046	722	69.00%	30.97%
	NW4	18	14	77.50%	22.45%
West	W1	831	491	59.10%	40.90%
	W2	1,822	1,191	65.40%	34.62%
	W3	495	409	82.60%	17.43%
South West	SW1	1,614	580	35.90%	64.05%
	SW2	1,250	805	64.40%	35.59%
	SW3	1,221	709	58.10%	41.94%
	SW4	1,880	1,015	54.00%	46.01%
Sub Total (B)		**12,821**	**7,604**	**59.30%**	**40.69%**
South	S1	1,016	764	75.10%	24.86%
	S2	1,309	992	75.80%	24.24%
	S3	1,169	635	54.40%	45.63%
	S4	1,234	813	65.90%	34.08%
East	E1	963	618	64.20%	35.83%
	E2	854	517	60.50%	39.51%
	E3	744	411	55.20%	44.79%
	E4	651	353	54.20%	45.76%
South East	SE1	1,840	1,192	64.80%	35.21%
	SE2	1,417	844	59.60%	40.40%
	SE3	911	524	57.50%	42.52%
Sub Total (C)		**12,108**	**7,663**	**63.30%**	**36.71%**
Million Liter/Month (D = A+B+C)		**34,036**	**20,636**	**60.60%**	**39.37%**
MLD (E = D / 31)		**1,098**	**666**	**60.60%**	**39.37%**
Daily Average Supply Amount *		**1,348**	**666**	**49.40%**	**50.62%**

* Daily average supply amount is the water production in WTP.

Source: BWSSB (May/2015)

4) Leak Sources and Other Information Related to UFW

Although not many analysis was made regarding to the cause of leak, the result from the report "Unaccounted for Water and Reduction and Control and Water Distribution System Rehabilitation" by Thames Water – L&T Consortium (Final Version, September 2006) was shown below;

a) Leak Sources

- Main sources of leaks were mains, then service pipes and then stand posts:

Table 3.2.23 Leak Source

Leak locations	Mains	Service pipes	Stand Posts	Remarks
Phase 1	38%	32%	18%	Design and Implementation
Phase 2	72% (98.5% at joints)	17%		Maintenance
Phases 1 and 2	54.8%	24.8%	10.3%	Area: 21 km^2 Population:: 400,000 person Connection: 32,074

Source: DPR for UFW Dec/2013

b) Condition of Customer Meters Found

- 19% of meters were broken or non-functional.
- 30% of meters were >10 years old

c) Illegal Connections Found

- 349 of the illegal connections was found

d) Deference of Length of Mains between Actual and Recorded

- Length of mains in project area was ultimately found to be 363 km whereas BWSSB records only showed 270 km at the start of the contract.

e) Legitimate but Unbilled Consumers

- 2,579 properties were legitimate but unbilled, mainly due to poverty.

f) DMA Improvements

- Average zonal pressure across all DMAs increased from 3.20 m to 4.18 m.
- In average, final leakage was 28%.

g) Financial Analysis

- The payback period of the work undertaken was less than 1.8 years based on a production cost of 16 INR/m^3.

3.3 On-going Water Supply Project

3.3.1 Water Supply and Sewerage Master Plan

The M/P (Master Plan) for water supply and sewerage development covering entire BBMP area commenced through the contract-out to foreign consultants in July/2015 to complete in August/2016. After almost one year, as of August/2016, the contractor could not submit even draft plan to BWSSB. JICA Survey Team had an occasion to discuss with M/P Consultants planning conditions and basic framework. The results of discussions are summarized in Table 3.3.1.

Table 3.3.1 Discussion Results with M/P Consultants on Basic Conditions for Planning Purpose

Major Item	Considerations in the Preparation Process of M/P	Discussion Results
Population projection	Draft population projected range from 18 to 22 Million	The population in 2051 may be more or less about 20 Million.
Future unit domestic water consumption rate	150 lpcd (National standard)	To follow CPHEEO manual for Metro Cities
Unit consumption rate for Non-Domestic water use	50 lpcd demand for non-domestic usage	Domestic water consumption usually includes about 10% of non-domestic water. If there is a need to consider large consumers, study is necessary.
GW (Ground Water)	GW is not counted as potential water source.	Current assessment of GW usage is about 500 MLD. It is necessary to confirm with BWSSB on the condition to disregard GW.
Rainwater harvesting	Currently under study on rainwater use	Not considered for potable purposes.
Re-use of treated sewage	35-40% of treated sewage may be used.	Further study is necessary, because of considerably higher percentage than present practices.

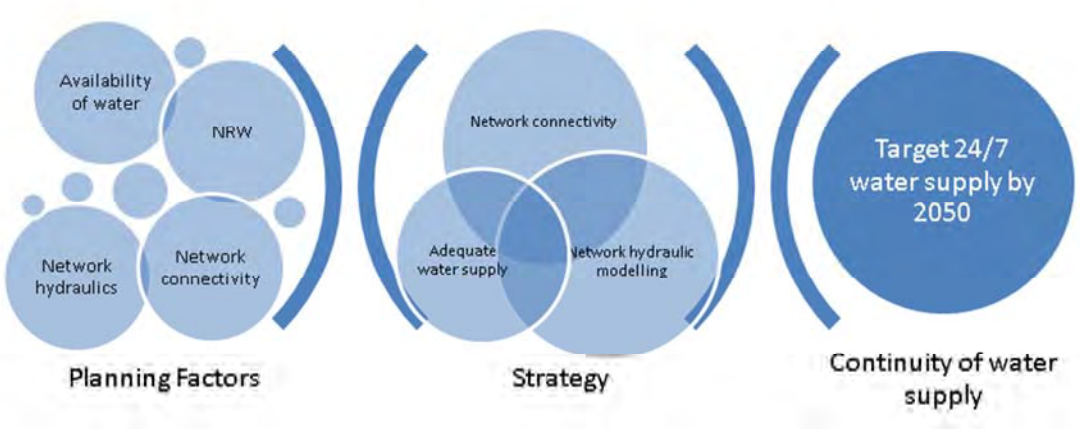
It was confirmed that basic conditions /assumptions for the planning of water supply and sewerage development/improvement are on the same line between on-going M/P and this study. With regard to water source availability through the future, it was agreed with BWSSB that “Identification of Sources for Sustainable Water Supply to Greater Bengaluru”, prepared by the Expert Committee constituted by the Government of Karnataka shall be used for water source study.

The M/P Consultants submitted partial draft plan to BWSSB at the end of the year 2016. The following are relevant information for the implementation of Preparatory Survey.

(1) Basic Policy/Conditions/Criteria for Water Supply

1) Water Supply Services through the Year (24 hour/7 days water supply)

JICA preparatory survey aims to realize 24/7 (24 hour/7 days) water supply for the target year in 2034 for 110 Villages according to international standard (Planned water source and water supply facilities allow for the achievement of the service level). M/P has not been approved officially, but the draft of M/P also assumed to achieve 24/7 water supply by 2050. The following figure presents criteria for continuity to water supply.



Source: Master plan

Figure 3.3.1 Basic Policy for Water Supply

2) Water Demand

a) Per Capita Water Consumption

Item	JICA Preparatory Survey	Master Plan	Remarks
Domestic & Non-domestic	150 lpcd	-	CPHEEO
Domestic	-	135 lpcd	SLB (Service Level Benchmark)
Non-domestic	-	27 (20% of domestic)	Not clear

b) UFW

Item	JICA Preparatory Survey	Master Plan	Remarks
Intermediate	(2034) 25%	(2035) 35%	
Ultimate	(2049) 16%	(2050) 15%	

(2) Water Balance

The demand and source gaps are different between JICA Preparatory Survey and the M/P. The following are determined through discussions with BWSSB. The demand by JICA Survey is shown in Chapter 5.

- Adopt 150 lpcd to follow CPHEEO manual.
- Adopt water allocation amount as CWSS water source, 1,460 MLD for Stage I to IV and 775 MLD for Stage V.
- Adopt less UFW (Unaccounted for Water mainly caused by physical losses) in the medium term considering UFW reduction project for Core area and construction year for ULB and 110 Villages.
- Consider groundwater as part of available water source.

Table 3.3.2 Comparison of Water Demand and Supply Balance between JICA Survey and M/P

Item			JICA Prepara-tory Survey	Master Plan		
				Low	Average	High
Intermediate	Year		2034	2035		
	Population		14,111,000	13,900,000	15,350,000	16,800,000
	Domestic	lpcd	150/30	135	135	135
		MLD	2,071	1,877	2,072	2,268
	Non-domestic			20%	20%	20%
		lpcd		27	27	27
		MLD		375	414	454
	Per Capita	lpcd	150*	162	162	162
	Consumption		2,071	2,252	2,487	2,722
	Loss/NRW		22%	35%	35%	35%
	Demand		2,608	3,464	3,826	4,187
	Cauvery	1-IV	1,460	1,354	1,354	1,354
		V	775	700	700	700
	Groundwater		500			
	Source		2,735	2,054	2,054	2,054
	Gap		127	-1,410	-1,772	-2,133
Ultimate	Year		2,049	2,050		
	Population		19,358,000	19,123,917	20,961,959	22,800,000
	Domestic	lpcd	150/30	135	135	135
		MLD	2,903	2,582	2,830	3,078
	Non-domestic			20%	20%	20%
		lpcd		27	27	27
		MLD		516	566	616
	Per Capita	lpcd	150*	162	162	162
	Consumption		2,903	3,098	3,396	3,694
	Loss/NRW		16.0%	15%	15%	15%
	Demand		3,456	3,645	3,995	4,345
	Cauvery	1-IV	1,460	1,354	1,354	1,354
		V	775	700	700	700
	Groundwater		500			
	Source		2,735	2,054	2,054	2,054
	Gap		-721	-1,591	-1,941	-2,291

Note: * Per capita water consumption of 150 lpcd is used as recommended in CPHEEO Manual

3.3.2 New 300 MLD WTP Project (In Lieu of Existing Stage I and II WTPs)

The WTPs of CWSS Stage I and II were commissioned in the year 1974 and 1982 respectively, each of 135 MLD capacity. The rate of filtration comes down during high turbidity levels during the monsoon season which is in the range of 10 to 80 NTU compared to the normal turbidity during non-monsoon period of zero (0) to five (5) NTU.

Two (2) alternatives are studied in the DPR prepared by the consultant (TATA Consulting Engineers Ltd.) selected by BWSSB and they are:

- Rehabilitation of existing Stage I and II WTPs
- Construction of new WTP for Stage I and II

The estimate for the rehabilitation of the existing Stage I and II WTPs would be 1,290 Million INR. On the other hand, the construction of new 300 MLD for Stage I and II WTPs was estimated at 1,200 Million INR. Based on above, it was recommended to construct new 300 MLD WTP.

The water source is from existing conveyance pipe (Stage I and II) and water is planned to be pumped by existing PS (Stage I and II). The new 300 MLD WTP is expected to be completed in AUG/2018 and the fund is from JNNURM (Jawaharlal Nehru National Urban Renewal Mission) and KUIDFC (Karnataka Urban Infrastructure Development and Finance Cooperation).

3.3.3 On-going UFW Project

Through Stage IV Phase 2 project, BWSSB has taken up "UFW reduction and distribution system improvement works in the Core area of Bengaluru" covering 3 water supply zones: South, West and Central catering to 400,000 consumer connections (almost 60% of the total consumer connections of Bengaluru, which are 650,000). These contracts were arranged in the similar lines based on the results obtained from the UFW Pilot Project implemented by BWSSB in the Central Business District (CBD) with the area of 16 km^2 in the year 2003-2005. The project focuses on only physical losses including leakage and illegal connections (UFW), which is less than Non-Revenue Water (NRW).

(1) Details of Existing Contracts for "Improvement to Water Distribution System, Reduction UFW & Leakage Control in Central Division, West Division and South Division"

Though the contract period of almost three (3) years have passed in all of the three (3) contract packages, the results in terms of UFW savings are found to be less than expected. The major reason of the delay to achieve target UFW 16% is caused by the delay of DMA installation (as shown in (2) Contract status of the packages: 20%-40%). The scope of work of the contracts is same for all the packages and the summary of the scope of work and other contract features are summarized in Table 3.3.3. Location map of the area is shown in Figure 3.3.2. The definition of UFW is as shown below in the contract document.

This Project is a component of "Bangalore Water Supply and Sewerage Project (Phase2)" funded by JICA. The contractors are "Larsen & Turbro Ltd" and "JV of Suez Environment and SPML" and the supervise consultant is "JV of Nippon Jogesuido Sekkei Co., Ltd., Mott MacDonald Ltd., TATA Consulting Engineers Limited".

$$\text{Initial \% UFW} = \frac{X - (A + B + C + D)}{X} \times 100\ \%,$$

Where:

X = Water input to the system (DMA) during the period (typically 1 month)
A = Water billed during the period
B = Water legally supplied but not billed (including slum and standpost consumption) during the period
C = Operational use (scouring, jetting, dust suppression, etc.) during the period
D = Tankers metered and billed/unbilled during the period

Table 3.3.3 Outline of Contracts for UFW Reduction and Distribution Improvement

Item	Unit	2b South	2a West	1a Central
Contract		Jul/2012	Nov/2013	Nov/2013
Construction Period	Month	3	3	3
O&M Period	Years	5	5	5
Expected Completion		Sep 2016	Jun 2017	Jun 2017
Awarded Price	M INR	1,531	3,158	1,843

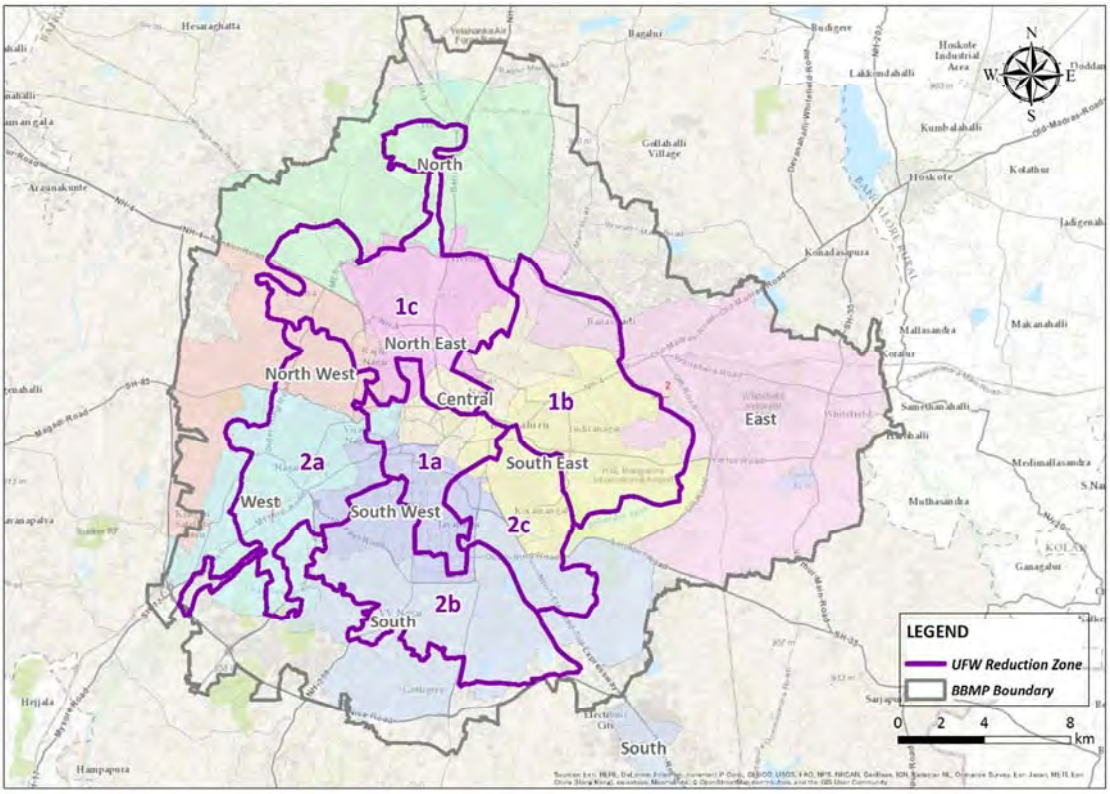


Figure 3.3.2 UFW Reduction Project Area (1a, 2a and 2b are on-going)

The contractors for the project were selected by BWSSB through ICB. BWSSB has experience on the similar project as mentioned above (UFW Pilot Project implemented by BWSSB in the Central Business District).

The Scope of Work for the above Contract is shown below.

1) Works Contract Scope of Work

Duration – 3 years

- Baseline survey of the distribution system which includes

⇒ Network Survey

⇒ Elevation Survey

⇒ Consumer Survey

⇒ House Service Connection and Consumer Meter survey

- Updating of the existing GIS (Geographic Information System) incorporating the survey details
- Development of Hydraulic Model for the project area considering future growth for at least next 20 years
- District Meter Area (DMA) Design, formation and Establishment: A DMA area is designed based on hydraulic calculation of distribution network, after network survey in the entire contract area. The conditions include that an average water pressure in each network shall be 17m and number of house connections shall be 1,500 to 2,000.
- Installation of District Meters
- Establishment of Baseline UFW Levels in each DMA: Baseline 44% and target 16%. When a DMA is established, a valve with flow meter is installed at the inlet/s and outlet/s to and from the DMA network area.
- Implementation of Mandatory capital Works

  ⇒ Replacement of PVC mains with DI / HDPE pipes

  ⇒ Replacement of mains less than 100mm dia. with DI / HDPE pipes

  ⇒ Replacement of associated House Service Connections (PE or PPR pipes)

  ⇒ Replacement of non-working consumer meters.
- Undertake Network Rehabilitation works

  ⇒ Rehabilitation and replacement of all old leaking assets like pipes (feeder and distribution), fittings, valves etc.

  ⇒ Rehabilitation and replacement of leaking house service connections

  ⇒ CCTV survey of mains to determine inside encrustation

  ⇒ Corrosion mapping of the mains
- Reduction of UFW

  ⇒ Detection and repair of Leakages

  ⇒ Detection of Leakages with advanced technology like Gas detection by using Helium or mixed gas of Nitrogen and Hydrogen.

  ⇒ Estimation of Slum Consumption

  ⇒ Estimation of Public Tap Consumption

  ⇒ Control of illegal connections

  ⇒ Meter Testing and Metering error estimation

  ⇒ Meter Reading errors estimation

  ⇒ Accounting of Operational Usage
- Achievement of UFW target of 16%

2) O&M Contract Scope of Work:

Duration – 5 years

- Operation and Maintenance of the DMAs
- Monitoring and maintenance of the achieved UFW Levels

- Undertaking UFW reduction activities
- Undertake any capital works, if required

3) Contractor Selection

Contractor was selected through ICB with two (2) envelope method. BWSSB hires consultants to supervise the contract of the project.

(2) Status of the Contract Packages

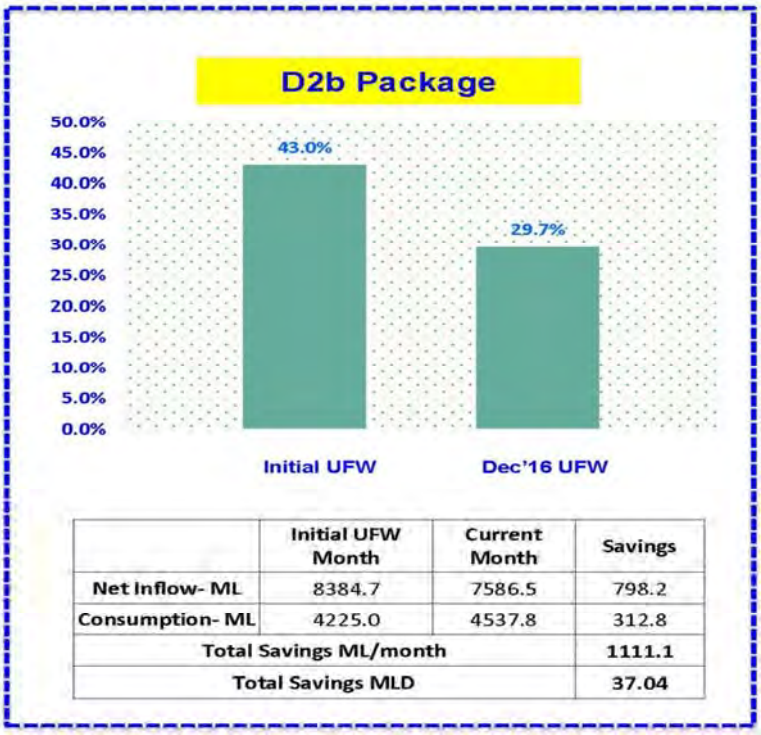
The status of each of the contract packages is summarized in Table 3.3.4.

Table 3.3.4 Outline of Work Volume for UFW Reduction and Distribution Improvement

Item	Unit	2b (South)	2a (West)	1a (Central)	Sub-Total
Area	km^2	52.0	52.0	26.5	130.5
Consumer Connections	Nos	171,000	171,000	70,000	412,000
Distribution Pipeline Replacement (DI pipes)	m	194,000	166,000	65,000	425,000
Feeder Pipeline Replacement (MS pipes)	m	8,400	7,500	Nil	15,900
DMA	Nos	83	83	43	209
Consumer Water Meter Replacement	Nos	56,000	58,000	17,000	131,000
House Service Connection Replacement	Nos	26,000	39,000	6,000	71,000

1) 2b (South Zone)

This contract was executed by Larsen and Toubro Limited (L&T), one of the largest infrastructure conglomerate in India. The work including Survey, Design, Engineering, DMA formation for the total project area in this package was completed. A total of 83 DMAs were formed. All the DMA electromagnetic meters were fixed and the Initial/Base UFW levels for each DMA were established. The UFW status on Dec 16, 2016 is shown in Figure 3.3.3.



	Initial UFW Month	Current Month	Savings
Net Inflow- ML	8384.7	7586.5	798.2
Consumption- ML	4225.0	4537.8	312.8
Total Savings ML/month			1111.1
Total Savings MLD			37.04

Figure 3.3.3 UFW Improvement in Contract 2b

The work for this contract was completed on September 2016. After that, the network layout and flow records can be monitored in web site. Several images in the web site are presented in the figures; from Figure 3.3.4 to Figure 3.3.6. The these information of 2a (West) and 1a (Central) are not available.

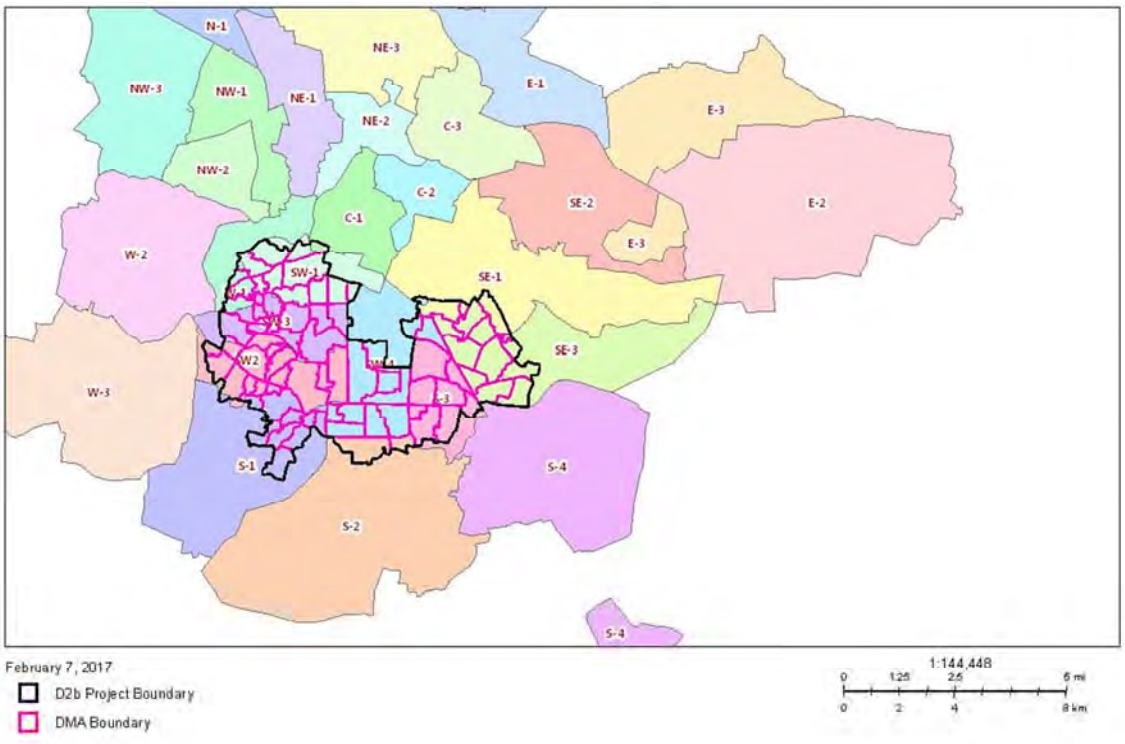


Figure 3.3.4 DMA Boundary

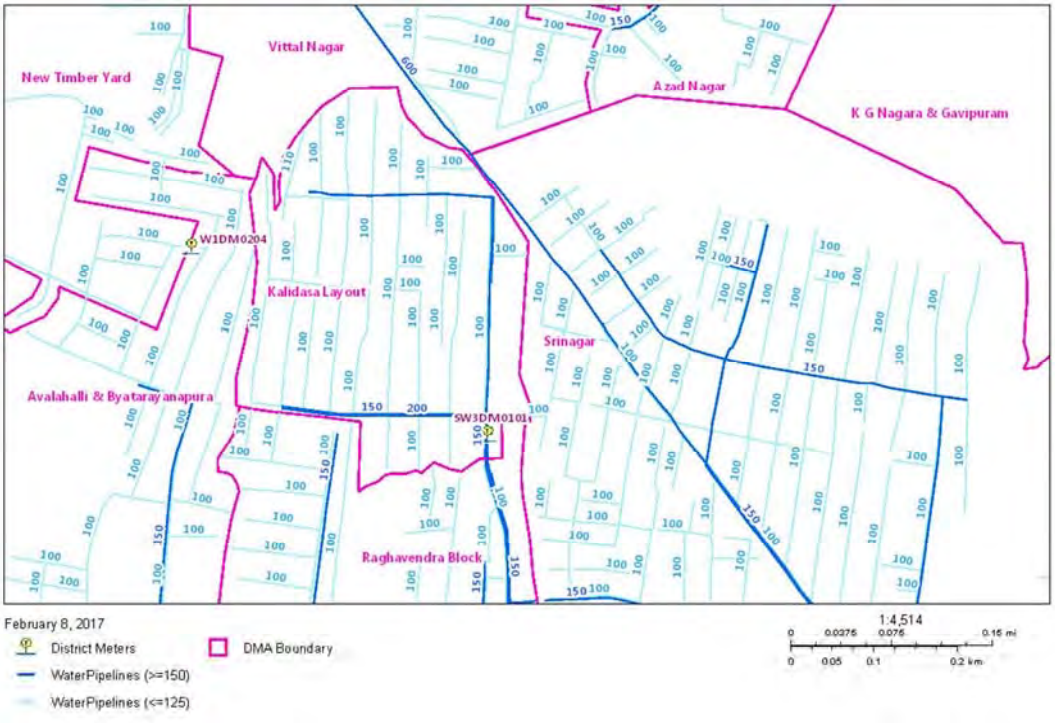


Figure 3.3.5 Example of Pipe Layout and DMA Flowmeter Installation

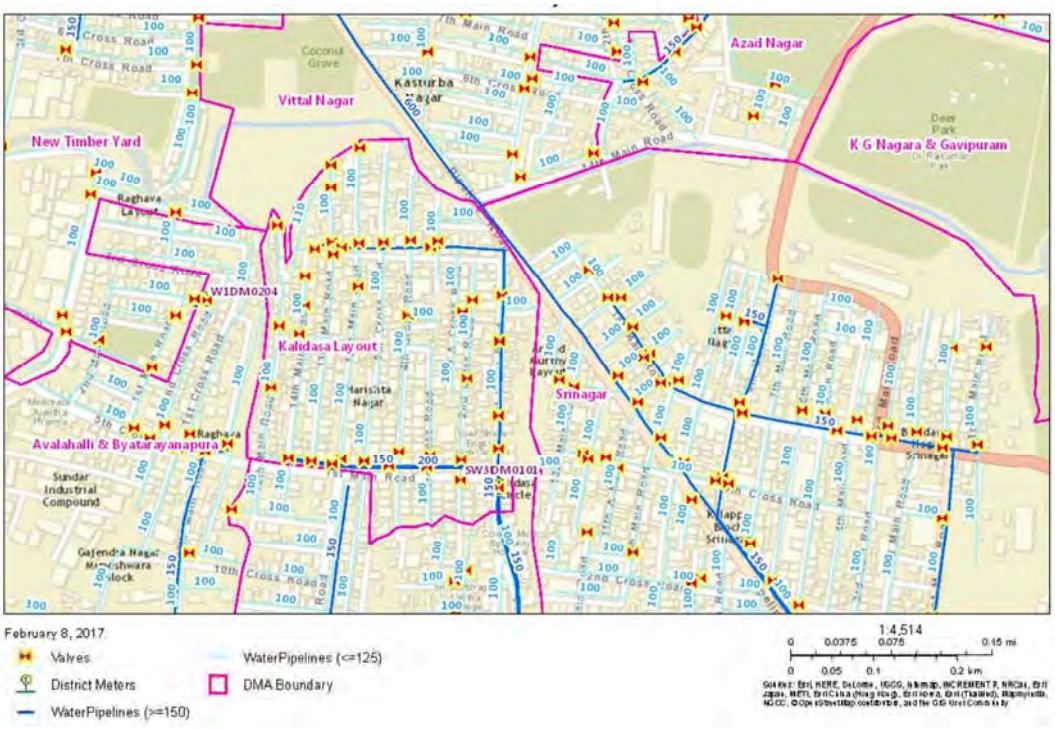


Figure 3.3.6 Example of Valve Installation

2) 2a (West Zone)

This work was also undertaken by Larsen and Toubro Limited (L&T). The work including Survey, Design, and Engineering for the subject area was completed, though construction/improvement work is still on the way. A total of 83 DMAs was planned to form. DMA electromagnetic meters were fixed and the Initial/ Base UFW levels for 62 DMAs had been established out of the planned 83 DMAs as of March/2017 and

UFW reduction work is under progress in 51 DMAs. The work includes replacement of old pipes with the diameter of less than 100mm and PVC pipes as well as non-working consumer meters. Once the mandatory works are completed the UFW reduction work including leakage detection and repair, free water usage reduction etc. will be taken up at these DMAs.

Although UFW reduction has been achieved up to a certain level at some DMAs, there is still a substantial need to improve UFW aiming at the contractual target of 16%. Present status of UFW levels at the various DMAs are as shown in Table 3.3.5.

Table 3.3.5 UFW Performance Level on Completed DMAs

Categories of UFW Levels	Nos. of DMAs April/2016
UFW Levels (<= 16) %	3 DMAs
UFW Levels (16 – 30) %	16 DMAs
UFW Levels (30-40) %	13 DMAs
UFW Levels (>40)%	19 DMAs
New Assessed DMAs	
Total	51 DMAs

3) 1a (Central Zone)

This work was contracted out to the consortium; Suez Environment, France and SPML, India. The work for Survey, Design, and Engineering for the subject area was completed and construction/improvement work is on the way. It was planned that a total of 43 DMAs shall be formed. However, DMA electro-magnetic meters were fixed and the Initial/ Base UFW levels for only 13 DMAs were established. As of March, 2017, the progress was not sufficient, mainly caused by the locational problem with heavy traffic in the center and old part of Bengaluru city. In addition, this area was apprehended to have the highest UFW level in the BBMP area.

In this contract, the following distribution system improvement works have been implemented in the various DMA areas. However, as of March/2017, UFW reduction work was under taken at only 13 DMAs. In other DMAs mandatory capital works are under progress, which includes replacement of old pipes with less than 100 mm dia. and PVC pipes as well as replacement of non-working consumer meters. Once the mandatory works are completed the UFW reduction work including leakage detection and repair, free water usage reduction etc. will be undertaken in these DMAs. Present status of UFW levels in the various DMAs are summarized in Table 3.3.6.

Table 3.3.6 UFW Performance Level on Completed DMAs

Categories of UFW Levels	Nos. of DMAs April/2016
UFW Levels (<= 16) %	1 DMA
UFW Levels (16 – 30) %	
UFW Levels (30-40) %	4 DMAs

Categories of UFW Levels	Nos. of DMAs April/2016
UFW Levels (>40)%	8 DMAs
New Assessed DMAs	
Total	13 DMAs

(3) UFW SCADA Server

The UFW SCADA server was established under each UFW reduction contract. Inflow data to the DMAs and water supply flow to slum areas are collected through the electromagnetic flow meters equipped with GSM modem. In the meantime, the Automatic Meter Reading (AMR) server established by BWSSB themselves collects data on the transferred flow among the DMAs through bulk flow meters which measure inter-transfer flow among the DMAs. There are also the data on water supply flow to households loaded to a billing server through the memory cards which are inserted to handy POS device for storage water meter reading data. The collected data on the inflow to the DMA and the water supply to slum areas, and the water supply to households can be used for calculation of the water balance between the inflow and the total water consumption within the DMA concerned. It is preferable that the data on water supply to households in the billing server should be transferred automatically to the UFW SCADA servers over a communication medium for assisting operating staff to analyze UFW reduction.

3.4 Existing SCADA System

3.4.1 General

Programmable Logical controller (PLC) based SCADA systems were initially introduced to CWSS Stage III and expanded to cover the water supply and sewerage network during Stage IV Phase 1 and 2, while Stage I and Stage II of the Cauvery water supply systems have remained without SCADA systems and no control and automation whatsoever.

During Stage IV Phase 1 & Phase 2, the SCADA system was introduced to control and monitor the water treatment and distribution system along with the sewerage system. The PLCs have been installed at the water treatment plants, the clear water pump stations, the sewage treatment plants, and the intermediate sewage pump stations to achieve automatic operations of all plant processes, collecting and sending field data to upper level operator station of the SCADA system.

In MIS-2 (Management Improvement system) contract under Phase 2, a centralized SCADA center has been setup at Shimsha Bhavan, BWSSB Jayanagar, which is the substitution of the centralized SCADA center established at BWSSB headquarters under Phase 1, but was not functioning.

The centralized SCADA system is required, so as to provide a dashboard view of the entire water treatment & distribution network along with the sewerage network to BWSSB personnel and to have a means of monitoring the individual water treatment & distribution facilities, as well as the sewage treatment plants and the intermediate sewage pump stations.

The centralized SCADA center hereinafter referred to as "CSC", setup at Shimsha Bhavan is designed to integrate the TK Halli WTPs, the TK Halli PSs, the Harohalli PSs, the Tataguni PSs and GLRs. The CSC is also designed to integrate, AMR SCADA server, Bulk meter server and the UFW SCADA servers. The field data from these plants are eventually transmitted to the BWSSB head office via web servers to enable monitoring for entire water supply system in Bengaluru.

The UFW SCADA servers are designed to monitor/collect inflow data from each DMA. In addition to the same, water supply to slum areas are monitored through the help of field electromagnetic flow meters equipped with a GSM modem, which transmit the flow data to the UFW SCADA servers located at Shimsha Bhavan. The AMR SCADA project is currently under execution for collecting the data of water transfer flow among the DMAs through bulk flow meters.

The UFW server generates the reports on totalized flow to each DMA and the slum areas within the related DMA. The UFW server and the AMR SCADA server have not covered all areas yet, since the implementation of the flow meters and the household water meters have been currently in progress. There is no function of water distribution/supply management within the DMAs provided in the UFW server. Further, the SCADA system above mentioned is not closely linked with MIS.
The billing server is located at the BWSSB main office at Cauvery Bhavan .The billing server is a standalone system. The server accepts data manually. The data is collected by meter inspectors reading mechanical type household water meters. The meter inspectors input the data to the POS machine, which generates the bill based on the difference between the previous data logged and the current data. The disadvantage with manual collection of data is that there is a possibility of human errors in data input.

The management capacity for the CSC has been developed by BWSSB, since operating staff for CSC components along with the remote station components have been trained during operation and maintenance period after completion of the installation of the Centralized SCADA system. It is generally required for the operating staff of the Centralized SCADA system and other SCADA systems to maintain the following knowledge.

- General idea/knowledge about the water supply facility and sewerage facility processes,
- General idea/knowledge about the components of the SCADA systems such as the front end processors, the operator stations, the engineering stations, the historian stations, the printers, the Ethernet managed switches, General Packet Radio Service (GPRS) modems, etc.,
- General idea/knowledge about report generation and alarm/event list generation,
- General idea/knowledge about trouble shooting of the SCADA system components.

3.4.2 Water Treatment and Distribution Network Monitoring

Under Stage IV Phase 2, PLC based SCADA systems were introduced significantly at the local plant level, i.e. Water treatment plants, water pumping stations, ground level reservoirs, sewage treatment plants, intermediate sewage pumping stations and terminal sewage pumping stations under various contracts and different contractors executing the work. The system configuration adopted under various

contracts have been illustrated and explained in brief below:

(1) WTP

The water treatment plant under Stage IV Phase 2 has been equipped with PLC based SCADA system. The control and automation system was designed for complete auto (automatic) operation of the entire facility in the water treatment plant and allows for manual override of the control system when the control system is unavailable.

The control system has been designed and equipped with redundancy both at the PLC levels and SCADA level (dual redundancy). While, the PLCs are configured with hot standby formation to cope with failure of a working PLC by switching over instantaneously to the other standby PLC, the SCADA servers are configured in dual redundant formation not to miss the field data transmitted from the field process level. Consequently, the reliability of the SCADA system is enhanced through the redundant configuration of the PLCs and the SCADA servers.

The SCADA software has been equipped with unlimited tag license so as to cater to any future expansion or addition of modules. The system configuration in Figure 3.4.1 represents the control system architecture existing at the TK Halli WTP. The control system is designed with hot standby PLC system with simplex inputs and outputs.

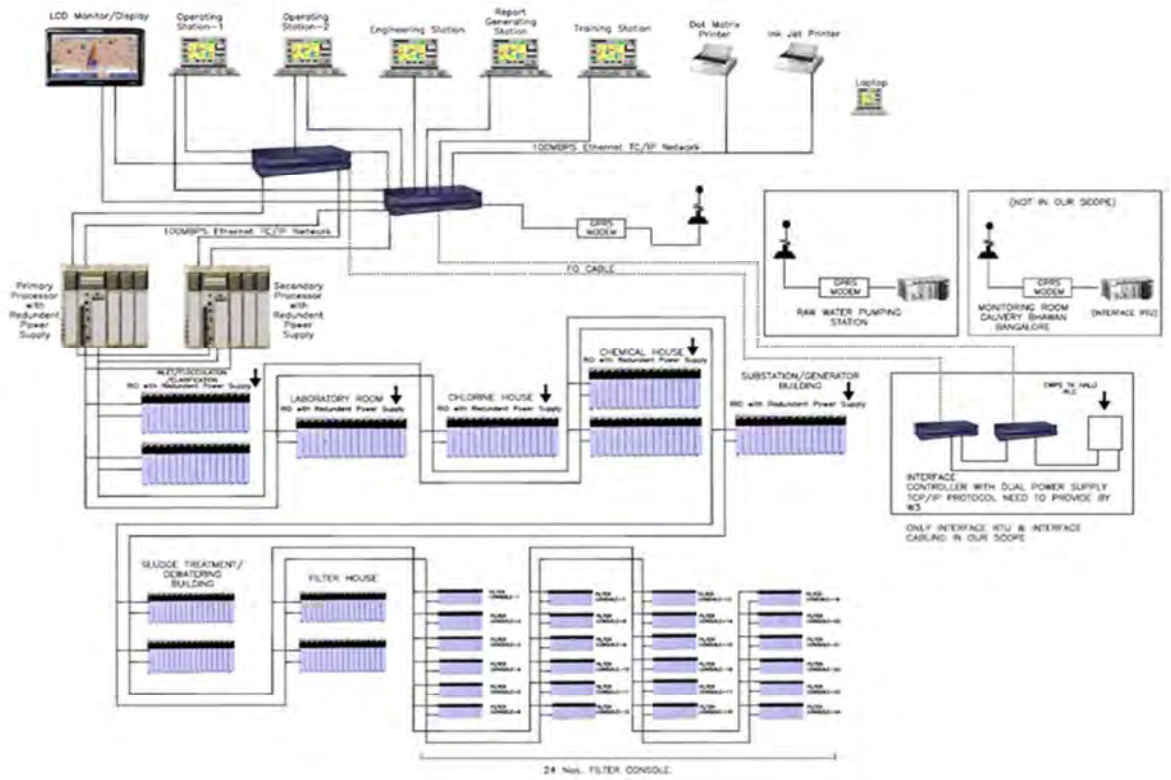


Figure 3.4.1 SCADA Control System Configuration at TK Halli WTP

The SCADA system is further enhanced by a predictive maintenance software module and operational data management software (M/s Falconeer) which is installed on the top of system architecture to fetch data from SCADA. The operational management software monitors and predicts the process disruptive conditions, then advises predictive maintenance procedures. The control system comprises engineering stations and operator stations, in addition to online & offline printing system which helps in alarm and report printing. The engineering station and the operator station play a role of assisting the plant operator to set any parameters and operate the plant without interfering with the SCADA servers. In addition to the same, standalone PLC panels in the plant are equipped with panel HMI (Human Machine Interface) to enable the plant operator to view the particular process and take corrective actions if required. The HMI serves as a visual aid of the particular process which can be accessed from the field itself as the HMI is installed on panels which are standalone and next to the process facility.

The communication interface which is required to transmit the plant operational data to the CSC comprises UHF data telemetry system with licensed frequency.

(2) Water Distribution Network (Pumping Stations)

The water distribution network under Stage IV Phase 2, which essentially comprises pumping stations at TK Halli, Harohalli and Tataguni. These facilities are equipped with PLC based SCADA system. The control and automation system has been designed for complete auto (automatic) operation of the entire facility and allows for manual override of the control system when the control system programmed in the PLC is unavailable. The surge systems downstream of the pumping stations are also monitored from the respective control system.

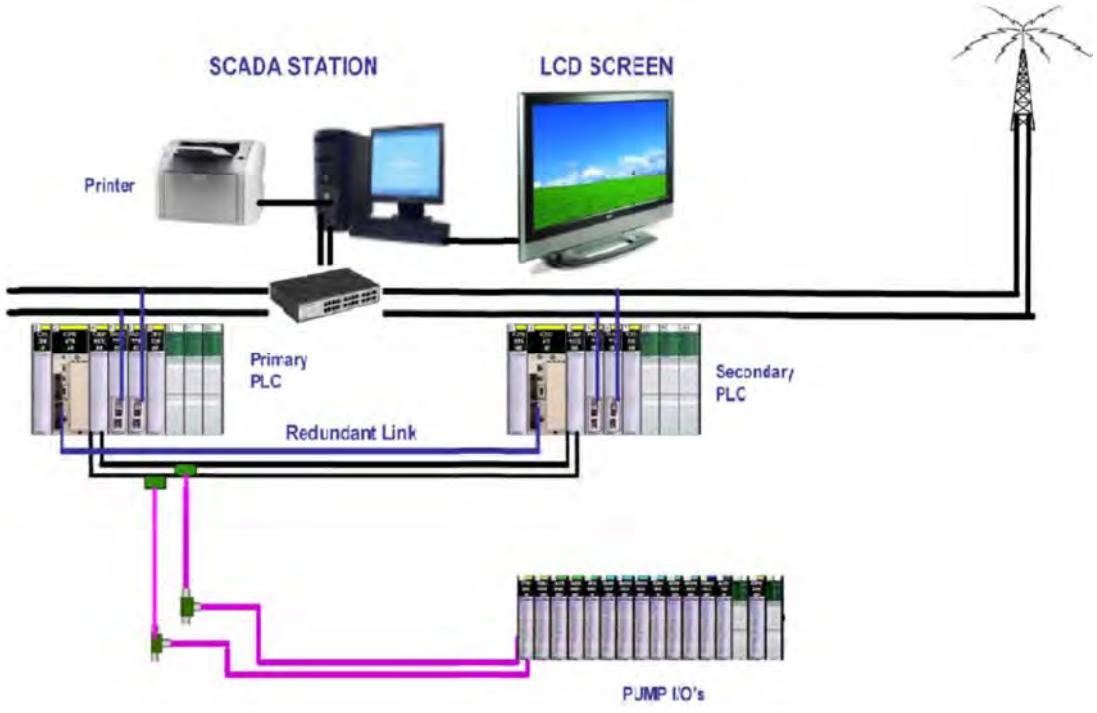


Figure 3.4.2 System Architecture at Pumping Stations

The control system has been designed and equipped with redundancy both at the PLC levels and SCADA level (dual redundancy). The SCADA software has been equipped with unlimited tag license.

The communication system interface consists of UHF telemetry network, through which the pumping station operational data is transmitted in real time to the CSC, installed at Shimsha Bhavan.
The ground level reservoirs (6 Nos) which were constructed during Phase-II are equipped with remote telemetry unit (RTU) with GPRS to transmit the level data to the CSC in real time.

The pumped water to the OHTs and/or the GLRs in Bengaluru city is gravitated to the distribution network. The operating staff (from the contractor) for the water supply facilities are generally with sufficient experience of water supply system and basic knowledge about the SCADA system. The inlet and outlet valves at the GLRs are manually operated by the operating staff when required by referring to the water levels of the GLRs, which are monitored and transmitted to the CSC.

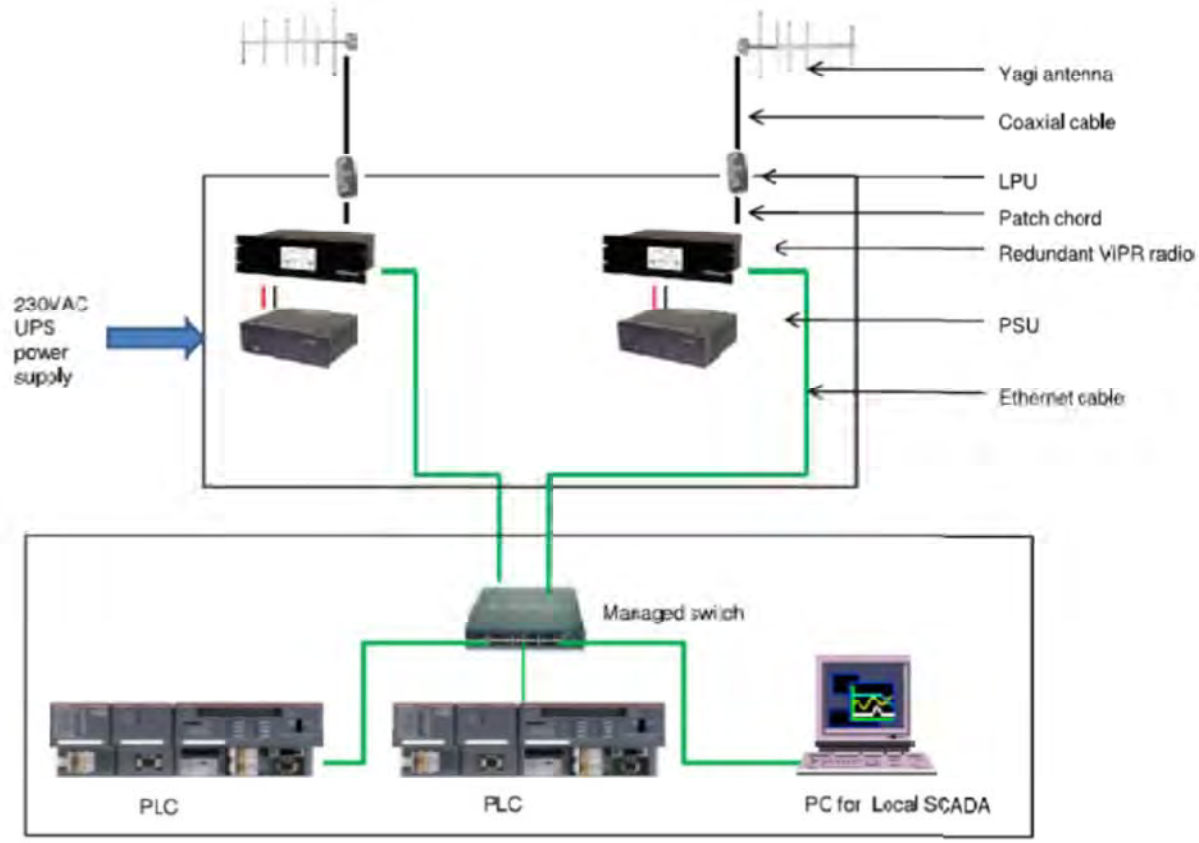


Figure 3.4.3 System Architecture for Data Communication at Remote Stations

3.4.3 Centralized SCADA Center at Shimsha Bhavan

A centralized SCADA system has been setup at BWSSB office at Shimsha Bhavan. The CSC has been designed for integration of current water treatment & distribution facilities along with the sewerage facilities. The CSC has been sized to accommodate any future expansion of the water treatment & distribution facilities along with the sewerage facilities. The CSC is currently integrated with the water treat-

ment plant of Stage IV, pumping stations and the ground level reservoirs. The sewage treatment plants which are currently under construction shall be integrated with the CSC in due course of time when the data is made available before final commissioning stage.

Under the contract, the CSC contractor is to operate and maintain the CSC for a period of seven (7) years after completion of the installation works. The CSC contractor under the operation and maintenance period is required to integrate any plant/station which is commissioned during these seven years. There may be a SCADA system maintenance service contracted to the original contractor for the SCADA system through a mutual agreement reasonably acceptable by the both parties after the completion of the operation and maintenance for the seven (7) year period.

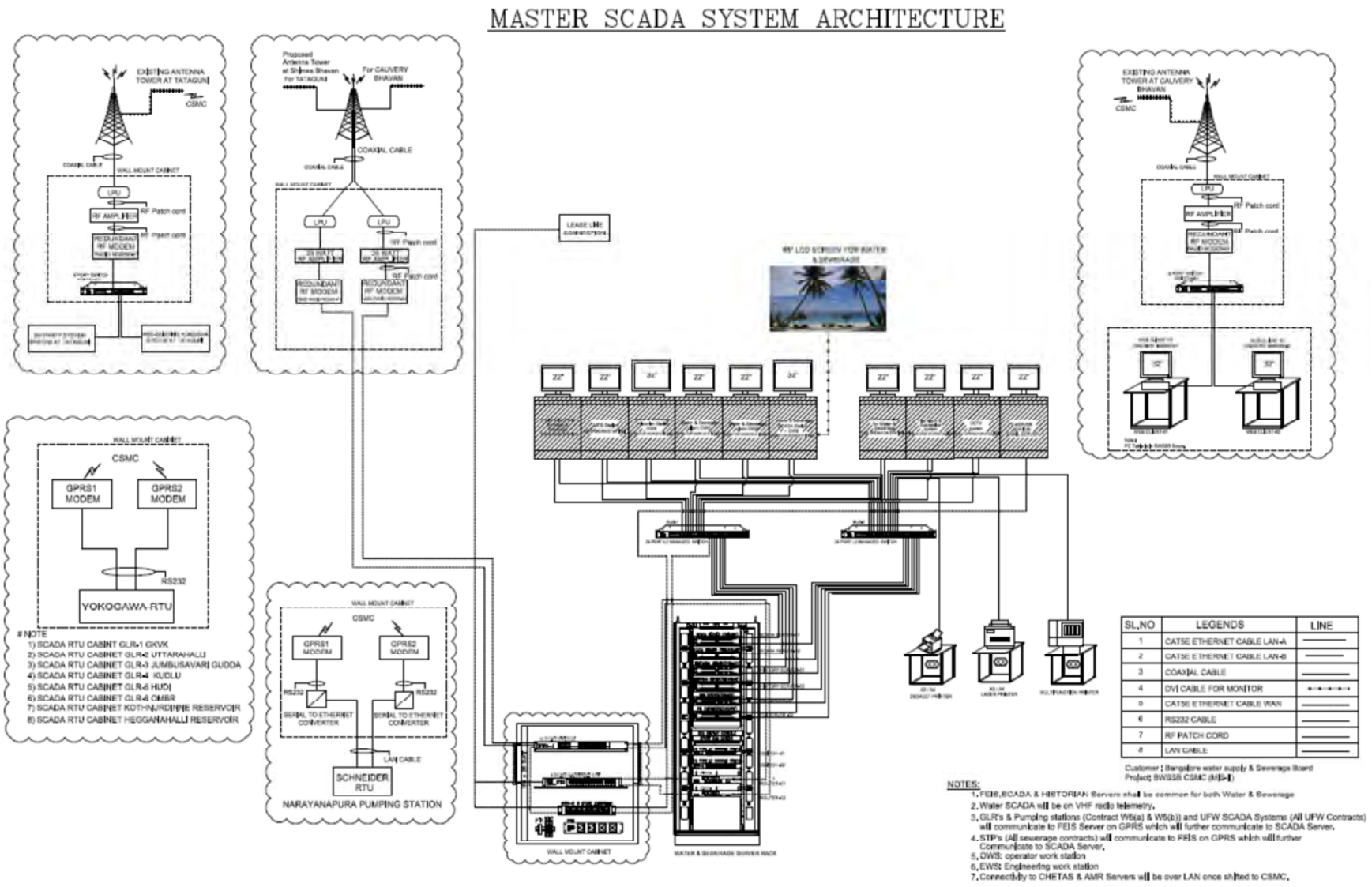


Figure 3.4.4 System Architecture at Centralized SCADA Center (CSC)

The CSC is also scheduled to be integrated with the AMR SCADA server. The AMR SCADA stands for automatic meter reading SCADA servers wherein data from bulk flow water meters is transmitted in real time to the SCADA servers. The SCADA servers are located at the CSC location, wherein the SCADA server is integrated via OPC to the CSC SCADA server.

The CSC SCADA servers are also integrated with the UFW SCADA servers, which play roles of monitoring water supply flow rates and pressures measured and collected at DMAs within the water distribution network. Further, the UFW servers generate reports such as daily, monthly and yearly reports, which assist the operating staffs aiming adequate water distribution to consumers. Under UFW related contracts, D1a – Distribution improvement and leakage reduction project (UFW) for Central Division, D2a – Distribution improvement and leakage reduction project (UFW) for West Division and D2b – Distribution improvement and leakage reduction project (UFW) for South Division, each UFW Zone has been provided with a SCADA system (Dual redundant system). Under three (3) different contracts (D2A, D1A & D2B), the UFW SCADA systems have been established. SCADA system under D2B contract is the master SCADA for the entire UFW zone. The UFW SCADA is also integrated with the SDC (Slum Bulk meter) meters to have a complete view of the entire water distribution network within Bengaluru city. There are several components consisting of many kind of SCADA systems which can be supplied by different vendors/manufactures. In this case it is possible for these supplied from different vendors/manufactures to communicate each other over an open protocol e.g. OPC (OLE (Object Linking and Embedding) Process Control) smoothly.

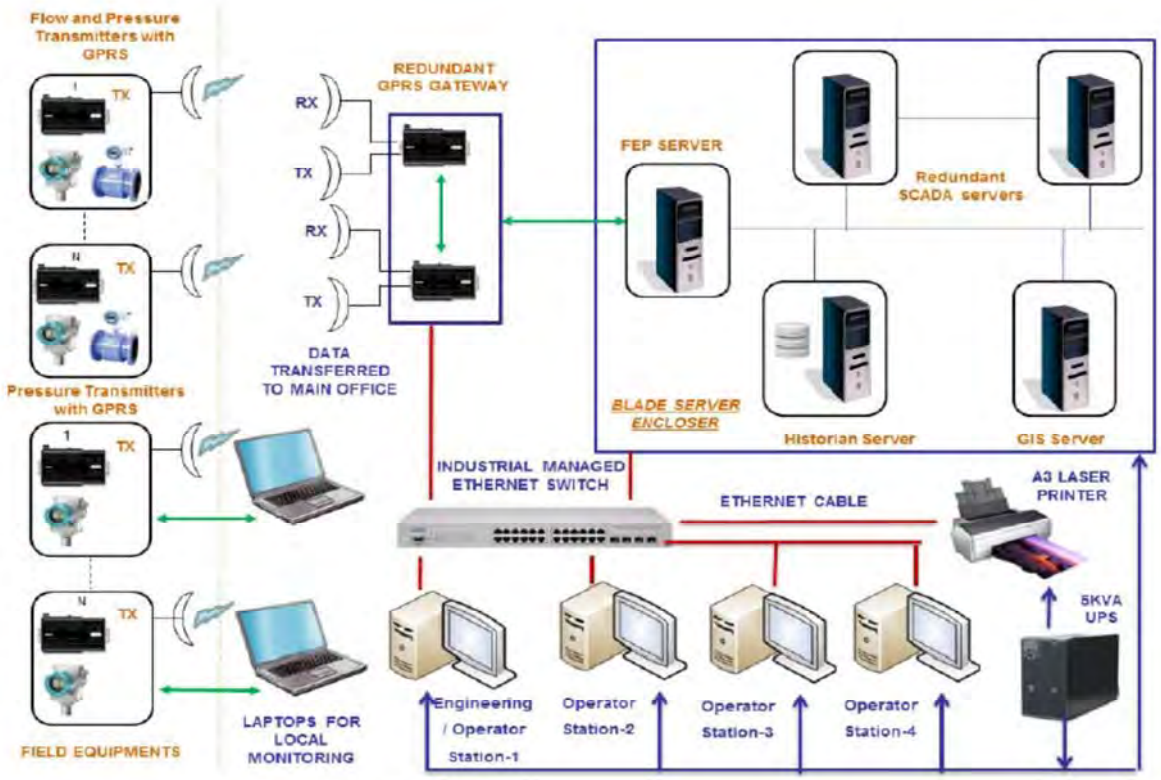


Figure 3.4.5 UFW SCADA System Architecture (Typical for each Contract)

The CSC is designed integrating water treatment & distribution network SCADA servers, the AMR SCADA server, and UFW SCADA servers, BWSSB shall have a complete monitoring of the entire water supply system from intake to distribution network within the city. The data is available at web servers and the same can be accessed via web clients by BWSSB personnel.

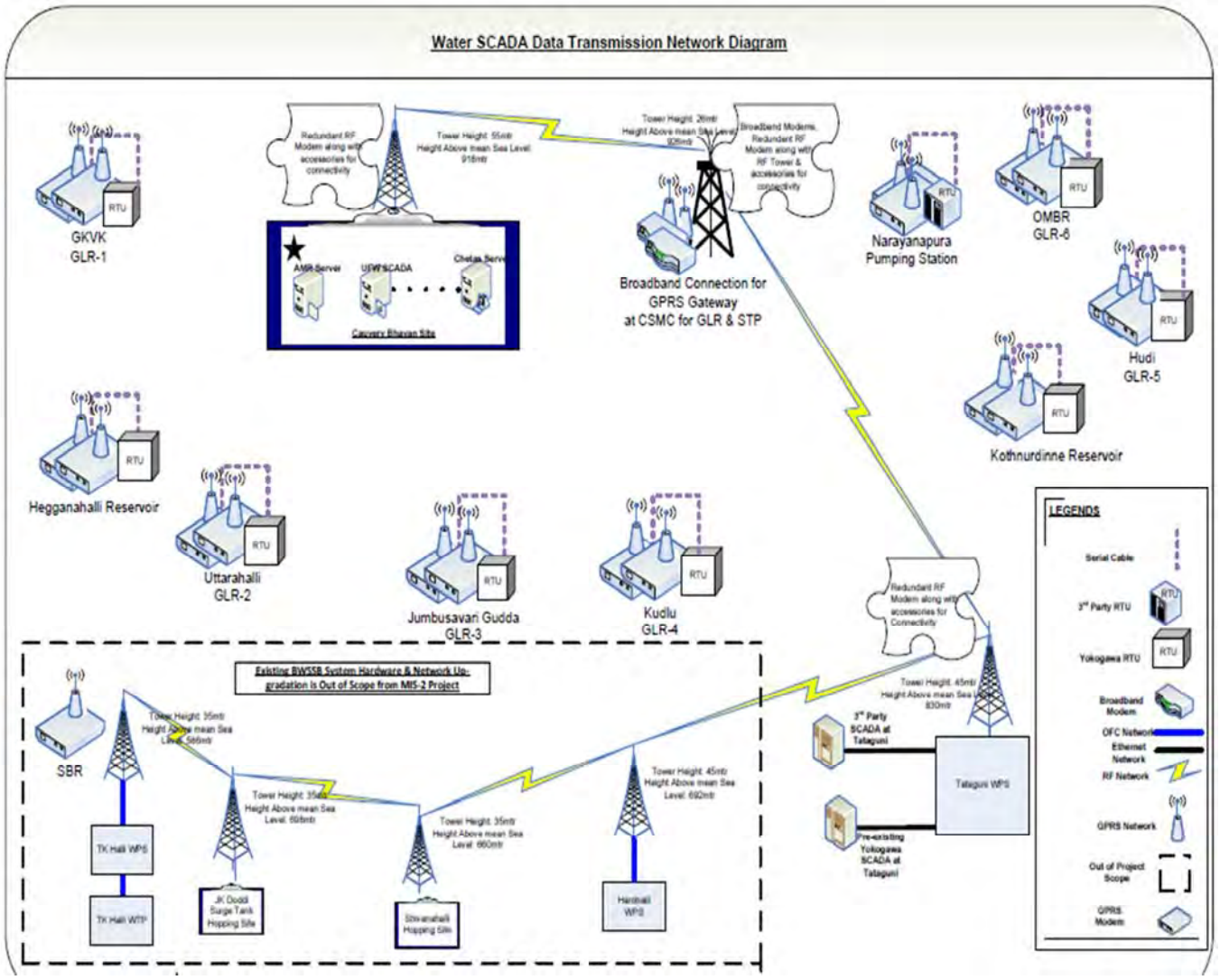


Figure 3.4.6 Water SCADA Network Diagram

The above diagram depicts the communication network adopted for data transmission from TK Halli (water treatment) up to the CSC at Shimsha Bhavan. The RF (Radio Frequencies, UHF) is utilized as communication medium among the transmission pumping stations, while at the sites of JK Doddi Surge Tank and the CSC, the GPRS wireless network is utilized for GLRs.

3.4.4 Sewerage SCADA System

The sewage treatment plants setup under Phase-II are equipped with the PLC based SCADA system. The control and automation system has been designed for complete auto (automatic) operation of the entire facility and allows for manual override of the control system when the control system is unavailable.

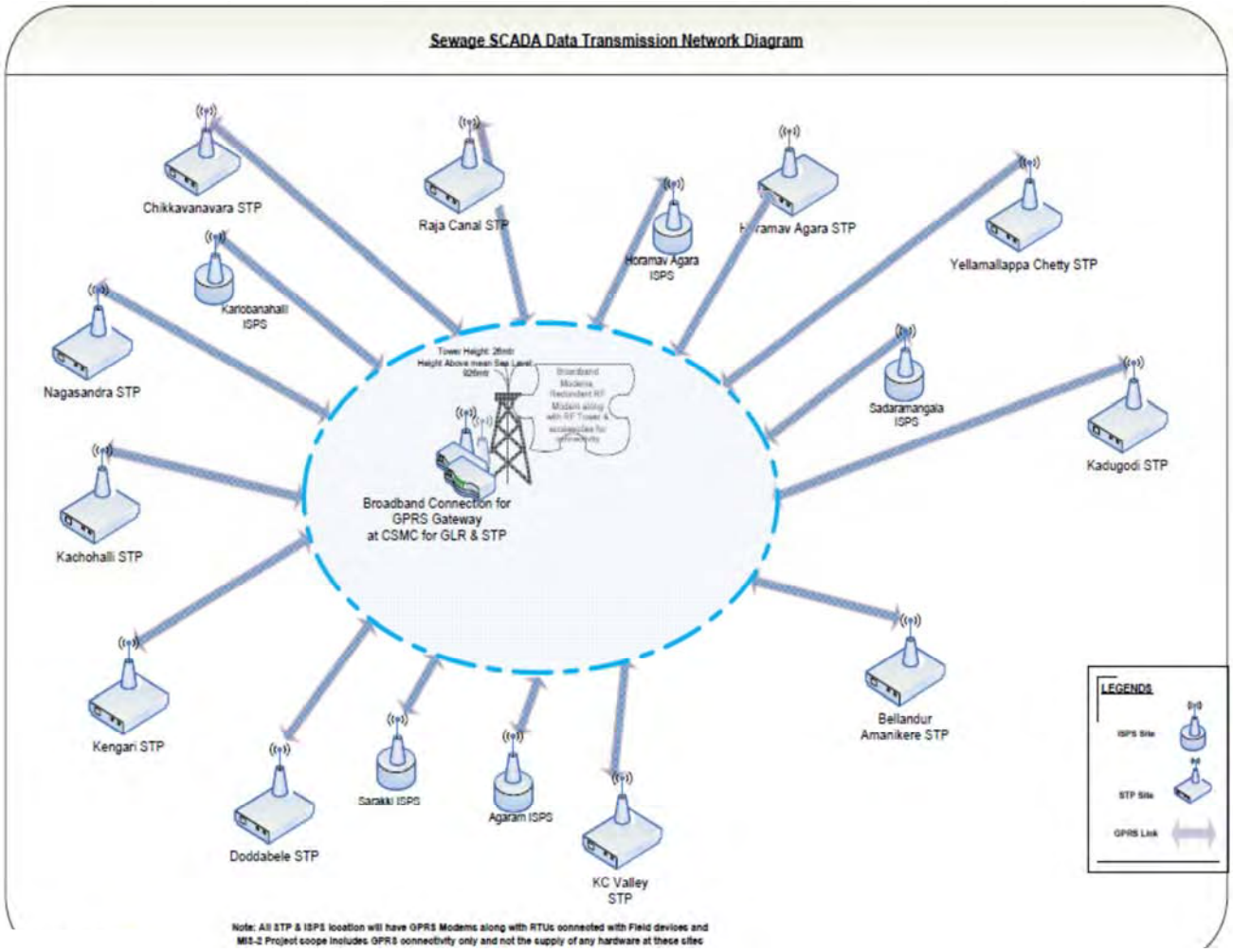


Figure 3.4.7 Sewerage SCADA Data Transmission Network Diagram

The control system has been designed and equipped with redundancy both at the PLC levels and SCADA level (dual redundancy). The SCADA software is equipped with unlimited tag license so as to cater to any future expansion or addition of modules.

The following diagram depicts the control system architecture adopted at one of the STP's –K&C Valley STP. The control system architecture is typical across all the STP's which are being set up. All the STP's shall be integrated with the centralized SCADA center, such that real time plant operational data can be monitored from the central location.

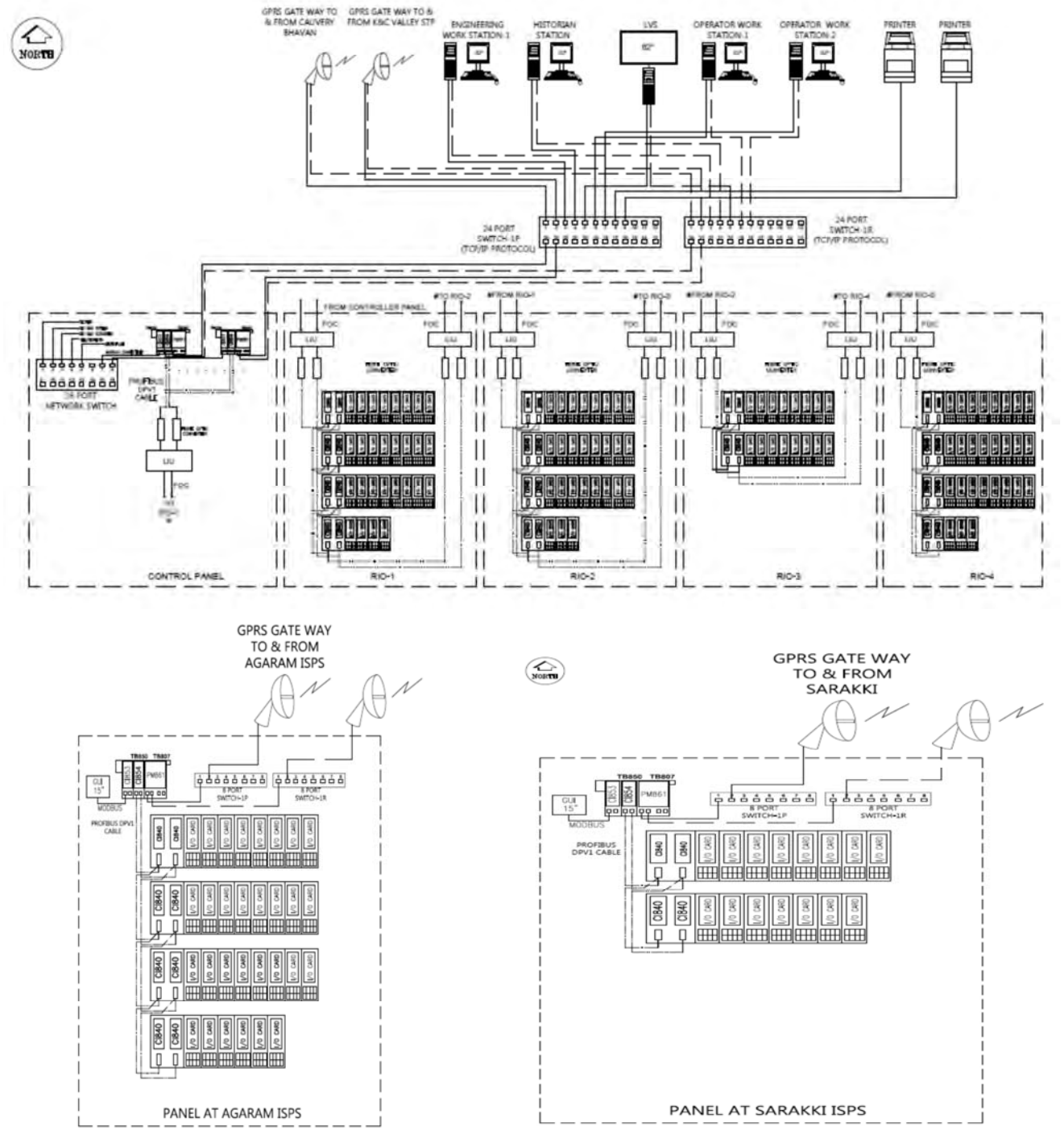


Figure 3.4.8 Typical Control System Architecture at STP

Each STP implemented/expanded in BWSSP* Phase 1 and the STP expanded at V Valley with 60 MLD have been equipped with a local SCADA system, which enables automatic operation of the plant equipment.

* BWSSP is the abbreviation of Bengaluru Water Supply and Sewerage Project, which is used for the water supply and sewerage project implemented in BBMP under JICA funding. Thus, CWSS Stage IV Phase 1 and 2 (only water supply component) coincides with BWSSP Phase 1 and 2, though BWSSP includes a sewerage component.

The local SCADA consists of a PC based operator station, a MIMIC graphic panel, a printer and PLC panels. Field data are collected by hard-wired method to the MIMIC panel and the PLC panels. The operator station connects the MIMIC panel, the PLCs and the printer through RS 232C or RS 485 for data communication. The SCADA system configuration at V Valley with 60 MLD is shown in Figure 3.4.9.

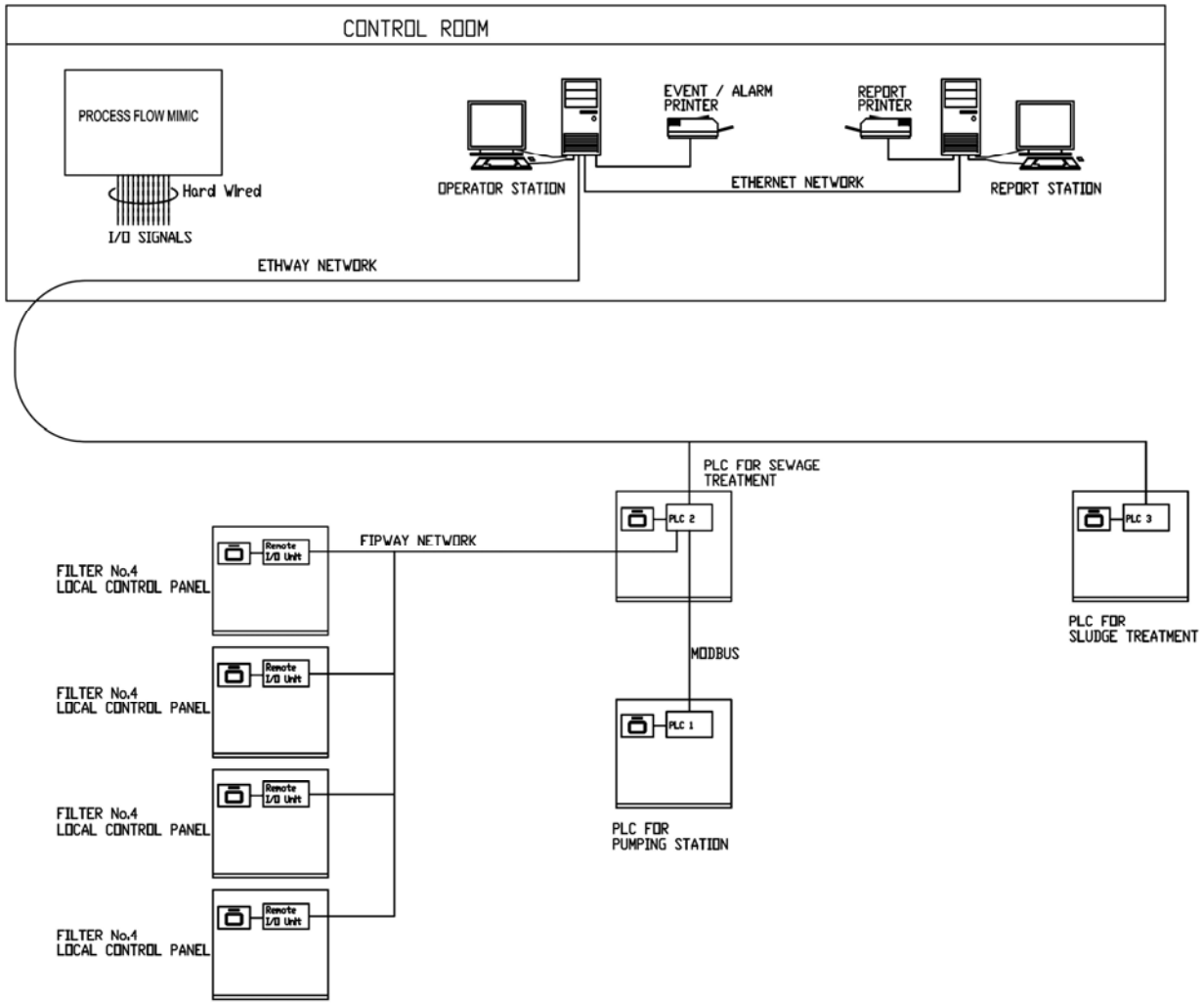


Figure 3.4.9 Typical Control System Architecture at STP –Phase-1

For any control and automation system to function as desired, it is important to select the right vendor to supply and execute the control and automation projects. The various vendors who have experience to form the control and automation solution for both water and sewerage systems at BWSSB are listed below.

i. M/s Schneider Electric
ii. M/s Mitsubishi Electric
iii. M/s Yokogawa
iv. M/s Siemens
v. M/s ABB

Chapter 4 Existing Sewerage Facilities and On-going/ Planned Sewerage Projects

4.1 Present Sewerage Services

Table 4.1.1 shows the information on sanitation/sewerage services at present in the BBMP area according to BWSSB web site. Majority of households have toilet facilities, but sewerage service coverage is limited to about 40%. It is reported that inflow sewage into existing STP exceeds treatment capacity with about 6%, which is discharged without treatment (*Source: Service levels in urban water and sanitation sector status report (2010-11), MoUD, 2012*). On the other hand, it is concluded in this survey that about 55% of generated sewage in the Core area and part of ULB area is collected and treated at the existing STPs (as of beginning of February 2017, sewerage service area is limited to the Core area and part of 5 ULBs.), as presented in Chapter 8, Water Pollution Status in Public Water Bodies. The records of inflow sewage volume into the existing STPs include sewage collected from house connections and from drainages through interceptors, which means 55% service coverage is regarded as an apparent percentage.

Table 4.1.1 Sanitation /Sewerage Services

Item		Status (%)
Sanitation/Sewerage	Toilet facility coverage (by water sealed toilet and dry type toilet)	100.0
	Sewerage service coverage	38.0
	Collection efficiency by sewage collection systems	55.0
	Adequacy of sewage treatment capacity (inflow sewage %)	106.0
	Efficiency in redressal of customer complaints	94.0
	Cost Recovery	110.0
	Efficiency in collection of sewage charges	97.0

Note: Information in the table is from web site of BWSSB.

Presently, the sludge from septic tanks/soak pits are removed using sludge cleaning equipment operated by private operators. The private operators provide services on receipt of the request from customers with pay. The septic tanks are usually demolished and buried after construction of sewerage systems.

The boundary between BWSSB and private customers on the sewerage facilities is as follows:

- Up to the junction box from private house is under responsibility of house owner.
- House connections from junction box to public sewer is responsibility of BWSSB.

4.1.1 Sewerage Services by District

Investigations on sewerage service coverage in Bengaluru area was conducted in 2011 census. They did not define sanitary sewerage and instead using storm drainage as the facilities to carry sanitary sewage and storm water. Table 4.1.2 presents service coverage by drainage facility type. Majority of Core area

belong to District 5.

Table 4.1.2 Number and Percentage of Households by Type of Drainage Connectivity for Sewage Outlet

Sl. No.	Name of Sub-district	Area	Total number of households	Number and percentage of households by type of drainage connectivity for waste water outlet		
				Closed drainage	Open drainage	No drainage
1	Bengaluru North	Total	75,881	18.90%	61.86%	19.23%
		Rural	62,245	17.64%	61.16%	21.20%
		Urban	13,636	24.66%	65.06%	10.27%
2	Bengaluru South	Total	44,832	26.29%	50.78%	22.93%
		Rural	35,718	16.05%	57.84%	26.11%
		Urban	9,114	66.40%	23.14%	10.46%
3	Bengaluru East	Total	22,317	19.29%	58.74%	21.97%
		Rural	22,317	19.29%	58.74%	21.97%
		Urban	0	0%	0%	0%
4	Anekal	Total	128,132	30.20%	52.03%	17.77%
		Rural	87,348	26.63%	49.70%	23.66%
		Urban	40,784	37.83%	57.02%	5.16%
5	Not under any sub-district	Total	2,105,894	83.72%	13.47%	2.81%
		Rural	0	0%	0%	0%
		Urban	2,105,894	83.72%	13.47%	2.81%
District-Bengaluru		**Total**	**2,377,056**	**1,832,088(77.07%)**	**433,141(18.22%)**	**111,827(4.7%)**
		Rural	**207,628**	**44,286(21.33%)**	**115,251(55.51%)**	**48,091(23.16%)**
		Urban	**2,169,428**	**1,787,802(82.41%)**	**317,890(14.65%)**	**63,736(2.94%)**

Source: BWSSB

According to 2011 census on toilet facilities, about 80% of toilet facilities are either connected to sewer system or septic tanks, while about 14% of toilets are unsanitary type (dry type), as shown in Table 4.1.3. Figure 4.1.1 shows the location of four sub-districts. According to the information, connection ratios to conduits and open channels are about 77% and 18%, respectively. About 5% are not connected drainage facilities, of which only 3 % in urban area, while 23% in rural area. Sanitation facilities have been provided in the BBMP area expanding from the Core area to the surrounding areas to cope with increasing population. Presently, the remote areas, such as 110 Villages merged into the BBMP need urgent countermeasures to improve sanitation conditions.

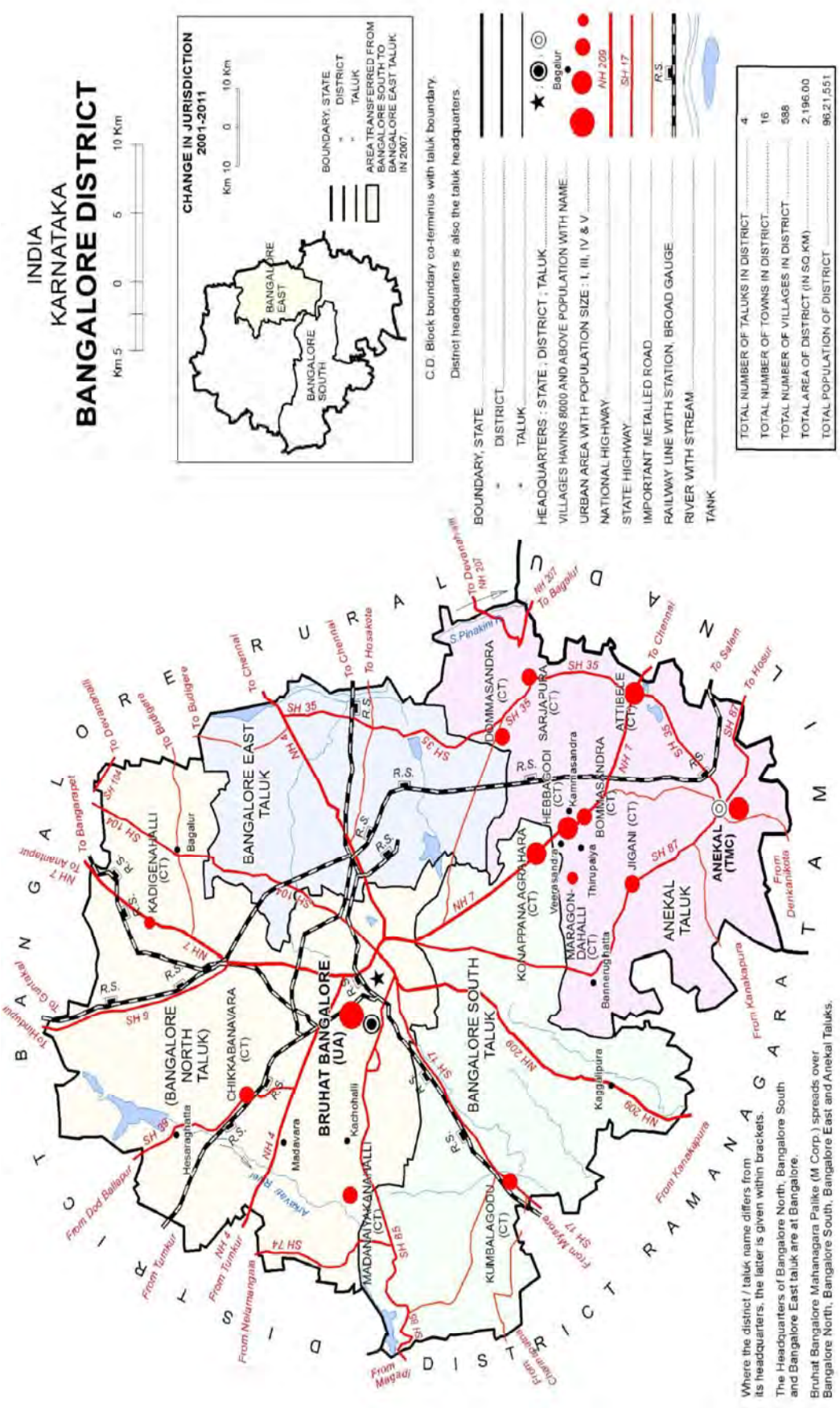


Figure 4.1.1 Sub-district of Bengaluru

Source: Census 2011

Table 4.1.3 Number and Percentage of Households by Type of Toilet Facility

Sl. No	Name of Sub-district	Area	Total number of households	Flush/ Pour latrine			Pit Latrine		Night Soil disposed into open drain	Service Latrine		No latrine within premises	
				Piped sewer system	Septic tank	Other system	With slab/ Ventilated improved pit	Without slab/ open pit		Night soil removed by human	Night soil serviced by animals	Public Latrine	Open
1	Bengaluru North	Total	75,881	13.51%	18.32%	0.98%	48.27%	0.49%	0.13%	0.02%	0.03%	0.92%	17.35%
		Rural	62,245	11.59%	13.32%	1.17%	52.28%	0.56%	0.15%	0.02%	0.04%	0.99%	19.88%
		Urban	13,636	22.27%	41.16%	0.09%	29.97%	0.15%	0.04%	0%	0%	0.56%	5.76%
2	Bengaluru South	Total	44,832	21.80%	7.39%	2.42%	42.83%	0.33%	0.18%	0.02%	0.38%	1.89%	22.74%
		Rural	35,718	11.77%	8.12%	2.81%	47.66%	0.41%	0.21%	0.03%	0.48%	2.03%	26.49%
		Urban	9,114	61.11%	4.54%	0.92%	23.90%	0.02%	0.04%	0%	0.01%	1.37%	8.08%
3	Bengaluru East	Total	22,317	15.02%	25.93%	2.10%	35.85%	0.40%	0.16%	1.31%	0.57%	1.09%	17.56%
		Rural	22,317	15.02%	25.93%	2.10%	35.85%	0.40%	0.16%	1.31%	0.57%	1.09%	17.56%
		Urban	0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
4	Anekal	Total	128,132	17.98%	22.40%	1.78%	33.34%	1.06%	2.20%	0.20%	0.22%	2.06%	18.77%
		Rural	87,348	14.43%	17.15%	1.41%	37.40%	0.68%	0.23%	0%	0.17%	2.53%	26.00%
		Urban	40,784	25.59%	33.65%	2.57%	24.65%	1.85%	6.40%	0.63%	0.33%	1.04%	3.29%
5	Not under any sub-district	Total	2,105,894	79.28%	5.57%	0.82%	10.38%	0.17%	0.24%	0.15%	0.22%	1.55%	1.62%
		Rural	0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		Urban	2,105,894	79.28%	5.57%	0.82%	10.38%	0.17%	0.24%	0.15%	0.22%	1.55%	1.62%
District-Bengaluru		**Total**	**2,377,056**	**72.19%**	**7.11%**	**0.91%**	**13.68%**	**0.23%**	**0.34%**	**0.16%**	**0.22%**	**1.56%**	**3.59%**
		Rural	**207,628**	**13.19%**	**15.39%**	**1.65%**	**43.46%**	**0.57%**	**0.20%**	**0.15%**	**0.22%**	**1.82%**	**23.34%**
		Urban	**2,169,428**	**77.83%**	**6.32%**	**0.84%**	**10.83%**	**0.20%**	**0.35%**	**0.16%**	**0.22%**	**1.53%**	**1.70%**

Source: BWSSB

4.2 Sewer System

4.2.1 Core Area

Sewerage networks of Core area are divided into seven (7) areas by the valleys. The Core area of Bengaluru is 245 km^2, which is the older part of the city. BWSSB is responsible for the people in this area to supply water and provide sewerage services. Several schemes were implemented to supply water to the city. For collection of sewage generated in the city, about 3,300 km of smaller diameter pipelines are laid. To transmit the collected sewage to the treatment plants, 300 km of larger diameter pipes are laid. Some of the sewers are about 40 to 50 years old. Due to various reasons, viz. aging of sewers, encroachment of sewers, damages in the sewerage system, crown corrosion of sewers, abuse of sewers, direct discharges from the houses built on the side of storm water drain, direct discharges from apartments, new layouts etc., some sewage is flowing through storm water drains and entering lakes, which causes pollution in the lakes. Following are the service area covered by sewerage systems in the Core area. Service area coverage is 93.5% (229 km^2/245 km^2), which is almost the same as drainage connection ratio of 95%.

Table 4.2.1 Sewerage Service Area in the Core Area

Major and Minor valleys		Area (km^2)	
K&C	Koramangala	73	37
	Challaghatta		36
Hebbal		48	
Vrishabhavathi		38	
Arkavathi		35	
Taverekere		19	
Kathariguppe		16	
Total		229	

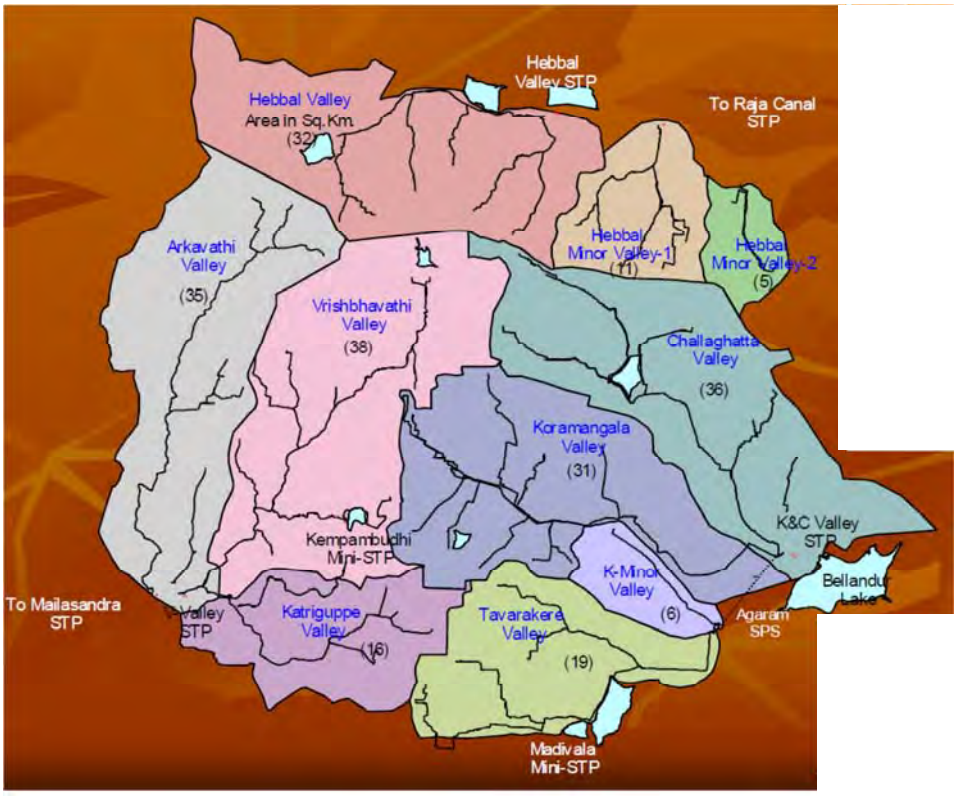
Source: BWSSB

Figure 4.2.1 shows sewerage service area by valley in the Core area. Table 4.2.2 summarizes sewer length by diameter.

Table 4.2.2 Sewer Length by Diameter in the Core Area

Less than 400mm diameter		Above 400 mm diameter	
150mm dia.	1,490 km	Total length	297 km
175mm dia.	450 km		
225mm dia.	1,600 km		
300mm dia.	275 km		
Total length	3,815 km		
Manholes	128,000 Nos.	Manholes	6,793 Nos.

Source: BWSSB



Source: CS04- Presentation (BWSSB)

Figure 4.2.1 Sewerage Service Area by Valley in Core Area

4.2.2 ULB Area

ULB areas are located at the fringe of the Core area and currently sewerage systems are under construction. Locations of the systems are shown in the latter part of this section.

4.3 Intermediate Sewage Pump Stations (ISPS)

4.3.1 Summary of Existing ISPSs

Eight (8) ISPSs were constructed under *BWSSP Phase 1, as shown in Table 4.3.1.

*BWSSP Phase 1 (Bengaluru Water Supply and Sewerage Project Phase 1); BWSSP is the project implemented under the financial assistance by Japanese Government (JBIC). BWSSP Phase 1 coincides with the project for CWSS Stage IV Phase 1 (used by GoK and BWSSB). In BWSSP Phase 1 sewerage component for Core area and parts of ULBs, STPs and main sewers were funded by JBIC, while lateral sewers were funded by BWSSB and BDA. On the other hand, BWSSP Phase 2 sewerage component has been under way with financial assistance from JICA for STPs. While, main sewers and lateral sewers were financed in the combination of World Bank (50% as KMRP Project), GoI (38%) and GoK (12%).

Table 4.3.1 Existing ISPSs

Name of ISPS	Location	Final Destination	Design Capacity(MLD)

Name of ISPS		Location	Final Destination	Design Capacity(MLD)
1	Agaram	Core Area	K&C Valley 30MLD STP	65
2	Subramanya Pura	R.R. Nagar Zone	Mailasandra 75MLD STP	50
3	Bagalkunte	Dasarahalli Zone	Nagasandra 20MLD STP	30
4	Kaggadasapura	K.R. Puram CMC	Kadabeesanahalli 50MLD STP	30
5	Horamavu	Bytrayanapura zone	Raja Canal 40MLD STP	30
6	N.K.Halli	Dasrahalli CMC	Nagasandra 20MLD STP	25
7	Basavapura	K.R. Puram CMC	K.R. Puram 20MLD STP	20
8	Myadarahalli	Dasarahalli Zone	Bagalkunte ISPS	15

Source: JICA Survey Team

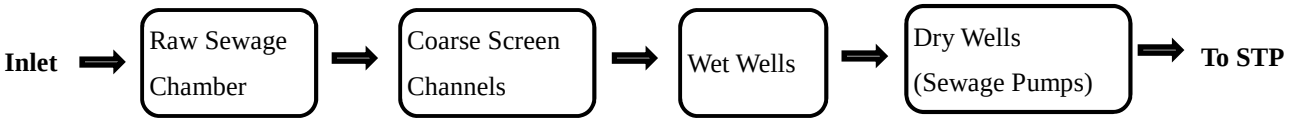
4.3.2 Present Situation of Agaram 65 MLD ISPSs

Information on Agaram ISPS, which is the largest ISPS among the 8 ISPSs of BWSSP Phase 1, is as follows:

(1) Year of Commissioning: 2004

(2) Flow Diagram

The ISPS comprises a raw sewage chamber, two coarse screen channels that have automatic coarse screens, two wet wells, and two dry wells that have 4 nos. sewage pumps.



(3) Major Equipment

- Sluice Gates: 5 Nos.
- Coarse Screens: Automatic Climber Type, Opening 50mm; 2 Nos.
- Sewage Pumps: 1000 m^3/h, 132kW, 4 Nos. (3w+1S)
- Hoist: 5ton; 1 Nos.
- Diesel Generator (D.G.): 500kVA, 1 Nos.
- Transformer: 500kVA, 2 Nos.
- UPS system: 4 hours backup capacity for instrument control panel
- PLC: Equipped with battery backed EEPROM and redundant power supply system to avoid down time during power failure
- Level Switch: float type

(4) State of Equipment

Presently, the ISPS is running with full capacity. The equipment is operated without any problem. Screenings caught at the coarse screens are removed with a full of two (2) ton container per day, which include many plastic materials. Photo 4.3.1 to Photo 4.3.3 presents concerned facilities. Power failures occur about 10-20 times per month and DG (Diesel Generator) is operated for about 7-12 hours per

month.

Photo 4.3.1 Coarse Screens

Photo 4.3.2 Sewage Pumps

Photo 4.3.3 Container for Screenings

4.4 Sewage Treatment Facilities (including on-site sewage treatment facilities)

4.4.1 Overview of Existing STPs in Core and ULB Area

In the 1970s, two major STPs; K&C Valley STP and V-Valley, were constructed as primary treatment plant. Then, in the 1990s, the two STPs were upgraded to Secondary treatment level and another STP, Hebbal STP, was constructed. After that, the three STPs have been playing a major role to treat sewage in Core Area. In the 2000s, BWSSP Phase 1 Project was taken up and 8 STPs were constructed to cope with rapid population growth in the city. The total capacity of the STPs in Core area and ULB area is 721 MLD consisting of 536 MLD in Core Area and 185 MLD in ULB area. Table 4.4.1 shows information on existing STPs. Figure 4.4.1 presents service area of the existing STPs (secondary treatment). Table 4.4.2 shows existing private STPs in Bengaluru city, the treatment capacity of which is about 20% of the total treatment capacity of existing /on-going STPs.

Table 4.4.1 Information on Existing Sewage Treatment Plants

Name of STP		Service Area	Project scheme	Design Capacity (MLD)	Treatment Process
1	K&C Valley	Core Area	Before BWSSP, Phase 1	218	Activated Sludge Process (ASP)
2	V(Vrishabhavathi) Valley	Core Area	Before BWSSP, Phase 1	180	Trickling Filter (TF)
3	Hebbal	Core Area	Before BWSSP, Phase 1	60	ASP
4	Raja Canal	Core Area	BWSSP, Phase 1	40	Extended Aeration (EA)
5	K&C Valley	Core Area	BWSSP, Phase 1	30	EA
6	Madivara	Core Area	Before BWSSP, Phase 1	4	Upflow Anaerobic Sludge Blanket (UASB)+ Oxidation Pond
7	Cubbon Park	Core Area	Before BWSSP, Phase 1	1.5	Membrane Bio Reactor
8	Labaugh	Core Area	Before BWSSP, Phase 1	1.5	EA
9	Kempbudhi (Iti Colony)	Core Area	Before BWSSP, Phase 1	1	EA
10	Mailasandra	R.R. Nagar CMC Dasarahalli CMC	BWSSP, Phase 1	75	EA
11	Kadabesanahalli	Mahadevpura CMC K.R. Purum CMC	BWSSP, Phase 1	50	EA
12	Nagasandra	Dasarahalli CMC	BWSSP, Phase 1	20	EA
13	K.R. Purum	K.R. Purum CMC	BWSSP, Phase 1	20	UASB
14	Yelahanka (Allasandara)	Yelahanka CMC	BWSSP, Phase 1	10	ASP+Filtration
15	Jakkur	Yelahanka CMC	BWSSP, Phase 1	10	UASB+EA

Source: JICA Survey Team

Table 4.4.2 Capacity of Private STPs

Classification		Total Capacity (MLD)	
Private STPs*	Year 2009	28	141
	2010	22	
	2011	21	
	2012	17	
	2013	27	
	2014	19	
	2015	7	

Source: JICA Survey Team

*Note: Private STP means individually installed STP by apartment house, hotel and shopping mall.

Source: Excreta Matters_CSE_2012

Figure 4.4.1 Locations of Existing STPs

4.5 Reuse of Treated Sewage from BWSSB STPs

Present reuse volume of treated sewage is summarized in Table 4.5.1 based on billing data supplied by BWSSB. It can be seen that about six (6) MLD to eight (8) MLD is sold to various consumers.

Table 4.5.1 Present Reuse of Treated Sewage in Bengaluru

Name of the User		Nov-15	Dec-15	Jan-16	Feb-16	Mar-16	Apr-16	May-16
1	Arvind Mills			14,941	17,495	13,626	18,908	16,515
2	Bhagyalakshmi Farms			1,847	1,692	4,767	4,848	4,472
3	Chinnaswamy Stadium							744
4	Horticulture Dy. Director		68,960	71,158	72,189	78,960	81,020	84,865
5	Karnataka Golf Course			26,037	16,171	18,618	19,484	13,467
6	NECE			600	600	600	600	600
7	Paranjape Schemes Bengaluru	6	147	19	135	98	132	
8	Project Manager L & T			40	77	13	21	42
9	STW			630	1,057		1,259	1,176
10	Tangline Development Ltd.			1,078	1,277	1,538	14,752	13,049
11	TTW			72,935	76,286	74,292	90,438	81,291
12	Wonder Blues			600	600	600	1,200	600
Grand Total		**6**	**69,107**	**189,885**	**187,579**	**193,112**	**232,662**	**216,820**
Quantity of treated sewage sold in MLD		**0.20**	**2.30**	**6.33**	**6.25**	**6.44**	**7.76**	**7.23**

Source: JICA Survey Team

4.5.1 Utilization ratio of Existing STPs in Core and ULB Areas

An overall average ratio of inflow sewage volume to the total capacity of STPs in Core and ULB areas is approximately 70% at present. Utilization ratios of the respective existing STPs in Core and ULB areas is shown in Table 4.5.2. The reason why the low ratio of utilization at V-Valley is that some of the existing facilities are not working properly and the present inflow is controlled as low as the actual capacity.

Table 4.5.2 Utilization Ratio of Existing Sewage Treatment Plants

Name of STP		Age	Treatment Process	Design Capacity (MLD)	Present Inflow (MLD)	Ratio of Utilization	Remarks
1	K&C Valley	More than 20 years	ASP	218	180.48	82.7%	Average Jan.-Dec. in 2015
2	Vrishabhavathi (V-) Valley	More than 20 years	TF	180	61.73	34.3%	Average Jan.-Dec. in 2015
3	Hebbal	More than 15 years	ASP	60	54.96	91.6%	Average Jun. in 2016
4	Raja Canal	More than 10 years	EA	40	28.25	70.6%	Average Jan.-Dec. in 2015
5	K&C Valley	More than 10 years	EA	30	29.77	99.2%	Average Jan.-Dec. in 2015
6	Madivara	More than 15 years	UASB	4	-	-	

Name of STP		Age	Treatment Process	Design Capacity (MLD)	Present Inflow (MLD)	Ratio of Utilization	Remarks
7	Cubbon Park	More than 20 years	MBR	1.5	0.70	46.7%	Average Jan.-Dec. in 2015
8	Labaugh	More than 10 years	EA	1.5	1.413	94.2%	Average Jan.-Dec. in 2015
9	Kempbudhi (ITI Colony)	More than 10 years	EA	1	1	100%	Average Jun. in 2016
10	Mailasandra	More than 10 years	EA	75	60.68	80.9%	Average Jan.-Dec. in 2015
11	Kadabesanahalli	More than 10 years	EA	50	32.74	65.5%	Average Jan.-Dec. in 2015
12	Nagasandra	More than 10 years	EA	20	13.53	67.6%	Average Jan.-Dec. in 2015
13	K.R. Purum	More than 10 years	UASB	20	21.57	107.8%	Average Jan.-Dec. in 2015
14	Yelahanka (Allasandara)	More than 10 years	ASP +Tertial	10	7.96	79.6%	Average Jan.-Dec. in 2015
15	Jakkur	More than 10 years	UASB	10	8.70	87.0%	Average Jan.-Dec. in 2015
Total				721	503.48	69.9%	-

Source: JICA Survey Team

4.5.2 Effluent Quality of Existing STPs in Core and ULB Areas

The effluent water quality at existing STPs is shown in Table 4.5.3 and Table 4.5.4. According to the data on organic substances and nitrogen in the effluent at the STPs, existing BWSSB standards are followed except for those at V-Valley (180 MLD) STP. However, new standards that are to be adopted for new STPs guided by Central Pollution Control Board (CPCB) are more stringent, thus, the effluent quality even at the newer STPs in BWSSP Phase 1 does not meet the requirements. While, a five year of grace period for performing an obligation is given for the existing STPs. The improvement of effluent water quality need to be achieved in the expansion/ repair stages.

Table 4.5.3 Effluent Water Quality (BOD, COD, TSS) at Existing STPs

Name of STP		Age	Treatment Process	BOD (mg/l)	COD (mg/l)	TSS (mg/l)	Remarks
Existing BWSSB Standards				Not more than 20	Not more than 250	Not more than 30	
New Standards for new STPs				Not more than 10	Not more than 50	Not more than 10	
1	K&C Valley 218 MLD	More than 20 years	ASP	11.32	54.32	14.94	Average Jan.-Dec. in 2015
2	V-Valley 180MLD	More than 20 years	TF	34.12 NG	142.41	40.67 NG	Average Jan.-Dec. in 2015

Name of STP		Age	Treatment Process	BOD (mg/l)	COD (mg/l)	TSS (mg/l)	Remarks
3	Hebbal 60MLD	More than 15 years	ASP	14.5	123.07	23.79	Average Jun. in 2016
4	Raja Canal 40MLD	More than 10 years	EA	6.68	52.51	6.45	Average Jan.-Dec. in 2015
5	K&C Valley 30 MLD	More than 10 years	EA	9.17	52.40	12.74	Average Jan.-Dec. in 2015
6	Madivara 4 MLD	More than 15 years	UASB	-	-	-	
7	Cubbon Park 1.5 MLD	More than 20 years	MBR	1.92	17.58	<1	Average Jan.-Dec. in 2015
8	Labaugh 1.5 MLD	More than 10 years	EA + Tertiary	2.17	15.35	1.23	Average Jan.-Dec. in 2015
9	Kempbudhi 1 MLD	More than 10 years	EA	3.05	12.08	3.88	Average Jun. in 2016
10	Mailasandra 75 MLD	More than 10 years	EA	7.11	33.35	9.03	Average Jan.-Dec. in 2015
11	Kadabesanahalli 50 MLD	More than 10 years	EA	15.44	48.37	18.72	Average Jan.-Dec. in 2015
12	Nagasandra 20 MLD	More than 10 years	EA	12.11	83.91	13.77	Average Jan.-Dec. in 2015
13	K.R. Purum 20 MLD	More than 10 years	UASB	11.97	78.75	20.54	Average Jan.-Dec. in 2015
14	Yelahanka 10 MLD	More than 10 years	ASP +Tertiary	4.38	88.67	4.38	Average Jan.-Dec. in 2015
15	Jakkur 10 MLD	More than 10 years	UASB	17.97	149.29	18.95	Average Jan.-Dec. in 2015

Source: JICA Survey Team

Table 4.5.4 Nitrogen in the Effluent at Existing STPs

Name of STP		Treatment Process	T-KN (mg/l)	NH4-N (mg/l)	Nitrate Nitrogen (mg/l)	Remarks
Existing BWSSB Standards			**Not more than 100**	**Not more than 50**	**Not more than 10**	
New Standard for new STPs			**Not more than 10 (as T-N)**	**Not more than 5**	**Not more than -**	
1	Raja Canal 40 MLD	EA	10.5	4.48	1.0	10th July in 2016
2	K&C Valley 30 MLD	EA	8.4	-	1.5	Average Jan. in 2016
3	Mailasandra 75 MLD	EA	5.26	3.08	-	17th Feb. in 2014
4	Kadabesanahalli 50 MLD	EA	6.71	-	6.03	Average Jan. in 2016

Source: JICA Survey Team

4.5.3 New Effluent Standards

The new effluent standards at STPs were notified by the CPCB on November 2nd 2015. The comparison between existing and new standards of BWSSB is shown in Table 4.5.5. Required performance and additional functions to be observed under the new standard for existing STPs are summarized below.

(1) Nitrogen Removal Performance

Some existing STPs constructed by BWSSP Phase 1 have a nitrogen removal function, however, the performance seems to be insufficient. Enhanced nitrogen removal performance is required to meet the standard.

(2) BOD/COD Removal Performance

The existing STP in secondary treatment level that meet the new standards is only Mailasandra STP.

(3) Additional Removal Function for Phosphorus

No secondary STP has a phosphorus removal function in its treatment process excepting for tertiary treatment plant and there is few data on phosphorus in the existing STPs.

(4) Addition of the Disinfection Equipment and Monitoring of Residual Chlorine

Although they have a chlorination contact tank, chlorine is not dosed at the most of existing STPs. There is no regulation on fecal coliform in the existing standards of BWSSB, but, it is considered in the new standards.

Table 4.5.5 Comparison of Existing and New Effluent Standards at STPs

Parameter	Existing Standards of BWSSB	New Standards desired from CPCB
pH	5.5 to 9.00	6.5 to 9.00
BOD_5	20 mg/l	10 mg/l
COD	250 mg/l	50 mg/l
SS	30 mg/ Lit	10 mg/l as TSS
TK-N	100 mg/l	10 mg/l as T-N
NH_4-N	50 mg/l	5 mg/l
Nitrate Nitrogen	10 mg/l t	-
Dissolved Phosphate	5 mg/l	-
PO_4-P		2 mg/l
Fecal Coliform		230 MPN/ 100ml
Total Residual Chlorine	Not more than 1 mg/l	-

Source: JICA Survey Team

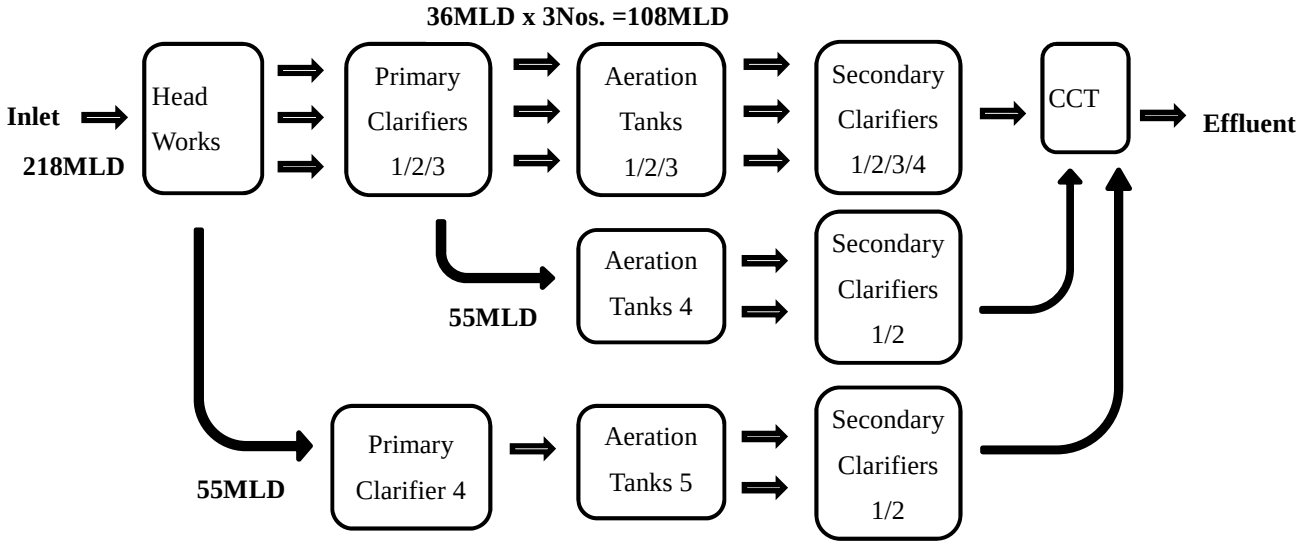
4.5.4 Present Situation of Existing STPs in Core and ULB Areas

(1) Koramangala & Challaghatta (K & C) Valley 218 MLD STP

This STP is the oldest and the largest STP in Bengaluru, commissioned in 1974 as a primary treatment plant, and it was upgraded to secondary level in 1990. In 2006, it was extended further and finally became 218 MLD STP. First STP was constructed in 1990 using conventional Activated Sludge Process with 108 MLD and then two sets of sewage treatment facilities with a capacity of 55 MLD were added in 2006.

1) Flow Diagram

The flow diagram is shown below and the major facilities are presented in Table 4.5.6.



2) Status of Equipment

Since the STP has been getting decrepit, some equipment needs repair and rehabilitation. All coarse screens were not working and need to repair. One of the three biological facilities for 108 MLD, a primary clarifier, an aeration tank and a secondary clarifier, were not operated for maintenance. Since the sludge thickener for 55 MLD is under maintenance, the centrifuges did not work. The operation condition in biological treatment is good, although chlorine is not dosed (a chlorination contact tank exists). Photo 4.5.1 to Photo 4.5.6 present major facilities of the STP.

Table 4.5.6 Major Facilities at K &C Valley 218 MLD STP

Facility	Dimensions	Operation state
1 Head Works (218MLD)		
(1) Coarse Screens 1	2.4mW x Opening 50 mm x 3 Nos.	3 Nos. not working.
(2) Coarse Screens 2	2.4mW x Opening 20 mm x 3 Nos.	3 Nos. not working.
(3) Grit Chamber	Horizontal Square, 15mW x 15mL x 2Nos.	
2 Primary Clarifier		
(1) 163MLD (108+55)	39.62mDia. x 3.04mSWD x 3Nos.	1 tank under repair.
(2) 55 MLD	44mDia. x 3.0mSWD x 1Nos.	
3 Aeration Tank		
(1) 108 MLD	40mW x 78mL x 3.6mSWD x 3Nos.	1 tank under repair.
(2) 55 MLD	42.23mW x 78mL x 3.9mSWD x 1Nos.	

Facility	Dimensions	Operation state
(3) 55 MLD	47.195mW x 78mL x 3.9mSWD x 1Nos.	
4 Secondary Clarifier		
(1) 108 MLD	44.8mDia. x 3.73mSWD x 3Nos.	1 tank under repair.
	36.58mDia. x 3.65mSWD x 1Nos.	
(2) 55 MLD	38.0mDia. x 3.5mSWD x 2Nos.	
(3) 55 MLD	42.5mDia. x 3.5mSWD x 2Nos.	
5 Chlorination Contact Tank		Not dosing
6 Sludge Thickener	Gravity thickener	
(1) 108 MLD	16.75mDia. x 4.0mSWD x 3Nos.	
(2) 55 MLD	25mDia. x 3.0mSWD x 1Nos.	
(3) 55 MLD	31.2mDia. x 3.0mSWD x 1Nos.	Under repair.
7 Dewatering		
(1) 163 MLD	Sludge Drying Bed 33mW x 39mL x 18Nos.	
(2) 55 MLD	Centrifuge, 25m^3/h x 3 Nos.	
8 Substation		
(1) 163 MLD	11kV 630A VCB Panel 1 Incomer, 2 Outgoing Transformer 1000kVA x 2 Nos.	
(2) 55 MLD	11kV 800A VCB Panel 1 Incomer, 2 Outgoing Transformer 1600kVA x 2 Nos.	Blowers for 163 MLD is included
9 Diesel Generator	625 kVA x 1Nos.	

Source: BWSSB

Photo 4.5.1 Coarse Screens

Photo 4.5.2 Grit Chamber

Photo 4.5.3 Primary Clarifier

Photo 4.5.4 Aeration Tank

Photo 4.5.5 Secondary Clarifier

Photo 4.5.6 Treated water

(2) Mailasandra 75 MLD STP

The STP is the largest STP among the seven STPs of BWSSP Phase 1, commissioned in 2006, extended aeration added Modified Ludzack-Ettinber process for removing of nitrogen.

1) Flow Diagram

The flow diagram is shown below and the major facilities are presented in Table 4.5.7.

2) Status of Equipment

The operation condition of biological treatment is excellent. Approximately 3 MLD of treated water is used for gardening or polishing of factory. Although chlorination contact tank exists, chlorine is not dosed. The generated sludge is reused for agriculture after dewatering by two methods, which are Sludge Drying Beds and Centrifuge. Photo 4.5.7 to Photo 4.5.10 present major facilities of the STP.

Table 4.5.7 Major Facilities at Mailasandra 75 MLD STP

Facility	Dimensions	Operation state
1 Head Works (218 MLD)		
(1) Fine Screens	Step type, Opening 6 mm x 3 Nos.	good
(3) Grit Chamber	Horizontal Square, 9.8mW x 9.8mL x 3Nos.	good
2 Anoxic Tank	7.02mW x 37.2mL x 3.99mSWD x 3Nos.	
(1) Mixer	Submersible type, 9Nos.	good
3 Aeration Tank	37.2mW x 148.8mL x 3.99mSWD x 3Nos.	
(1) Aerator	Surface Aerator x 50HP x 48Nos.	good
4 Secondary Clarifier	37mDia. x 3.5mSWD x 6Nos.	good
5 Chlorination Contact Tank	10mW x 30mL x 3.5mSWD x 3Nos.	Not dosing
6 Sludge Thickener	20mDia. x 4mSWD x 2Nos.	good
7 Dewatering		
(1) Centrifuge	30m^3/h x 3Nos.	good
(2) Sludge Drying Bed	10mW x 25mL x 20Nos.	good
8 Substation		
(1) Transformer	2500kVA x 2 Nos., 630kVA x 2 Nos.	good
9 Diesel Generator	750 kVA, 600kVA	good

Source: BWSSB

Photo 4.5.7 Fine Screens

Photo 4.5.8 Grit Chamber

Photo 4.5.9 Aeration Tank

Photo 4.5.10 Treated Water

4.5.5 Present Situation in 110 Villages

There is no planned sewerage system in 110 village areas. The present sanitation facilities are household septic tanks and soak pits. In the absence of proper sewerage system, the sludge and raw sewage generated in the areas are discharged through open drains/ nalas to nearby lakes/ water bodies. This is adversely affecting the environment condition.

4.5.6 Tertiary Treated Sewage Utilization

Table 4.5.8 summarizes existing tertiary treatment plants. The water is supplied to the consumers with pay. Table 4.5.9 shows consumer lists.

Table 4.5.8 Tertiary Treatment Plants

STP	Capacity (MLD)	Cost	Sale	User
V-Valley	60	10-12 INR/kl	25 INR/kl	Power station and industries
Yelahanka	10		1.8 mil. INR/month	International airport, BEL, Rail wheel factory and others
Cubbon Park	1.5		0.675 mil. INR/month	Landscape irrigation of park
Lalbagh	1.5		0.675 mil. INR/month	Landscape irrigation of park
Total	73			

Note: mil.INR= Million Indian Rupee

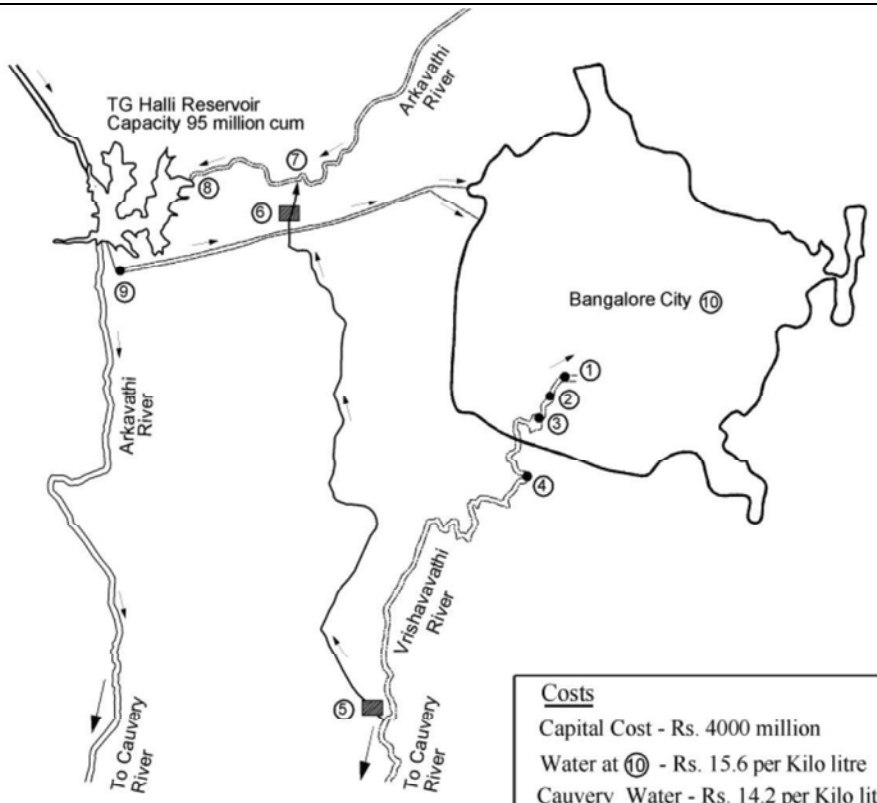
Source: BWSSB 2011, 'Wastewater treatment', presentation made to Union ministry of urban development, Delhi

Table 4.5.9 Tertiary Treated Water Utilization

Sl. No.	Consumer	Sewage (KLD)
1	International Airport	1,000
2	BEL	1,200
3	Wheel and Axle Plant – Railway	300
4	ITC Limited	300
5	IAF	200
6	Aravind Mills	1,000
7	Cubbon Park	1,500
8	Lalbagh	1,500
Total		7,000 (=7 MLD)
Selling Rate		25 INR/kl
Revenue		45.0 Million INR/yr.

Source: BWSSB

Figure 4.5.1 shows schematic drawing on the reuse of treated sewage, discharge of effluent from the STPs for the recycling of the water in Cauvery river basin.



① Virshavhavathi STP - 180 MLD
② Mailasanvra STP - 75 MLD
③ Kengeri STP - 60 MLD
④ Chodenapura STP - 40 MLD
④-⑤ 65 metre Cascade Fall in River over 20 Km
⑤ Water Treatment Plant at Ampapura - 152 MLD
⑤-⑥ 1700 mm Pumping main for 33 Km - 147 MLD
⑥ U F and R O plant at Tavarakere - 147 MLD
⑥-⑦ Pathogen free water to river valley - 140 MLD
⑦ Entry location into Arkavathi fresh water course
⑧ Entry into T. G. Halli fresh water reservoir
⑨ Water treatment plant with hardness removal
⑨-⑩ Pumping mains to Bangalore City distribution
⑩ Bangalore City

Costs
Capital Cost - Rs. 4000 million
Water at ⑩ - Rs. 15.6 per Kilo litre
Cauvery Water - Rs. 14.2 per Kilo litre

Quality Renovation by the Advanced Treatment

	Colour	Odour	B O D	C O D	N	P	TDS	pH	Pathogens
Raw Sewage	Grey	Fowl	350	750	As occurs		650	7.2 - 7.5	As occurs
Water at ⑩	Clear	Fresh	Nil	70	Nil	Nil	275	6.7 - 7.3	Nil

Status of Bangalore Water Demand and Availability

Year	Population million	Million Liters Daily (MLD)		
		Demand	Availability	Shortage
2001	5.4	870	540	330
2007	7.5	1219	840	379
2015	8.8	1720	1500	220
2021	10	2125	1500	625
2036	12.5	2550	1500	1050

Status of Bangalore Water Demand and Availability

Pilot Indirect Potable Water Augmentation by 135 MLD by Advanced Reuse from City Sewage at Bangalore
Sanctioned in January 2008 under JnNURM Grant Funding for Seeking Public Acceptance Which is of course a Long Drawn Process

Source: BWSSB

Figure 4.5.1 Schematic of Treatment for Reuse in Bengaluru

4.6 Tariff for Water Supply and Sewerage Services, and Cost Recovery

4.6.1 Present Practice for Water and Sewerage Tariff

The tariff has revised two times in 2005 and 2014, but these revisions were not enough to cover O&M cost, depreciation and interest on loans in the past. In 2015, total income and expenditures are 11.41 Billion INR and 14.90 Billion INR, respectively. The following are present arrangements for different customers.

(1) Domestic Water Use

Tariff is established using a progressive charge system. Sewerage tariff is set as sanitary charge adding to the water charge and with a uniform rate of 25% to water charge. Domestic consumers are categorized into 6 income groups by monthly water consumption; slum, poor, low income, middle income, higher than the middle income and the highest income groups. The current monthly average water charge per household is 100 INR, which is about 0.6% of average monthly household income (16.610 INR).

(2) Non-Domestic Water Use

Revenue percentage of non-domestic water use is 16% of the total income of BWSSB, while non-domestic water consumption is 11% of the total water consumption. Tariff is established using a progressive charge system depending on the amount of water consumption. Sewerage tariff is set as sanitary charge adding to the water charge with a uniform rate of 25%. The unit price per water consumption for non-domestic water use is set significantly higher than that for domestic water use.

(3) Other Special Arrangements

1) Bulk Water Use

Bulk water supply is provided both for domestic and non-domestic uses. Large facilities including schools, swimming pool. etc. are consumers with larger water consumption. A fixed charge system is adopted for this water supply, regardless to the amount of water consumption. The sanitary charge is practiced in the same manner as domestic water use with 25% to water charge.

2) Other Charges

There are other several charges such as special sanitary charge and new connection charge. However, these charges are only less than 5% of domestic and non-domestic charges. In case of having supplementary water supply by deep well or water tanks in addition to water connections, BWSSB levies additional charge as special sanitary charge. New connection charge is imposed on the consumers one time in newly connecting water supply or sewerage pipes.

4.7 On-going Sewerage Project

4.7.1 Water Supply and Sewerage Master Plan

As of February, 2017, Sewerage System Modelling Report and Master Planning Criteria Report were submitted as a part of the draft M/P by M/P Consultants. The following are relevant conditions/assumptions for the implementation of Preparatory Survey.

(1) Per capita Sewage Generation

The same methodology has been used both in the M/P and JICA Survey, per capita water consumption rate is different between this survey result and M/P draft. As a result, per capita sewage generation rate is different as shown in Table 4.7.1. After discussion with BWSSB, per capita water consumption rate of 150 lpcd was decided to use for BWSSB sector project. Unit sewage generation rate is also determined at 132 lpcd.

Table 4.7.1 Sewage Generation Rate Comparison between JICA Survey and Master Plan

Item	JICA Preparatory Survey	Master Plan	Remarks
Domestic & Non-domestic	Water consumption x conversion rate + groundwater intrusion 150 lpcd x 0.8 x (1+10%) = 132 lpcd	Not clear figure is presented, but applying same methodology 162 lpcd x 0.8 x (1+10%) = 143 lpcd	M/P shall follow national standard as JICA Survey applied.
Master Plan For the Strategic Master Plan, wastewater generation will be assumed at 80% of water supplied to end-users as per the recommendations of the CPHEEO (2013). The resultant daily wastewater generation The design infiltration value shall be limited to a maximum of 10% of the design value of sewage flow as recommended in CPHEEO manual.			

Source: JICA Survey Team

(2) Raw Sewage Quality

Inflow sewage quality for design of STPs was recommended by JICA Survey as shown in Table 4.7.2. These figures are same as those for the BWSSP Phase 2 project supported by present records at existing STPs. These figures shall be used for the design of STPs.

Table 4.7.2 Inflow Sewage Quality

Item	Unit	JICA Preparatory Survey
BOD_5	mg/l	350
COD	mg/l	800
TSS	mg/l	450
T-N	mg/l	70
T-P	mg/l	7

Source: JICA Survey Team

(3) Treated Sewage Quality

Required effluent quality shall follow updated regulations as shown in Table 4.7.3.

Table 4.7.3 Treated Sewage Quality

Item	Unit	JICA Preparatory Survey
BOD_5	mg/l	10

Item	Unit	JICA Preparatory Survey
COD	mg/l	50
TSS	mg/l	10
T-N	mg/l	10
T-P	mg/l	2

Source: JICA Survey Team

4.7.2 On-going Sewerage Construction Work

(1) General

Sewerage project for the ULBs under BWSSP, Phase 2 Project, has been implemented. Most of the sewer systems were completed excepting for some connections. Although the construction of STPs was financially assisted by Japanese ODA loan, but sewers were constructed using local fund under the management by BWSSB. The main offices of the local contractors are Mumbai, Delhi and other cities, but majority of them have regional/business offices in Bengaluru city. They have experience on the sewer construction and the performance is generally acceptable in the project. The following are major reasons on some delay in the implementation of sewerage project.

- Right of way issues (military lands, lake authority lands, railway crossing and private land owners)
- In some contract, poor resource mobilization by the contractors
- Untimely power connection for commissioning of STPs

The packaging for the sewerage project for many ULBs are based on the combination of more than two component work including sewers and STPs. The following three (3) options for one package are applied for sewerage project considering the capability of local contractors.

- Sewers and STP/s in one (1) ULB
- Sewers in two (2) ULBs
- Sewers and STP/s in two (2) ULBs

(2) ISPS

Presently five (5) ISPSs are under construction in BWSSP, Phase 2, as shown in Table 4.7.4.

Table 4.7.4 On-going ISPSs

Name of ISPS		Location	Final Destination	Project scheme	Design Capacity (MLD)
1	Agaram	Core Area	Amanikere 90 MLD STP	BWSSP, Phase-2	120
2	Raja Canal	Bytrayanapura Zone	Horamavu 20 MLD STP	BWSSP, Phase 2	40
3	Saraki	Bommanahalli CMC	Agaram ISPS	BWSSP, Phase 2	18

Name of ISPS		Location	Final Destination	Project scheme	Design Capacity (MLD)
4	Kribhuvanahalli	Dasarahalli Zone	Nagasandara 20 MLD STP	BWSSP, Phase 2	9
5	Sadaramangala	K.R. Puram CMC	Yellamallappa Chettikere 15 MLD STP	BWSSP, Phase 2	5

Source: JICA Survey Team

(3) STP

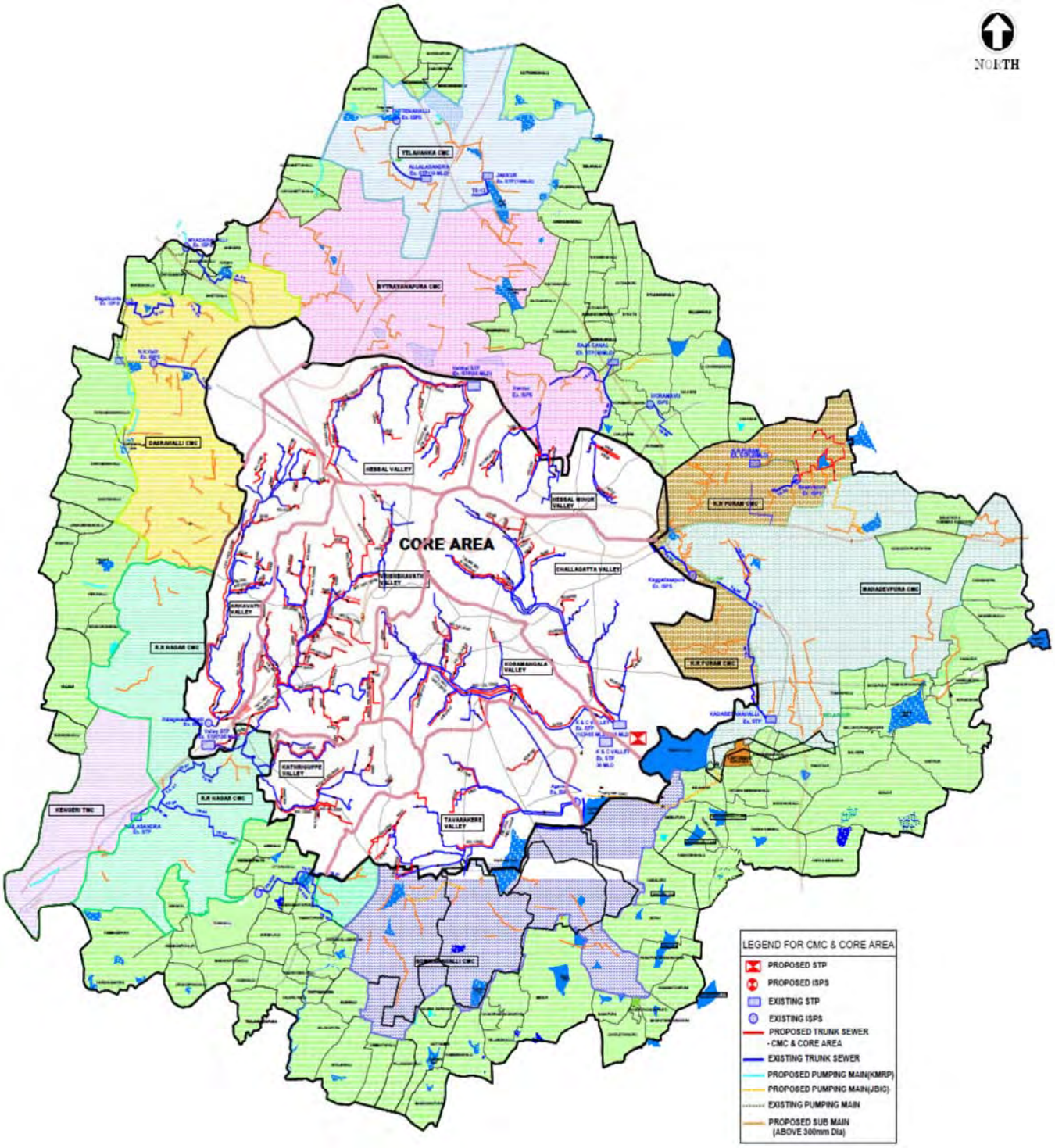
Information on the on-going STPs is shown in Table 4.7.5.

Table 4.7.5 On-going STPs in Bengaluru

S/N	Project scheme	STP location	Capacity (MLD)	Treatment Process
1	BWSSP, Phase 2	Bellandur Amani-kere	90	Activated sludge process
2	BWSSP, Phase 2	Kengeri	60	Activated sludge process
3	BWSSP, Phase 2	K & C valley	60	Activated sludge process
4	BWSSP, Phase 2	Raja canal	40	Extended aeration
5	BWSSP, Phase 2	Horamavu Agara	20	Sequencing Batch Reactor (SBR)
6	BWSSP, Phase 2	Nagasandra	20	SBR
7	BWSSP, Phase 2	Doddabele	20	SBR
8	BWSSP, Phase 2	Yellamallappa Chetty	15	SBR
9	BWSSP, Phase 2	Kadugodi	6	SBR
10	BWSSP, Phase 2	Chikkabanavar	5	SBR
TOTAL			336	

Source: JICA Survey Team

Figure 4.7.1 shows existing and on-going sewerage systems in the BBMP area. In Core area, augmentation of existing sewers has been provided, while in ULBs, sewers are under installation according to the plan as of the beginning of March/2017.



Source: BWSSB

Figure 4.7.1 Existing and On-going Sewerage Systems (Core Area and 8 ULBs)

4.8 Re-use of Effluent after Sewage Treatment

4.8.1 Needs Survey

As of today, BWSSB has not established a permanent organization for the promotion of effluent re-use. However BWSSB conducted needs survey through contract-out in case an industrial complex is planned to be developed near the sewage treatment plant/s. Latest experience is reported under the title of "Conducting Demand Survey for the Supply of Tertiary Treated Water (New water) from Tavarakere/Nagasandra to Peenya Industrial Area for Non Potable Purpose", which was carried out in July/2015. The following are the results of the survey.

Peenya and Dasarahalli industrial area mainly consists of knitting industries where water usage is minimal. The majority of the industries utilize their own deep wells in their premises and/or effluent from sewage treatment plant. In view of the above the industries are not much keen in taking tertiary treated water from BWSSB. It was concluded that the demand of tertiary treated water at Peenya and Dasarhalli industrial area is about 3.0 MLD.

4.8.2 Management Methods

For the management in the re-use of effluent from STPs, two methods are comparatively studied and summarized in Table 4.8.1. The application of both methods; public and PPP seems to be difficult, due to the limitation of tariff setting by BWSSB against required cost for O&M of the facilities.

Table 4.8.1 Comparison Methods for the Management of Effluent Re-use from STPs

Item	Public Management	Application of PPP
Manner of Procurement	Facilities shall be constructed using public budget and O&M will be carried out through contract-out.	A series of requirements for the provision of the services of effluent re-use will be implemented applying public offering method. Scope of Work will be decided based on the proposal of prospective bidders.
Financial sustainability	It seems to be difficult to set up a tariff ensuring sustainable financial arrangements in case of V-Valley area where groundwater is available.	
Project Effectiveness	A certain level of effect may be expected.	If the same cost invested by public works is applied in case of the PPP project, a sufficient effect may be expected in provision of contractor's ingenious contrivance. But, if the investment cost is insufficient, the work can't be continued resulted in lower effect of the project.
Construction period	BWSSB has an advantage in the implementation of this kind of work, as BWSSB experienced similar project in V-Valley.	In application of similar construction methods, the work can be completed within the similar period as public works. However, in case that many different proposals are submitted by bidders, it may take a longer period for the selection of a contractor.
O&M of facilities	It is common in the BBMP that	An effective O&M can be expected, since a

Item	Public Management	Application of PPP
	operation and maintenance of constructed facilities is committed to the contractor, thus the manner is similar to the application of PPP.	series of work will be undertaken by the same contractor including planning and design, construction and O&M of the facilities.
Organizational set up	At the existing facilities, same contractor who undertook construction work continues O&M work. Thus, it is similar to that of PPP.	Experts of the contractor participate in the requirements for the O&M work. Thus, there is no need of technical experts in BWSSB side.
BWSSB plan	BWSSB has an intension to implement project using PPP method. However, it seems to be difficult to financially manage only using collected charges according to present tariff system.	

Source: JICA Survey Team

4.8.3 Practical Re-use of the Effluent

BWSSB encountered problems to increase customers supplying effluent from existing STPs in V-Valley. A major reason on this problem is the requirement of costly transmission pipelines with a larger diameter from the STP to customers' site. Generally, sewage treatment cost is higher than water treatment cost. In addition, a scale merit for the construction of transmission pipelines can't be expected, as the demand is limited in the subject area. Availability of groundwater is also an adverse condition against the promotion of effluent re-use. Under these conditions, the environment for the re-use of effluent is not supportive through the future.

On the other hand, buildings with a certain size in the BBMP area are obliged to treat generated sewage. In this regard, re-use of effluent from individual buildings and small development areas will be put into practice. In these cases, cost for the transmission pipelines may be minimized because the volume between generated sewage and demand (toilet flush water, gardening water, etc.) may be almost same. The administrator of the buildings can manage sewage treatment to meet the need of the customers, which leads to effective re-use of effluent from the STPs. Furthermore, above mentioned practices in the existing built-up area will help supplement water demand. This kind of arrangements have been made in Metropolitan Tokyo and Fukuoka city in Japan and its effectiveness is confirmed. The similar effects may be expected in the BBMP area.

Chapter 5 Water Demand Projection for the Three Areas by Target Year

5.1 Population Projection by Area

5.1.1 Manner of Population Projection

The Master Plan for Water Supply and Sewerage Development for the BBMP was commenced from 2015 including projection of frame values. However, even draft projection of population was delayed. Therefore, comparative study of existing projections for the BBMP was made for the purpose of water balance study.

There are 10 information sources related to data/report on population projection including BDA, BMRDA (Bengaluru Metropolitan Region Development Authority), Aus AID, Citizens Forum, Ch2M Hill (foreign consultants), Center for Policies and Prices, Economics and Statistics Directorate, Expert Committee, Metro and BWSSB (internet information). The projections for future decades are made, though base year and final target year are different among them. Before comparative study on the projections by different information sources, trends on past decade population were analyzed referring to other major cities and their expanding area (potential expansion area) in India. The study results will suggest the tendency of population trend for next decade in the BBMP. After population projection for future three decades in the BBMP, those for the three study areas are projected for the planning target years (with reference year 2024 for water balance study).

5.1.2 Decade Population Records in Bengaluru City

Population census results in Bengaluru in the past decades from 1941 to 2011 are presented in Table 5.1.1. The population in Bengaluru city had grown in proportion to its expansion of jurisdiction, aside from the increase by the migration from surrounding areas and other cities in India.

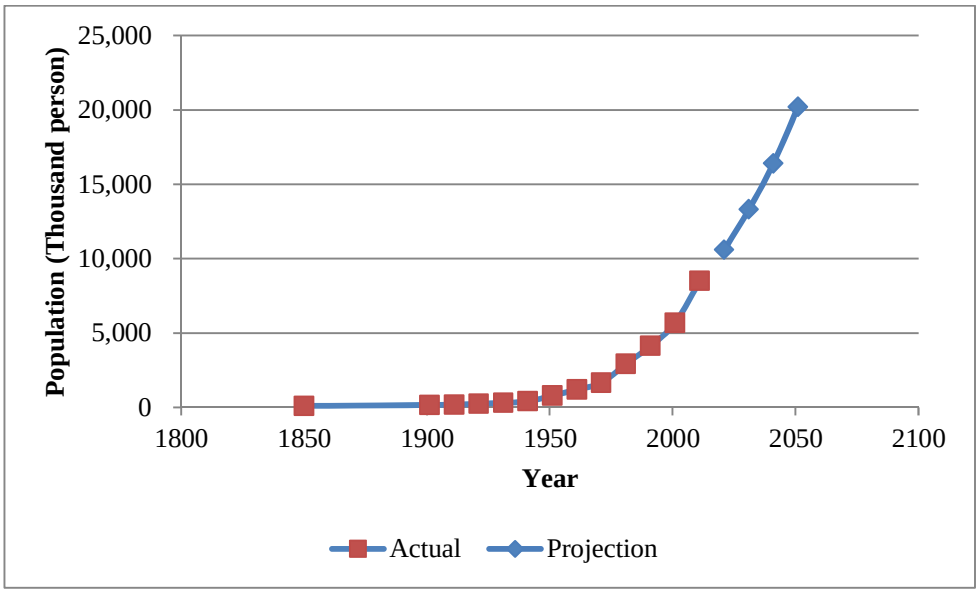
Table 5.1.1 Census Population in BBMP

Year	Population (person)	Percentage Increase	Remarks
1941	406,760		Municipal Corporation of the City of Bengaluru in 1949, under the Bengaluru City Corporation Act
1951	778,977	91.51%	
1961	1,207,000	54.95%	
1971	1,654,000	37.03%	
1981	2,922,000	76.66%	
1991	4,130,000	41.34%	
2001	5,101,000	23.51%	BBMP consists of only Bengaluru city (Core area) up t to year 2006.
2011	8,494,000	66.52%	In 2007 Core area, 8 ULBs and 110 Villages were merged into BBMP.

Source: JICA Survey Team

In January 2007, the Karnataka Government issued a notification to merge the areas under existing Bengaluru Mahanagara Palike with seven City municipal council (CMC), one Town municipal council (TMC) and 110 Villages around the city to form a single administrative body, Bruhat Bangalore Mahanagara Palike. The process was completed by April 2007 and the body was renamed "Bruhat Bengaluru Mahanagara Palike".

The growth rate in BBMP (Bengaluru city) from the year 1971 was very high, the major causes of which are shown in Figure 5.1.1.



Source: JICA Survey Team

Figure 5.1.1 Population Trend in BBMP

5.1.3 Population Growth in the Past Decade

The population growth trend in the past decades in some Indian Cities and Urban Agglomerations (which are an extended city or town area comprising the central Core (usually a municipality) and any suburbs linked by contiguous urban area.) are presented in Table 5.1.2.

Table 5.1.2 Population Growth Rate (%) in Major Cities in India: 1981-2011

Municipal Corporations	Population Growth Rate by Decade (%)		
	1981-1991	1991-2001	2001-2011
Delhi	26.13	37.08	11.42
Bengaluru	41.34	23.51	66.52
Kolkata	33.13	3.93	-1.88
Hyderabad	20.40	19.50	87.22
Greater Mumbai	20.41	20.68	3.87

Source: Census of India, 1981, 1991, and 2011

Some major urban agglomerations in India show a declining growth rate in the last two decades. The trend of decade-wise growth rates from 1981-2011 for major metropolitan regions like Delhi Urban Agglomeration, Kolkata Urban Agglomeration and Mumbai Urban Agglomeration show declining tendency. However, Hyderabad and Bengaluru Urban Agglomerations show different move of growth rates; a decline from 1981-1991to 1991-2001 followed by an increasing growth rate 2001-2011. This increasing trend may be expected to continue in Bengaluru, due to a rapid urbanization merging 8 ULBs and 110 Villages into BBMP area.

Table 5.1.3 shows the same tendencies of growth rates in the potential expansion area (urban agglomeration) of each city as shown in Table 5.1.2. In case of Bengaluru (BBMP plus surrounding 13 towns and urban outgrowth), further population growth in the BBMP is implied.

Table 5.1.3 Population Growth Rate (%) in Major Urban Agglomeration in India: 1981-2011

Urban Agglomerations	Decadal Growth Rate (In percentages)		
	1981-1991	1991-2001	2001-2011
Delhi-NCT	51.45	47.02	20.96
Bengaluru UA	44.85	37.98	45.53
Kolkata UA	19.88	19.81	6.87
Hyderabad UA	70.62	32.18	34.96
Greater Mumbai UA	52.76	30.52	17.01

Source: Census of India, 1981, 1991, and 2011 UA: Urban Agglomerate

As a result of the study on the population trend of Bengaluru city in the past three decades, a considerable growth may be expected in the next decade.

5.1.4 Existing Population Projections for Bengaluru City

A number of studies on population projection were carried out for Bengaluru by various organizations in connection with Infrastructure Development for the city. Assumptions/conditions for the projections prepared by ten reference information sources are summarized in Table 5.1.4

Table 5.1.4 Authorities/ Information Sources on Existing Population Projection

Authorities/Information Sources	Conditions/Assumptions for the Projection
Bengaluru Development Authority (BDA)	"Master Plan 2015" was prepared by Bangalore Development Authority between 2003 and 2005 and final plan was completed in 2007. Base year used for population projections is 2001. The annual growth rate for BMP area (100 wards) is assumed to be 0.78%.
Bengaluru Metropolitan Region Development Authority (BMRDA)	The base year for BMRDA projections seems to be 2001. The details of the projections are not available. It appears that population growth assumed is about 25%.
Aus AID	The report was prepared in 2002 including population projection for the BMA (1,279 km^2). The projection was made with the base year 1991 and target year 2025.

Authorities/Information Sources	Conditions/Assumptions for the Projection
Citizens Forum	To be filled after information is available.
Ch2M Hill and B&E Engineers	The report was completed in June 2011 including population projection with the base year 2001. The projection results are similar to those prepared by BWSSB in application of similar growth rates.
Center for Policies & Prices	To be filled after information is available.
Economics and Statistics Directorate	The report for population projection was completed in 2013 to cover Bengaluru agglomeration. The projection was made yearly from 2011 to 2021 and decade ones from 2021 to 2051. The annual growth rate of 4.24% is adopted up to 2051.
Expert Committee	Population projection was shown for the year 2011 as base year 2001 based on Ch2M Hill and B & E Engineers projections. The growth rates for future decades are employed as follows: 4% up to 2031, 3% up to 2041 and 2% up to 2051.
Metro	Population was projected for the Metro area for the years 2021 and 2041 without projection for intermediate years. The projection figures are higher than those by BWSSB.
BWSSB website information	Information from website on the projection (2.2, 3.05, 1.80 and 1.87) for the years 2011-2012, 2021-2031, 2031-2041, 2041-2051. Different growth rates are used for Core, ULBs and 110 Villages areas.

Source: JICA Survey Team

Table 5.1.5 and Figure 5.1.2 present existing projection results by different authorities/ information sources. Table 5.1.6 shows population density on projected population in the final target year by authority/ information source. A wide range of the population projections prepared by these agencies is evident. The projections made by BDA, BMRDA and Aus Aid, as well as those under for Bengaluru Metro do not cover the design period for this project up to the year 2049. However, the growth rates adopted in these studies may be utilized for this survey.

Table 5.1.5 Existing Population Projection by Different Authorities/ Information Sources

Unit: Thousand Person

No.	1	2	3	4	5	6	7	8	9	10
Year	**BDA**	**BMRDA**	**Aus AID**	**Citizens Action Forum**	**Ch2M Hill**	**Center for Policies and Prices**	**Economics and Statistics Directorate**	**Expert Committee**	**Metro**	**BWSSB**
Base Year	2001	2001	1991			2001	2001		2001	
2011	8,499	8,499	7,880	9,000	8,015	8,499	8,499	96.21		8,499
2021	9,969	10,650	9,420	11,500	9,968	12,581	12,867	14,221	11,100	10,581
2031		13,500	11,250	14,000	13,589	18,622	19,480	21,080		14,296
2041				17,000	16,273	27,566	29,490	28,330	22,000	17,085
2051				22,000	19,640	40,804	44,646	34,540		20,561

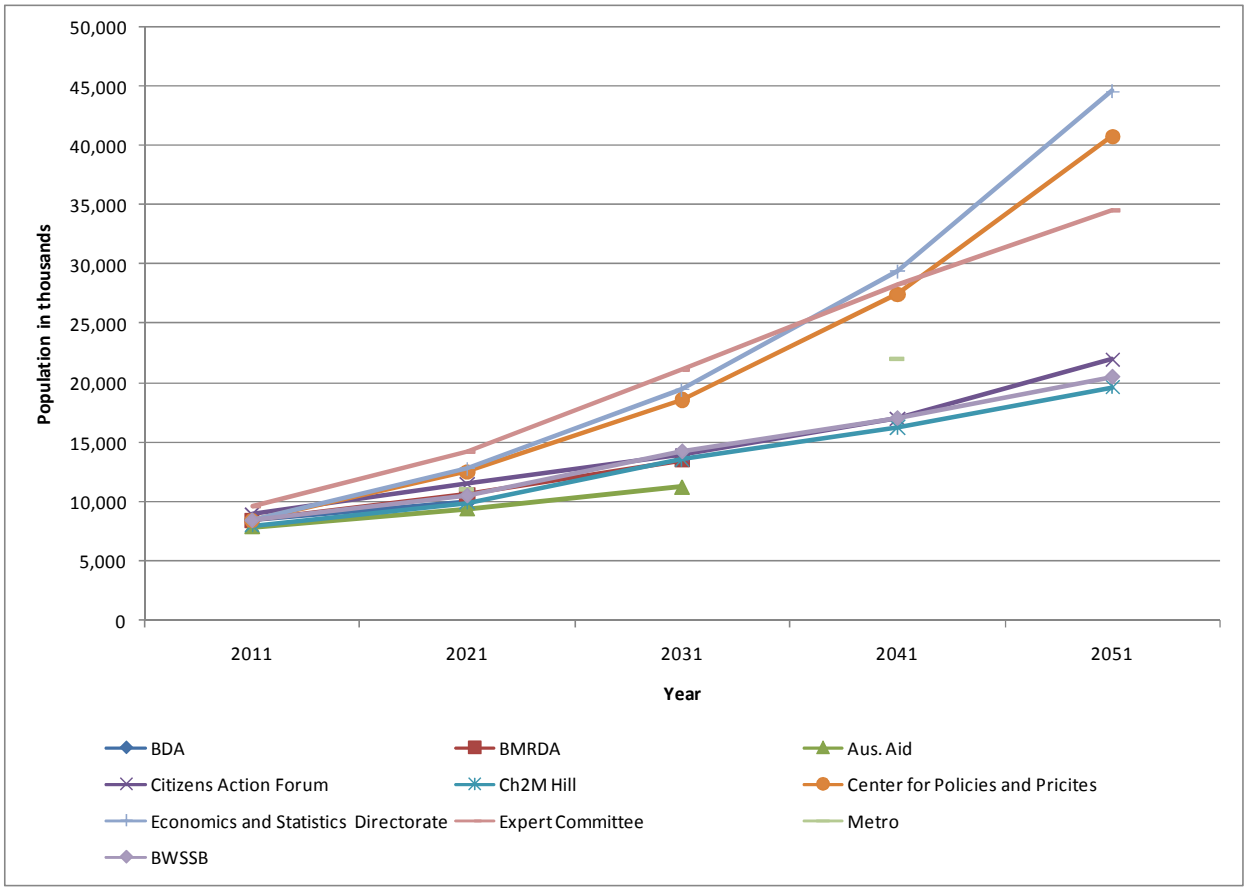
Source: JICA Survey Team

Table 5.1.6 Population density by Different Authority/ Information Source

Unit: Person/km^2

No.	1	2	3	4	5	6	7	8	9	10
Year	**BDA**	**BMRDA**	**Aus AID**	**Citizens Forum**	**Ch2M Hill**	**Center for Policies and Prices**	**Economics and Statistics Directorate**	**Expert Committee**	**Metro**	**BWSSB**
2051				**27,500**	**24,550**	**51,005**	**55,807**	**43,175**		**25,701**

Source: JICA Survey Team



Source: JICA Survey Team

Figure 5.1.2 Existing Population Projection by different Authorities/ Information Sources

The projections made by the following three agencies/company are omitted from this study, due to excessively high population density proposed with more than 400 persons/ha in 2051 (Generally, a ceiling density is assumed to be about 300 persons/ha).

(1) Centre for Policies and Prices
(2) Economics and Statistics Directorate
(3) Expert Committee.

Proposed growth rates by the above three organizations seem to be non-realistic, because of the following reasons, aside from common practices on population density in the city planning.

1) Extremely high average population density with more than 30,000 persons/km^2 would put an excessive pressure on existing and planned infrastructures such as roads and housing etc.
2) Additional demand on infrastructures would be unsustainable, especially water supply and sewerage facilities. If the population in the BBMP increase up to 30 to 40 Million at final target year, additional water sources will be required for the intake of 1,500 MLD (about 20 TMC) or more, which is not easy. In this connection, the limitation of water supply will be an important control factor of the population in the BBMP.

The population projections made by Citizens Forum, Ch2M Hill and BWSSB are almost on the same level based on 2011 census results considering population trend in the last decade.

5.1.5 Projection of Population in the BBMP for the Water Balance Study

The study results on the projection of population by the on-going M/P for water supply and sewerage development were not available as of June, 2016, hence population in the BBMP, broken down into three areas, are projected in this study for the "water balance study" referring to existing study results as discussed in the previous sub-sections. The three areas consist of Core area, ULBs (7 CMC & 1 TMC) and 110 Villages. Table 5.1.7 summarizes basic information on the areas after BBMP was organized in 2007.

Table 5.1.7 Basic Information on Subject Areas for Population Projection

Area	Composition	Population in 2011 (Million)
Core	132 wards of Bengaluru city	5.422
ULBs	7 CMC + 1 TMC	1.969
110 Villages	110 Villages	1.103
BBMP Total		8.494

Source: JICA Survey Team

Administratively, BBMP area comprises 3 zones in Core area and 5 zones in the combined area of ULBs and 110 Villages. However, these administrative zones which were arranged recently are not used as a unit for the purpose of population projections in order to use existing study results (prepared in the past) effectively.

BBMP area has experienced a rapid population growth in the past decades, as mentioned above. However, the tendencies of population densities in the areas are generally characterized as follows:

- Core area: Population is saturated with a ceiling density.
- ULBs & 110 Villages: Population is continuously growing with different growth rate by sub-area.

The following assumptions/conditions are directly considered for the projection of decade population from 2021 to 2051. The formula adopted is $A= A_0 (1+ r)^n$: A- population after n years, A_0- population in base year, r- growth rate and n-years.

1) Core Area: The growth rate shall be fixed through the future with a lower rate under the saturated conditions at present. The annual growth rate is assumed at 0.78 by BDA "Master Plan 2015" for the decade 2011-2021. The rate is assumed to be applied until the year 2051.
2) 110 Villages: The population for the next three decades were authorized through a tripartite meeting by BDA, BBMP and BWSSB. The overall average annual growth rate for future decades are: 4.38% for 2011-2021, 3.75% for 2021-2031, 3.25% for 2031-2041 and 3.0% for 2041-2051. Additional population for R. R. Nagar Zone developed by BDA are considered, the details are shown in Table 5.1.8.

Presently, 110 Villages are organized into 5 administrative zones, which are considered for 110 Villages water supply and sewerage plan in the existing DPR. The population in R.R. Nagar has been revised to take into account new BDA developments by 79,657 (FY2019), 124,575 (FY2034), and 182,762 (FY2049), respectively. Minor mathematical revisions have also been undertaken in other zones. The revised population for villages of Hemigepura and Sompura in R.R. Nagar have been highlighted in Table 5.1.8.

Table 5.1.8 Revised Population for Hemigepura and Sompura in R.R. Nagar

No	Village Name	2011	2019	2034	2049
1	Hemigepura Village (considered in DPR)	4,961	6,990	12,114	19,196
	Additional population due to Hemigepura - Banashankari Phase 6, Block 10 development		47,571	76,891	107,512
	Total Hemigepura		54,561	89,005	126,708
2	Somapura Village (considered in DPR)	1,358	1,914	3,316	5,255
	Additional population due to Sompura - Banashankari Phase 6, Block 6 development		32,086	47,684	75,250
	Total Sompura		34,000	51,000	80,505
Increased population			79,657	124,575	182,762
Total two (2) villages population			88,561	140,005	207,313

Source: JICA Survey Team

Table 5.1.9 shows revised population projection for the five zones by target year.

Table 5.1.9 Revised Population Projections in 110 Villages Area

Name of Zone	2019	2024	2034	2049
Bytrayanapura	339,849	413,003	588,921	933,196
Mahadevpura	315,053	382,871	545,957	865,116
Bommanahalli	398,482	484,256	690,523	1,094,195
R.R. Nagar	310,618	375,452	524,910	817,245
Dasarahalli	270,606	328,855	468,914	743,037
Total	1,634,608	1,984,437	2,819,225	4,452,789

Source: JICA Survey Team

3) ULBs: There are three references on the projection of annual growth rate for ULBs as shown below.

- 1.3%: Adopted from 2021 to 2036 in the DPR for 110 Villages Water Supply and Sewerage Project (low growth rate). This rate is assumed to continue until 2051.
- 2.36%: Adopted from 2021 to 2036 in the NMT report on improvement of water supply (medium growth rate). This rate is assumed to continue until 2051.
- Same growth rates from 2011 to 2051 as those adopted for 110 Villages in the DPR for 110 Villages Water Supply and Sewerage Project (high growth rate)

The population by area are projected using annual growth rates assumed in the above item 1) to item 3) by area. The range of the population (maximum to minimum figures) is caused by the application of different population growth rates for ULBs. Table 5.1.10 to Table 5.1.15 shows projected population.

Table 5.1.10 Population Projection (High growth)

Item	Growth Rate (Compounded Annual Growth rate)			Population(person)			
	Core	ULBs	110 Villages	Core	ULBs	110 Villages	Total
Area(km^2)				213.1	262.02	233.98	709.1
Base Year	2011	2001	2001	2011	2001	2001	
2011		4.40%	4.40%	5,422,033	1,969,414	1,103,515	8,494,962
2021	0.78%	4.38%	4.38%	5,860,109	3,023,500	1,778,698	10,662,307
2031	0.78%	3.75%	3.75%	6,333,580	4,369,091	2,562,035	13,264,704
2041	0.78%	3.25%	3.25%	6,845,305	6,015,776	3,519,773	16,380,852
2051	0.78%	3.00%	3.00%	7,398,375	8,084,700	4,722,416	20,205,494

Note: Growth rates were authorized by BDA, BWSSB, BBMP and DHV for 110 Villages Project, 19 August 2014

Source: JICA Survey Team

Table 5.1.11 Population Projection (medium growth)

Item	Growth Rate (Compounded Annual Growth rate)			Population(person)			
	Core	ULBs	110 Villages	Core	ULBs	110 Villages	Total
2011		4.40%	4.40%	5,422,033	1,969,414	1,103,515	8,494,962
2021	0.78%	4.38%	4.38%	5,860,109	3,023,500	1,778,698	10,662,307
2031	0.78%	2.36%	3.75%	6,333,580	3,817,797	2,562,035	12,713,412
2041	0.78%	2.36%	3.25%	6,845,305	4,820,760	3,519,773	15,185,838
2051	0.78%	2.36%	3.00%	7,398,375	6,087,210	4,722,416	18,208,001

Source: JICA Survey Team

Table 5.1.12 Population Projection (low growth)

Item	Growth Rate (Compounded Annual Growth rate)			Population(person)			
	Core	ULBs	110 Villages	Core	ULBs	110 Villages	Total
2011		4.40%	4.40%	5,422,033	1,969,414	1,103,515	8,494,962
2021	0.78%	4.38%	4.38%	5,860,109	3,023,500	1,778,698	10,662,307
2031	0.78%	1.30%	3.75%	6,333,580	3,440,365	2,562,035	12,335,980
2041	0.78%	1.30%	3.25%	6,845,305	3,914,704	3,519,773	14,279,782
2051	0.78%	1.30%	3.00%	7,398,375	4,454,442	4,722,416	16,575,233

Source: JICA Survey Team

Projected population for the planning years as well as assumed year (2024) to start operation of the facilities by Stage V project are shown in Table 5.1.13. The population in BBMP for the final target year (2049) arrived at 19,357,692 and the population density arrived at 24,244 pop/km^2. Comparing with the population density of Bengaluru with Mumbai (28,508 pop/km^2)*, Chennai (26,603 pop/km^2) *, Kolkata (24,718 pop/km^2) * and Delhi (11,297 pop/km^2) *, the projected population in Bengaluru is possible.

*Source: State of India's Cities, Bengaluru Public Affairs Center, 2012

Table 5.1.13 Population Projection (high growth)

Item	Growth Rate (Compounded Annual Growth rate)			Population(person)			
	Core	ULBs	110 Villages	Core	ULBs	110 Villages	Total
2016	0.78%	4.38%	4.38%	5,636,817	2,440,189	1,418,292	9,495,298
2019	0.78%	4.38%	4.38%	5,769,750	2,775,080	1,634,608	10,179,438
2024	0.78%	3.75%	3.75%	5,998,307	3,376,559	1,984,437	11,359,303
2034	0.78%	3.25%	3.25%	6,482,945	4,809,070	2,819,225	14,111,240
2049	0.78%	3.00%	3.00%	7,284,297	7,620,606	4,452,789	19,357,692

Source: JICA Survey Team

Table 5.1.14 Population Projection (medium growth)

Item	Growth Rate (Compounded Annual Growth rate)			Population(person)			
	Core	ULBs	110 Villages	Core	ULBs	110 Villages	Total
2016	0.78%	4.38%	4.38%	5,636,817	2,440,189	1,418,292	9,495,298
2019	0.78%	4.38%	4.38%	5,769,750	2,775,079	1,634,608	10,179,437
2024	0.78%	2.36%	3.75%	5,998,308	3,242,656	1,984,437	11,225,401
2034	0.78%	2.36%	3.25%	6,482,945	4,094,526	2,819,225	13,396,696
2049	0.78%	2.36%	3.00%	7,284,297	5,809,754	4,452,789	17,546,840

Source: JICA Survey Team

Table 5.1.15 Population Projection (low growth)

Item	Growth Rate (Compounded Annual Growth Rate)			Population(person)			
	Core	ULBs	110 Villages	Core	ULBs	110 Villages	Total
2016	0.78%	4.38%	4.38%	5,636,817	2,440,189	1,418,292	9,495,298
2019	0.78%	4.38%	4.38%	5,769,750	2,775,079	1,634,608	10,179,437
2024	0.78%	1.30%	3.75%	5,998,308	3,142,956	1,984,437	11,125,701
2034	0.78%	1.30%	3.25%	6,482,945	3,576,291	2,819,225	12,878,461
2049	0.78%	1.30%	3.00%	7,284,297	4,340,847	4,452,789	16,077,933

Source: JICA Survey Team

The draft population projection for the BBMP area were received from BWSSB in January 2017. The projection is made considering triggers related to infrastructure development by Bengaluru City Government (Metro Phase I & II from 2020 to 2050, BDA housing scheme and peripheral ring road). For each of the catalysts, an associated net residential population density has been assumed. For residential areas, the floor area ratio (FAR) is directly linked to the population density. Based on study results on correlation between population density and FAR, the following net densities are organized by catalyst and projected year as shown in Table 5.1.6.

Table 5.1.16 Net Population Density by Catalyst by Projected Year

Catalyst	Resulting net residential population density (people per hectare)		
	2020	2035	2050
Metro Phase I	600 to 800	400 to 600	800 to 1,000
Metro Phase I (Extension)	Natural Growth	400 to 600	800 to 1,000
Metro Phase II	Natural Growth	200 to 400	600 to 800
Metro + BDA	Natural Growth	400 to 600	600 to 800

Note: Draft Master Planning Criteria, issued on May 27, 2016
Source: JICA Survey Team

The triggers are listed in the M/P including the development of ring road along the boundary between Core area and 110 Villages and railway as well as presence of commercial/industrial activity and availability of land. As a result of the study, the population are projected between 19,123,917 and 22,797,957 for BBMP in 2050 (Details on the projection are included in Supporting Report 5.1.1).
Referring to the projection in the M/P, above mentioned high growth rate was adopted in this survey. About 20,000,000 projected in the M/P for the year 2050 coincide with the projected population using high growth rate in this survey.

5.2 Water Use by Different Types of Users

According to BWSSB, water users in BBMP are categorized into many types including domestic for common households, slum people, public faucets/taps, water lorry users, etc. Major water sources are Cauvery River water and ground water. Information on present water use by water source (river water and groundwater) is summarized in Table 5.2.1. The number of service connections and water consumption in slum area are 8% and 3%, respectively. The percentage of public taps and water lorry is less than 1%.

Table 5.2.1 Breakdown of Water Connection and Consumption by Use

Source	Category	Connection (Nos)	Ratio	Consumption (MLD)	Ratio	UFW	Water Source (MLD)
Cauvery	Domestic	817,322	90%	587	77%		
	Common HH	*748,664*	*82%*	*565*	*(74%)*		
	Slum	*68,658*	*8%*	*23*	*(3%)*		
	Non Domestic	45,157	5%	43	6%		
	Partial ND	40,557	4%	80	11%		
	Public Taps	371	0%	2	0%		
	Water lorry	32	0%	0	0%		
	Others	4,831	1%	47	6%		
	Total	908,270	100%	759	100%	48%	1,461
Ground Water	Core ULB			336		16%	400
	110Villages			84		16%	100
	Total			420			500
Grand total				1,179			1,961

Source: BWSSB

Per capita water consumption in slum area arrives at about 30 lpcd based on slum population of about 720 thousand (refer to Table 2.3.5, Chapter 2) and water consumption of 23MLD in the above table. This consumption rate is usually considered for the point source water supply (Level I water supply system).

The population in slum area is projected to diminish gradually with reduction ratios to present population; 50% in 2034 and 100% in 2049 in line with government's economic development and social improvement in BBMP.

Based on the composition of water users in the BBMP, domestic water use by common households may be used for macrocosmic study on water demand.

5.3 Unit Water Consumption Rate

5.3.1 Present Unit Water Consumption Rate

Per capita water consumption rate at present is calculated at 146 lpcd including domestic and other non-domestic water supply, as shown in Table 5.3.1, considering water sources available including groundwater and surface water from Cauvery River. It is noted that these figures are under condition of limited water supply, only 6 hours by alternate days. Served population in the service area are assumed to be 100%, because most of population are served by BWSSB either full or partial water supply base supplemented by groundwater (Groundwater use is managed by BWSSB for private use in the area without BWSSB piped water supply).

It was reported by BWSSB that before the completion of Stage IV Phase 2 in 2012 (upon services commencement by Stage IV Phase 1), the per capita water consumption was about 120 lpcd as of year 2011 (67.5 lpcd without consideration of groundwater supply). Presently, the unit water consumption rate (covering the need of domestic, commercial, and small industrial uses) seems to be a common large city level after Stage IV Phase 2 water supply.

Table 5.3.1 Unit Water Consumption Rate at Present (Water Source: Surface and Groundwater)

Item	As of 2016			Reference: as of 2011
	CWSS Stage I, II, III & IV Phase 1 & 2	Groundwater	Total	CWSS Stage I, II, III & IV Phase 1
Water Supply by CWSS (MLD)	1,460	500	1,960	960
Water Consumption (MLD, assumed UFW: Cauvery- 48% & Groundwater- 16%)	759.2	420	1,179.2	499.2
BBMP Population in 2016 (Million)	8.077	8.077	8.077	7.391
Per capita water consumption rate (lpcd)	94.0	52.0	146.0	67.5

Note: Served population in 2016 and 2011 are those in Core and ULB areas.

Source: JICA Survey Team

5.3.2 Domestic Water

According to the CPHEEO's Manual on water supply and treatment published by Ministry of Urban Development, 150 lpcd was adopted for the water consumption as Metropolitan and Mega cities with piped water supply where sewerage systems exist. The recommended per capita water supply levels as per CPHEEO Manual is shown in Table 5.3.2.

Table 5.3.2 Recommended per capita Water Supply Levels as per CPHEEO Manual

Sr. No	Classification of Towns / cities	Recommended Maximum Water Supply Levels
1	Towns provided with piped water supply without sewerage system	70 lpcd
2	Cities provided with piped water supply where sewerage system is existing / contemplated	135 lpcd
3	Metropolitan and Mega cities provided with piped water supply where sewerage system is existing / contemplated	150 lpcd (Adopted)

Note 1: In Urban areas where water is provided through public stand posts 40 lpcd should be considered
Note 2: Figures exclude Unaccounted for water, which should be restricted to 16%
Note 3: Figures include requirements of water for commercial, institutional, and minor industries. However, bulk water supply to such establishments should be assessed separately with proper justification.

As per BWSSB's billing record in May 2016, the industrial consumption in the BBMP area is about 20 MLD. The water supply for larger industries is provided using tertiary treated sewage, which is not combined with domestic water supply through BWSSB water supply systems. Water supply by BWSSB includes only small-size commercial and industrial water requirements.

5.3.3 Non-Domestic Water

Table 5.3.3 shows BWSSB's billing data in the last 6 months from 2015 to 2016. There are items of "partial non-domestic" and "others", which are difficult to categorize into domestic use nor non-domestic. Thus, to calculate the Ratio of Non-Domestic against "Domestic and Non-domestic", these items were excluded and the non-domestic percentage ranges from 9.2 % to 9.5 %. The ratio is almost same as 10% of 150 lpcd in CPHEEO manual, which is equivalent to 15 lpcd for commercial use.

Table 5.3.3 Category-wise Water Consumption

Unit: MLD

Row No	Category	2015	2016				
		Dec.	Jan.	Feb.	Mar.	Apr.	May
1	Domestic	483	438	403	395	420	406
2	Multi House	-	81	104	107	127	128
3	Non-Domestic	37	39	39	38	40	39
4	Partial Non-Domestic	59	62	64	60	64	63
5	Domestic High Rise	59	64	63	62	66	63

Row No	Category	2015	2016				
		Dec.	Jan.	Feb.	Mar.	Apr.	May
6	Non-Domestic High Rise	0	0	0	0	0	0
7	Partial Non-Domestic High Rise	14	14	15	16	18	18
8	Industries	20	20	20	20	22	22
9	Others	17	19	18	18	20	20
10	Gap	723	670	598	715	621	689
11	Total Receipts	1,413	1,407	1,325	1,432	1,397	1,448
12=1+2+5	Domestic	542	582	571	563	613	597
13=3+6+8	Non Domestic	57	59	59	58	62	61
13/(12+13)	**Ratio of Non-Domestic**	**9.5%**	**9.3%**	**9.4%**	**9.3%**	**9.2%**	**9.3%**

Note: High rise- BLDGs with more than 15m high; Gap= Row No 11 – (sum of row No 1 to 9); Others include 23 areas including Defense area, BIAL, Institutions, bulk supply to Kanakpura area, etc.

Source: BWSSB

5.4 Projection of UFW Percentages by Target Year by Area

5.4.1 Core and ULB Areas

(1) Present UFW Conditions

As mentioned in Section 3.2.4 (8), overall UFW percentage in the BWSSB service area at present is reported at 48%. UFW in Core and ULB areas is estimated using area-wise consumption data in 2015 as shown in Table 5.4.1 and performance record of on-going UFW reduction results as shown in Table 5.4.2.

Table 5.4.1 Area-wise Consumption Record in 2015

Area	Core Area	ULB Area	Total	Remarks
Average Daily Consumption in 2015 (MLD)	396	282	678	Industrial consumption supplied by deep well is excluded
Composition (%)	58	42	100	

Source: JICA Survey Team

Table 5.4.2 Average UFW Reduction Performed by on-going Project

Project	Area (km^2)	UFW Ratio (%)	Remarks
D2b in Area (I)	52	33.4	South
D2a in Area (I)	52	33.8	West
D1a in Area (I)	26.5	55	Central
Weighted Average	130.5	37.9→38	=(52x33.4+52x33.8+26.5x55) /130.5

Source: BWSSB

On-going UFW project area (Area (I) covered by the 3 contracts for South, West and Central areas) and future project area (Area (II) to cover North, East and South-East areas) are 130.5 ha and 108.0 ha, respectively. The proportion of water supply is assumed 55:45 in use of the area ratio. UFW ratio in Area (I)

is 38% as shown in Table 5.4.2.

The proportion of consumption between Core area and ULB area is 58:42 from the Table 5.4.1. 0.52 (=1 - 0.48) is divided to 0.30 for Core area and 0.22 for ULB area as shown in Figure 5.4.1. UFW ratios in Area (II) and that of ULB are assumed at 65% (in the pilot UFW project the initial UFW was estimated at 64% in the CBD area of Bengaluru) and 35%, respectively, to balance the water flow in BWSSB service area. Under the above assumptions, an average UFW at present in Core area is 55% and that in ULB is 35 % (overall average is 48%).

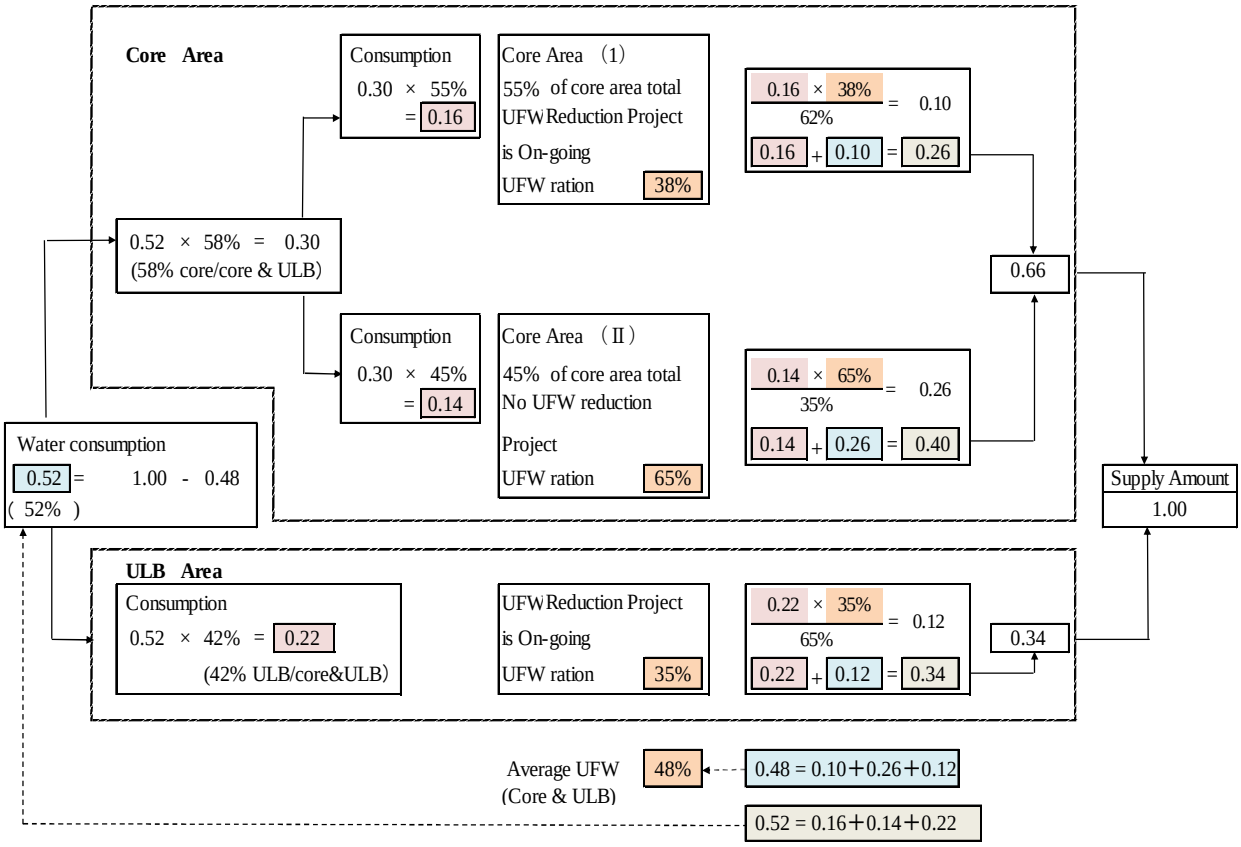


Figure 5.4.1 Analysis of Present Water Consumption and UFW for Core and ULB Areas

(2) Proposed UFW Ratio

After three years of replacement/rehabilitation work in Stage IV Phase 2, a high UFW reduction ratio (16%) has not been achieved. The following gradual reduction of UFW is assumed for the target years.

- UFW ratio is 16% in long-term target year of 2049
- UFW ratio is 23% in the intermediate target year of 2034

  2 %/year reduction is applied from 48 % at 2016 until 2023, 1 %/year reduction is applied after 2023 up to 16 %.

Using the above assumptions, UFW rates from 2016 to 2049 are assumed by area as shown in Table 5.4.3.

Table 5.4.3 Proposed UFW Ratio by Area

Area		2016	2019	2024	2034	2049
Core Area	Area (I)	38	35	30	23	16
	Area (II)	65	45	36	23	16
	Core Overall	55	40	33	23	16
ULB Area		35	35	33	23	16
Core & ULB Area		48	37	33	23	16

Source: JICA Survey Team Unit: %

5.4.2 110 Villages Area

No water supply system is operated by the BWSSB in the 110 Villages area. The final target rate of 16% will be adopted for newly developed distribution system, according to present practice used in Phase 2 Project (almost same figure as that suggested in CPHEEO Guideline).

5.5 Groundwater User and Water Consumption

A total of 400 MLD groundwater is used in Core and ULBs and 100 MLD is used in 110 Villages. Population to be served by BWSSB water supply systems and by individual systems using groundwater are estimated as follows:

In the areas served by individual water supply systems using groundwater, UFW is assumed to be 16% (It is assumed that comparatively small systems are maintained with an ideal UFW percentage.), while in the BWSSB served areas, it is considered with a rage of 33 to 16%. The population to be served by the individual systems are calculated in assumption of 150 lpcd consumption rate and UFW 16%. The population to be served by BWSSB systems are calculated subtracting the population to be served by individual systems from administrative population in each study area as shown in Table 5.5.1.

Table 5.5.1 Water Consumer and Water Loss

Item	Unit	Core	ULB	110 V	Total
Groundwater Consumer	Person	1,640,800	599,200	560,000	2,800,000
Per Capita Consumption	lpcd	150	150	150	
Groundwater Consumption	MLD	246	90	84	420
Water Loss (UFW)	%	16	16	16	
Groundwater Yield	MLD	293	107	100	500

Source: JICA Survey Team

5.6 Water Demand Projection by Area

5.6.1 Water Demand Projection

Water demand by study area in the BBMP was summarized by target year as shown in Table 5.6.1 to Table 5.6.4 for 2016, 2024, 2034, 2049, respectively.

Table 5.6.1 Water Demand by Study Area in BBMP for Target Year (1)

Item	Unit	2016			
		Core	ULB	110 V	Total
Population	Person	5,637,000	2,440,000	1,418,000	9,495,000
Service Ratio		71%	75%	0%	61%
Served Population	Person	3,996,200	1,840,800	0	5,837,000
House Connection Population	Person	3,538,200	1,526,800	0	5,065,000
Per Capita Consumption	lpcd	145	145	0	145
Daily Consumption	MLD	513	221	0	734
Slum Population	Person	458,000	314,000		772,000
Per Capita Consumption	lpcd	30	30	30	30
Daily Consumption	MLD	14	9	0	23
Daily Average Water Consumption	MLD	527	230	0	757
UFW		48%	48%	16%	48%
Daily Average Water Demand	**MLD**	**1,013**	**442**	**0**	**1,455**
Load Factor		1.0	1.0	1.0	1.0
Daily Maximum Water Demand	MLD	1,013	442	0	1,455
Existing Supply	MLD				1,460
Additional Needs	MLD				
Groundwater Consumer	Person	1,640,800	599,200	560,000	2,800,000
Per Capita Consumption	lpcd	150	150	150	
Groundwater Consumption	MLD	246	90	84	420
Water Loss		16%	16%	16%	
Groundwater Abstraction	MLD	293	107	100	500
Total Water Demand	MLD	**1,306**	**549**	**100**	**1,955**

Source: JICA Survey Team
Note: (Water Consumption) = (Population) x (Unit Water Consumption Rate: 150 lpcd)
(Water Demand) = (Water Consumption) / (1 - UFW)
*Water Demand is considered with groundwater use by private system. Assumed UFW ratio for private system is different from BWSSB for Core and ULB area.
Slum population: 718,666 person shown in Table 2.3.5 of sub-section 2.3.4. In addition, public tap consumer was estimated as 52,900 by its consumption of 1,587 m3/day at May 2016 assuming the per capita consumption of 30 lpcd. Total slum population becomes is 772,000 (718,666 + 52,900).
Slum population was estimated as decreasing up to 50 % at 2034 and 0 % at 2044.

Table 5.6.2 Water Demand by Study Area in BBMP for Target Year (2)

Item	Unit	2024			
		Core	ULB	110 V	Total
Population	Person	5,998,000	3,377,000	1,984,000	11,359,000
Service Ratio		73%	82%	72%	75%
Served Population	Person	4,357,200	2,777,800	1,424,000	8,559,000

Item	Unit	2024			
		Core	ULB	110 V	Total
House Connection Population	Person	3,899,200	2,463,800	1,424,000	7,787,000
Per Capita Consumption	lpcd	150	150	150	150
Daily Consumption	MLD	585	370	214	1,169
Slum Population	Person	458,000	314,000		772,000
Per Capita Consumption	lpcd	30	30	30	30
Daily Consumption	MLD	14	9	0	23
Daily Average Water Consumption	MLD	599	379	214	1,192
UFW		33%	33%	16%	30%
Daily Average Water Demand	**MLD**	**894**	**566**	**255**	**1,715**
Load Factor		1.0	1.0	1.0	1.0
Daily Maximum Water Demand	MLD	894	566	255	1,715
Existing Supply	MLD				1,460
Additional Needs	MLD				255
Groundwater Consumer	Person	1,640,800	599,200	560,000	2,800,000
Per Capita Consumption	lpcd	150	150	150	
Groundwater Consumption	MLD	246	90	84	420
Water Loss		16%	16%	16%	
Groundwater Abstraction	MLD	293	107	100	500
Total Water Demand	MLD	**1,187**	**673**	**355**	**2,215**

Source: JICA Survey Team

Table 5.6.3 Water Demand by Study Area in BBMP for Target Year (3)

Item	Unit	2034			
		Core	ULB	110 V	Total
Population	Person	6,483,000	4,809,000	2,819,000	14,111,000
Service Ratio		75%	88%	80%	80%
Served Population	Person	4,842,200	4,209,800	2,259,000	11,311,000
House Connection Population	Person	4,613,200	4,052,800	2,259,000	10,925,000
Per Capita Consumption	lpcd	150	150	150	150
Daily Consumption	MLD	692	608	339	1,639
Slum Population	Person	229,000	157,000		386,000
Per Capita Consumption	lpcd	30	30	30	30
Daily Consumption	MLD	7	5	0	12
Daily Average Water Consumption	MLD	699	613	339	1,651
UFW		23%	23%	16%	22%

Item	Unit	2034			
		Core	ULB	110 V	Total
Daily Average Water Demand	**MLD**	**908**	**796**	**404**	**2,108**
Load Factor		1.0	1.0	1.0	1.0
Daily Maximum Water Demand	MLD	908	796	404	2,108
Existing Supply	MLD				1,460
Additional Needs	MLD				648
Groundwater Consumer	Person	1,640,800	599,200	560,000	2,800,000
Per Capita Consumption	lpcd	150	150	150	
Groundwater Consumption	MLD	246	90	84	420
Water Loss		16%	16%	16%	
Groundwater Abstraction	MLD	293	107	100	500
Total Water Demand	MLD	**1,201**	**903**	**504**	**2,608**

Source: JICA Survey Team

Table 5.6.4 Water Demand by Study Area in BBMP for Target Year (4)

Item	Unit	2049			
		Core	ULB	110 V	Total
Population	Person	7,284,000	7,621,000	4,453,000	19,358,000
Service Ratio		77%	92%	87%	86%
Served Population	Person	5,643,200	7,021,800	3,893,000	16,558,000
House Connection Population	Person	5,643,200	7,021,800	3,893,000	16,558,000
Per Capita Consumption	lpcd	150	150	150	150
Daily Consumption	MLD	846	1,053	584	2,483
Slum Population	Person	0	0		0
Per Capita Consumption	lpcd	30	30	30	30
Daily Consumption	MLD	0	0	0	0
Daily Average Water Consumption	MLD	846	1,053	584	2,483
UFW		16%	16%	16%	16%
Daily Average Water Demand	**MLD**	**1,007**	**1,254**	**695**	**2,956**
Load Factor		1.0	1.0	1.0	1.0
Daily Maximum Water Demand	MLD	1,007	1,254	695	2,956
Existing Supply	MLD				1,460
Additional Needs	MLD				1,496
Groundwater Consumer	Person	1,640,800	599,200	560,000	2,800,000
Per Capita Consumption	lpcd	150	150	150	
Groundwater Consumption	MLD	246	90	84	420

Item	Unit	2049			
		Core	**ULB**	**110 V**	**Total**
Water Loss		16%	16%	16%	
Groundwater Abstraction	MLD	293	107	100	500
Total Water Demand	MLD	**1,300**	**1,361**	**795**	**3,456**

Source: JICA Survey Team