No.

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
NATIONAL RIVER CONSERVATION DIRECTORATE (NRCD)
MINISTRY OF ENVIRONMENT AND FORESTS

THE STUDY ON WATER QUALITY MANAGEMENT PLAN FOR GANGA RIVER IN THE REPUBLIC OF INDIA

FINAL REPORT

VOLUME III MASTER PLAN FOR PROJECT CITIES

VOLUME III-4 SEWERAGE MASTER PLAN FOR VARANASI CITY

JULY 2005

TOKYO ENGINEERING CONSULTANTS CO., LTD.
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FINAL REPORT
ON
WATER QUALITY MANAGEMENT PLAN FOR GANGA RIVER
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VOLUME III-4

SEWERAGE MASTER PLAN FOR VARANASI

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ABBREVIATIONS

AD/MM	Average Day / Max Month
ADF	Average Daily Flow
ADWF	Average Dry Weather Flow
AIWSP	Advanced Integrated Wastewater Stabilization Ponds
AL	Aerated Lagoon
AS	Activated Sludge
ASR	Aquifer Storage and Recovery System
Avg	Average
AWT	Advanced Wastewater Treatment
BOD	Biochemical Oxygen Demand
CI	Cast Iron
CMS	Cubic Meter per Second
CO_2	Carbon Dioxide
CPCB	Central Pollution Control Board
CWR	Clear Water Reservoir
DLW	Diesel Locomotive Work
DO	Dissolved Oxygen
DPR	Detailed Project Report
ES	Equalization/Storage
FAB	Fluidised Aerated Bioreactor
FS	Feasibility Study
FSA	Future Service Area
GAP	Ganga/Gomti Action Plan
GoAP	Gomti Action Plan
GIS	Geographical Information System
gpd	Grams per day
GOI	Government of India
GOJ	Government of Japan
GWI	Ground Water Infiltration
HDR	High-Density Residential
HP	Horse Power
I/I	Infiltration/Inflow
ISC	Indian Standard Code
JICA	Japan International Cooperation Agency
JS	Jal Sansthan
KVA	Kilo Volt Ampere
LDR	Low-Density Residential
lpcd	Litres per capita per day
lpm	Litres per minute
lps	Litres per second
MC	Municipal Corporation
MDR	Medium-Density Residential
mg/l	Milligrams per Litre
ML	Million Litres
mld	Million Litres per Day
MLSS	Mixed Liquor Suspended Solids
MP	Maturation Pond / Master Plan
MPN	Most Probable Number per 100ml
MPS	Main Sewage Pumping Station
MPS	Meter per Second
MUD	Ministry of Urban Development
MoEF	Ministry of Environment and Forests
N/A	Not Available
NBC	National Building Code
NH_3-N	Ammonia-Nitrogen
NRCD	National River Conservation Directorate
NSA	Non Sewerage Area
O&M	Operations and Maintenance
PDWF	Peak Dry Weather Flow
PFR	Project Feasibility Report
PS	Pumping Station
PSC	Pre-Stressed Concrete
RAS	Return Activated Sludge
SMF	Sankat Mochan Foundation
SPS	Sewage Pumping Station
SS	Suspended Solids
SSO	Sanitary Sewer Overflow
STP	Sewage Treatment Plant
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
UASB	Up flow Anaerobic Sludge Blanket
UFW	Unaccounted for Water
UPJN	Uttar Pradesh Jal Nigam
UPPCB	Uttar Pradesh Pollution Control Board
USAID	United States Agency for International Development
UV	Ultra Violet
VCP	Vitrified Clay Pipe
WAS	Waste Activated Sludge
WRF	Water Reclamation Facility
WSP	Waste Stabilization Pond
WTP	Water Treatment Plant
YAP	Yamuna Action Plan

GLOSSARY OF TERMS

Aerated Lagoons*:* Like WSPs but with mechanical aeration. Oxygen requirement mostly from aeration and hence more complicated and higher O&M costs requires less land than WSP.

Activated-Sludge Process: A biological wastewater treatment process in which a mixture of wastewater and biologically enriched sludge is aerated to facilitate aerobic decomposition by microbes.

Advance Wastewater Treatment: Treatment process designed to remove pollutants that are not adequately removed by conventional secondary treatment processes.

Aeration: The addition of air or oxygen to water or wastewater, usually by mechanical means, to increase dissolved oxygen levels and maintain aerobic conditions.

Anaerobic Digestion: Sludge stabilization process in which the organic material in biological sludge is converted to methane and carbon dioxide in an airtight reactor.

Assimilative Capacity: The ability of a water body to received wastewater and toxic materials without deleterious effects on aquatic life or the humans who consume the water.

Average Daily Flow: The total flow past a physical point over a period of time divided by the number of days in that period.

Biochemical Oxygen Demand (BOD): A standard measure of wastewater strength that quantifies the oxygen consumed in a stated period of time, usually 5 days and at 20^{o}C.

Biological Process: The process by which the metabolic activities of bacteria and other micro organisms break down complex organic materials to simple, more stable substances.

Bio solids: Solid organic matter recovered from municipal wastewater treatment that can be beneficially used, especially as a fertilizer. *Bio solids* are solids that have been stabilized within the treatment process, whereas sludge has not.

Chlorination: The addition of chlorine to water or wastewater, usually for the purpose of disinfection.

Coliform Bacteria: Rod shaped bacteria from intestinal track of man used as an indication that pathogenic organisms may also be present.

Collection System: In wastewater, a system of conduits, generally underground pipes, that receives and conveys sanitary wastewater and/or storm water. In water supply, a system of conduits or canals used to capture a water supply and convey it to a common point.

Composting: Stabilization process relying on the aerobic decomposition of organic matter in sludge by bacteria and fungi.

Dechlorination: The partial or complete reduction of residual chlorine by any chemical or physical process.

Design Storm: The magnitude of a storm on which the design of a system and/or facility is based; usually expressed in terms of the probability of an occurrence over a period of years.

Diffused-Air Aeration: The introduction of compressed air to water by means of submerged diffusers or nozzles.

Digester*:* A tank or vessel used for sludge digestion.

Disinfection: The selective destruction of disease-causing microbes through the application of chemicals or energy.

Diurnal: A daily fluctuation in flow or composition that is of similar pattern from one 24-hour period to another.

Effluent: Partially or completely treated water or wastewater flowing out of a basin or treatment plant.

Fine-Bubble Aeration: Method of diffused aeration using fine bubbles to take advantage of their high surface areas to increase oxygen-transfer rate.

Fixed Film Process: Biological wastewater treatment process whereby the microbes responsible for conversion of the organic matter in wastewater are attached to an inert medium such as rock or plastic material. Also called *attached-growth process.*

Force Main: The pipeline through which flow is transported from a point of higher pressure to a point of lower pressure.

Friction Factor: A measure of the resistance to liquid flow that results from the wall roughness of a pipe or channel.

Gravity Thickening: A process that uses a sedimentation basin designed to operate at high solid loading rate, usually with vertical pickets mounted to revolving sludge scrapers to assist in releasing entrained water.

Grit Chamber: A settling chamber used to remove grit from organic solids through sedimentation or an air-induced spiral agitation.

Head Loss: The difference in water level between the upstream and downstream sides of a conduit or a treatment process attributed to friction losses.

Headworks: The initial structure and devices located at the receiving end of a water or wastewater treatment plant.

Infiltration: Water entering a sewer system through broken or defective sewer pipes, service connections, or manhole walls.

Influent: Water or wastewater flowing to a basin or treatment plant.

Invert: The lowest point of the internal surface of a drain, sewer, or channel at any cross section.

Land Application: The disposal of wastewater or municipal solids onto land under controlled conditions.

Lift Station: A chamber that contains pumps, valves, and electrical equipment necessary to pump water or wastewater.

Methane: A colourless, odourless combustible gas that is the principal by-product of anaerobic decomposition or organic matter in wastewater. Chemical formula is CH_4.

Mixed Liquor Suspended Solids (MLSS): Suspended solids in the mixture of wastewater and activated sludge undergoing aeration in the aeration basin.

Nitrification: Biological process in which ammonia is converted first to nitrite and then to nitrate.

Nutrient: Any substance that is assimilated by organisms to promote or facilitate their growth.

Pathogen: Highly infectious, disease-producing microbes commonly found in sanitary wastewater.

Peak Flow: Excessive flows experienced during hours of high demand; usually determined to be the highest 2-hour flow expected under any operational conditions.

Preliminary Treatment: Treatment steps including screening, grit removal, preparation, and/or flow equalization that prepare wastewater influent for further treatment.

Pump Station: (see lift station)

Primary Clarifier: Sedimentation basin that precedes secondary wastewater treatment.

Primary Treatment: Treatment steps including sedimentation and/or fine screening to produce an effluent suitable for biological treatment.

Rising Main : (see force main)

Reclaimed Wastewater: Wastewater treated to a level that allows its reuse for a beneficial purpose.

Return Activated Sludge (RAS): Settled activated sludge that is returned to mix with raw or primary settled wastewater.

Sanitary Sewer Overflow (SSO): Overloaded operating condition of a sanitary sewer that results from inflow/infiltration.

Screening: (1) A treatment process using a device with uniform openings to retain coarse solids. (2) A preliminary test method used to separate according to common characteristics.

Scum: Floatable materials found on the surface of primary and secondary clarifiers consisting of food wastes, grease, fats, paper, foam, and similar matter.

Secondary Clarifier: A clarifier following a secondary treatment process and designed for gravity removal of suspended matter.

Secondary Treatment: The treatment of wastewater through biological oxidation after primary treatment.

Sludge: Accumulated and concentrated solids generated within the wastewater treatment process that have not undergone a stabilization process.

Sludge Dewatering: The removal of a portion of the water contained in sludge by means of a filter press, centrifuge, or other mechanism.

Sludge Stabilization: A treatment process used to convert sludge to a stable product for ultimate disposal or use and to reduce pathogens to produce a less odorous product.

Suspended-Growth Process: Biological wastewater treatment process in which the microbes and substrate are maintained in suspension within the liquid.

Thickening: A procedure used to increase the solids content of sludge by removing a portion of the liquid.

Trickling Filters: Sewage passes down through a loose bed of stones, and the bacteria on the surface of the stones treats the sewage. An aerobic process in which bacteria take oxygen from the atmosphere (no external mechanical aeration). Has moving parts, which often break down.

Total Suspended Solids (TSS): The measure of particulate matter suspended in a sample of water or wastewater. After filtering a sample of a known volume, the filter is dried and weighed to determine the residue retained.

Waste Activated Sludge (WAS): Excess activated sludge that is discharged from an activated-sludge treatment process.

Wetlands Treatment: A wastewater treatment system using the aquatic root system of cattails, reeds, and similar plants to treat wastewater applied either above or below the soil surface.

Waste Stabilization Pond: Large surface area ponds that provide treatment essentially by action of sunlight, encouraging algal growth which provides the oxygen requirement for bacteria to oxidize the organic waste. Requires significant land area, but one of the few processes which is effective at treating pathogenic material. Natural process with no power/oxygen requirement. Often used to provide water of sufficient quality for irrigation, and very suited to hot, sunny climates.

UASB: Anaerobic process using blanket of bacteria to absorb polluting load. Suited to hot climates. Produces little sludge, no oxygen requirement or power requirement, but produces a poorer quality effluent than processes such as ASP. (NOTE: other anaerobic processes exist, but UASB is the most common at present).

Collection System Terminology

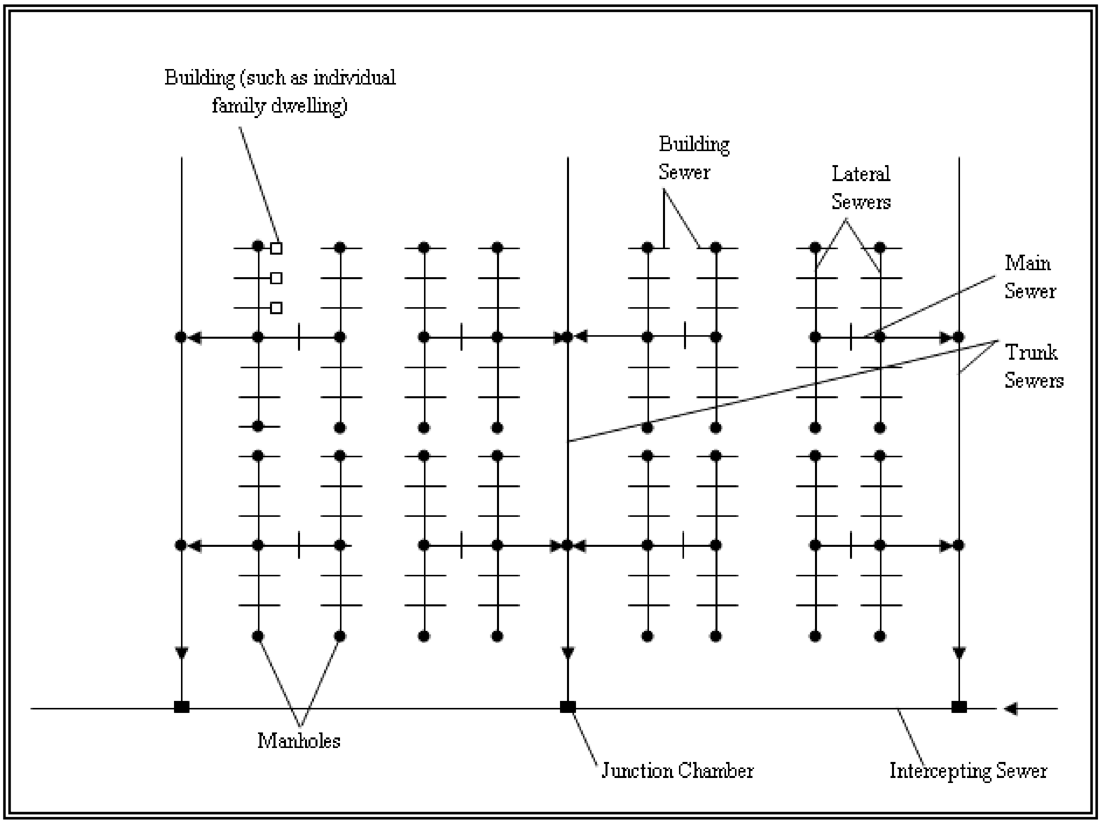
1. ***Interceptor Sewer:*** A sewer that receives flow from a number of other sewers or outlets for disposal or conveyance to a treatment plant.

2. ***Manhole:*** An opening in a vessel or sewer to permit human entry. Also called *manway*.

3. ***Trunk Sewer:*** Trunk sewers are large sewers that are used to convey wastewater from main sewers to treatment or other disposal facilities or to large intercepting sewers.

4. ***Main Sewer:*** Main sewers are used to convey wastewater from one or more lateral sewers to trunk sewers or to intercepting sewers.

5. ***Lateral Sewer:*** Lateral sewers form the first element of a wastewater collection system and are usually in streets or special easements. They are used to collect wastewater from one or more building sewers and convey it to a main sewers.



CHAPTER 1

EXECUTIVE SUMMARY

CHAPTER 1 EXECUTIVE SUMMARY

1.1 GENERAL

This is the Master Plan report for pollution control and sewerage development in Varanasi city. The initial stage of this study examined prospective urban development to the year 2030, evaluated alternative sewerage projects, and selected the priority components for the Feasibility Study (FS).

The methodology of this study has been to determine the least cost approach for meeting Varanasi City's sewerage and water pollution control needs. This has involved the consideration of existing infrastructure and proposals by UPJN for GAP-II, alternative service coverages, alternative technologies, and alternative wastewater treatment and disposal methods.

Water supply and sanitation services are inadequate for Varanasi’s present population. Sewer infrastructure is old, and poorly maintained. Water supply is intermittent, and adverse sanitary conditions (including defecation in the open) cause increasing hazards to public health.

A summary of relevant population, water supply and wastewater data is presented in Table 1.1. Varanasi city's population is projected to double from 1.28 million in 2003 to 2.71 million by 2030. At present total wastewater load is about 289 mld vs. installed treatment capacity of 88 mld (80 mld at Dinapur and 8 mld at Bhagwan pur). The amount of wastewater collected and diverted to treatment is only 30% of the total amount generated. Remaining 70% of the wastewater is discharged to Varuna river and Ganga river through open drains.

Table 1.1 Project Data Sheet, Varanasi

(1) Population

	2003	2015	2030
Municipal	1,157,510	1,627,540	2,220,700
Outside municipal boundary	126,989	268,518	491,350
Floating	57,874	81,378	111,036
Total	1,342,373	1,977,436	2,823,086

(2) Water Supply

		2003	2015	2030
Population served by municipal system		1,215,480	1,708,900	2,823,086
Demand	mld	232	336	490
Water supply treatment capacity				
Existing	mld	310	310	310
Proposed	mld		200	200
Total	mld	310	510	510
Water source				
Municipal-river	mld	123	510	510
Municipal-wells	mld	143	143	143
Private	mld	67	67	67
Other	mld	7	7	7
Total	mld	340	727	727

(3) Wastewater

		2003	2015	2030
Total population		1,342,373	1,977,436	2,823,086
Population in sewer service area		976,223	1,371,717	2,708,520
Population connected to sewer		435,525	988,718	2,117,315
Percentage of connected population		32%	50%	75%
Wastewater return rate per capita	lpcd	215	185	155
Total wastewater generation	mld	289	366	438
Amount intercepted	mld	210	272	420
Treatment capacity				
Existing	mld	88	88	80
Sanctioned	mld		37	37
Proposed	mld		200	313
Total	mld	88	325	430

1.1.1 Need for a Sewerage Master Plan

The GAP proposals focus on reducing pollution loads by diverting sewage at the tail end of drains during dry weather only. GAP does not address the need for removing sewage from the drains to prevent pollution during wet weather. Nor does it address issues of public health and sanitation within the city.

In the absence of a sewerage master plan urban development continues without adequate infrastructure for public health and sanitation. New sources of pollution crop up as the population grows and as new areas develop:

- Existing sewer facilities are overtaxed, effluent at treatment plants becomes a significant pollutant load
- The amount of wastewater in open drains increases thereby overflowing at existing diversion facilities
- New sources of pollution appear as natural drains serve as outlets for wastewater from new developments

Diversion facilities constructed under GAP are not designed to operate during wet weather, therefore the use of open drains for wastewater disposal will remain a significant source of pollution during wet weather.

Diversion of drains, as proposed under GAP is an important first step for improving water quality. However, the Government of India and NRCD have recognized that the benefits of GAP will be short lived unless these activities are framed within a more holistic approach to the development of sewerage infrastructure in large urban centers. In the absence of a comprehensive plan, efforts at pollution control will always remain reactive, never quite catching up with the source of the problem.

1.1.2 Key Issues for the Implementation of Sewerage Master Plan

1) Adopting a decentralized approach

The Sewerage Master Plan divides the urban centre into sewerage districts. A decentralized approach has been favoured to minimize conveyance costs and reduce the size of sewerage facilities. Smaller treatment works will simplify site selection and land acquisition. Furthermore, it is generally easier to manage the operation and maintenance of smaller facilities.

2) Coordinating development of branch sewers with trunk sewers

The trunk facilities identified in the Master Plan are the backbone of the sewerage system. It will open the way for extending the branch sewer network into parts of the city that are not presently served. It is essential that existing and future development areas be connected to this backbone in order achieve water quality, health and sanitation objectives. JAL Sansthans, and Nagar Nigams must implement programs for improving and extending the branch sewer system. A concentrated effort will be required to connect existing and future growth areas, else the trunk sewer system will fail because there will be insufficient wastewater to achieve self-cleansing velocities.

3) Adopting and adhering to the Sewerage Master Plans

The Master Plans for sewerage must be formally adopted by the authorities responsible for the development of cities. A formal mechanism is required to make it mandatory for Development Authorities and Housing Boards to adhere to the Master Plan. Continuing in the present mode whereby new colonies are developed without proper outlet to trunk sewer facilities will only add to the drainage and pollution problems of the city.

4) Cost sharing for trunk facilities: user pay principle

Implementation of new developments must proceed in a planned manner. Major trunk facilities should be extended to service planned communities. In keeping with the user pay principle, it should be made mandatory by law for developers, whether private or Government to share in the cost of trunk sewers and treatment plant.

5) Land acquisition for future facilities

Land identified for sewage treatment works and pumping stations must be acquired as soon as possible and reserved for the future development of the sewerage system. Similarly, right of way and maintenance easements are required along trunk sewer alignments to prevent encroachment.

6) Power cuts

Pumping stations and treatment plants must be provided with a reliable and continuous power supply. These facilities must be designated as essential services and should be given top priority for service by the electrical utility. Emergency power generators must be provided at all facilities and funding for fuel must be guaranteed to prevent overflows of untreated sewage.

1.2 OVERVIEW OF THE MASTER PLAN

The Sewerage Master Plan is developed for areas within the greater limits of the Municipal Corporation (as defined by the Development Authority) that have or will have population densities greater than 120 persons per hectare. Approximate population densities based on a visual interpretation of land use are derived from satellite images.

The City of Varanasi has been divided into 4 sewerage districts. Each sewerage district having it's own sewage treatment works.

(mld)

STP	District	Status	2003	2015	2030
Dinapur STP	1	E/R	80	80	80
Sathwa STP	2	P	-	200	225
Bhagwan pur STP	3	E/R	8	8	0
Ramna STP	3	S/A	-	37	75
Lohta STP	4	P	-	-	50
Total			88	325	430

STP	District	Process	Effluent Discharge	Disinfections
Dinapur STP	1	Activated sludge	Irrigation and Ganga River	Add chlorination
Sathwa STP	2	UASB++	Irrigation and Ganga River	Chlorination
Bhagwanpur STP	3	Activated sludge	Ganga River	Add chlorination
Ramna STP	3	Stabilization pond	Water body and Irrigation	Maturation ponds
Lohta STP	4	UASB++ or Aerated lagoons	Ganga River through Varuna River	Chlorination

E: Existing, A: Augmentation, S: Sanctioned, ++: Post treatment, R: Rehabilitation

1.3 RECOMMENDATIONS

Major interventions are necessary to reduce river pollution and improve sanitation to all the population and to cope with its future growth. The following recommendations are identified in this report:

1) ***Rehabilitate main trunk sewer*****:** This intervention is required to reduce the amounts of wastewater that overflow to surface drains and to reduce the risk of a catastrophic failure. In addition to cleaning and repair of the system it will be necessary to survey

the whole system and to store record drawings and data in a readily accessible form to facilitate maintenance and planning.

2) ***Rehabilitate Ghat pumping stations*:** pumping equipment is old and poorly maintained. Pumps and diesel generators should be updated, and operation should be automated. Capacity at Harish chandra ghat and Trilochan ghat pump stations should be increased to prevent overflows during peak periods. Significant institutional capacity building and reorganization will be required to ensure sustainable operation and maintenance of the pump stations with emphasis on continuous and reliable operation of diesel generators during power interruptions.

3) ***Intercept all drains along the Varuna river and divert to treatment*:** This intervention is required to reduce pollutant loads to Ganga and Varuna rivers. This intervention includes: interceptor sewer along the left and right bank of the Varuna, nala tapping arrangements, 150 mld pumping station at Chauka ghat and 200 mld treatment plant at Sathwa.

4) ***Eliminate bypass overflows at Konia MPS*:** Augmentation of Dinapur STP is not cost-effective. Flows in excess of 80 mld should be diverted to the sub-central district and treated at the new STP in Sathwa. Konia MPS requires the addition of a fourth line of low lift and high lift pumps to improve standby capacity at peak flow conditions. The diversion gate on Rajghat outfall sewer must be rehabilitated and closed to prevent overflows to Ganga River. Operation of the gate must be automated to allow opening in case of emergencies. A low level overflow is required at Konia MPS to prevent surcharging of the main trunk sewer when the screw pumps stop.

5) ***Intercept Assi/Nagwa nala and divert to treatment*:** This intervention is required to protect the water supply intake and the bathing ghats. This intervention includes: interceptor sewer along the left and right bank of Assi nala, Nagwa MPS (GAP-II – sanctioned 37 mld) and Ramna STP (GAP-II – sanctioned 37 mld).

6) ***Install disinfection facilities at Dinapur and Bhagwanpur STP*:** This intervention will reduce the levels of faecal coliforms in order to meet effluent criteria. In the case of Bhagwanpur this intervention will reduce the risk of contaminating the raw water supply and bathing ghats located downstream.

7) ***Extend the secondary sewerage system*:** This intervention is required to improve sanitary conditions in the areas of the city that are without sewers. Eventually sewerage should be provided in all urban areas where densities exceed 120 persons per hectare. Conventional waterborne sewerage should only be extended to areas where water supply systems provide a minimum of 135 lpcd. Small bore sewerage systems should be considered where water supply services are not adequate, for example in trans-Varuna district.

8) ***Implement regulations, collection and treatment systems for on-site sanitation*:** Peripheral areas where population densities are less than 120 persons per hectare should be provided with proper on-site sanitation systems. This intervention is also required to improve sanitary conditions and reduce the amount of pathogens in the environment. Systems for collecting and treating septage are required.

As shown in Figure 1.1, there is at present a large gap between existing treatment capacity and wastewater load. Therefore, there is an urgent need to provide treatment plants and trunk sewers. These urgent projects should be carried out as Stage I, within 5 to 10 years of adopting the Sewerage Master Plan i.e. 2010 to 2015.

After 2015, the emphasis will be on providing branch sewers and connecting households to the collection system in order to increase the amount of wastewater diverted to treatment plants.

As shown in Figure 1.2, the largest component of the cost during Stage I is for trunk sewers. At Stage II the largest cost component becomes branch sewers. Treatment plants are a relatively small part of the overall cost. The total estimated direct costs including contingency and land acquisition are as follows:

(Crores)

Item	Stage I	Stage II	Total
Direct Cost	426.3	369.7	796.0
Physical Contingency (20%)	85.3	73.9	159.2
Land Acquisition	32.4	27.2	59.6
Total	544.0	470.8	1,014.8

Direct cost does not include house connection cost

1.4 SELECTION OF PRIORITY PROJECTS FOR FEASIBILITY STUDY

A list of all infrastructure projects identified in the Master Plan is shown in Table 1.2. Priority projects are defined as projects that should be implemented as soon as possible (before 2015) to achieve pollution reduction targets. These projects include diversion of all drains that have been identified as a source of pollution by UPJN. Priority projects are included in the scope of the Feasibility Study.

Projects that have already been sanctioned by UPJN are not identified as priority projects because it is assumed they will be fully implemented in the near future.

Table 1.2 Component of Priority Project

Item	Priority
(1) Rehabilitation of Ghat Pumping Stations (District 1) - Ghat area is most densely populated area including old city, and the pollution load to Ganga river is high - Ghat Pumping Stations are decrepit, so wastewater is discharged directly to Ganga river - Fuel for generators of Ghat Pumping Stations is not enough - This rehabilitation is expected to be direct reduction of pollution load to Ganga river - Rehabilitation of five Ghat Pumping Stations	A
(2) Rehabilitation of Existing Treatment Plant and Pumping Stations (District 1) - Konia SPS - Dinapur STP	A
(3) Installation of Assi Nala Interceptors (District 3) - Assi nala is located just upstream of water intake - Assi nala is located upstream of main Ghat area, and it is main pollution source - Wastewater discharged from Assi nala to Ganga river tends to flow along left bank (near Ghats) without dilution with main Ganga river flow - This component is expected to be direct reduction of pollution load to Ganga river - Installation of Assi nala interceptor - Installation of outfall trunk sewer to Ramna STP (sanctioned) - Installation of Nagwa PS (sanctioned) - Installation of Ramna STP (sanctioned) - Rehabilitation of Bhagwanpur STP - Installation of lateral trunk sewers - Land acquisition - Branch sewers	A
(4) Resolution of Overload of Dinapur STP (District 1 and 2) - Overload of Dinapur STP causes wastewater discharge to Varuna river and Ganga river - So, new STP is necessary to complement Dinapur STP - Also, new trunk sewer is necessary to convey excess wastewater to proposed Sathwa STP - Rehabilitation of Dinapur STP and Konia PS - Rehabilitation of old trunk sewer - Installation of relief trunk sewer (downstream component, sanctioned) - Installation of rising main from Chauka ghat MPS - Installation of Chauka ghat MPS and Sathwa STP - Land acquisition - Branch sewers	A

Item	Priority
(5) Measures for Sub-Central Area (District 2) - Sub-Central area is the most densely populated area next to Central area or Ghat area, and the pollution load to Ganga river is rather high - Installation of relief trunk sewer (upstream component) - Installation of Varuna interceptor of right bank - Installation of lateral trunk sewers - Branch sewers	A
(6) Measures for Trans-Varuna Area (District 2) - Not so populated area compared to Sub-Central area, but the pollution load to Varuna river is high - Population growth rate is estimated higher than Sub-Central area - Installation of Varuna interceptor of left bank - Installation of Narokhar nala SPS, Saraiya nala SPS and Chouka ghat left bank SPS and their rising mains - Installation of lateral trunk sewers - Branch sewers	A
(7) Other Projects District 1 - Replacement of M/E of Konia SPS and Ghat SPS - Replacement of M/E of existing Dinapur STP - Branch sewers District 2 - Installation of lateral trunk sewers in Trans Varuna - Installation of Sathwa No.1 SPS and Sathwa No.2 SPS, and their rising mains - Replacement of M/E of Chauka ghat SPS - Augmentation of Sathwa STP - Branch sewers District 3 - Installation of lateral trunk sewers in Future Sewerage Area - Replacement of M/E of Nagwa nala SPS - Augmentation of Ramna STP - Branch sewers District 4 - All facilities	B

A: Works to be implemented before 2015
B: Works to be implemented before 2030

Table 1.3 Stage I Project - Implementation Cost

(Million Rs.)

Project	Estimated Cost	+Physical Contingency	Cumulative Cost
1. Rehabilitate Ghat PS and Main Trunk Sewer			
(a) Rehabilitation of five Ghat PS	92.5	111.0	
(b) Rehabilitation of Old Trunk Sewer	612.5	735.0	
(c) Branch Sewer in District 1	39.4	47.3	
Sub Total	744.4	893.3	893.3
2. Rehabilitate Konia MPS and Dinapur STP			
(a) Rehabilitation of Konia PS	78.2	93.8	
(b) Rehabilitation of Dinapur STP	12.0	14.4	
Sub Total	90.2	108.2	1,001.5
3. Assi Nala Interceptors to reduce flow in Nala upstream of Ghats			
(a) Installation of Assi Nala interceptor at both bank	145.2	174.2	
(b) Rehabilitation of Bhagwanpur STP	1.2	1.4	
(c) Installation of Lateral Trunk Sewers	109.7	131.7	
(d) Branch Sewer in District 3	212.9	255.5	
Sub Total	469.0	562.8	1,564.3
4. Resolution of Overload of Dinapur STP			
(a) Installation of Rising Main from Chaukaghat MPS	43.8	52.6	
(b) Installation of Outfall Trunk Sewer to Sathwa STP	663.1	795.7	
(c) Installation of Chaukaghat MPS	533.0	639.6	
(d) Land acquisition for Chaukaghat MPS	4.0	4.0	
(e) Installation of Sathwa STP	600.0	720.0	
(f) Land acquisition for Sathwa STP	316.0	316.0	
Sub Total	2,159.9	2,527.9	4,092.2
5. Sub-Central Area (District 2)			
(a) Installation of Relief Trunk Sewer (Upstream component)	74.3	89.1	
(b) Installation of Varuna Interceptor of Right Bank	233.2	279.9	
(c) Installation of Lateral Trunk Sewers	217.5	261.0	
(d) Branch Sewer in District 2	55.9	67.1	
Sub Total	580.9	697.1	4,789.3
6. Trans-Varuna Area (District 2)			
(a) Installation of Varuna Interceptor of Left Bank	225.3	270.4	
(b) Installation of Lateral Trunk Sewers	80.6	96.8	
(c) Naroka Nala SPS	114.8	137.8	
(d) Land Acquisition of Naroka Nala SPS	4.0	4.0	
(e) Installation of Rising Main of Naroka Nala	12.6	15.2	
(f) Branch Sewer in District 2	105.6	126.7	
Sub Total	543.0	651.6	5,440.9
Total	4,587.5	5,440.9	

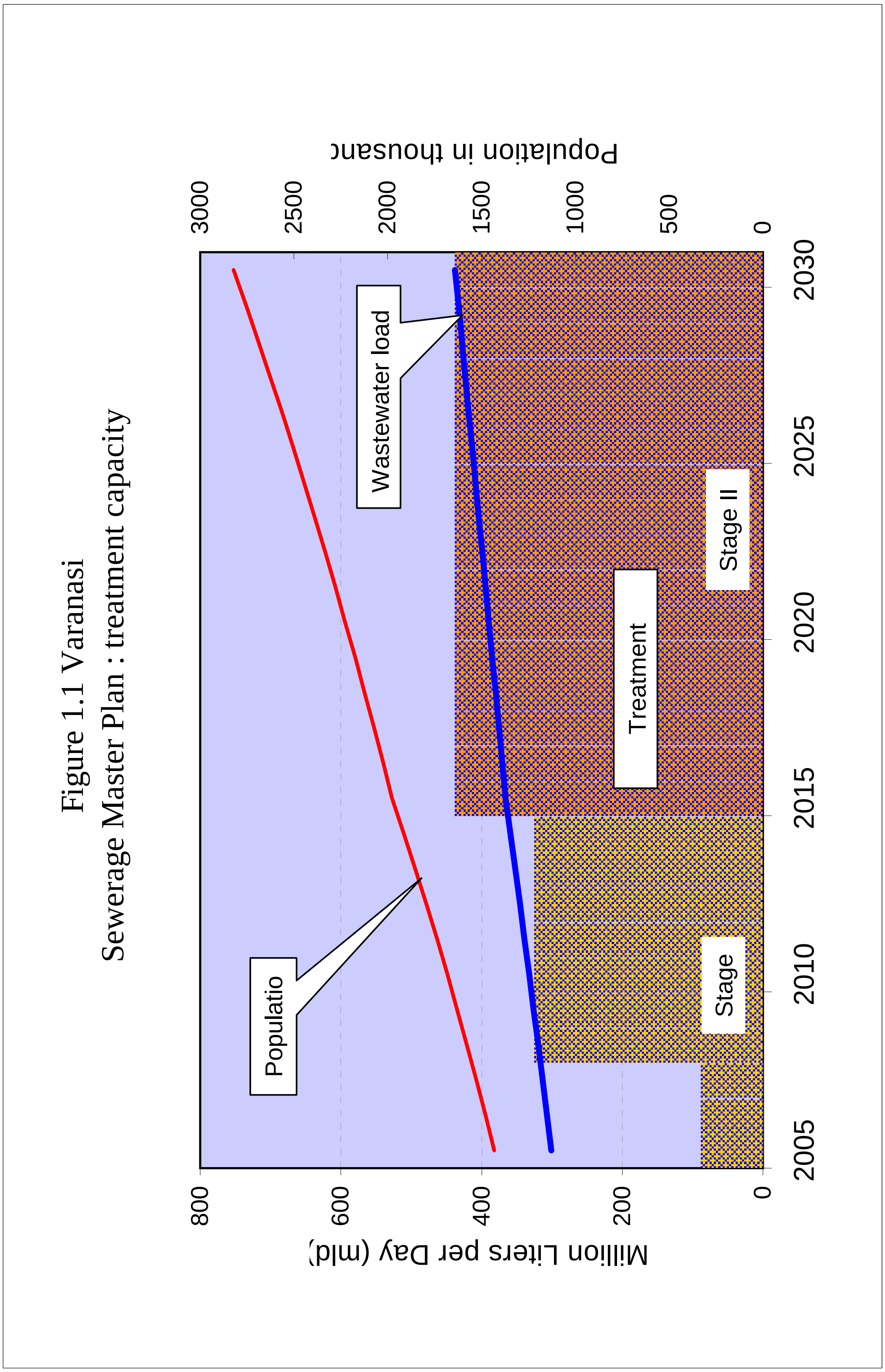
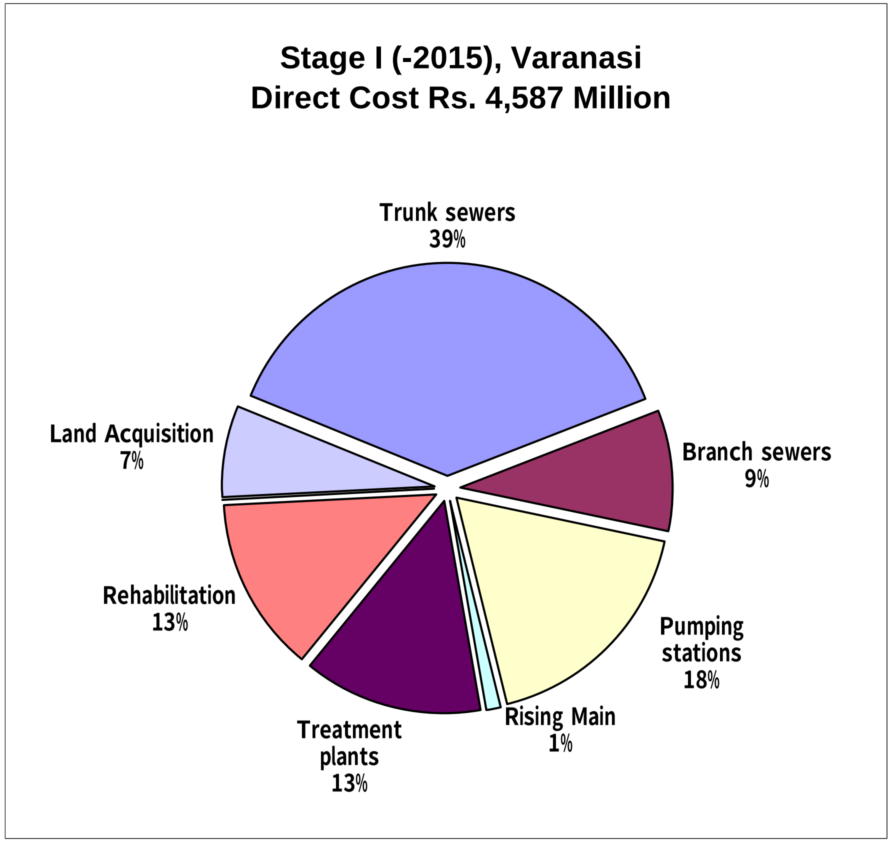


Figure 1.1 Varanasi
Sewerage Master Plan : treatment capacity



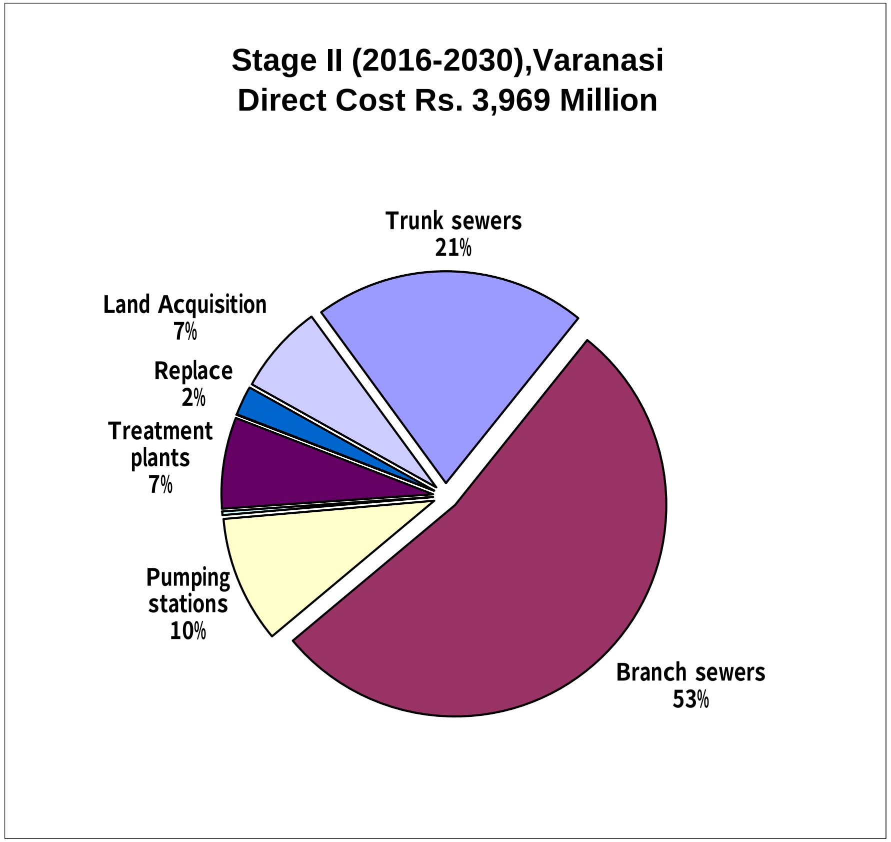


Figure 1.2 Estimated Cost of Sewerage, Breakdown of Direct Construction Cost

CHAPTER 2

INTRODUCTION

CHAPTER 2 INTRODUCTION

2.1 BRIEF HISTORY OF THE CITY

The eternal and ancient city of Varanasi is a religious place on the bank of the holiest river Ganga. It is a magnificent city with myriad attractions both as an exalted place of pilgrimage and micro center of faith. It is one of the most important places of pilgrimage for Hindus and Buddhists the world over.

According to 'Vaman Puran', the Varuna and Assi rivers originated from the body of the primordial person at the beginning of time itself. The tract of the land lying between them is called Varanasi and believed to be the holiest of all pilgrimages. The Pali version of Varanasi is 'Banarasi' which ultimately gave birth to the name Banaras. The city is also famous as Kashi [derived from the root Kas which means to shine] the city of spiritual light. Steeped in tradition and mythological legacy, Kashi is the original ground created by Lord Shiva and Parvati, upon which they stood at the beginning of time.

According to the historians, the city was founded some ten centuries before the birth of Christ. The city is mentioned in the Holy Scriptures like Vaman Puran, Buddhist Texts and in the epic 'Mahabharat'. Puranic literature relates its existence to at least three millennia. Varanasi proudly tells that it was the birth place of St. Kabir, worship place of Bhakta Ravidas and composing place of Mahakavya Sri Ramcharitmanas by Goswami Tulsidas. Varanasi is also renowned for its rich Tapestry of music, arts, crafts and education.

Thousands of tourists visit the city daily from far and near places of India and all across the world. It is a unique city where the past and present, eternity and continuity live side by side. The city rises through the high northern bank on the outside curve of Ganga to form a magnificent panorama of buildings in many varieties of Indian architecture. The unique relationship between the city and sacred river is the essence of Varanasi – the land of Sacred Light. Varanasi is the microcosm of Hinduism, a city of traditional classical culture. Glorified by myth and legend and sanctified by religion, it has always attracted a large number of pilgrims and worshiped from time immemorial.

Varanasi's principal attractions for pilgrims and tourists are a long string of bathing Ghats along the Ganga river, including famous Dashashvamedh Ghat, Kashi Vishvanath Temple, Nepali Temple, Durga Temple, Sarnath, its silk brocade sarees and carpets, Ramnagar Fort, Chunar Fort, Banaras Hindu University, Kashi Vidya Peeth, etc.

Besides a place of pilgrimage and tourists interests, Varanasi is a fast growing commercial, industrial and trading center of Uttar Pradesh and Central India. It is also a center of art, craft and education in the form of Banaras Hindu University.

2.2 PRESENT WASTEWATER SYSTEMS

In total the city of Varanasi's wastewater collection and treatment facilities include a collection system and three wastewater treatment plants. The collection system covers about 40% the city area and most of this is within the old, densely populated centre core. The treatment plants provide approximately 100 mld of treatment capacity. The total amount of wastewater measured in drains and at STPs in 2000 was about 240 mld of which 122 mld was diverted into the sewer collection system.

Households that are not connected to sewers discharge sullage (wastewater from kitchen/bathing and grey water from septic tanks) directly to street drains that ultimately discharge to the rivers. Sanitary wastewater (from toilets) is discharged to soak pits or septic tanks where solids are retained and partially reduced in volume.

UPJN is responsible for pollution prevention and planning capital projects for sewerage. UPJN also operates and maintains large pumping stations and treatment plants. Jal Sansthan is responsible for maintenance of trunk sewers, lateral sewers and collection of revenue from house connections.

2.3 REVIEW OF EXISTING INFORMATION

The following background information regarding the city of Varanasi's wastewater collection and treatment capabilities were provided to the JICA Study Team:

- Process design calculations, unit wise details and site plan for Bhagwanpur STP
- Process design calculations, unit wise details and site plan for Dinapur STP
- Influent and effluent wastewater characteristics at both treatment plants
- Report on State of the Environment for Varanasi, CPCB, 2000
- UPJN revised Project Feasibility Report (PFR) 1998-99 for GAP-II proposals
- UPJN Detailed Project Reports (DPR) 2000-2001 for GAP-II proposals including cost estimates:
    - Relieving Trunk Sewer
    - Prevention of sewage overflow at Ghat pumping stations and interceptor sewers for untapped drains
    - Nagwa nala MPS interception and diversion works
    - Ramna STP
- Feasibility Study of interceptor sewers and AIWPS technology for the prevention of pollution of Ganga at Varanasi, SMF and USAID, 1997.
- Expert Committee Report for implementation of Ganga Action Plan Phase-II in Varanasi
- Census data 2001 for wards administered by Varanasi Municipal Corporation

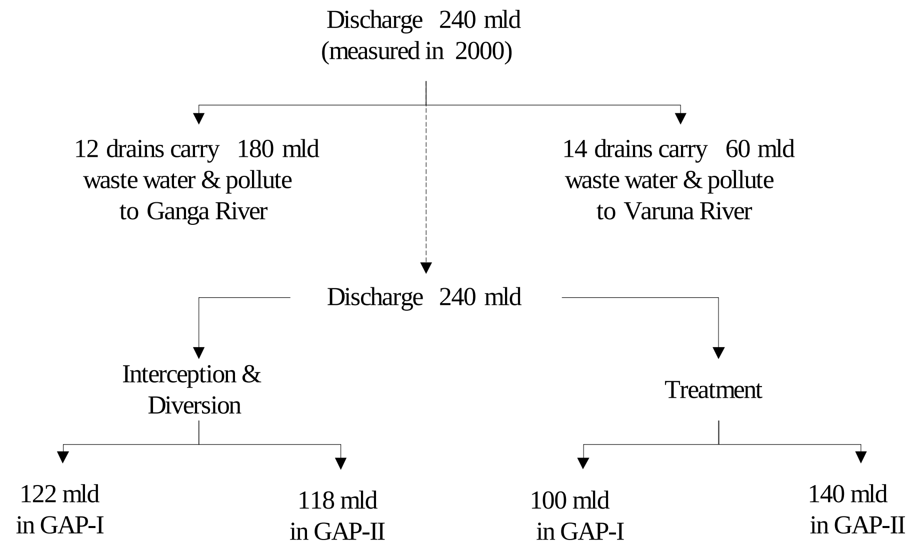
2.3.1 Summary of Ganga Action Plan

In response to growing concern over water quality and environmental degradation UPJN has planned a phased pollution abatement program. The Ganga Action Plan Phase I (GAP-I) was launched in June, 1986 to reduce the amount of untreated wastewater reaching the Ganga river. Schemes completed by Jal Nigam under GAP-I are summarized as follows:

- Relining Orderly Bazaar trunk sewer in 1994
- Five Ghat pumping stations: located along the left bank of the Ganga river.
- Assi main pumping station and rising main to BHU STP
- Konia main pumping station and rising main to Dinapur STP
- Diversion of main trunk sewer to Konia main pumping station
- Sewage treatment works:

a.	Dinapur STP	80 mld
b.	BHU/Bhagwan pur STP	8 mld
c.	DLW STP	12 mld

GAP-I intercepted only about 50% of wastewater flows. Therefore pollution levels in the Ganga remain high.



Source: flows measured by UPJN, year 2000

GAP-II is aimed at intercepting and diverting the remaining flows along Ganga and Varuna rivers. The following works have been proposed by UPJN for GAP-II:
Sanctioned projects:

- Increase pumping capacity at Harish chandra ghat and Trilochan ghat SPS
- Provide new Ghat interceptor sewers to Trilochan ghat SPS
- Provide new pump station to intercept flows at Nagwa drain.
- New 37 mld STP at Ramna to treat flow intercepted at Nagwa
- Relieving trunk sewer in sub-central district

Projects not yet sanctioned (but identified in PFR)

- Augment capacity of Bhagwan pur STP
- MPS at Chauka ghat to convey flows from relief sewer for treatment at Sathwa
- Section of relief sewer crossing the Varuna river connecting to proposed Chauka ghat MPS.
- New 200 mld STP at Sathwa to treat flows from relief sewer
- Interceptor sewer along both banks of Varuna river
- Augmentation of Dinapur STP to 96 mld

Projects implemented under GAP-I have not provided the intended improvements in water quality along the Ghats. The weakest links in the scheme are the pumping stations that intercept the major drains. At present sewage overflows occur at these stations during daily power failures lasting between 8 to 12 hours. Although emergency power generators are provided, the operating authority (UPJN) has insufficient funds for the purchase of diesel fuel. Furthermore, some of the stations have insufficient capacity to deal with dry weather flows which have increased beyond the quantities predicted. Under GAP-II, UPJN has proposed a relief sewer to reduce the amounts of sewage flowing to the Ghat pumping stations.

2.3.2 Sankat Mochan Foundation/USAID Proposal

In 1997 the Sankat Mochan Foundation (local NGO) with support from USAID consultants carried out a detailed feasibility study to provide a gravity interceptor sewer along the Ghats of Ganga river and along the Varuna river that would eliminate the need for the pumping stations. The proposal included a waste stabilization pond located in the Sota a sand bar of the Ganga river approximately 5 km downstream of the city. In April 1997 the Varanasi Nagar Nigam passed a resolution supporting the preparation of detailed project proposals by experts of the SMF and certain experts supported by USAID.

The SMF proposal is significantly different from the UPJN proposals for GAP-II and a great deal of time has been spent trying to reconcile the two into one common plan. Several public interest litigations (PIL) on this matter have been filed as shown in Appendix B-1.

In an effort to speed up the implementation of remedial measures, NRCD ordered the constitution of an Expert Committee to evaluate the proposals submitted by UPJN and SMF. A report issued in March 2000 by the Expert Committee provides an excellent overview of the wastewater management problems in Varanasi as well as a concise technical assessment of the two proposals. The Expert Committee Report is provided in Appendix B-2 for reference. The JICA Study Team concurs with the recommendations of the Expert Committee.

The JICA Study Team is of the opinion that construction of an interceptor along the Ghats using open trench excavation is not feasible for three reasons:

- access for construction equipment, and transportation of materials is impossible.
- acute disruption to the pilgrims and residents,
- potential structural damage to the historical Ghats and surrounding buildings caused by excavation works and dewatering.

Furthermore the JICA Study Team is of the view that operation and maintenance of the proposed interceptor scheme would not be sustainable for the following reasons:

- To operate properly the interceptor requires the continuous operation of a very large pumping station. Any power outrage at this station will result in surcharging of the interceptor. Depending on the length of the power outrage, sewage would back-up the pipe and overflow at several points along the Ghats.
- The size of the pumping station would create a significant maintenance challenge for operating agency. Repair and maintenance of large pumps becomes a problem as does the cleaning of a very deep and large sump well.
- Cleaning, and inspection of a large, deep interceptor is beyond the capabilities of VNN and Jal Sansthan. Although specialized contract services could be engaged these are likely to be very costly. Again, space constraints will make access difficult if not impossible.

For these reasons the JICA Study Team has selected the option of diverting wastewater flows in excess of the optimum capacity of existing trunk sewer facilities away from the core city and the Ghats. The Master Plan proposes the urgent project to rehabilitate the Ghat pumping stations, and increase their capacity where required. From a technical perspective these stations can intercept all dry weather flows as long as funding for diesel fuel is given top priority. It is generally accepted and understood by senior officials at NRCD and UPJN that the stations do not immediately address the issue of wet weather pollution since they are not designed to deal with storm water. This issue can only be addressed by implementing and maintaining a properly planned sewerage network and gradually disconnecting sources of wastewater from the nalas.

The JICA Study Team also considered the treatment plant site proposed by SMF because the use of waste land is obviously less costly to acquire and less disruptive to communities. The Study Team’s primary concern with the selected site is the potential for flooding and erosion damage because the treatment plant will be located in the Ganga river channel.

There has also been a lot of debate over the impact of filling the channel at Sota. The USAID team has carried out a detailed analysis of the effects on sediment transport, velocities, deposition and erosion. However, there is a great deal of uncertainty since the banks of the Ganga river are susceptible to erosion. The JICA Study Team concurs with Expert Committee recommendation that detailed physical modeling is required before deciding suitability of the Sota site.

In conclusion, the JICA Study Team has adopted treatment plant sites on the basis of a decentralized approach because it is of the opinion that it would not be advisable nor practical to let the wastewater from a large city area first come to the Ghats, and then intercept it and divert it elsewhere when other feasible options and alternatives are available.

2.3.3 Infrastructure Issues

Key issues identified in previous studies that must be addressed by the Master Plan include:

1) On-site systems:

Pour flush toilets discharging to leach pits or septic tanks are the most popular on-site sanitation facility. In the core area, space limitation constrains the installation of on-site sanitation system and construction of a private toilet within the household. Leach pits require periodic emptying, which is done manually in an unhygienic manner. There is no centralized service for cleaning of on-site systems. Septic tanks and leach pits overflow and discharge to street side drains, which contributes to the pathogen load in the environment.

2) Discharge of sullage:

A large proportion of households' sullage water from kitchen, bathing and laundry is discharged into street side drains. This compounds the problem arising from inadequate surface water drainage. The reluctance to discharge sullage to the sewer is due to the frequency of and duration of sewer blockages.

3) Inadequate sewerage coverage and low connection ratios:

Of the total volume of sewage generated within the city, only a small proportion enters the main sewerage system. A large fraction enters the surface water drainage system either directly or through spillage from damaged or blocked sewers. This pollutes the water environment and results in unsanitary living conditions particularly when it rains.

4) Ingress of storm water and solid waste into sewer system:

Damaged manholes, sewer defects particularly around the nalas and connections of nalas to the sewerage system have led to the increased risk of solid waste entering and blocking the system. There is currently no way of controlling the amount of storm water that enters the system at locations where drains have been diverted. Storm water overloads the sewer system and causes overflows to the rivers. Augmentation of trunk sewer and treatment capacities to deal with storm water runoff is too costly. Therefore a solution is required for storm water by-pass

CHAPTER 3

CITY PLANNING AND POPULATION PROJECTIONS

CHAPTER 3 CITY PLANNING AND POPULATION PROJECTIONS

3.1 UNDERSTANDING PAST AND EXISTING POPULATION

The focus of this section of the study is to document from available information the existing population in Varanasi, understand their spatial distribution, and then develop population growth and distribution scenarios.

The city of Varanasi has a uniquely different growth character, in comparison to other cities (Kanpur, Allahabad and Lucknow) in this study. Varanasi's growth is complemented by the movement of people from surrounding areas for occupational reasons, tourist traffic as a result of its heritage value, and special events associated with the spiritual importance of the Ganga at Varanasi.

In this project study the detailed analysis of the Varanasi region has been focussed on the municipal extents of Varanasi and the areas under the master plan document. The peripheral growth areas outside of the municipal extents have also been examined and considered for the future growth and expansion of the city. Areas adjacent to the existing municipal extents have been defined in our study as the peri-urban areas. Collectively, these areas are the focus of the population projections and distribution study. Most of the efforts of this study are concentrated on these areas, examining intra-area growth patterns and trends using satellite imagery, field observations, and inputs of local agencies.

In addition to these areas, the growth of the Varanasi region is complemented by the proximal townships of Ram nagar and Mughal sarai, both of which lie across the Ganga river, east of Varanasi. These townships provide alternative growth areas to the city of Varanasi itself and have been included in the overall master plan vision for Varanasi and can have an important effect on the growth patterns in Varanasi city, should significantly improved transportation connectivity exist.

The models for across-river developments are numerous, such as the Delhi-Noida growth, where the demographic shifts are influenced by the proximity to the parent city, and catalysed by efficient connectivity. For this study however we have not developed extrapolations for such eventualities and considering business as usual, in the absence of any major road network enhancement scenarios, have adopted the growth projections similar to those in the master plan documents. This area has not been the subject of extensive analysis for spatial growth patterns and population distribution as have the municipal and its surrounding peri-urban areas.

The base data used for this study was (provisional census) data obtained from the Census of India, with detailed urban area population and municipal ward for 2001 and the 1991 census data summaries. This data provided the numeric basis for benchmarking the actual population and its decadal growth for the past decade. This information was complemented with past decadal growth rates and population data for earlier decades from the master plan documents.

The ward-wise population data for the municipal wards provides the detail for understanding the population distribution across the landscape of the city. Comparison of the data available from the 1991 census and the 2001 provisional census reflects a change in the urban extent and the number of municipal wards. Increasing from 40 wards in 1991, the current municipal area is now divided into 91 administrative areas.

Table 3.1 (a) Decadal Population and Growth Rate of Varanasi Urban Area

Year	Urban Area Population	Decadal Growth Rate	Source
1931	207,650		Census Figures (From Master Plan 2011 Report)
1941	266,002	28%	Census Figures (From Master Plan 2011 Report)
1951	355,771	34%	Census Figures (From Master Plan 2011 Report)
1961	489,864	38%	Census Figures (From Master Plan 2011 Report)
1971	617,934	26%	Census Figures (From Master Plan 2011 Report)
1981	773,865	25%	Census Figures (From Master Plan 2011 Report)
1991	1,030,863	33%	Census Figures
2001	1,202,443	17%	Census Figures

Table 3.1 (b) Decadal Population and Growth Rate of Ram Nagar and Mugal Sarai

Year	Ram Nagar		Mugal Sarai Nagar Paika		Mugal Sarai Railway Settlement	
	Population	Growth Rate	Population	Growth Rate	Population	Growth Rate
1931	12,493		3,545			
1941	12,953	3.68%	5,567	57.04%		
1951	14,022	8.25%	7,332	31.70%	8,153	
1961	16,088	14.73%	10,600	44.57%	10,486	28.62%
1971	17,242	7.17%	13,583	28.14%	15,029	43.32%
1981	23,298	35.13%	48,063	253.85%	21,161	40.80%
1991	30,118	29.27%	66,529	38.42%	24,976	18.03%
2001 (M/P Projections)	39,108 (census)	29.85%	80,992	22%	29,567	18%
2011 (M/P Projections)	46,647	23%	111,469	38%	37,025	25%

Data from TCPO Master Plan 2011 for Ram Nagar and Mughal Sarai.

3.2 UNDERSTANDING DISTRIBUTION OF EXISTING POPULATION

As described in the methodology under the City Planning and Population Projections report, the project team developed an understanding of the existing population distribution across the urban areas of Varanasi. Comparing this population distribution with a visual interpretation of the satellite imagery helped in a better characterization of the urban development pattern into patches of varying population density levels. This approach helped in assessment of the urban development character of the city in the face of limitations of time and resources under this project.

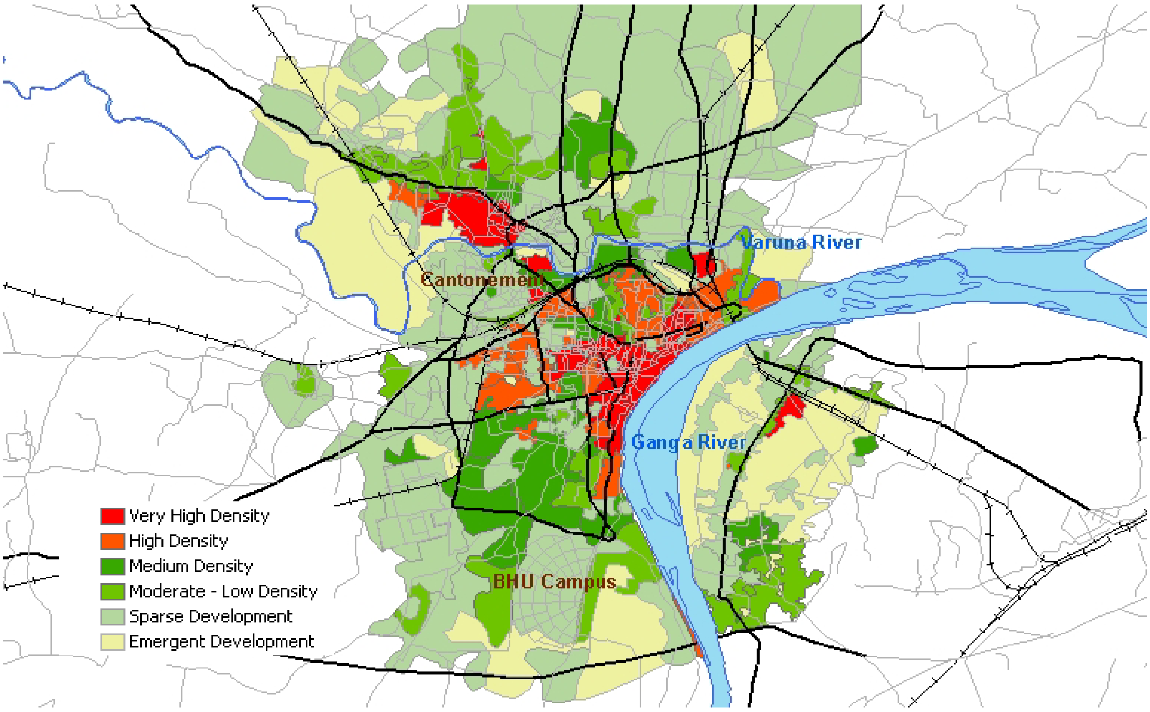


Figure 3.1 Satellite Imagery Interpretation for Development Density

3.3 POPULATION GROWTH PROJECTIONS

The basis of developing the population projections for this study has been the information collected from the Census Department, Lucknow, information provided by Varanasi Nagar Nigam, and from data made available in the master plan documents through the Development Authority and the Town & Country Planning Office in Varanasi.

To establish the growth rates, available data on past decadal growth rates was analysed. By adding in the current data from the 2001 provisional census, the growth rates from past reports were updated. At a macro-level, the overall urban growth rates were estimated to be declining from the high growth rate seen for the decade 1981-1991. In interpreting these growth rates to direct conversions of population growth, margin for adjustment has to be allowed for variances due to differential growth rates in the urban areas that lie within the Varanasi master plan area but outside of the municipal and peri-urban areas.

Since the master plan documents were developed prior to the 2001 census, especially in the case of Varanasi, the census data assisted in benchmarking the actual population and growth rates in comparison to the master plan itself. This tie-in of existing population with growth projections becomes an important pivotal point for developing future growth scenarios.
Additional considerations in the development of population forecasts is the overall slowdown projected in population growth and national urban development directions to encourage growth of new urban centres and counter-magnets to existing cities. This national level trend is reflected in the master plan documents of all cities examined under this study, especially Varanasi.

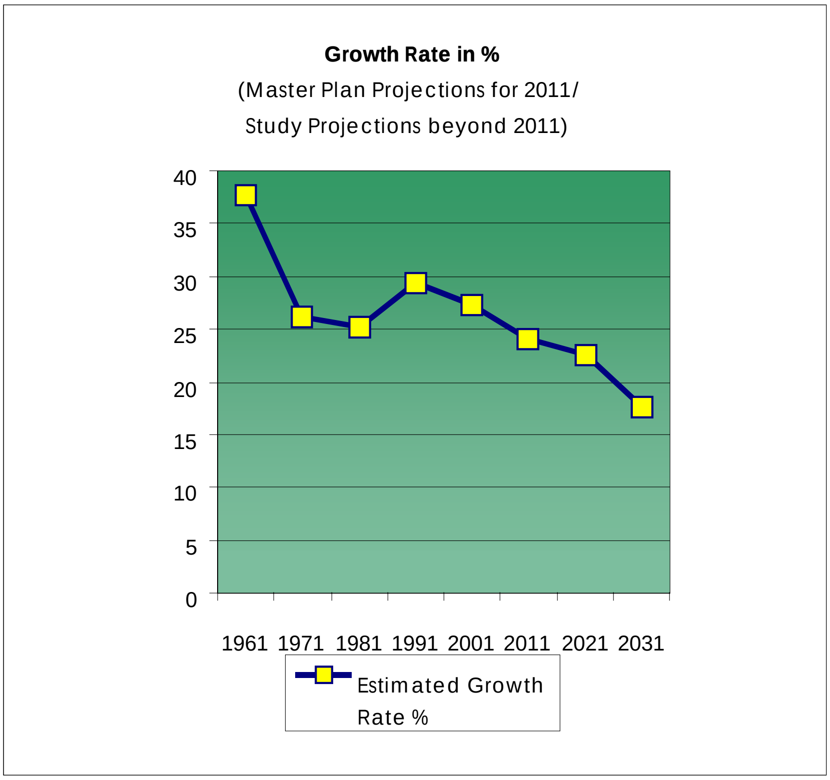
To develop a rational growth rate for the future, differing growth rates were considered. The pertinent issues to recognize here are that by projecting the growth trends based on the census data from 1961 to 1991 and master plan projections upto 2011, we see declining decadal growth rate. Projecting these trends further, the extrapolated growth rates up to 2031 are projected in the Table below. By benchmarking the growth projections to new information available from the 2001 provisional census, new considerations emerge. The difference between the projected master plan population for 1991 and 2001 and the measured census based population for the same time periods results in a downward revision of the growth rate for 2001. Attempting to achieve a decadal population similar to the projected population based on interpolated master plan growth rates, the revised growth rates would have to be significantly increased to achieve similar numbers.

Table 3.2 Master Plan Projections (1)

Year	Master Plan based Population Projections*	Master Plan-based Growth Rates	Projections Benchmarked with Census Data	Revised Projected Growth Rates
1961	489,864	37.69%		
1971	617,934	26.14%		
1981	773,865	25.23%		
1991	1,000,747	29.32%		
2001	1,274,000	27.30%	1,202,443	16.64%
2011	1,621,000	24.13%	1,572,836	30.80%
2021	1,985,704	22.50%	1,984,718	26.19%
2031	2,334,686	17.57%	2,347,159	18.26%

** These projections are for the Varanasi urban area and exclude the projections for the trans-Ganga areas of Ramnagar and Mughal Sarai.*

It is however unlikely that such high growth rates can be achieved as shown in column 5 of the Table above. However, with the intent of including higher safety margins in the overall projections, which will form the basis of subsequent design efforts, these higher end-point populations have been used as the basis of refining our study population growth and dispersion.



Reanalysing the data for population forecasting by different methods, additional estimates were prepared for the total Urban Area Population of Varanasi City. These analysis are presented in the table below. Comparing this analysis and that generated earlier, the higher number was preferred for its inherent safety factor in developing long-term estimates.

Table 3.3 Master Plan Projection (2)

Item	2001	2011	2021	2031
Geometric	1,258,038	1,532,681	1,890,298	2,278,408
Arithmetic	1,173,053	1,417,946	1,651,917	1,863,750
Incremental	1,223,142	1,563,224	1,947,081	2,414,191
Average	1,202,443	1,504,617	1,829,765	2,170,759

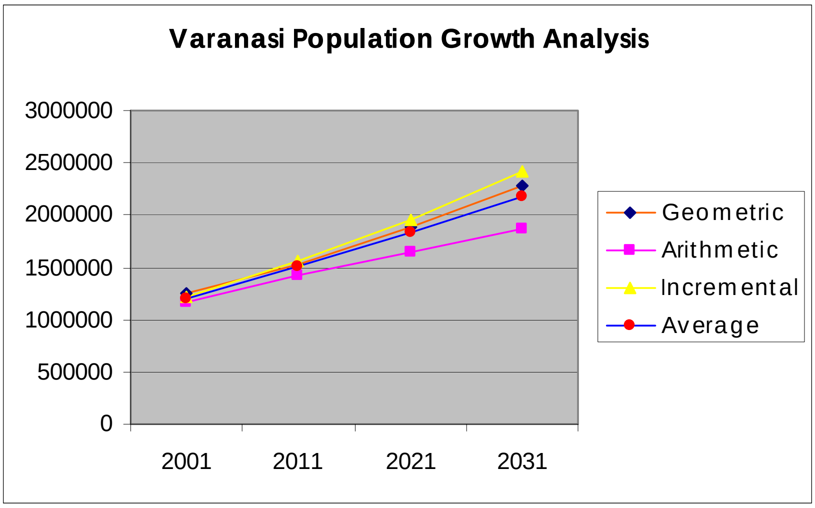


Figure 3.2 Master Plan Projections

During the course of the project, another detailed analysis of population growth rates and estimates was presented by UPJN based on their “Technical Statement on Population Projections”. This document establishes growth projections again based on the master plan but without the benefit of the 2001 provisional census data. As per the growth projections presented in this table (given below), the UPJN provides population estimates up to the year 2033.

Table 3.4 Master Plan Projection (3)

Item	2003	2008	2013	2018	2033
Geometric	1,251,523	1,414,830	1,599,446	1,808,153	2,612,350
Arithmetic	1,077,349	1,137,745	1,198,941	1,258,537	1,439,725
Incremental	1,121,014	1,213,663	1,315,383	1,423,772	1,800,959
Simple Graph	1,100,000	1,180,000	1,240,000	1,320,000	1,560,000
Semi-Log	1,250,000	1,420,000	1,590,000	1,800,000	2,650,000
UPJN Detailed Distribution by Ward	1,417,000	1,617,000	1,823,000	2,039,000	2,492,000

The UPJN document argues for the selection of the projected population based on the semi-log method, identifying this to be more reasonable than the other forecast estimates in the same table. The detailed distribution of the population by wards (based on the 1991 ward definitions) however provides population estimates that are higher than any of these estimates for the initial growth projection years and lower than the UPJN document target year of 2033. This inversion reflects UPJN's estimates to be of a much higher initial growth rate in this decade with a slow down in later decades.

In the present day context of the report preparation in 2004, with available data from the 2001 census, it would appear that the forecast population for the year 2003 is substantially over-projected than actual numbers. Although based on the initial municipal extent of 1991, it has to be logically expected that this population forecast for 2003 would encompass the urban population included in the expanded municipal extent of 2001, and any successive forecasts would correspond to the spatial extents of the increased geographical area under the municipal limits. By this logic, the expanding urban extents of municipalities are accommodated while forecasting population growth and vice-versa, the increased population of a municipality will directly correlate to future action of expanding the municipal limits.

Hence, although the UPJN suggests that the population forecasts are for the municipal extent in the present day context, in reality it implies the population that would lie within the municipal extent of the time interval for which the population is being forecast.

With the target year of the study established as 2030, the Study Team required intermediate stages of population projections for the year 2015 that would coincide with the stages of activity defined in the Sewerage Master Plan development. To correlate population with existing conditions on the ground, it was further required that the final analysis include estimates for the year 2003. Using the 2001 population as the base, and applying growth rates based on ward characteristics, the final ward-wise population numbers were generated. The detailed Table with ward wise population estimates for 2003 and forecasts for 2015 and 2030 has been included in the end of this chapter.

It is a logical progression then to expect the exercise of population forecast to be complemented with a spatial distribution of the population and a forecast of the increased extent of urbanization which will encompass the forecasted population. This has been addressed in the section on Population Distribution Projections.

3.4 POPULATION DISTRIBUTION PROJECTIONS

3.4.1 Defining Urban Character of Municipal Wards and Peri-Urban Areas

The urban character of Varanasi is complex, extended between the old city of Varanasi and the more contemporary growths that are happening now in more peripheral limits of the municipal areas. The high-density of built form in the old city precludes much growth of population in this area which is adjacent to the ghats along the west-bank of the Ganga River.

Adjacent to the ghats and the old-city are the densely packed developments that by their proximity to the ghats and their longevity of existence have become the cultural fabric of the city. Much of the structures and infrastructure in these areas are in poor physical condition, however the complexity of development and ownership patterns makes it difficult to imagine a radical change in the future years in these areas.

For purposes of growth analysis and population increase, these areas have been collectively categorized as the city core. In this area the expectation is to see almost no additional growth and the master plan projects policies that are actually aimed at decongesting these areas possibly resulting in negative growth.

The municipal areas adjacent to the city core are constantly under greater development pressure due to the proximity to the city core and all the services and cultural attraction. This area reflects a plotted development pattern with individual land ownership and development providing the maximum potential for growth directed through individual investment. This pattern of development still remains relatively disorganized although the road networks are wider than the city core and the built form is less congested. The development pressures on these areas remains high and population growth in these areas are likely to impose significant additional burden on the rather limited existing infrastructure. These areas have been categorized as “proximal areas” in developing the growth analysis and population projections for the municipal areas.

The peripheral areas encompassed by the municipal wards in Varanasi have a strikingly different development pattern than the rest of the city. The growing presence of planned housing developments by the State Housing Board, through the Varanasi Development Authority. These developments are increasingly attractive for the resident population as they provide a more organized development form with infrastructure being relatively in better condition. The demand for such developments is increasing and with the participation of governmental and private development groups, the growth on the peripheral areas is likely to be much higher in comparison to other parts of the city.

Major catalysts for growth are the plans for development of the new ring road to the north of the city which will over the next decades come into developed form, spanning a greater urban development density in the northern parts of Varanasi. Also, the development of major road systems connecting to the National Highways on the southern extent of the city is already causing a spurt in development in this area. Combined with plans for a transport nagar in the western extremity of Varansi and the connectivity across the Ganga to the eastern bank (to Ram nagar and Mughal sarai) the growth of urban areas and the population of Varanasi outside of the municipal wards are likely to continue to accelerate. These areas have been considered in detail in the Master Plan for Varansi and growth projections and distribution of the urban population of Varanasi has taken these growth factors into consideration for the purpose of our study.

3.4.2 Defining Ward Characteristics

For the purposes of assigning growth rates by municipal wards, the following ward characteristics were defined and growth rates allocated. Based on an analysis of the growth characteristics of each ward, depending on its current density, road network, master-plan designation, and adjacent ward characteristics, the individual ward growth rates were redefined.

Table 3.5 Growth Characteristics Defined

Ward Character	General Range Growth Rate*
Ghats	0.10%
Core Area	0.2% to 1%
Proximal to City Core	1% to 5%
Developed areas adjacent to Varuna	5% to 7.5%
Open areas adjacent to Varuna	7.5% to 10%
Near BHU	3% to 10%
Peripheral Areas	3% to 5%

* *Outliers to these growth rates exist and are a result of localized characteristics which in instances have a lower or higher growth rate than that for the defined ward characteristics*

3.4.3 Influence on Development Characteristics

A detailed, step-wise population distribution methodology has been described in the report on City Planning and Population Growth. As applied to Varanasi, the infrastructure is evidently one of the most important catalysts for growth and its presence, and the condition of the same, shapes the urban growth of the city.

The city of Varanasi is divided by the Varuna river, running west to east, through the city, into the cis-Varnua and the trans-Varuna regions. The cis-Varuna area is the older city area with spiritual and tourist attractions including the river ghats, the temples, and the old shopping by lanes of the city that attract the tourists. These attractions remain concentrated in the city core, surrounding which are the older residential neighbourhoods of the city. South of the city core is the Banaras Hindu University Campus that provides a relief to the expanding high-urban density of Varanasi, giving way to more rapidly growing areas of the city, in part due to the availability of open space, and to a large extent due to the connectivity to the central city by the road networks, as well as the links to the regional highway at the southern extent of the city.

Being predominantly a spiritually important tourist destination, the city core has remained an attractive area for businesses centred around tourist activities to continue to grow and prosper. Consequently, this area continues to see added development pressures, even in the face of the master-plan efforts to decongest these areas and encourage further growth away from the city core.

Directed by the Varuna on the north and the boundary formed by the highway connectivity on the south, the growth patterns in this part of Varanasi are expected to be an infill of available developable space, pushing further out to the west, along and beyond the railway colony development.

The development patterns evident from the satellite imagery clearly reflect the influence of the road networks across the urban landscape of Varanasi. As one follows the urbanization radiating outward from the highly congested city core, the growth across the Varnua river is funnelled through the limited connectivity cross the river. This growth extends outward following the traces of the roads leading to Sarnath (north) and Jaunpur (north-west). On the southern side of the city, the growth rapidly moves across the network of roads reaching south past the BHU campus, towards the highway. On the west, the growth extends out from the central parts of the city to the railway colony and other large clusters of development that have emerged outside of the current municipal extents. On the east side, the Ganga river forms the natural boundary, with bridges across to Ramnagar and Mughalsarai encouraging growth of these townships, positioning them as complementary development areas, should the road connections be enhanced.

3.4.4 Data Constraints and Limitations

It was noted that the municipal ward boundaries drawn on the maps provided had no clear landmarks or reference systems to accurately register them to the satellite imagery and other GIS-based data. For this reason, the ward boundaries tend to seem slightly askew of what would be expected as logical boundaries of the wards if drawn directly on the imagery itself. Revisions to these boundaries were made late in the project progress as a result of feedback provided by UPJN. These corrections helped revise the ward boundaries along the Varuna river and along the southern edge of the city to more appropriately document the reality.

The limited time on this project did not allow for detailed ground truthing and assessment of the actual development density across Varanasi. Consequently, the inputs of local agencies were essential in validating the existing conditions. Recent inputs helped understand the change in development trends across the southern part of the city. As a result of this, re-examination of the growth projections was undertaken and data recompiled with the inputs of UPJN.

Past studies and population projections available to the project team (from the Varanasi Master Plan, and from UPJN Varanasi Office) have been done using 1991 census data. In comparing and contrasting this information with the 2001 census data, direct comparisons are difficult due to differing spatial boundaries and municipal extents. The municipal boundaries for both time periods have not been easily available, however having obtained them, the spatial extents of most wards have been confirmed to be different as well as the number of wards and the overall spatial extent have increased in 2001 from that in 1991.

Table 3.6 Population Projection by Ward (Page 1 of 2)

ID	Ward Name	WardCh	POP 2001	PD2001	POP2003	PD2003	POP2015	PD2015	POP2030	PD2030
1	Lahar Tara	PROX	12,384	427	12,633	436	13,818	476	14,561	502
2	Indra Pur	Open/ Varuna	15,694	67	18,990	81	38,211	163	62,184	265
3	Chhittanpura	CORE	13,135	1,459	13,188	1,465	13,400	1,489	13,465	1,496
4	Narayan	Open/ Varuna	14,313	77	16,540	89	33,283	179	59,878	322
5	Tarna	Open/ Varuna	13,027	30	15,763	36	45,124	103	99,119	226
6	Nadeshwar	PERIP	12,877	165	14,197	182	24,538	315	37,670	483
7	Pahadiya	Devloped/ Varuna	20,506	128	22,608	141	39,076	244	59,988	375
8	Kamal Garha	CORE	15,874	529	15,938	531	16,194	540	16,272	542
9	Kaji Saidullapura	CORE	14,561	455	14,634	457	14,989	468	15,147	473
10	Jalalipura	PROX	14,608	239	15,050	247	17,993	295	20,429	335
11	Rasulpura	CORE	15,758	927	15,821	931	16,076	946	16,153	950
12	Nawapura	CORE	13,989	350	14,270	357	15,150	379	16,327	408
13	Saraiyan	PERIP	15,854	148	16,820	157	23,063	216	31,039	290
14	Alai Pura	PROX	12,823	164	13,604	174	18,291	234	20,766	266
15	Saray Surjan	PROX	13,669	144	16,539	174	35,855	377	51,165	539
16	Madan Pura	GHAT	11,945	1,991	11,969	1,995	12,113	2,019	12,241	2,040
17	Rajghat	PERIP	22,373	254	23,736	270	32,546	370	40,988	466
18	Katehar	CORE	12,678	1,585	12,729	1,591	12,934	1,617	12,996	1,625
19	Ghausabad	PERIP	15,708	126	17,318	139	31,101	249	47,745	382
20	Ramerpur	Open/ Varuna	16,228	49	18,753	57	44,667	135	90,182	272
21	Sikraul	Devloped/ Varuna	13,826	94	15,978	109	30,954	211	47,520	323
22	Dara Nagar	CORE	11,052	425	11,107	427	11,377	438	11,497	442
23	Taktakpur	Devloped/ Varuna	11,881	105	13,730	122	23,731	210	36,431	322
24	Senpura	CORE	7,193	654	7,222	657	7,338	667	7,373	670
25	Mavaiya	Open/ Varuna	13,169	27	15,218	32	36,247	75	94,509	196
26	Jaitpura	CORE	16,067	699	16,131	701	16,391	713	16,470	716
27	Sarnath	Open/ Varuna	12,049	16	13,924	18	33,164	43	86,472	113
28	Shivpurwa	PERIP	11,757	112	12,962	123	20,730	197	26,106	249
29	Baluabir	CORE	10,105	1,123	10,145	1,127	10,309	1,145	10,359	1,151
30	Salem Pura	CORE	14,312	550	14,369	553	14,601	562	14,671	564
31	Khojwan	PROX	10,684	227	11,335	241	17,123	364	23,731	505
32	Loco Hitpura	PERIP	11,847	146	13,061	161	20,888	258	26,306	325
33	Dhup Chandi	PROX	13,490	225	13,898	232	16,616	277	18,866	314
34	Jagat Ganj	PROX	15,920	300	16,401	309	19,610	370	21,772	411
35	Dashaswamedh	GHAT	9,441	858	9,460	860	9,574	870	9,675	880
36	Kamalpur	CORE	14,588	1,042	14,646	1,046	14,882	1,063	14,954	1,068
37	Bag Hada	GHAT	11,206	560	11,228	561	11,364	568	11,484	574
38	Sarsauli	Open/ Varuna	19,675	133	21,692	147	30,927	209	41,624	281
39	Shivala	GHAT	11,719	533	11,742	534	11,884	540	12,010	546
40	Piyari Kala	CORE	12,275	767	12,324	770	12,523	783	12,583	786
41	Ramapura	CORE	9,700	462	9,749	464	9,985	475	10,090	480
42	Raj Mandir	GHAT	10,749	1,792	10,771	1,795	10,900	1,817	11,015	1,836
43	Prahalad Ghat	GHAT	11,476	1,913	11,499	1,916	11,638	1,940	11,761	1,960
44	Garh Vasi Tola	GHAT	9,640	1,377	9,659	1,380	9,776	1,397	9,879	1,411
45	Kagi Pura	PROX	12,576	273	12,956	282	15,491	337	17,587	382
46	Beniya	CORE	12,781	492	12,832	494	13,039	501	13,102	504
47	Eshwar Gangi	CORE	8,177	303	8,341	309	8,856	328	8,949	331
48	Hadha	CORE	11,621	581	11,668	583	11,856	593	11,913	596
49	Madhyameshwar	CORE	9,433	472	9,471	474	9,623	481	9,670	483
50	Kameshwar Mahadev	GHAT	9,401	1,343	9,420	1,346	9,533	1,362	9,634	1,376
51	Raja Bazar	Devloped/ Varuna	9,273	98	10,716	113	18,522	195	28,434	299
52	Saptasagar	CORE	9,841	757	9,880	760	10,040	772	10,088	776
53	Braham Nal	GHAT	5,339	334	5,350	334	5,414	338	5,471	342
54	Gola Dina Nath	CORE	9,284	928	9,321	932	9,471	947	9,517	952
55	Pan Dareeba	CORE	8,269	413	8,310	416	8,512	426	8,602	430
56	Nariya	F / BHU	17,068	263	18,107	279	27,354	421	33,691	518
57	Pande Haweli	CORE	7,601	585	7,631	587	7,754	596	7,792	599
58	Lallupura Kalan	CORE	12,286	723	12,335	726	12,534	737	12,594	741
59	Basniyan	CORE	13,327	666	13,380	669	13,596	680	13,661	683
60	Lallupura Khurd	PROX	12,289	195	12,660	201	15,137	240	17,186	273
61	Hukul Ganj	Devloped/ Varuna	13,781	147	15,926	169	27,526	293	42,257	450
62	Lahang Pura	CORE	11,634	1,163	11,681	1,168	11,869	1,187	11,926	1,193
63	Laksa	CORE	12,788	388	13,045	395	13,712	416	13,857	420
64	Durga Kund	PROX	11,142	139	13,482	169	28,129	352	38,985	487
65	Tulsipur	PERIP	18,082	176	19,183	186	27,351	266	37,906	368
66	Til Bhandeshwar	CORE	13,397	1,489	13,451	1,495	13,667	1,519	13,733	1,526
67	Bangali Tola	GHAT	6,039	671	6,051	672	6,124	680	6,189	688

Table 3.6 Population Projection by Ward (Page 2 of 2)

ID	Ward Name	WardCh	POP 2001	PD2001	POP2003	PD2003	POP2015	PD2015	POP2030	PD2030
68	Sundarpur	F / BHU	14,414	262	15,292	278	23,100	420	28,452	517
69	Kaal Bhairav	CORE	8,281	460	8,322	462	8,524	474	8,614	479
70	Revadi Talab	CORE	9,187	707	9,224	710	9,372	721	9,418	724
71	Karaundi	F / BHU	13,862	87	16,773	105	45,392	284	64,774	405
72	Sigra	PROX	9,303	137	10,257	151	17,056	251	23,638	348
73	Shivpur	Devloped/ Varuna	13,076	108	15,111	125	26,118	216	40,096	331
74	Binayak	PROX	14,865	275	15,314	284	18,310	339	20,789	385
75	Bajardiha	PERIP	19,864	168	21,074	179	30,046	255	41,642	353
76	Sarai Gowardhan	CORE	7,319	523	7,348	525	7,467	533	7,503	536
77	Bhelupur	PROX	10,598	230	10,918	237	13,054	284	14,821	322
78	Katuapura	CORE	9,193	766	9,230	769	9,379	782	9,424	785
79	Nai Basti	Devloped/ Varuna	10,183	196	10,699	206	14,110	271	18,168	349
80	Om Kaleshwar	PROX	8,319	347	8,486	354	9,282	387	10,003	417
81	Jangamwadi	CORE	8,594	409	8,628	411	8,838	421	8,931	425
82	Pandeypura	Devloped/ Varuna	7,907	104	9,138	120	15,793	208	25,331	333
83	Chetganj	CORE	6,908	345	7,047	352	7,481	374	7,560	378
84	Khajuri	Devloped/ Varuna	12,316	99	14,233	114	24,600	197	39,456	316
85	Kamachha	PROX	10,386	142	10,806	148	13,704	188	15,792	216
86	Jolha	PROX	12,018	240	12,381	248	14,803	296	16,807	336
87	Pishach Mochan	CORE	8,297	638	8,330	641	8,464	651	8,505	654
88	Ghasyari Tola	PERIP	6,958	104	7,671	114	12,268	183	16,511	246
89	Bhadaini	GHAT	9,152	572	9,170	573	9,281	580	9,379	586
90	Nagwan	F / BHU	10,197	100	12,338	121	33,390	327	47,648	467
91	Sp. Charge NER	PERIP	4,474	84	5,170	98	11,641	220	19,219	363
	MUNICIPAL AREAS		**1,092,925**		**1,157,510**		**1,627,540**		**2,220,700**	
	Urban Area Addition		**92,800**		**101,419**		**171,740**		**239,861**	
	Cantonement		**17,246**		**20,400**		**24,935**		**30,391**	
	TOTALS		**1,202,971**		**1,279,328**		**1,824,215**		**2,490,952**	

CHAPTER 4

WATER SUPPLY SYSTEMS

CHAPTER 4 WATER SUPPLY SYSTEMS

4.1 MUNICIPAL WATER SUPPLY

Jal Sansthan is responsible for providing safe and potable drinking water. Municipal piped water supply dates back to 1892. In the early years, a water treatment plant was constructed at Bhelupur. Water was initially treated through slow sand filters. The slow sand filters were later replaced by rapid gravity filters to meet the demand from increasing population. Capacity was recently increased to 310 mld under a World Bank project.

Varanasi city is divided into 2 water supply districts namely cis-Varuna and trans-Varuna. These two districts are further divided into16 zones for the distribution of water. The zoning is shown in Figure 4.1.

The main source of raw water for the municipal piped water supply system is the Ganga river. Intake of water from the river in 2003 was about 123 mld (approximately 50% of the total water supplied). Water is lifted and pumped at Bhadaini raw water pumping station and taken to Bhelupur water works where it is treated.

The entire trans-Varuna area and some recently developed localities in cis-Varuna are supplied exclusively by ground water. In 2003, approximately 143 mld was extracted from 107 deep tube wells operated by Jal Sansthan.

In addition to tube wells operated by Jal Sansthan, there are many privately owned and institutional tube wells that provide approximately 67 mld. A total of 1,559 hand pumps provide an estimated 7 mld of water in places of water scarcity.

Table 4.1 Total Water Production: Varanasi City

Sl.	Item	Source (mld)	
		Ganga River	Tube wells
1	Municipal piped water supply*	123	143
2	BHU Campus (estimated by UPJN)		11.75
3	Cantonment		5
4	Railways		10
5	Private wells		40
6	Hand pumps		7
	Total 339.75 mld	123	216.75

* Production figures reported for 2003 by Jal Sansthan

BHU (Banaras Hindu University) has its own water supply network with about 15 tube wells, two used exclusively for the farms and the remaining for drinking water supply. Water production at BHU has been estimated at 23.5 mld based on an installed pumping capacity of 259,000 gallons per hour x 20 hours per day. BHU authorities estimate that approximately 50% of the water is used for gardening, farming and other horticultural purposes. Therefore about 11.75 mld is used by the BHU campus residents.

4.2 QUANTITY OF WATER SUPPLIED AND CONSUMED

The total quantity of water supplied to the present population (in 2003) is approximately 340 mld. Population served by water supply system is as follows:

Table 4.2 Average Per Capita Water Production: Varanasi City

Item	Water Production (mld)	Population 2003	Average Per Capita Production (lpcd)
Municipal & private systems (1)	323	1,174,408	275
Cantonment	5	17,500	290
BHU	11.75	22,500	511

(1) Population is municipal area population plus 5% net in-migration less BHU population as estimated by JICA Study Team.

Presently the average per capita water production (excluding Cantonment and BHU campus) is approximately 275 lpcd. Actual water consumption is impossible to determine since most services are un-metered. Assuming UFW of 30% (as estimated by Jal Sansthan), the actual consumption would be in the order of 212 lpcd.

As noted in a recent report “Report on State of the Environment for Varanasi, CPCB, 2000”, not all areas are served equally. The trans-Varuna area is facing an acute shortage of water because the distribution system is not well developed. Findings from the CPCB report indicate a supply of only 60 lpcd in the trans-Varuna, which would be insufficient to support water borne sewerage.

4.3 WATER SUPPLY PROBLEMS THAT AFFECT THE DEVELOPMENT OF SEWERAGE

1) Over pumping has reduced the yield of tube wells and the availability of water is no longer satisfactory. Water resources are limited and as the population continues to grow the per capita production is expected to decrease.
2) Water supply in trans-Varuna area is at present inadequate to meet demand and insufficient to support water borne sewerage. Considerable improvements in water supply infrastructure will be required before conventional sewerage can be implemented.
3) Municipal water supply is intermittent: 5:00 to 9:00 and 17:00 to 21:00. This creates a problem for maintaining self-cleansing velocities in sewers.
4) Raw water quality at the Bhadaini intake in Ganga river does not meet the required bacteriological and BOD standards for use as a potable water source.
5) The Nagwa/old Assi nala discharges sewage to the Ganga less than 1 km upstream of the water supply intake. The nala carries treated effluent from DLW STP and wastewater from the urban area along the nala. Bhagwanpur STP discharges treated effluent less than 1km upstream and many new sewage outfalls are growing in this area due to urban settlement with unplanned sewerage.

4.4 MASTER PLAN FOR IMPROVED WATER SUPPLY

In 2000, UP Jal Nigam proposed a plan to improve distribution and augment capacity of municipal water supply. The implementation of additional treatment capacity and strengthening of the distribution is essential to support the development of sewerage system. The plan is divided into two phases but timeframes are not provided because the projects have not been sanctioned and funding sources have not been secured. Costs identified in the pre-feasibility report are as follows:

Phase I Rs. 1,400 Lakh
Phase II Rs. 13,000 Lakh

Total Rs. 14,400 Lakh

Details of the improvement program are provided in Tables 4.3 and 4.4.

Table 4.3 Phase I – Proposed Works to Strengthen Present Water Supply System

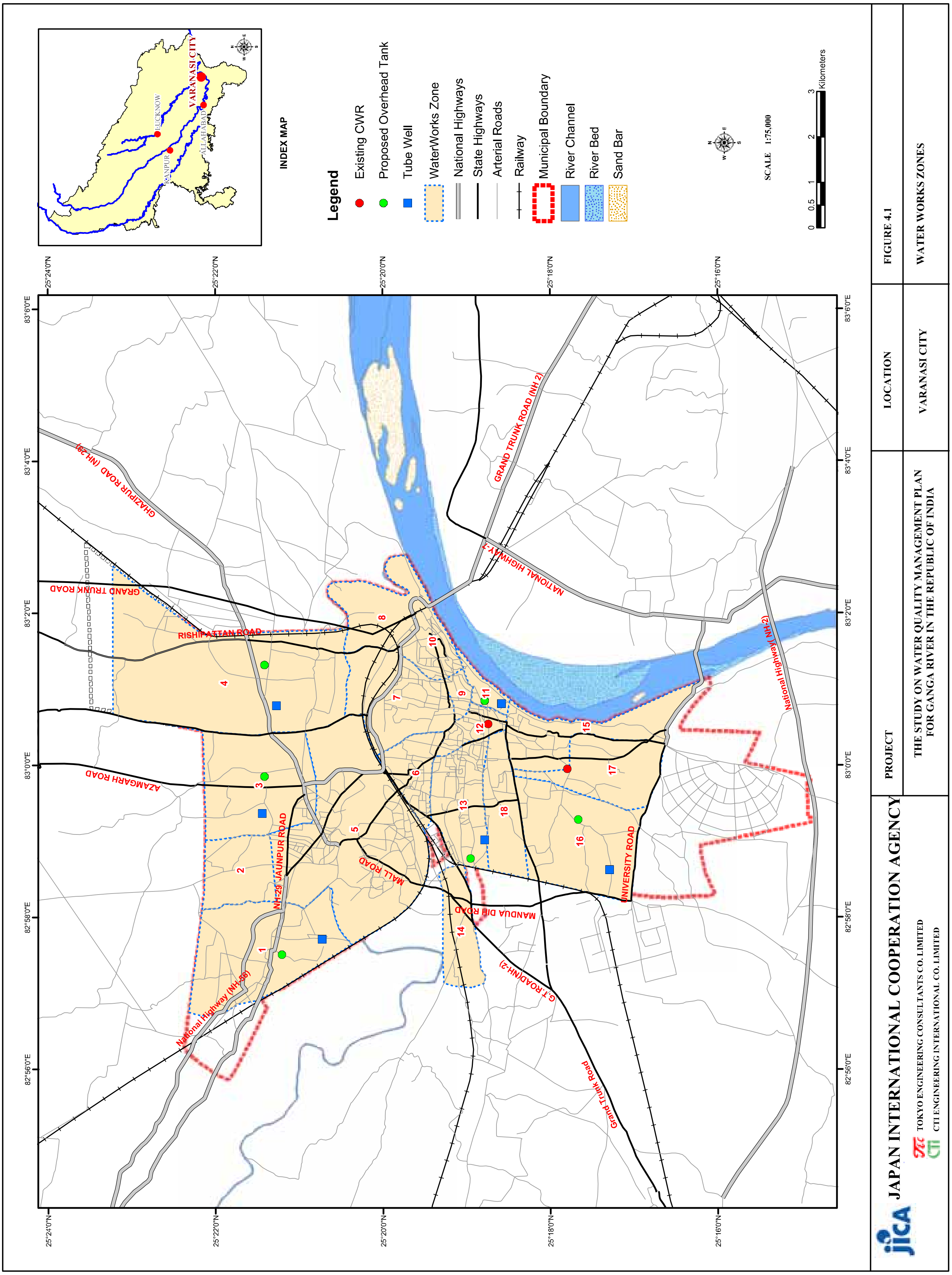
Sl.	Proposed works	Quantities	Estimated cost (Rs. Lakh)
1	Construction of second water works (near Garhwa Ghat) upstream of Nagwa Nala including 2 clear water reservoirs with capacity of 25,000 m^3 each	200 mld	8000
2	New 600mm dia. ductile iron feeder main to replace 40 year old 24" dia. steel pipe from Bhelupura Jal Sansthan to Benia clear water reservoir.	3.5 km	300
3	New 600mm dia. rising main from Benia clear water reservoir to densely populated areas in Chowk zone.	3.0 km	250
4	New reinforced concrete overhead storage tanks in following zones:	8,300 m^3	300
	Chowk zone	2,500 m^3	
	Lanka zone	1,500 m^3	
	Pandeypur zone	1,000 m^3	
	Sheopur zone	1,500 m^3	
	Paharia zone	1,500 m^3	
	Sigra zone	800 m^3	
5	New tube wells	6 no.	150
6.	Conversion of old slow sand filters of size 60m x 30m x 2m into clear water reservoirs to enhance storage capacity of Bhelupur water works by 36 mld	10 no.	200

The proposed 200 mld treatment plant is sized to meet water demand for 2035 in the following zones:

Distribution zone	Demand
1 Bhelupur	87
2 Lanka	22
3 Lahartara	29
4 Trans-Varuna	52
Total Raw Water Requirement	190 + 5% = 199.5

Table 4.4 Phase II – Proposed Works to Augment Capacity for Year 2035

Sl.	Proposed works	Quantities	Estimated cost (Rs. Lakh)
1	Strengthening of water supply system in 11 zones of CIS-Varuna and 6 zones of Trans-Varuna by laying new distribution system	305 km	3,200
2	Distribution system to sub-urban areas	170 km	
3	New reinforced concrete overhead storage tanks in following zones:	18,000 m^3	1,260
	- Lahartara zone	2,250 m^3	
	- UP College zone	2,250 m^3	
	- Civil Lines zone	2,250 m^3	
	- Sub-urban areas	5 x 2,250 m^3	
4	Re-organization and strengthening of intake works for existing water treatment works		540


INDEX MAP
LUCKNOW
KANPUR
ALLAHABAD
VARANASI CITY
Legend
Existing CWR
Proposed Overhead Tank
Tube Well
WaterWorks Zone
National Highways
State Highways
Arterial Roads
Railway
Municipal Boundary
River Channel
River Bed
Sand Bar
SCALE 1:75,000
0 0.5 1 2 3
Kilometers
GHAZIPUR ROAD (NH 29)
GRAND TRUNK ROAD
RISHIPATTAN ROAD
AZAMGARH ROAD
NH-29 JAUNPUR ROAD
MALL ROAD
MANDUA DIH ROAD
G.T.ROAD(NH-2)
National Highway (NH-56)
UNIVERSITY ROAD
GRAND TRUNK ROAD (NH 2)
NATIONAL HIGHWAY-7
National Highway (NH-2)
Grand Trunk Road
FIGURE 4.1
WATER WORKS ZONES
LOCATION
VARANASI CITY
PROJECT
THE STUDY ON WATER QUALITY MANAGEMENT PLAN FOR GANGA RIVER IN THE REPUBLIC OF INDIA
JAPAN INTERNATIONAL COOPERATION AGENCY
TOKYO ENGINEERING CONSULTANTS CO. LIMITED
CTI ENGINEERING INTERNATIONAL CO. LIMITED

CHAPTER 5

SEWERAGE PLANNING FRAMEWORK

CHAPTER 5 SEWERAGE PLANNING FRAMEWORK

This section identifies the criteria used for planning sewerage improvements as well as evaluating sewerage development strategies.

5.1 PLANNING HORIZON

The planning horizon for the sewerage master plan is 2030 with phased implementation of sewerage projects occurring in 5-year intervals. The first phase will consist of priority projects that should be completed within one to five years following the adoption of the Master Plan.

The capacity of civil works is sized for the projected requirements in the year 2030. The capacity of mechanical and electrical systems is planned for the year 2015 with provision for future expansion by adding or changing pumps in subsequent phases as flows increase.

Land requirements for sewage treatment works are based on the projected capacity required for the year 2030. In the first phase, treatment works would be implemented with capacity for the year 2015 and provision for future expansion to ultimate design capacity.

5.2 PLANNING CAPACITY

The timing for future sewerage infrastructure and the expansion of capacity depends on actual population growth and wastewater flows. “Planning capacity” refers to maintaining the infrastructure capacity above projected loadings. In general planning capacity serves three purposes:

1) It allows the system to remain effective over the period required to implement capital improvement projects (typically 2 to 5 years). Coupled with projected demands, planning capacity gives the city a mechanism to initiate master planning updates and staged improvements over the planning horizon. This allows the city to stay ahead of system needs.
2) Planning capacity can allow the system to accommodate unplanned growth over short time periods without unduly overtaxing the system, thereby allowing the city to plan or adjust infrastructure upgrade schedules to accommodate the growth.
3) Planning capacity is necessary to address flow variations. Wastewater flow can vary considerably from projected flows depending on actual population growth trends, connection rates and changes in per capita water consumption. Flows can also vary considerably over the short term. In Varanasi seasonal variations are associated with infiltration and inflow due to rainfall and groundwater during the monsoon season. The floating population (visitors, and workers) magnifies diurnal flow variation.

Planning capacity has been included by sizing main trunk facilities and treatment plants assuming 100% of the wastewater generated will be intercepted and conveyed via the sewer network.

Future capital improvements such as expansion of treatment plants or augmentation of capacity at pumping stations has been identified based on population growth projections. In reality changes should be triggered at 10% of the design capacity during the growth phase in each sewerage service district. As the district approaches the phase where it has maximized growth within its boundaries, and it’s population has stabilized (for example central district), wastewater needs will be driven primarily by maintenance of the existing system. During this phase 5% represents a reasonable target for triggering capital improvements.

5.3 LEVEL OF SERVICE

Reducing the pollutant loads to water resources and improving the living environment for residents of Varanasi are important issues that must be addressed by appropriate sanitation and sewerage interventions. These long-term goals can only be met if the existing sewerage infrastructure is fully utilized and extended to serve all densely populated urban areas.

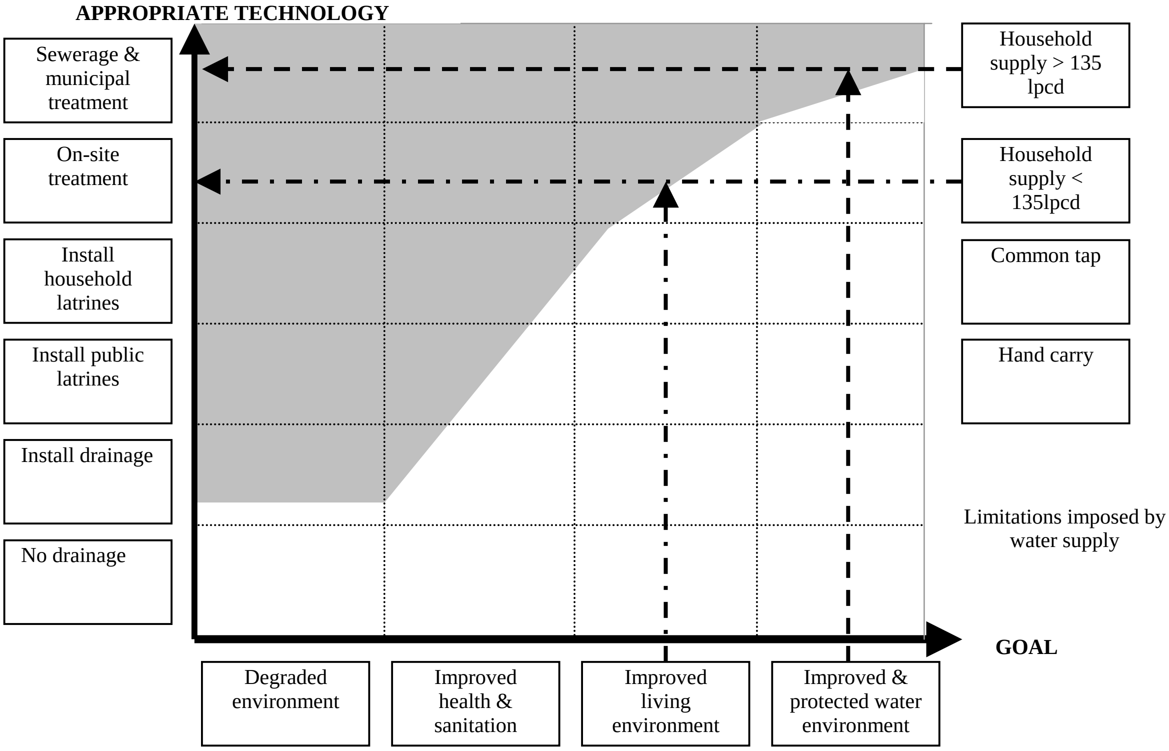


Figure 5.1 Goal and Level of Service Matrix

Sewerage is an appropriate method of meeting pollution control goals when two criteria are met:

1) As shown in Figure 5.1 the technology used to achieve a given goal depends on the level of water supply. The goal of protecting the water environment can only be met by providing conventional sewerage and only if water supply is sufficient to produce self-cleansing velocities. As prescribed by Indian Standard Code IS 1172 and National Building Code a minimum per capita water supply of 135 lpcd is required to sustain conventional sewerage.

2) Another limiting factor is population density. Current practice and experience in other developing countries indicates that conventional sewerage is seldom cost effective in urban areas where the population density is less than 120 persons per hectare.

Wherever these two criteria cannot be met, properly constructed on-site treatment systems should be used and upgraded over time as population density increases or to complement improvements in water supply services. The goals, levels of service and stepwise implementation approach proposed for each district/area are as follows:

Table 5.1 Step-wise Approach to Sewerage Development

Goal	Densely populated urban areas				Disadvantaged communities	Sparsely populated peripheral areas
	Central district	Sub-central district	Trans-Varuna district	Assi-BHU district		
Protecting water environment	Sewerage and off-site treatment	Sewerage and off-site treatment	Sewerage and off-site treatment	Sewerage and off-site treatment		
Improving living environment			On-site treatment			Provide on-site treatment
Improved health and sanitation					Low cost sanitation & drainage	
Present situation	60% sewered Pollution to Ganga River	30% sewered Pollution to Ganga and Varuna River	No sewerage + Water deficit Discharge to Varuna River	20% sewered	Inadequate sanitation	Degraded environment

5.4 SEWERAGE DEVELOPMENT STRATEGY

Development of sewerage will, wherever possible, be integrated with existing GAP infrastructure in order to reduce the overall investment cost.

1) Existing infrastructure should, where economically feasible, be rehabilitated before investing in new works. This approach will in most cases be more cost effective and result in more immediate benefits such as improved treatment levels.

2) Eventually sewerage should be provided in all urban areas where densities exceed 120 persons per hectare and water supply is sufficiently developed to support water borne sewerage (i.e. > 135 lpcd).

   - Households with water connections should be obligated to connect to sewer systems if they are located in areas that are already sewered.
   - Households that have adequate water supply connections but are located in areas where trunk sewers will likely not be provided for some time should be required to improve their sanitation by upgrading their existing cesspits or septic tanks. In later years they should be connected to the extended sewer network.
   - Households that do not have adequate water supply should, for the immediate future, be served by pour flush toilets with new cesspits or septic tanks. The choice between cesspits or septic tanks depends on whether enough land is available for the more efficient and cost effective septic tanks.

3) Peripheral areas where population densities are 120 persons per hectare or less should be provided with proper on-site sanitation systems. This intervention is also required to improve sanitary conditions and reduce the amount of pathogens in the environment. Systems for collecting and treating septage are required.

4) Development of new housing colonies in peripheral areas requires special measures to ensure they are in line with urban master plans, water supply and sewerage master plans. It may not be possible or cost effective to extend trunk sewers into these colonies until

several years later. It is proposed that in new developments, sewerage systems including small-scale treatment works should be built ahead of trunk sewer facilities with the cost borne by the developer in accordance with user-pay principal. As the overall sewerage master plan is implemented, the small-scale decentralized treatment facilities in various colonies can be shut down in a planned order once the trunk collector sewers and centralized treatment facilities are completed.

5) Institutional reform and capacity building will be required to ensure that operating authorities have the ability and equipment to properly manage and finance the operation and maintenance of sewerage schemes. Otherwise continued development will not be sustainable.

6) Whether planned or not, it is often the case that people will be living illegally on publicly owned land, land used by railroads, along nalas or similar areas. Although it is undesirable, people are living there, and usually they cannot easily be relocated. Most of these people are living in extremely bad sanitary conditions and their needs for improved sanitation cannot be ignored. It is difficult to move ahead with sewerage in these areas because people do not have land ownership rights or cannot afford such services. The same holds true in economically disadvantaged communities where people cannot afford the connection and service charges for sewerage. Therefore, realistic measures are required to ensure a proper level of sanitation is attained in these areas. Non-sewerage schemes and low cost sanitation improvements are discussed in a separate report.

7) The implementation and monitoring of on-site treatment facilities in urban centers must be formalized to make them more effective. Formalizing on-site treatment will require:

a. Setting standards for construction of pit latrines, septic tanks and soak away pits
b. Regulating construction through the issuance of permits and follow-up inspections
c. Regulating maintenance intervals of septic tanks and cesspits through mandatory collection
d. Providing equipment and facilities for collection and disposal of septage
e. Regulating municipal and/or private sludge collection services through licensing and manifest system to ensure proper disposal.

5.5 SEWER SERVICE AREAS AND POPULATIONS

5.5.1 General

Future population projections are an integral component of planning for future wastewater infrastructure. These projections have been developed by JICA Study Team with reference to 2001 census data and the city's land use master plan for 2030. Using computerized GIS tools the projected populations for each ward is allocated to each sewage district in proportion to the area falling within each district.

Proposed sewer service areas and non-service areas for 2030 are presented in Figure 5.2. The Sewerage Master Plan is developed for areas within the greater limits of the Municipal Corporation (as defined by the Development Authority) that have or will have population densities greater than 120 persons per hectare. Approximate population densities based on a visual interpretation of land use are derived from satellite images. Potential service areas lying outside the present municipal administrative boundary have been designated as future service areas (FSA). Areas that do not meet required densities within the planning horizon of 2030 are identified as non-sewerage areas (NSA). These areas have the potential of contributing significant wastewater loads to the Varuna and Ganga rivers and as such will require proper on-site sanitation and treatment systems to reduce the amount of wastewater discharged to surface drains. In the longer term beyond 2030, on site treatment systems in designated non-service areas can be converted to sewerage as population density increases.

5.5.2 Sewerage Districts

The city is presently divided into four sewerage districts located within current municipal corporation limits. Under the present sewerage master plan the existing districts are re-aggregated into 3 Districts to correspond roughly with natural drainage catchments. These Districts are described as follows:

- District 1 is the Central City Sewerage District draining to Dinapur STP. This area includes the old city, about 1km in breadth and 5km along the Ganga river from Assi to Raj Ghat. This area is covered by branch sewers connecting to the old trunk sewer and the Orderly Bazaar trunk sewer. Wastewater that does not enter the sewer system follows open drains that discharge to Ghat pumping stations along the Ganga river. Densities in this area are very high and this area urgently requires reinforcement of branch sewers and household connections.
- District 2: Zone 2A is the Sub-Central District on the cis-Varuna side west of the city centre and zone 2B is a slice of the trans-Varuna district along the Varuna river up to the ridge line defined by the Jaunpur road. Wastewater in these two zones will be collected at Chauka ghat MPS. Wastewater that does not enter the sewer system follows natural drainage patterns discharging to the Varuna river and Assi nala to the south. In this District, many new colonies have been developed but there is no sewerage system. In a few localities branch sewers were laid and have either been connected to the old trunk sewer or to open drains. Densities in this area are generally greater than 500 persons per hectare. Therefore this area should be sewered as soon as possible.
- District 2: Zone 2C is the trans-Varuna District north of the Jaunpur road. Wastewater in this area generally falls to the north and to the east. This area is experiencing rapid growth and projected populations indicate that densities will be much greater than 120 persons per hectare before 2015. Therefore this area should be sewered as soon as possible.
- District 3 is the BHU/Assi District south of the city. At present this area is mainly the Banares Hindu University campus which is fully sewered. The other areas around and near the campus up to the river bank are developing rapidly. Only one sewer was laid for Lanka area. There is development of residential colonies beyond Municipal Corporation limits leading to Ram nagar pontoon bridge and Bhagwan pur village behind the university campus. The area between DLW and University is already built up but there is no sewerage system. Wastewater discharged in this area follows natural drains flowing into Nagwa/old Assi nala and Nakkhi nala.

5.5.3 Future Service Areas

Future service areas outside the current Municipal Corporation limit are described as follows:

- FSA1 is north of the trans-Varuna District just outside the current Municipal Corporation limit. Wastewater generated in this area tends to flow north and east towards Sathwa. Population projections indicate that densities in this area will be greater than 120 person per hectare by the year 2015. Therefore this area is designated as a future service area.
- FSA2 is west of the current Municipal Corporation limit, and bounded by Northeastern railway. Wastewater in this area tends to flow north to the Varuna river near Lohta. Census data and visual interpretation of land use indicates that densities in this area will be greater than 120 persons per hectare before 2015. Therefore this area is designated as a future service area.
- FSA3 is west of FSA2 and bounded by the Northern railway line. Population projections indicate that densities in this area could reach 120 persons per hectare around 2020

- FSA4 is outside the current Municipal Corporation limit and surrounds the area occupied by BHU campus. Wastewater in this area drains to Assi nala and Nakkhi nala which discharge to Ganga river upstream of the water supply intake and Ghats. Projected populations indicate that densities will be greater than 120 persons per hectare after around 2015 therefore this area is designated as a future service area. Households in this area will require formal on-site sanitation/treatment systems to reduce pollutant loads between now and 2015. It is anticipated that the area between the existing city and the newly constructed GT Road by-pass will be developed within 5 to 10 years and a suitable arrangement for wastewater disposal will be required.

5.5.4 Non-Sewerage Areas

Non-serviced areas are identified as follows:

- NSA1 is within current Municipal Corporation limits to the east of the Trans-Varuna district. It includes the local community of Sarnath. Wastewater generated in this area drains naturally into Narokar nala which discharges to the Varuna river.
- NSA2 is within current Municipal Corporation limits to the extreme north west of the trans-Varuna District.

Projected populations in both these areas indicate that densities will remain below 120 persons per hectare for the planning horizon and therefore these areas are designated as a non-sewered area. Households in these areas will require formal on-site sanitation/treatment systems to reduce pollutant loads.

5.5.5 Populations: Sewer Service and Non-service Areas.

Populations used for calculating wastewater loads are summarized below for proposed sewerage districts.

Table 5.2 Populations in Sewer Service Areas

Sewer Service Area	2003	2015	2030
District 1	512,737	560,292	604,734
District 2	534,902	801,238	1,123,008
District 3	148,194	292,905	473,969
District 4	79,709	172,752	291,085
Total	1,275,542	1,827,187	2,492,796
NSA 1	43,140	93,166	215,724
NSA 2	23,691	57,083	114,567
Non-sewer Service Area Total	66,831	150,249	330,291
Grand Total	1,342,373	1,977,436	2,823,087
Cantonment	17,500	17,500	17,500

Includes floating population; NSA = non-sewered area

5.6 WATER CONSUMPTION PER CAPITA

The quantity of wastewater to be intercepted and treated will depend on the population and on the amount of water consumed.
The Manual on Water Supply and Treatment (Ministry of Urban Development, New Delhi, May 1999) recommends the following values for planning municipal water supply system for domestic and non-domestic purposes:

Table 5.3 Guideline Values for Future Per Capita Water Supply

Sl.	Classification of towns/cities	Recommended maximum net per capita water supply (lpcd)
1	Towns provided with piped water supply but without sewerage system	70
2	Cities provided with piped water supply where sewerage system is existing or contemplated	135
3	Metropolitan and mega cities provided with piped water supply where sewerage system is existing or contemplated	150

Figures exclude unaccounted for water (UFW), which should be limited to 15%
Figures include requirements for water for commercial, institutional and minor industries. However, the bulk supply to such establishments should be assessed separately with proper justification

The present estimated per capita consumption is 212 lpcd, which is higher than 150 lpcd proposed by Indian guidelines for planning water supply systems. The JICA Study Team recommends using the higher value for planning sewerage in order to provide a more realistic estimate of wastewater volumes for Phase I projects. However, in accordance with planning guidelines, these higher per capita rates are decreased gradually to 150 lpcd by 2030 to reflect the effects of limited water resources.

The following values for domestic water consumption are adopted in the Master Plan (including allowance for commercial, institutional and minor industries)

2003: 212 lpcd + 30% UFW allowance = 276
2015: 180 lpcd + 25% UFW allowance = 225
2030: 150 lpcd + 15% UFW allowance = 173

The allowance for UFW is gradually reduced to 15% to meet Indian planning guidelines. This assumes that some programs for reducing UFW will be implemented.

5.7 WASTEWATER RETURN FACTOR AND PER CAPITA CONTRIBUTION

Wastewater generated per capita is calculated using the proposed per capita water supply rates:

Table 5.4 Per capita Wastewater Generation Rates

Item	2003	2015	2030
Per capita water consumption (lpcd)	276	225	173
Return factor	0.70	0.75	0.80
Per capita wastewater discharge (lpcd)	193	169	138
+ Infiltration allowance 10%	212 (say 215)	185 (say 185)	152 (say 155)

The wastewater return factors are within the range of 0.7 and 0.8 in accordance with Manual on Sewerage and Sewage Treatment (Ministry of Urban Development, December 1993). Although per capita water supply rates will gradually decrease, it is expected that water distribution will be improved to serve a larger percentage of the population. In parallel with water supply improvements, sewerage coverage will be extended to more homes. Therefore it is expected that a higher percentage of the population will be able to use flush toilets. Therefore, the return factor is increased gradually from 0.7 to 0.8 to reflect improving water distribution services and sanitation levels.

The wastewater per capita generation adopted in the Master Plan are crosschecked against the total flow measured in drains across the city. Total flow measured in 2000 for areas within the Municipal Corporation limits (including cantonment) was about 232 mld (240 mld less about 8 mld discharged by DLW STP to Assi nala). Assuming the total wastewater flow has increased in proportion to population growth, it would give a total flow of about 251 mld in 2003 from an estimated 1,214,408 people and thus a per capita wastewater contribution of 207 lpcd. This is sufficiently close to calculated contribution to validate the assumed per capita wastewater contribution for 2003.

5.8 PREDICTED WASTEWATER QUANTITY

5.8.1 Total Wastewater Quantity

The population for each sewerage district, including future service areas and non-service areas is multiplied by per capita contribution to obtain estimated wastewater flow presented in Table 5.5.

Table 5.5 Projected Total Wastewater Production

(mld)

	2003	2015	2030
Wastewater discharge rate	**215 lpcd**	**185 lpcd**	**155 lpcd**
Sewer service area			
District 1	110.2	103.7	93.7
District 2	115.0	148.3	174.1
District 3	31.9	54.2	73.5
District 4	17.1	32.0	45.1
Sub-total	274.2	338.2	386.4

	2003	2015	2030
Wastewater discharge rate	**215 lpcd**	**185 lpcd**	**155 lpcd**
Non sewer areas			
NSA 1	9.3	17.2	33.4
NSA 2	5.1	10.6	17.8
Cantonment	3.8	3.2	2.7
Sub-total	18.2	31.0	53.9
Total	292.3	369.2	440.3

Detailed calculations showing sewage generated by ward and by sewerage district for the years 2003, 2015 and 2030 are presented in Table 5.6.

5.8.2 Sewer Connection Ratios

The number of households connected to sewers at present is very low. Present connection rates are estimated by comparing wastewater flows measured in nalas to the total wastewater generated by the population in the catchment area (see Table 5.7).

The Master Plan identifies a number of trunk sewer facilities and lateral sewers. However the full benefits of these facilities cannot be realized unless a program to improve coverage of branch sewers and household connections is carried in parallel. Future targets are proposed as a means of identifying the quantities of infrastructure and approximate budget requirements needed over the planning horizon.

The ultimate sewer connection ratio of 80% has been selected to meet water quality improvement goals. However, achieving such a target may not be realistic given the large number of projects that have to be implemented in such a short timeframe. Furthermore, it is not only a question of providing new infrastructure. There is also a huge backlog of maintenance and repairs to restore existing system.

Table 5.8 Existing and Proposed Sewer Connection Targets

Sewer Area	Stage I- Feasibility study target			Stage II
	2003	2010	2015	2030
District 1: Central District (core)	60%	65%	70%	80%
District 2: Sub-Central Zone A	30%	35%	40%	80%
District 2: Trans-Varuna Zones B	0%	0%	30%	50%
District 2: Trans-Varuna Zones C	0%	0%	0%	50%
District 2: FSA-1	0%	0%	0%	50%
District 3: Assi-BHU District	20%	40%	60%	80%
District 3: FSA-4	0%	0%	0%	50%
District 4: FSA-2	0%	0%	0%	50%
District 4: FSA-3	0%	0%	0%	50%

5.9 WASTEWATER STRENGTH

Wastewater composition differs from one situation to the other and is dependant on the level of sanitation, water usage, type of collection system, retention time in sewers and infiltration. Characteristics influence the choice of treatment method, extent of treatment and quantities of solids produced.

Average Bio-chemical Oxygen Demand (BOD) and Total Suspended Solids (TSS) are the two most important factors for sizing treatment plants in the Master Plan. JICA Study Team conducted a sampling programme to determine wastewater characteristics. Various contributing drains were identified for this purpose and the influent wastewater at Dinapur and Bhagwanpur STP were also measured.

Table 5.9 Summary of Measured Wastewater Characteristics

Parameter		Nalas				Sewer			
		Talia Bagh	Nagwa	Shivala	Narokhar	Central Jail	Konia Outfall	Dinapur STP	Bhagwanpur STP
BOD	mg/l	55	59	82	68	65	132	300	55
COD	mg/	86	189	176	144	128	304	480	104
TSS	mg/	40	170	66	156	132	360	428	56
pH		7.0	7.0	7.0	8.4	7.4	7.1	6.9	7.0
Temp.	^{0}C	30	29	29	28	28	28	28	28

Source: JICA Study Team monitoring Nov 4 to 6, 2003

Theoretical wastewater strength is calculated based on the amount of wastewater discharged per capita, BOD loading of 45 grams/person/day and SS loading of 90 grams/person/day.

Parameter	Unit	2003	2015	2030
Per capita wastewater	lpcd	215	185	155
BOD	mg/l	209	243	290
TSS	mg/l	419	486	580

These values compare favourably with those observed at Dinapur STP. However, the values measured at Bhagwanpur STP are much weaker. Dilute wastewater can be expected because of the very large amount of wastewater from tapped drains. BOD and TSS values during the earlier phases of the project will likely be weaker than those calculated above because a large portion of the flow will be from tapped drains. However, as sewerage coverage and household connection rates are improved the BOD and SS values will increase. Therefore, wastewater strength used for preliminary process calculations and sizing of treatment facilities should be based on a proportional blend using proposed connection ratios. The BOD strength recommended for design of future wastewater facilities has been calculated for each district and is presented in Table 5.10.

5.10 ENVIRONMENTAL QUALITY STANDARDS

The degree of treatment depends on the standards specified by the Central Pollution Control Board and adopted by the NRCD.

Table 5.11 Treated Effluent Quality Standards

Parameter	Unit	Discharged to water bodies	Discharged to land for agriculture
Total suspended solids	mg/l	50	100
BOD (5 days at 20deg C)	mg/l	30	50
COD	mg/l	250	-
Faecal coliforms**	MPN/100 ml	Desirable < 1000 Max < 10,000	< 10,000
pH value		5.5-9.0	5.5-9.0
Sulphides	mg/l (as S)	2.0	-
Total Chromium	mg/l (as Cr)	2.0	5.0

** NRCD Guidelines, August 2002

Irrespective of final mode of disposal, faecal coliform in treated effluent should not exceed 10,000 MPN/100ml. This will require that all treatment plants have some form of disinfection process or tertiary treatment process for reducing fecal coliform counts.

5.11 CHOICE OF TREATMENT TECHNOLOGY

5.11.1 Treatment Options

The performance of several treatment plants implemented under GAP and YAP has been reviewed by the Study Team with the objective of identifying which processes would be most suitable for future treatment facilities. Findings of the review are reported in Vol. III-11 Supporting Report. “Case Study on Sewage Treatment Plants under River Action Plan”.
A qualitative comparison of treatment processes is presented in Table 5.12.

The choice of a treatment technology is driven primarily by the availability of land, the ability of the process to meet required effluent criteria and total life cycle cost. If sufficient land can be provided, then the JICA Study Team recommends that Waste Stabilization Ponds be used since these will provide the most reliable treatment at the lowest annual operating cost.

Where land is limited, the following processes should be considered (in order of preference) with the addition of post treatment to reduce faecal coliform:

- Aerated Facultative Ponds (AL) <50 mld
- Up-flow Anaerobic Sludge Blanket (UASB) for flows > 50 mld
- Fluidized aerated Bio-reactor (FAB) for flows up to 70 mld

5.11.2 Post Treatment Options for UASB Technology

The Upflow Anaerobic Sludge Blanket (UASB) treatment process is in general unable to meet the required effluent criteria without the addition of post treatment processes. Typically UASB is suitable for treatment of very high BOD waste from industries as a form of pre-treatment before disposal to municipal wastewater treatment systems. Data from a number of UASB plants indicates that the effluent is highly anoxic because of dissolved gases. Thus the effluent exerts a very high immediate oxygen demand on receiving streams, i.e., same effect as a high BOD load. The BOD, sulphide and sulphate contents in UASB effluent generally exceed NRCD effluent standards for discharge to inland waters even with 1-day polishing ponds as post treatment.

The option of combining UASB with some form of aerobic post treatment has been suggested by the Steering Committee for the present Study. For obtaining better effluent quality the following post-treatment alternatives may be taken into consideration:

- Trickling filter
- Aerated lagoons

(1) Trickling Filter

In this option high rate trickling filters would be applied instead of an effluent polishing pond. The trickling filters are followed by final sedimentation tanks. Sludge from the sedimentation tanks is sent to drying beds. A trickling filter is a biological filter system, in which wastewater is continuously distributed over a bed of media. The wastewater organic and nitrogen components will give rise to bacterial growth as a biofilm onto the fixed media. The bacteria remove BOD, and if sufficiently low loading rates are applied the nitrification (conversion of ammonia to nitrate) will also occur.

Trickling filters may be expected to reduce the BOD and sulphide content of the wastewater appreciably, bringing these parameters well within the standards. They will, however, not be sufficient to bring faecal coliform counts within the desired standards. Nevertheless, they greatly improve effluent quality.

Assuming a raw wastewater BOD of 300 mg/l, the effluent from a typical 200 mld UASB can be expected to have a BOD of 105 mg/l, representing a loading rate of 21,000 kg/day. A total of 20 trickling filters 36.0 m in diameter would be necessary.

After the trickling filters, final sedimentation should be provided with a surface loading rate of 1 $m^3/m^2/hr$. Three sedimentation tanks with a diameter of 59.5 m would be required.

The total land requirement for 200 mld UASB is roughly 54 hectare. Substituting trickling filters for final polishing ponds would require 42 ha (54-16 for FPU +4 for TF). The investment cost for trickling filters is relatively high and so are the O&M requirements. Typical energy requirements would be in the range of 100 to 120 kW for pumping and 50 to 60 kW for ventilation.

The effluent quality would be much better than required by the standard. However Faecal Coliform levels remain higher than allowable:

TSS	20-30 mg/l
BOD	10-15 mg/l
Sulphides	0 mg/l
Faecal Coliform count	Aprox. 100,000 MPN/100ml

(2) Aerated Lagoons

In this alternative aerated lagoons would be applied instead of effluent polishing ponds. An aerated lagoon is a basin in which the wastewater is treated on a flow-through basis. Generally aeration is provided by floating aerator equipment. From the engineering aspect, they should be considered complete-mix reactors without recycle, having a residence time of minimum three days. After the aerated part, an area should be provided for sedimentation of the solids, which can be an unaerated end-part of the lagoon, or final sedimentation tanks, depending on the amount of solids to be settled.

Aerated lagoons require less surface than ponds because depth can be substantially larger (up to 4.0m), but since decay of faecal coliform is related more to HRT than to any other parameter, pond surface still would have to be fairly substantial unless chlorination is used for disinfection.

For a flow of 200 mld, the volume required to reduce BOD from 105 mg/l to 30 mg/l would require about a 1.5 day retention period. This is equivalent to 300,000 m^3, with a surface area of 320,000 m^2 assuming a 3.5 m depth in the aeration zone and 1.0m in the quiescent zone.
The total land requirement for 200 mld UASB including a 1 day FPU is roughly 54 hectare. Substituting aerated lagoons instead of final polishing ponds would require 70 hectare (54 – 16 for FPU + 32 for AL). Investment costs for aerated lagoons are in the order of Rs. 53 million.

The effluent quality can be estimated to be:

TSS	20-30 mg/l
BOD	5-10 mg/l
Sulphides	0 mg/l
Faecal Coliform count	Aprox. 10,000 to 100,000 MPN/100ml

Energy use would be in the range of 400 to 600 kW per hour, mainly determined by the energy used for the aerator equipment which varied depending on the season.

(3) Overall Comparison of Post Treatment Options:

Criteria	Post Treatment	
	Trickling filter	**Aerated lagoon**
Land	1	2
Investment cost	2	1
O&M	2	1
Effluent	2	1
Total	7	5

Most favorable=1

The ranking indicates that aerated lagoons provide the most cost effective post treatment of UASB effluent to enable it to meet the discharge criteria set by NRCD.

5.11.3 Unit Rates Applied in the Calculation of Treatment Costs

Land requirements and cost criteria used for comparison of options in Chapter 6 are as follows:

Table 5.13 Land Requirements and Cost per mld for Various Treatment Processes

(million Rs. /mld)

Treatment Process		Area Required (ha/mld)	Capital Cost			Annual O&M Cost
			Total	M/E	Civil	
Wastewater Stabilization Pond*	WSP	1.25	1.6	0.03 (2%)	1.57 (98%)	0.06
Aerated Lagoon + Chlorine Disinfection	AL1	0.35	2.5	0.50 (20%)	2.00 (80%)	0.30
Aerated Lagoon + Maturation Ponds	AL2	0.75	3.2	0.64 (20%)	2.56 (80%)	0.32
Activated Sludge + Chlorine Disinfection	AS1	0.20	2.7	1.08 (40%)	1.62 (60%)	0.36
Activated Sludge + Maturation Ponds	AS2	0.60	3.4	1.36 (40%)	2.04 (60%)	0.38
Fluidized Aerated Bed + Chlorine Disinfection	FAB	0.06	4.6	2.76 (60%)	1.84 (40%)	0.59
UASB with + Post Treatment (AL)	UASB++	0.35	3.0	1.05 (30%)	1.95 (70%)	0.13

Source: JICA Study Team "Evaluation of Sewage Treatment Plants" under GAP and YAP.
* WSP includes maturation ponds and cost of low lift pumps at head works
Capital costs exclude cost of land; O&M costs include energy costs and staffing costs.

WSP includes the use of maturation ponds to reduce faecal coliform counts. Other options assume disinfection using chlorine, which is inexpensive and generally very effective. Other alternative disinfection technologies are still being evaluated at pilot scale plants and have not yet been proven cost effective for large-scale applications.

5.12 SEWER DESIGN CRITERIA

Criteria used for the evaluation and preliminary sizing of trunk sewers, pumping stations criteria are in accordance with the Manual on Sewerage and Sewage Treatment (Ministry of Urban Development, December 1993) and current practice adopted in Detailed Project Reports.

<u>Sewers</u>

Peak factors:	Nalas	2.5
	Trunk sewers	2.5 for Population < 50,000
		2.25 for population 50,000 – 750,000
		2.00 for population > 750,000
Hydraulic design:		
Gravity pipes:	Manning's equation	$V= 1/n\ R^{2/3}\ S^{1/2}$,
	Roughness factor	n= 0.015 new/old pipe
		n= 0.017 old brick sewer
	Minimum velocity	0.60 m/s initial flow
		0.80 m/s ultimate flow
	Maximum velocity	3.00 m/s
	Maximum depth	d/D= 0.8 at ultimate peak flow
Pressure pipes:	Hazen William's formula	$V= 0.85\ C\ R^{0.63}\ S^{0.54}$
	Roughness factor	C= 100 new cast iron pipe
		C= 80 old cast iron pipe
		C= 110 PSC pipes
	Minimum velocity	0.8 m/s
	Maximum velocity	3.0 m/s

<u>Pumping stations:</u>

Peak factor:		2.0 for large stations
Sump detention time:	Vertical turbine pumps	5 minutes at ultimate peak flow
	Submersible pumps	3.75 minutes at ultimate peak flow
	Maximum	30 minutes at average flow
Minimum number of pumps		3 pumps each with capacity for ½ peak flow
		2 pumps each with capacity for the non-peak flow
At critical stations		50% standby capacity at peak hour,
		100% standby capacity at non-peak

Table 5.6.1 District wise Population and Wastewater Generation

(1) District wise Population

District	Zone	Area (ha)	2003			2015			2030		
			Resident	Floating	Total	Resident	Floating	Total	Resident	Floating	Total
District 1	Zone 1	1,022	478,378	34,359	512,737	515,837	44,455	560,292	548,248	56,486	604,734
District 2	Zone 2A	1,451	328,333	23,515	351,848	431,288	36,923	468,211	536,124	54,550	590,674
	Zone 2B	686	70,914	0	70,914	128,644	0	128,644	202,776	0	202,776
	Zone 2C	997	97,194	0	97,194	178,228	0	178,228	299,666	0	299,666
	FSA 1	149	14,946	0	14,946	26,156	0	26,156	29,892	0	29,892
	NSA 1 (Sarnath)	1,321	43,140	0	43,140	93,166	0	93,166	215,724	0	215,724
	Sub Total	4,604	554,527	23,515	578,042	857,481	36,923	894,404	1,284,182	54,550	1,338,732
District 3	Zone 3	1,382	111,638	0	111,638	214,570	0	214,570	291,188	0	291,188
	FSA 4	1,044	36,556	0	36,556	78,335	0	78,335	182,781	0	182,781
	Sub Total	2,426	148,194	0	148,194	292,905	0	292,905	473,969	0	473,969
District 4	FSA 2	761	60,292	0	60,292	114,601	0	114,601	155,561	0	155,561
	FSA 3	774	19,416	0	19,416	58,151	0	58,151	135,524	0	135,524
	Sub Total	1,535	79,708	0	79,708	172,752	0	172,752	291,085	0	291,085
-	NSA 2 (trans-Varuna)	471	23,691	0	23,691	57,083	0	57,083	114,567	0	114,567
Total		10,058	1,284,498	57,874	1,342,372	1,896,058	81,378	1,977,436	2,712,051	111,036	2,823,087

(2) District wise Wastewater Generation

District	Zone	2003			2015			2030		
		Resident	Floating	Total	Resident	Floating	Total	Resident	Floating	Total
District 1	Zone 1	102.9	7.4	110.2	95.4	8.2	103.7	85.0	8.8	93.7
District 2	Zone 2A	70.6	5.1	75.6	79.8	6.8	86.6	83.1	8.5	91.6
	Zone 2B	15.2	-	15.2	23.8	-	23.8	31.4	-	31.4
	Zone 2C	20.9	-	20.9	33.0	-	33.0	46.4	-	46.4
	FSA 1	3.2	-	3.2	4.8	-	4.8	4.6	-	4.6
	NSA 1 (Sarnath)	9.3	-	9.3	17.2	-	17.2	33.4	-	33.4
	Sub Total	119.2	5.1	124.3	158.6	6.8	165.5	199.0	8.5	207.5
District 3	Zone 3	24.0	-	24.0	39.7	-	39.7	45.1	-	45.1
	FSA 4	7.9	-	7.9	14.5	-	14.5	28.3	-	28.3
	Sub Total	31.9	-	31.9	54.2	-	54.2	73.5	-	73.5
District 4	FSA 2	13.0	-	13.0	21.2	-	21.2	24.1	-	24.1
	FSA 3	4.2	-	4.2	10.8	-	10.8	21.0	-	21.0
	Sub Total	17.1	-	17.1	32.0	-	32.0	45.1	-	45.1
-	NSA 2 (trans-Varuna)	5.1	-	5.1	10.6	-	10.6	17.8	-	17.8
Total		276.2	12.4	288.6	350.8	15.1	365.8	420.4	17.2	437.6

Table 5.6.2 Contributing Population by Sub-Catchment

District/ Zone	Sub Catchment	Resident									Floating			Total		
		Inside of Municipality			Outside of Municipality			Sub-Total								
		2003	2015	2030	2003	2015	2030	2003	2015	2030	2003	2015	2030	2003	2015	2030
District 1	1-01	3,556	4,136	4,601				3,556	4,136	4,601	255	356	474	3,811	4,492	5,075
	1-02	28,277	28,721	29,208				28,277	28,721	29,208	2,031	2,475	3,009	30,308	31,196	32,217
	1-03	35,423	36,324	36,922				35,423	36,324	36,922	2,544	3,130	3,804	37,967	39,454	40,726
	1-04	23,704	23,942	24,175				23,704	23,942	24,175	1,703	2,063	2,491	25,407	26,005	26,666
	1-05	33,835	34,341	34,675				33,835	34,341	34,675	2,430	2,960	3,573	36,265	37,301	38,248
	1-06	33,480	34,353	34,926				33,480	34,353	34,926	2,405	2,961	3,598	35,885	37,314	38,524
	1-07	18,506	18,879	19,103				18,506	18,879	19,103	1,329	1,627	1,968	19,835	20,506	21,071
	1-08	31,745	32,294	32,605				31,745	32,294	32,605	2,280	2,783	3,359	34,025	35,077	35,964
	1-09	43,254	45,774	47,639				43,254	45,774	47,639	3,107	3,945	4,908	46,361	49,719	52,547
	1-10	87,240	89,060	90,361				87,240	89,060	90,361	6,266	7,675	9,310	93,506	96,735	99,671
	1-11	18,117	21,389	24,095				18,117	21,389	24,095	1,301	1,843	2,483	19,418	23,232	26,578
	1-12	45,622	56,605	65,837				45,622	56,605	65,837	3,277	4,878	6,783	48,899	61,483	72,620
	1-13	36,473	49,669	62,497				36,473	49,669	62,497	2,620	4,281	6,439	39,093	53,950	68,936
	1-14	13,792	14,861	15,866				13,792	14,861	15,866	991	1,281	1,635	14,783	16,142	17,501
	1-15	15,036	15,117	15,265				15,036	15,117	15,265	1,080	1,303	1,573	16,116	16,420	16,838
	1-16	1,217	1,224	1,237				1,217	1,224	1,237	87	105	127	1,304	1,329	1,364
	1-17	5,124	5,150	5,200				5,124	5,150	5,200	368	444	536	5,492	5,594	5,736
	1-18	2,846	2,862	2,889				2,846	2,862	2,889	204	247	298	3,050	3,109	3,187
	1-19	1,131	1,136	1,147				1,131	1,136	1,147	81	98	118	1,212	1,234	1,265
District 2 Zone 2A	2-01	3,322	4,780	5,918				3,322	4,780	5,918	239	412	610	3,561	5,192	6,528
	2-02	17,880	22,739	27,899				17,880	22,739	27,899	1,284	1,960	2,874	19,164	24,699	30,773
	2-03	27,645	34,799	41,988				27,645	34,799	41,988	1,986	2,999	4,326	29,631	37,798	46,314
	2-04	12,619	15,549	17,869				12,619	15,549	17,869	906	1,340	1,841	13,525	16,889	19,710
	2-05	5,014	7,161	9,166				5,014	7,161	9,166	360	617	944	5,374	7,778	10,110
	2-06	5,363	8,012	10,680				5,363	8,012	10,680	385	690	1,100	5,748	8,702	11,780
	2-07	15,043	21,482	29,743				15,043	21,482	29,743	1,081	1,851	3,064	16,124	23,333	32,807
	2-08	3,455	5,494	7,451				3,455	5,494	7,451	248	473	768	3,703	5,967	8,219
	2-09	7,941	10,702	13,584				7,941	10,702	13,584	570	922	1,400	8,511	11,624	14,984
	2-10	1,966	3,248	4,432				1,966	3,248	4,432	141	280	457	2,107	3,528	4,889
	2-11	4,269	6,829	8,606				4,269	6,829	8,606	307	589	887	4,576	7,418	9,493
	2-12	4,069	5,810	7,437				4,069	5,810	7,437	292	501	766	4,361	6,311	8,203
	2-13	917	1,472	1,917				917	1,472	1,917	66	127	198	983	1,599	2,115
	2-14	12,802	20,476	25,789				12,802	20,476	25,789	920	1,765	2,657	13,722	22,241	28,446
	2-15	7,170	8,910	10,291				7,170	8,910	10,291	515	768	1,060	7,685	9,678	11,351
	2-16	6,276	9,091	11,075				6,276	9,091	11,075	451	783	1,141	6,727	9,874	12,216
	2-17	15,316	17,356	18,878				15,316	17,356	18,878	1,100	1,496	1,945	16,416	18,852	20,823

Table 5.6.2 Contributing Population by Sub-Catchment

District/ Zone	Sub Catchment	Resident									Floating			Total		
		Inside of Municipality			Outside of Municipality			Sub-Total								
		2003	2015	2030	2003	2015	2030	2003	2015	2030	2003	2015	2030	2003	2015	2030
District 2 Zone 2A	2-18	3,363	4,021	4,566				3,363	4,021	4,566	242	347	470	3,605	4,368	5,036
	2-19	4,411	5,352	6,170				4,411	5,352	6,170	317	461	636	4,728	5,813	6,806
	2-20	15,586	24,702	36,016	956	2,869	6,694	16,542	27,571	42,710	1,120	2,129	3,711	17,662	29,700	46,421
	2-21	7,527	8,804	9,705				7,527	8,804	9,705	541	759	1,000	8,068	9,563	10,705
	2-22	7,814	8,088	8,200				7,814	8,088	8,200	561	697	845	8,375	8,785	9,045
	2-23	15,418	16,911	17,828				15,418	16,911	17,828	1,107	1,457	1,837	16,525	18,368	19,665
	2-24	17,219	28,718	42,815				17,219	28,718	42,815	1,237	2,475	4,411	18,456	31,193	47,226
	2-25	66,401	69,825	71,905				66,401	69,825	71,905	4,769	6,018	7,408	71,170	75,843	79,313
	2-26	11,851	14,442	17,023				11,851	14,442	17,023	851	1,245	1,754	12,702	15,687	18,777
	2-27	6,787	12,137	18,923				6,787	12,137	18,923	487	1,046	1,950	7,274	13,183	20,873
	2-28	19,933	31,509	43,556				19,933	31,509	43,556	1,432	2,716	4,490	21,365	34,225	48,046
District 2 Zone 2B	2B-01	4,505	9,066	14,755				4,505	9,066	14,755				4,505	9,066	14,755
	2B-02	18,681	36,956	59,201				18,681	36,956	59,201				18,681	36,956	59,201
	2B-03	2,421	4,693	7,216				2,421	4,693	7,216				2,421	4,693	7,216
	2B-04	6,777	12,987	20,021				6,777	12,987	20,021				6,777	12,987	20,021
	2B-05	3,485	6,024	9,662				3,485	6,024	9,662				3,485	6,024	9,662
	2B-06	19,487	33,374	52,720				19,487	33,374	52,720				19,487	33,374	52,720
	2B-07	1,535	2,800	5,452				1,535	2,800	5,452				1,535	2,800	5,452
	2B-08	14,023	22,744	33,749				14,023	22,744	33,749				14,023	22,744	33,749
District 2 Zone 2C	2C-01	3,311	6,053	9,872				3,311	6,053	9,872				3,311	6,053	9,872
	2C-02	2,395	5,162	9,730				2,395	5,162	9,730				2,395	5,162	9,730
	2C-03	1,414	3,369	6,803				1,414	3,369	6,803				1,414	3,369	6,803
	2C-04	3,671	5,185	7,070				3,671	5,185	7,070				3,671	5,185	7,070
	2C-05	10,383	16,829	24,943				10,383	16,829	24,943				10,383	16,829	24,943
	2C-06	3,541	6,094	9,850				3,541	6,094	9,850				3,541	6,094	9,850
	2C-07	5,038	10,352	18,836				5,038	10,352	18,836				5,038	10,352	18,836
	2C-08	335	799	1,613				1,798	4,283	8,746				1,798	4,283	8,746
	2C-09	1,798	4,283	8,746				335	799	1,613				335	799	1,613
	2C-10	4,012	9,491	19,079				988	2,354	4,754				988	2,354	4,754
	2C-11	988	2,354	4,754				4,012	9,491	19,079				4,012	9,491	19,079
	2C-12	306	730	1,474				306	730	1,474				306	730	1,474
	2C-13	10,768	20,830	35,597				10,768	20,830	35,597				10,768	20,830	35,597
	2C-14	6,473	12,755	22,256				6,473	12,755	22,256				6,473	12,755	22,256
	2C-15	2,772	6,338	12,421				2,772	6,338	12,421				2,772	6,338	12,421
	2C-16	14,564	23,609	36,195				14,564	23,609	36,195				14,564	23,609	36,195
	2C-17	16,795	27,082	40,934				16,795	27,082	40,934				16,795	27,082	40,934
	2C-18	6,733	12,411	20,419				6,733	12,411	20,419				6,733	12,411	20,419
	2C-19	1,897	4,502	9,074				1,897	4,502	9,074				1,897	4,502	9,074

Table 5.6.2 Contributing Population by Sub-Catchment

District/ Zone	Sub Catchment	Resident									Floating			Total		
		Inside of Municipality			Outside of Municipality			Sub-Total								
		2003	2015	2030	2003	2015	2030	2003	2015	2030	2003	2015	2030	2003	2015	2030
District 2 FSA 1	2D-01				2,053	3,593	4,106	2,053	3,593	4,106				2,053	3,593	4,106
	2D-02				954	1,670	1,908	954	1,670	1,908				954	1,670	1,908
	2D-03				10,024	17,542	20,048	10,024	17,542	20,048				10,024	17,542	20,048
	2D-04				1,915	3,351	3,830	1,915	3,351	3,830				1,915	3,351	3,830
District 3 Zone 3	3-18	41,353	82,307	110,154				41,353	82,307	110,154				41,353	82,307	110,154
	3-01	4,079	10,405	14,758				4,079	10,405	14,758				4,079	10,405	14,758
	3-02	21,689	37,627	52,702				21,689	37,627	52,702				21,689	37,627	52,702
	3-03	7,860	12,025	15,408				7,860	12,025	15,408				7,860	12,025	15,408
	3-04	4,135	8,389	11,853				4,135	8,389	11,853				4,135	8,389	11,853
	3-05	2,225	4,592	6,374				2,225	4,592	6,374				2,225	4,592	6,374
	3-06	7,859	12,777	16,343				7,859	12,777	16,343				7,859	12,777	16,343
	3-07	1,598	3,625	5,001				1,598	3,625	5,001				1,598	3,625	5,001
	3-08	6,117	11,969	16,499				6,117	11,969	16,499				6,117	11,969	16,499
	3-09	4,992	8,183	10,480				4,992	8,183	10,480				4,992	8,183	10,480
	3-10	4,922	9,654	13,038				4,922	9,654	13,038				4,922	9,654	13,038
	3-11	1,960	5,305	7,572				1,960	5,305	7,572				1,960	5,305	7,572
	3-12	2,849	7,712	11,006				2,849	7,712	11,006				2,849	7,712	11,006
District 3 FSA 4	3-13				6,090	13,049	30,448	6,090	13,049	30,448				6,090	13,049	30,448
	3-14				4,443	9,520	22,213	4,443	9,520	22,213				4,443	9,520	22,213
	3-15				4,649	9,963	23,247	4,649	9,963	23,247				4,649	9,963	23,247
	3-16				11,261	24,130	56,303	11,261	24,130	56,303				11,261	24,130	56,303
	3-17				10,114	21,673	50,570	10,114	21,673	50,570				10,114	21,673	50,570
District 4 FSA 2	4-01	85	126	168	21,113	36,948	42,226	21,198	37,074	42,394				21,198	37,074	42,394
	4-02				2,289	4,953	8,366	2,289	4,953	8,366				2,289	4,953	8,366
	4-03				15,202	27,784	35,126	15,202	27,784	35,126				15,202	27,784	35,126
	4-04	5,093	11,467	18,933	16,510	33,323	50,742	21,603	44,790	69,675				21,603	44,790	69,675
District 4 FSA 3	4-05				4,219	12,559	29,141	4,219	12,559	29,141				4,219	12,559	29,141
	4-06				2,753	8,258	19,269	2,753	8,258	19,269				2,753	8,258	19,269
	4-07				2,528	7,583	17,694	2,528	7,583	17,694				2,528	7,583	17,694
	4-08				3,373	10,118	23,608	3,373	10,118	23,608				3,373	10,118	23,608
	4-09				32	96	224	32	96	224				32	96	224
	4-10				3,756	11,268	26,292	3,756	11,268	26,292				3,756	11,268	26,292
	4-11				2,682	8,047	18,776	2,682	8,047	18,776				2,682	8,047	18,776
	4-12				74	223	520	74	223	520				74	223	520
NSA 1 (Salnath)	5	43,140	93,166	215,724				43,140	93,166	215,724				43,140	93,166	215,724
NSA 2 (T-Vatuna)	6	23,691	57,083	114,567				23,691	57,083	114,567				23,691	57,083	114,567
	Total	1,157,510	1,627,540	2,220,700	126,989	268,518	491,350	1,284,499	1,896,058	2,712,050	57,874	81,378	111,036	1,342,373	1,977,436	2,823,086

Table 5.6.3 Wastewater Generation by Sub-Catchment

(mld)

District/ Zone	Sub Catchment	Resident									Floating			Total		
		Inside of Municipality			Outside of Municipality			Sub-Total								
		2003	2015	2030	2003	2015	2030	2003	2015	2030	2003	2015	2030	2003	2015	2030
District 1	1-01	0.76	0.77	0.71				0.76	0.77	0.71	0.05	0.07	0.07	0.81	0.84	0.78
	1-02	6.08	5.31	4.53				6.08	5.31	4.53	0.44	0.46	0.47	6.52	5.77	5.00
	1-03	7.62	6.72	5.72				7.62	6.72	5.72	0.55	0.58	0.59	8.17	7.30	6.31
	1-04	5.10	4.43	3.75				5.10	4.43	3.75	0.37	0.38	0.39	5.47	4.81	4.14
	1-05	7.27	6.35	5.37				7.27	6.35	5.37	0.52	0.55	0.55	7.79	6.90	5.92
	1-06	7.20	6.36	5.41				7.20	6.36	5.41	0.52	0.55	0.56	7.72	6.91	5.97
	1-07	3.98	3.49	2.96				3.98	3.49	2.96	0.29	0.30	0.31	4.27	3.79	3.27
	1-08	6.83	5.97	5.05				6.83	5.97	5.05	0.49	0.51	0.52	7.32	6.48	5.57
	1-09	9.30	8.47	7.38				9.30	8.47	7.38	0.67	0.73	0.76	9.97	9.20	8.14
	1-10	18.76	16.48	14.01				18.76	16.48	14.01	1.35	1.42	1.44	20.11	17.90	15.45
	1-11	3.90	3.96	3.73				3.90	3.96	3.73	0.28	0.34	0.38	4.18	4.30	4.11
	1-12	9.81	10.47	10.20				9.81	10.47	10.20	0.70	0.90	1.05	10.51	11.37	11.25
	1-13	7.84	9.19	9.69				7.84	9.19	9.69	0.56	0.79	1.00	8.40	9.98	10.69
	1-14	2.97	2.75	2.46				2.97	2.75	2.46	0.21	0.24	0.25	3.18	2.99	2.71
	1-15	3.23	2.80	2.37				3.23	2.80	2.37	0.23	0.24	0.24	3.46	3.04	2.61
	1-16	0.26	0.23	0.19				0.26	0.23	0.19	0.02	0.02	0.02	0.28	0.25	0.21
	1-17	1.10	0.95	0.81				1.10	0.95	0.81	0.08	0.08	0.08	1.18	1.03	0.89
	1-18	0.61	0.53	0.45				0.61	0.53	0.45	0.04	0.05	0.05	0.65	0.58	0.50
	1-19	0.24	0.21	0.18				0.24	0.21	0.18	0.02	0.02	0.02	0.26	0.23	0.20
District 2 Zone 2A	2-01	0.71	0.88	0.92				0.71	0.88	0.92	0.05	0.08	0.09	0.76	0.96	1.01
	2-02	3.84	4.21	4.32				3.84	4.21	4.32	0.28	0.36	0.45	4.12	4.57	4.77
	2-03	5.94	6.44	6.51				5.94	6.44	6.51	0.43	0.55	0.67	6.37	6.99	7.18
	2-04	2.71	2.88	2.77				2.71	2.88	2.77	0.19	0.25	0.29	2.90	3.13	3.06
	2-05	1.08	1.32	1.42				1.08	1.32	1.42	0.08	0.11	0.15	1.16	1.43	1.57
	2-06	1.15	1.48	1.66				1.15	1.48	1.66	0.08	0.13	0.17	1.23	1.61	1.83
	2-07	3.23	3.97	4.61				3.23	3.97	4.61	0.23	0.34	0.47	3.46	4.31	5.08
	2-08	0.74	1.02	1.15				0.74	1.02	1.15	0.05	0.09	0.12	0.79	1.11	1.27
	2-09	1.71	1.98	2.11				1.71	1.98	2.11	0.12	0.17	0.22	1.83	2.15	2.33
	2-10	0.42	0.60	0.69				0.42	0.60	0.69	0.03	0.05	0.07	0.45	0.65	0.76
	2-11	0.92	1.26	1.33				0.92	1.26	1.33	0.07	0.11	0.14	0.99	1.37	1.47
	2-12	0.87	1.07	1.15				0.87	1.07	1.15	0.06	0.09	0.12	0.93	1.16	1.27
	2-13	0.20	0.27	0.30				0.20	0.27	0.30	0.01	0.02	0.03	0.21	0.29	0.33
	2-14	2.75	3.79	4.00				2.75	3.79	4.00	0.20	0.33	0.41	2.95	4.12	4.41
	2-15	1.54	1.65	1.60				1.54	1.65	1.60	0.11	0.14	0.16	1.65	1.79	1.76
	2-16	1.35	1.68	1.72				1.35	1.68	1.72	0.10	0.14	0.18	1.45	1.82	1.90
	2-17	3.29	3.21	2.93				3.29	3.21	2.93	0.24	0.28	0.30	3.53	3.49	3.23

Table 5.6.3 Wastewater Generation by Sub-Catchment

(mld)

District/ Zone	Sub Catchment	Resident									Floating			Total		
		Inside of Municipality			Outside of Municipality			Sub-Total								
		2003	2015	2030	2003	2015	2030	2003	2015	2030	2003	2015	2030	2003	2015	2030
District 2 Zone 2A	2-18	0.72	0.74	0.71				0.72	0.74	0.71	0.05	0.06	0.07	0.77	0.80	0.78
	2-19	0.95	0.99	0.96				0.95	0.99	0.96	0.07	0.09	0.10	1.02	1.08	1.06
	2-20	3.35	4.57	5.58	0.21	0.53	1.04	3.56	5.10	6.62	0.24	0.39	0.58	3.80	5.49	7.20
	2-21	1.62	1.63	1.50				1.62	1.63	1.50	0.12	0.14	0.16	1.74	1.77	1.66
	2-22	1.68	1.50	1.27				1.68	1.50	1.27	0.12	0.13	0.13	1.80	1.63	1.40
	2-23	3.31	3.13	2.76				3.31	3.13	2.76	0.24	0.27	0.28	3.55	3.40	3.04
	2-24	3.70	5.31	6.64				3.70	5.31	6.64	0.27	0.46	0.68	3.97	5.77	7.32
	2-25	14.28	12.92	11.15				14.28	12.92	11.15	1.03	1.11	1.15	15.31	14.03	12.30
	2-26	2.55	2.67	2.64				2.55	2.67	2.64	0.18	0.23	0.27	2.73	2.90	2.91
	2-27	1.46	2.25	2.93				1.46	2.25	2.93	0.10	0.19	0.30	1.56	2.44	3.23
	2-28	4.29	5.83	6.75				4.29	5.83	6.75	0.31	0.50	0.70	4.60	6.33	7.45
District 2 Zone 2B	2B-01	0.97	1.68	2.29				0.97	1.68	2.29				0.97	1.68	2.29
	2B-02	4.02	6.84	9.18				4.02	6.84	9.18				4.02	6.84	9.18
	2B-03	0.52	0.87	1.12				0.52	0.87	1.12				0.52	0.87	1.12
	2B-04	1.46	2.40	3.10				1.46	2.40	3.10				1.46	2.40	3.10
	2B-05	0.75	1.11	1.50				0.75	1.11	1.50				0.75	1.11	1.50
	2B-06	4.19	6.17	8.17				4.19	6.17	8.17				4.19	6.17	8.17
	2B-07	0.33	0.52	0.85				0.33	0.52	0.85				0.33	0.52	0.85
	2B-08	3.01	4.21	5.23				3.01	4.21	5.23				3.01	4.21	5.23
District 2 Zone 2C	2C-01	0.71	1.12	1.53				0.71	1.12	1.53				0.71	1.12	1.53
	2C-02	0.51	0.95	1.51				0.51	0.95	1.51				0.51	0.95	1.51
	2C-03	0.30	0.62	1.05				0.30	0.62	1.05				0.30	0.62	1.05
	2C-04	0.79	0.96	1.10				0.79	0.96	1.10				0.79	0.96	1.10
	2C-05	2.23	3.11	3.87				2.23	3.11	3.87				2.23	3.11	3.87
	2C-06	0.76	1.13	1.53				0.76	1.13	1.53				0.76	1.13	1.53
	2C-07	1.08	1.92	2.92				1.08	1.92	2.92				1.08	1.92	2.92
	2C-08	0.07	0.15	0.25				0.07	0.15	0.25				0.07	0.15	0.25
	2C-09	0.39	0.79	1.36				0.39	0.79	1.36				0.39	0.79	1.36
	2C-10	0.86	1.76	2.96				0.86	1.76	2.96				0.86	1.76	2.96
	2C-11	0.21	0.44	0.74				0.21	0.44	0.74				0.21	0.44	0.74
	2C-12	0.07	0.14	0.23				0.07	0.14	0.23				0.07	0.14	0.23
	2C-13	2.32	3.85	5.52				2.32	3.85	5.52				2.32	3.85	5.52
	2C-14	1.39	2.36	3.45				1.39	2.36	3.45				1.39	2.36	3.45
	2C-15	0.60	1.17	1.93				0.60	1.17	1.93				0.60	1.17	1.93
	2C-16	3.13	4.37	5.61				3.13	4.37	5.61				3.13	4.37	5.61
	2C-17	3.61	5.01	6.34				3.61	5.01	6.34				3.61	5.01	6.34
	2C-18	1.45	2.30	3.16				1.45	2.30	3.16				1.45	2.30	3.16
	2C-19	0.41	0.83	1.41				0.41	0.83	1.41				0.41	0.83	1.41

Table 5.6.3 Wastewater Generation by Sub-Catchment

(mld)

District/ Zone	Sub Catchment	Resident									Floating			Total		
		Inside of Municipality			Outside of Municipality			Sub-Total								
		2003	2015	2030	2003	2015	2030	2003	2015	2030	2003	2015	2030	2003	2015	2030
District 2 FSA 1	2D-01				0.44	0.66	0.64	0.44	0.66	0.64				0.44	0.66	0.64
	2D-02				0.21	0.31	0.30	0.21	0.31	0.30				0.21	0.31	0.30
	2D-03				2.16	3.25	3.11	2.16	3.25	3.11				2.16	3.25	3.11
	2D-04				0.41	0.62	0.59	0.41	0.62	0.59				0.41	0.62	0.59
District 3 Zone 3	3-18	8.89	15.23	17.07				8.89	15.23	17.07				8.89	15.23	17.07
	3-01	0.88	1.92	2.29				0.88	1.92	2.29				0.88	1.92	2.29
	3-02	4.66	6.96	8.17				4.66	6.96	8.17				4.66	6.96	8.17
	3-03	1.69	2.22	2.39				1.69	2.22	2.39				1.69	2.22	2.39
	3-04	0.89	1.55	1.84				0.89	1.55	1.84				0.89	1.55	1.84
	3-05	0.48	0.85	0.99				0.48	0.85	0.99				0.48	0.85	0.99
	3-06	1.69	2.36	2.53				1.69	2.36	2.53				1.69	2.36	2.53
	3-07	0.34	0.67	0.78				0.34	0.67	0.78				0.34	0.67	0.78
	3-08	1.32	2.21	2.56				1.32	2.21	2.56				1.32	2.21	2.56
	3-09	1.07	1.51	1.62				1.07	1.51	1.62				1.07	1.51	1.62
	3-10	1.06	1.79	2.02				1.06	1.79	2.02				1.06	1.79	2.02
	3-11	0.42	0.98	1.17				0.42	0.98	1.17				0.42	0.98	1.17
	3-12	0.61	1.43	1.71				0.61	1.43	1.71				0.61	1.43	1.71
District 3 FSA 4	3-13				1.31	2.41	4.72	1.31	2.41	4.72				1.31	2.41	4.72
	3-14				0.96	1.76	3.44	0.96	1.76	3.44				0.96	1.76	3.44
	3-15				1.00	1.84	3.60	1.00	1.84	3.60				1.00	1.84	3.60
	3-16				2.42	4.46	8.73	2.42	4.46	8.73				2.42	4.46	8.73
	3-17				2.17	4.01	7.84	2.17	4.01	7.84				2.17	4.01	7.84
District 4 FSA 2	4-01	0.02	0.02	0.03	4.54	6.84	6.55	4.56	6.86	6.58				4.56	6.86	6.58
	4-02				0.49	0.92	1.30	0.49	0.92	1.30				0.49	0.92	1.30
	4-03				3.27	5.14	5.44	3.27	5.14	5.44				3.27	5.14	5.44
	4-04	1.09	2.12	2.93	3.55	6.16	7.86	4.64	8.28	10.79				4.64	8.28	10.79
District 4 FSA 3	4-05				0.91	2.32	4.52	0.91	2.32	4.52				0.91	2.32	4.52
	4-06				0.59	1.53	2.99	0.59	1.53	2.99				0.59	1.53	2.99
	4-07				0.54	1.40	2.74	0.54	1.40	2.74				0.54	1.40	2.74
	4-08				0.73	1.87	3.66	0.73	1.87	3.66				0.73	1.87	3.66
	4-09				0.01	0.02	0.03	0.01	0.02	0.03				0.01	0.02	0.03
	4-10				0.81	2.08	4.08	0.81	2.08	4.08				0.81	2.08	4.08
	4-11				0.58	1.49	2.91	0.58	1.49	2.91				0.58	1.49	2.91
	4-12				0.02	0.04	0.08	0.02	0.04	0.08				0.02	0.04	0.08
NSA 1 (Salnath)	5	9.28	17.24	33.44				9.28	17.24	33.44				9.28	17.24	33.44
NSA 2 (T-Vatuna)	6	5.09	10.56	17.76				5.09	10.56	17.76				5.09	10.56	17.76
	Total	248.84	301.09	344.26	27.33	49.66	76.17	276.17	350.75	420.43	12.45	15.04	17.21	288.62	365.79	437.64

Table 5.7 Flow of Nalas at Varanasi (in 2015 and 2030)

			Character of Catchment	Measured Flow (mld)	Sewered Rate (%)	Estimated Sewage (mld)	Estimated Gene. (mld)	GR of Population (2001-03)	Estimated Gene. (mld)	Sewered Rate (%)	Estimated Sewage (mld)	Estimated Nala Flow (mld)	GR of Population (2001-15)	Estimated Gene. (mld)	Sewered Rate (%)	Estimated Sewage (mld)	Estimated Nala Flow (mld)	GR of Population (2001-30)	Estimated Gene. (mld)	Sewered Rate (%)	Estimated Sewage (mld)	Estimated Nala Flow (mld)	Remarks
				in 2000				in 2003					in 2015					in 2030					
										Without improvement					Without improvement					Without improvement			
Ganga River	1	Nakkhi Drain	-	0.00																			Almost dry
	2	Samne Ghat Drain	-	0.00																			Almost dry
	3	Assi Nala	F/BTU	44.50	20.00	8.63	43.13	6.1	45.76	20.00	8.96	44.70	48.3	55.05	20.00	11.26	56.31	69.7	52.75	20.00	10.69	53.44	
	4	Shiwala Drain	Core	5.50	60	8.25	13.75	0.2	13.78	60	8.27	5.51	1.4	12.00	60	7.20	4.80	2.5	10.16	60	6.10	4.06	Intercepted and diverted to the city's sewer
	5	Harishchandra Ghat Drain	Core	2.50	60	3.75	6.25	0.2	6.26	60	3.76	2.50	1.4	5.45	60	3.27	2.18	2.5	4.62	60	2.77	1.85	Near Harishchandra Ghat SPS, Intercepted and diverted to the city's sewer
	6	Mansarovar Drain	Core	2.50	60	3.75	6.25	0.2	6.26	60	3.76	2.50	1.4	5.45	60	3.27	2.18	2.5	4.62	60	2.77	1.85	Near Mansarovar Ghat SPS, Intercepted and diverted to the city's sewer
	7	Dr. R. P. Ghat Nala (Ghora Nala)	Core	25.00	60	37.50	62.50	0.2	62.63	60	37.58	25.05	1.4	54.53	60	32.72	21.81	2.5	46.17	60	27.70	18.47	Near Dr.R.P. Gaht SPS, Intercepted and diverted to the city's sewer
	8	Jalesan Drain	Core	3.75	60	5.63	9.38	0.2	9.40	60	5.64	3.76	1.4	8.18	60	4.91	3.27	2.5	6.93	60	4.16	2.77	Near Jalesan Ghar SPS, Intercepted and diverted to the city's sewer
	9	Sankatha Ghat	Core	0.30	60	0.45	0.75	0.2	0.75	60	0.45	0.30	1.4	0.65	60	0.39	0.26	2.5	0.55	60	0.33	0.22	Intercepted and diverted to the city's sewer
	10	Trilochan Ghat Drain	Core	3.50	60	5.25	8.75	0.2	8.77	60	5.26	3.51	1.4	7.63	60	4.58	3.05	2.5	6.46	60	3.88	2.58	Intercepted and diverted to the city's sewer
	11	Telia Nala	Core	3.00	60	4.50	7.50	0.2	7.52	60	4.51	3.01	1.4	6.54	60	3.92	2.62	2.5	5.54	60	3.32	2.22	Near Trilochan Ghat SPS, Intercepted and diverted to the city's sewer
	12	Bhainsasur Nala	Core	0.40	60	0.60	1.00	0.2	1.00	60	0.60	0.40	1.4	0.87	60	0.52	0.35	2.5	0.74	60	0.44	0.30	
	13	Rajghat Railway Nala	Core	0.03	60	0.05	0.08	0.2	0.08	60	0.05	0.03	1.4	0.07	60	0.04	0.03	2.5	0.06	60	0.04	0.02	
	14	Rajghat Outfall	Core																				500m d/s of Malviya bridge Intercepted and diverted to the city's sewer
		sub total		90.98		78.36	159.34		162.21		78.84	91.27		156.42		72.08	96.86		138.60		62.20	87.78	
Varuna River (Right Bank)	1	Phulwaria Nala	Far	7.60	50	7.60	15.20	10.3	16.76	50	8.38	8.38	90.6	24.92	50	12.46	12.46	192.5	32.06	50	16.03	16.03	
	2	Sadar Bazar Nala	Far	2.00	30	0.86	2.86	10.3	3.15	30	0.94	2.21	90.6	4.69	30	1.41	3.28	192.5	6.03	30	1.81	4.22	
	3	Drain Of Hotels	Far	0.20	30	0.09	0.29	10.3	0.32	30	0.10	0.22	90.6	0.48	30	0.14	0.34	192.5	0.61	30	0.18	0.43	
	4	Raja Bazar Nala	Far	0.10	30	0.04	0.14	10.3	0.15	30	0.04	0.11	90.6	0.23	30	0.07	0.16	192.5	0.30	30	0.09	0.21	
	5	Teliabagh Nala	Far	18.00	30	7.71	25.71	10.3	28.35	30	8.50	19.85	90.6	42.15	30	12.64	29.51	192.5	54.22	30	16.27	37.95	
	6	Nala Near Nakhi Ghta	Prox	0.10	30	0.04	0.14	4.0	0.15	30	0.05	0.10	29.4	0.16	30	0.05	0.11	49.1	0.15	30	0.04	0.11	
Varuna River (Left Bank)	7	Central Jail Nala	Far	6.50	0	0.00	6.50	10.3	7.17	0	0.00	7.17	90.6	10.66	0	0.00	10.66	192.5	13.71	0	0.00	13.71	
	8	Orderly Bazar Nala	Far	7.00	0	0.00	7.00	10.3	7.72	0	0.00	7.72	90.6	11.48	0	0.00	11.48	192.5	14.76	0	0.00	14.76	
	9	Chamrautia Nala	Far	3.00	0	0.00	3.00	10.3	3.31	0	0.00	3.31	90.6	4.92	0	0.00	4.92	192.5	6.33	0	0.00	6.33	
	10	Nala Of Khajurl Colony	Far	1.50	0	0.00	1.50	10.3	1.65	0	0.00	1.65	90.6	2.46	0	0.00	2.46	192.5	3.16	0	0.00	3.16	
	11	Banaras Nala No.5	Far	1.00	0	0.00	1.00	10.3	1.10	0	0.00	1.10	90.6	1.64	0	0.00	1.64	192.5	2.11	0	0.00	2.11	
	12	Hukulgang Nala	Far	2.50	0	0.00	2.50	10.3	2.76	0	0.00	2.76	90.6	4.10	0	0.00	4.10	192.5	5.27	0	0.00	5.27	
	13	Nala Of Nai Basti	Far	3.00	0	0.00	3.00	10.3	3.31	0	0.00	3.31	90.6	4.92	0	0.00	4.92	192.5	6.33	0	0.00	6.33	
	14	Narokhar Nala	Far	7.50	0	0.00	7.50	10.3	8.27	0	0.00	8.27	90.6	12.30	0	0.00	12.30	192.5	15.82	0	0.00	15.82	
		sub total		60.00		16.34	76.34		84.17		18.01	66.16		125.11		26.77	98.34		160.86		34.42	126.44	
	Total			150.98		94.70	235.68		246.38		96.85	157.43		281.53		98.85	195.20		299.46		96.62	214.22	

Table 5.10 Calculated Future Wastewater Strength

		Condition	Ratio	BOD (mg)	
				Respective	Composite
District 1	2015	Sewered	70%	243	190
		Via Nalas	30%	66	
	2030	Sewered	80%	290	245
		Via Nalas	20%	66	
District 2	2015	Sewered	42%	243	140
		Via Nalas	58%	66	
	2030	Sewered	66%	290	215
		Via Nalas	34%	66	
District 3	2015	Sewered	38%	243	134
		Via Nalas	62%	66	
	2030	Sewered	69%	290	221
		Via Nalas	31%	66	
District 4	2015	Sewered	20%	243	101
		Via Nalas	80%	66	
	2030	Sewered	60%	290	200
		Via Nalas	40%	66	

Calculated Future Westawater Strength

		2003	2015	2030
Per capita wastewater	lcpd	215	185	155
Per capita BOD loading	g/d	45	45	45
BOD	mg/l	209	243	290

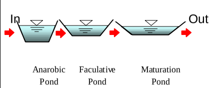
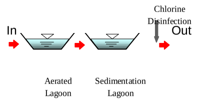
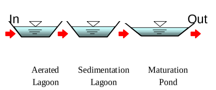
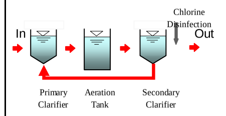
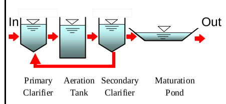
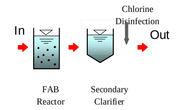
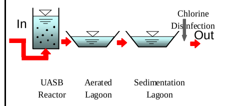
Measured Nala BOD Strength

Name of Nala	BOD(mg/l)
Talia Bagh Nala	55
Nagwa Nala	59
Shivara Nala	82
Narokhar Nala	68
Central Jail Nala	65
Average	66

District wise Overall Connecting Rate

	Year	Zone	Population	Connecting Rate	Pop. Connected	Overall Rate
District 1	2015		560,495	70%	392,347	70%
	2030		600,742	80%	480,594	80%
District 2	2015	Sub-Central	457,719	40%	183,088	
		Trans-Varuna1	116,123	30%	34,837	
		Trans-Varuna2	163,510	30%	49,053	
		FSA 1	26,156	30%	7,847	
		NSA	72,305	0%	0	
		From District 1	128,097	100%	128,097	
		Total	963,910		402,922	42%
	2030	Sub-Central	556,042	80%	444,834	
		Trans-Varuna1	178,132	60%	106,879	
		Trans-Varuna2	251,005	60%	150,603	
		FSA 1	29,892	60%	17,935	
		NSA	111,003	0%	0	
		From District 1	84,492	100%	84,492	
		Total	1,210,566		804,743	66%
District 3	2015	Assi/BHU	139,914	60%	83,948	
		FSA 4	78,335	0%	0	
		Total	218,249		83,948	38%
	2030	Assi/BHU	161,598	80%	129,278	
		FSA 4	182,781	60%	109,669	
		Total	344,379		238,947	69%
District 4	2015	FSA 2	108,826	30%	32,648	
		FSA 3	58,152	0%	0	
		Total	166,978		32,648	20%
	2030	FSA 2	143,192	60%	85,915	
		FSA 3	135,524	60%	81,314	
		Total	278,716		167,229	60%

Table 5.12 Qualitative Comparison of Treatment Process

		Treatment Method						
		WSP	AL	AL+	AS	AS+	FAB	UASB++
Process		Anarobic Pond +Faculative Pond +Maturation Pond	Aerated Lagoon +Sedimentation Lagoon +Chlorine Disinfection	Aerated Lagoon +Sedimentation Lagoon +Maturation Pond	Primary Clarifier +Aeration Tank +Secondary Clarifier +Chlorine Disinfection	Primary Clarifier +Aeration Tank +Secondary Clarifier +Maturation Pond	FAB reactor +Secondary Clarifier +Chlorine Disinfection	UASB reactor Aerated Lagoon +Sedimentation Lagoon +Chlorine Disinfection
Flow Sheet								
HRT (days)		14.0 Anarobic Pond(1d) +Faculative Pond(7d) +Maturation Pond(6d)	5.5 Aerated Lagoon(3.5d) +Sedimentation Lagoon(2d) +Chlorine Disinfection	9.5 Aerated Lagoon(3.5d) +Sedimentation Lagoon(2d) +Maturation Pond(4d)	0.5 Primary Clarifier(4hr) +Aeration Tank(4hr) +Secondary Clarifier(4hr) +Chlorine Disinfection	4.5 Primary Clarifier(4hr) +Aeration Tank(4hr) +Secondary Clarifier(4hr) +Maturation Pond(4d)	0.2 FAB reactor(2hr) +Secondary Clarifier(2hr) +Chlorine Disinfection	4.3 UASB reactor(8hr) Aerated Lagoon(2d) +Sedimentation Lagoon(2d) +Chlorine Disinfection
Land area (ha/mld)		1.25	0.35	0.75	0.2	0.6	0.06	0.35
Cost	Capital costs (Rs.10^6/mld)	1.6	2.5	3.2	2.7	3.4	4.6	3.5
	M&E cost (% of total)	0.02	0.2	0.2	0.4	0.4	0.6	0.35
	Annual O&M (Rs.10^6/mld)	0.06	0.2	0.22	0.36	0.38	0.59	0.4
Sludge handling		Manual desludging once in several years, then dry on beds.	Manual desludging once in several years, then dry on beds.	Manual desludging once in several years, then dry on beds.	Fitst thicken and digest, then dry on beds.	Fitst thicken and digest, then dry on beds.	Fitst thicken, then directly dry on beds.	Directly dry on beds.
Operational characteristics		Simplest	Simple	Simple	Skilled operation required	Skilled operation required	Skilled operation required	Simpler than activated sludge
Energy requirement (except initial pumping)		Negligible	Lower than activated sludge	Lower than activated sludge	Highest	Highest	Highest	Lelatively low
Performance stability		Affected by temperature and seasonal changes. Not susceptivle to power failure.	Less affected by temperature and seasonal changes than WSP. But affected by power failure.	Less affected by temperature and seasonal changes than WSP. But affected by power failure.	Not affected by wastewater characteristices and seasonal changes. But adversely affected by power failure.	Not affected by wastewater characteristices and seasonal changes. But adversely affected by power failure.	Not affected by wastewater characteristices and seasonal changes. But adversely affected by power failure.	Not affected by wastewater characteristices and seasonal changes. Not susceptivle to power failure.
Resorce recovery	Sludge	Less potential for application because the sludge is not be produced on continuous basis.	Less potential for application because the sludge is not be produced on continuous basis.	Less potential for application because the sludge is not be produced on continuous basis.	Substantial quantity of sludge is produced and have potential for application to manure or soil conditioner.	Substantial quantity of sludge is produced and have potential for application to manure or soil conditioner.	Substantial quantity of sludge is produced and have potential for application to manure or soil conditioner.	Substantial quantity of sludge is produced and have potential for application to manure or soil conditioner.
	Biogas	No biogas is produced.	No biogas is produced.	No biogas is produced.	Biogas is produced and have potential for generating electricity or selling them to consumers.	Biogas is produced and have potential for generating electricity or selling them to consumers.	No biogas is produced.	Biogas is produced and have potential for generating electricity or selling them to consumers.

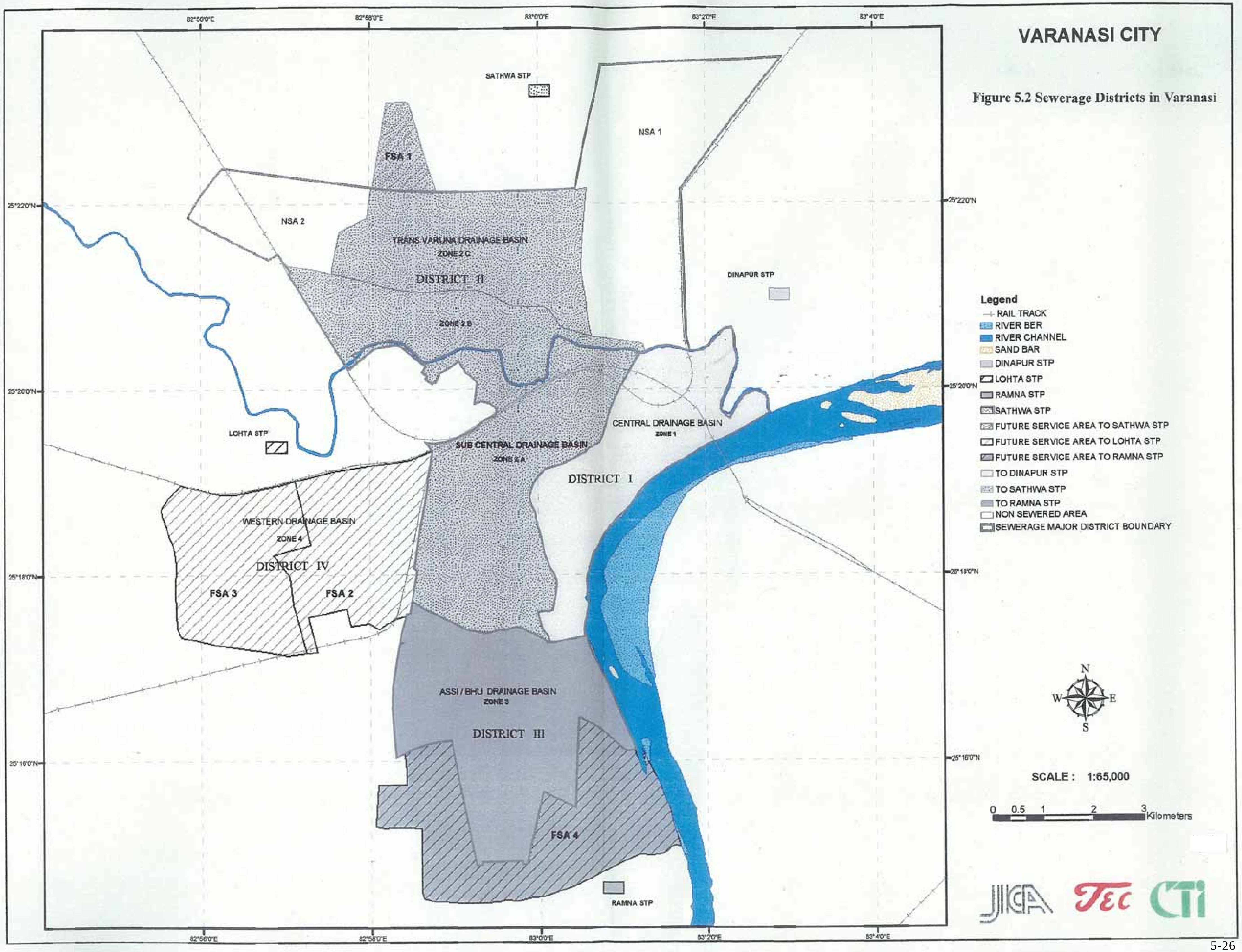


Figure 5.2 Sewerage Districts in Varanasi

CHAPTER 6

EVALUATION OF ALTERNATIVES

CHAPTER 6 EVALUATION OF ALTERNATIVES

6.1 SUMMARY

Projected wastewater flows far exceed present treatment plant capacities. Although the existing treatment plants can be expanded, the additional capacity is marginal. It will therefore be necessary to build new treatment plants. The treatment plants must be located where land is available and within reasonable proximity to the service area to minimize conveyance costs.

The options for laying out the future sewerage system are limited to a great extent by the location of treatment and collection facilities constructed under GAP-I or sanctioned under GAP-II. As discussed in Chapter 5, the city has been divided into 4 sewerage districts.

The following constraints/opportunities have been considered to formulate alternatives for configuring the collection network:

- The existing treatment plant at Dinapur can be augmented to a maximum of 100 mld
- Konia pump station has a firm pumping capacity of 90 mld
- The old trunk sewer has a maximum carrying capacity of 3,964 lps
- The STP proposed at Ramna has been sanctioned with a capacity of 37 mld and land acquisition of 50 ha for future expansion
- The interception of Assi/Nagwa nala and construction of a pump station to convey flows to Ramna has been sanctioned
- The relief sewer to Varuna river has been sanctioned and is presently under construction

A number of alternatives for each sewerage district have been evaluated in order to obtain the most appropriate system design. Each alternative has implications for the collection system, the sizing of pumping stations and capacity of new treatment works. Conceptual development of the sewerage system for each alternative is discussed and evaluated in the following sub-sections.

Schematic flow diagrams identifying proposed trunk sewers and treatment works are presented in Figures 6.1 and 6.2 for 2015 and 2030 respectively. Wastewater flow and population contributions are also indicated. Wastewater quantities used in the comparison of alternatives are based on these diagrams.

The key focus for evaluating the alternatives involves comparison of the estimated capital cost, and O&M costs to determine the least cost solution. Cost comparison tables for the alternatives are presented in this volume in Appendix A.
The following treatment processes are considered in the cost comparisons:

- AS: activated sludge
- AL: aerated lagoons
- FAB: fluidised aerated bio-reactor
- UASB++: up-flow anaerobic sludge blanket with aerated lagoons
- WSP: waste stabilization ponds

Except for WSP, the treatment process costs include chlorination of the effluent to reduce faecal coliform to acceptable limits. For WSP, faecal coliform reduction is achieved by large maturation and land requirements have been taken accordingly.

Land costs have been taken as 40 lakhs per ha (reported by UPJN Varanasi at Workshop on Feb 17 2004). Land area for each treatment process is taken from NRCD guidelines and a review by the JICA Study Team of existing STPs implemented under GAP and YAP. Similarly, capital costs and O&M costs are taken from the same review

Present value calculations are based on 5% interest rate and a 30 year life cycle with replacement of mechanical equipment after 15 years. Operation and maintenance costs (O&M) include energy costs.

6.2 DESCRIPTION OF ALTERNATIVES: DISTRICT 1

This is the central core of the City to the east along the Ganga river. The wastewater generated in the District is conveyed to Dinapur STP via the old trunk sewer and Konia pump station. The projected flow is larger than the 80 mld capacity of the treatment plant. Alternatives include augmenting the capacity at Dinapur STP and Konia MPS or diverting excess flows towards the sanctioned relief sewer for treatment at proposed Sathwa STP.

6.2.1 Influent Flow Projections

Three alternative flow scenarios are evaluated for Sewerage District 1.

Table 6.1 District 1: Flow Projections with and without Relief Sewer

(mld)

Item		2003	2015	2030
Present configuration				
	Average Flow at Konia MPS (no relief)	110.2	103.7	93.7
	Dinapur STP	80	80	80
	By-passed to Ganga	30.2	23.7	13.7
Alternative 1	Dinapur STP	100.0	100.0	100.0
	Diverted to relief sewer	10.2	3.7	0.0
Alternative 2	Dinapur STP	90.0	90.0	90.0
	Diverted to relief sewer	20.2	13.7	3.7
Alternative 3	Dinapur STP	80.0	80.0	80.0
	Diverted to relief sewer	30.2	23.7	13.7

6.2.2 Konia MPS

Details of the pumping station are provided in Chapter 7. The pump station has a firm capacity of 2,316 lps when 1 out of 3 pumps is out of service. The firm capacity of the pumping station is compared to the peak flows for the three alternative flow scenarios.

Table 6.2 Summary of Peak Flows at Konia MPS

Item	Average Flow (mld)	Peak flow (lps)	Present firm capacity (lps)	Future Firm Capacity (lps)
Alternative 1	100	2314	2,315	3,474
Alternative 2	90	2083		
Alternative 3	80	1851		

Note: peak flow = 2 x average flow

Alternative1 will require the addition of a 4th line of pumps at Konia MPS to improve standby capacity, reliability and to cope with peak hourly flows that could exceed the factor of 2 times average during wet weather. Space for future pumping units has been provided at the pumping station. In station piping has already been designed with provision for adding a 4th set of pumps therefore the capital costs are for providing and installing pump units and associated electrical supply and control panels. Alternatives 2 and 3 require no additional equipment.

Preliminary capital costs and O&M costs for Konia MPS for proposed Alternatives 1, 2, 3 developed and presented in Appendix A. Energy costs are calculated for all three options using actual pump characteristics and existing rising main conditions.

Table 6.3 Konia MPS: Preliminary Cost Comparisons for Capacity Alternatives

(Million Rs.)

Item	Alternative 1	Alternative 2	Alternative 3
Konia MPS Capacity (mld)	100.0	90.0	80.0
Capital Cost	31.7	-	-
O&M cost	14.5	11.3	9.3
Present Value	272.8	188.5	157.7

6.2.3 Dinapur STP

Details of the treatment plant are provided in Chapter 7. For alternatives 2 and 3 it is assumed that the existing activated sludge process will be expanded to achieve the additional capacity proposed under each alternative.

A preliminary evaluation of the process for each alternative loading condition is provided in Chapter 7. The assessment is based on original process design calculations and used to identify the modifications required at the treatment plant to enable the costing and comparison of alternatives. It is projected that the strength of sewage will gradually increase to 300 mg/l over the planning horizon on the basis of reduced per capita water supply. It is therefore recommended that calculations for augmentation be based on the higher future BOD strength. This assumption corresponds with the design criteria adopted for the existing treatment plant.

Modifications that are anticipated for each alternative flow are discussed below:

- All distribution chambers and plant piping have been designed with 20% excess capacity, i.e., 96 mld. Existing piping will need to be modified for the 100 mld Alternative 1.
- For each alternative, the weir-loading rate will be too high resulting in solids carry over. It may be possible to treat additional flows by adding a second weir to increase the total weir length.
- The hydraulic retention time for 90 mld and 100 mld are insufficient. Therefore 1 additional aeration tank will be required.
- For each alternative, the weir-loading rate will be too high resulting in solids carry over. Therefore the minimum weir length should be increased. Moreover, the hydraulic loading for 90 and 100 mld alternatives is reaching the upper limit of acceptable design criteria (30 m^3/m^2/day). Hence, one additional secondary clarifier will be required.
- In each case, it is proposed to modify the return sludge piping and pumping to allow wasting of sludge directly from the secondary clarifier to the digesters. This will help the operators in controlling the amount of sludge returned to primary to improve sludge settling characteristics and reduce sludge age to prevent anaerobic conditions.
- For the 90 and 100mld alternatives, the solids retention time is too low. Therefore one additional digester is required.

- For the 90 and 100mld alternatives, sludge production will exceed existing drying bed capacity by about 2000m^2 and 5000m^2, respectively. One option to providing additional drying beds might be to increase the depth of existing sludge drying beds.
- The present treatment process was not originally required to meet faecal coliform criteria and has consequently no provision for disinfection. Present discharge criteria will require reduction of faecal coliform to less than 10,000 MPN/ml. There is also no space for maturation ponds. Therefore the only feasible option will be gas chlorination.

A summary of preliminary costs is presented in Appendix A and summarized below.

Table 6.4 Dinapur STP: Preliminary Cost Comparisons (ASP)

(Million Rs.)

Item	Alternative 1	Alternative 2	Alternative 3
Dinapur STP Capacity (mld)	100.0	90.0	80.0
Augment Capacity (mld)	20.0	10.0	0.0
Capital Cost	54.0	27.0	-
O&M Cost	36.0	32.4	28.8
Present Value	654.3	568.3	482.3

A site plan showing the layout for 100 mld alternative is presented in Drawing C-10 in Appendix C.

6.2.4 Selection of Preferred Alternative For District 1

Alternatives for District 1 have an impact on wastewater flows in District 2. Therefore the selection of a preferred alternative must be carried considering the combination of alternatives for both districts.

6.3 DESCRIPTION OF ALTERNATIVES: DISTRICT 2

This is the Sub-central zone south of the Varuna river and the trans Varuna zone to the north. UPJN has already selected a site for a treatment plant at Sathwa. The treatment plant is intended to receive flows from the relief sewer serving the sub-central zone. Hydraulic capacities at Chauka ghat MPS and Sathwa STP will be influenced by the amount diverted to the relief sewer from District 1. The costs of the incremental flows for the three alternative flow scenarios must be compared to the cost of augmentation at Konia MPS and Dinapur STP to determine the optimum network configuration.

6.3.1 Influent Flow Projections

Projected flows at Sathwa are based on populations in sub-central, trans-Varuna districts and future service area FSA1. The amount of flows diverted to the relief sewer will depend on which alternative is selected for capacity upgrades at Konia MPS and Dinapur STP. The projected flows for each alternative are presented as follows:

Table 6.5 District 2: Flow Projections

(mld)

Item	2015			2030		
	Alt. 1	Alt. 2	Alt.3	Alt. 1	Alt. 2	Alt. 3
Amount diverted to relief sewer	3.7	13.7	23.7	0.0	3.7	13.7
Flow from Zone 2A	86.6	86.6	86.6	91.6	91.6	91.6
Flow from Zone 2B	23.8	23.8	23.8	31.4	31.4	31.4
Flow from NSA-1 (Sarnath)	17.2	17.2	17.2	33.4	33.4	33.4
Amount diverted from District 4 (temporary in 2015)	7.6	7.6	7.6	-	-	-
Sub-total flow at Chauka ghat MPS	138.9	148.9	158.9	156.4	160.1	170.1
Flow from FSA-1	4.8	4.8	4.8	4.6	4.6	4.6
Flow from Zone 2C	33.0	33.0	33.0	46.4	46.4	46.4
Total flow to Sathwa STP	176.7	186.7	196.7	207.4	211.1	221.1

Alt. 1= Dinapur STP 100mld Alt. 2=Dinapur STP 90 mld Alt. 3=Dinapur STP 80mld

The largest projected flow is 221 mld which would occur by the year 2030 if Dinapur remains at 80 mld. Additional capacity is added as a small planning margin and preliminary evaluation of various process costs is carried out for a 225 mld facility.

6.3.2 Sathwa STP: Selection of Treatment Process

UPJN has identified a 200 ha site near Sathwa where they plan to construct waste stabilization ponds. The system would include pre-treatment to remove grit and inorganic solids, followed by anaerobic ponds, facultative ponds and finally maturation ponds. Preliminary process calculations summarized in Table 6.6 indicate that the total land requirement would be about 281 ha (1.25 ha per mld).

The effluent would be discharged to unrestricted irrigation. Therefore faecal coliform levels should be reduced to at least 10,000 MPN or less.

The costs of WSP are compared to other process options in Table A1.3 in Appendix A to determine if other treatment processes, which require less land, might prove to be more cost effective.

Table 6.6 Sathwa STP: Preliminary Cost Comparison of Process Alternatives

(Million Rs.)

Item	WSP	AL	AS	UASB++
Capacity (mld)	225	225	225	225
Land area for treatment process (ha)	281	79	45	79
Land Cost	1,125	315	180	315
Capital Cost	360	563	608	675
Annual O&M	14	68	81	29
Life Cycle Cost (including land)	1,633	1,933	2,106	1,481

The comparison indicates that UASB++ offer the lowest present value cost followed closely by Waste Stabilization Ponds(WSP). WSP requires much land and initial capital costs including land acquisition are very high. Therefore the most cost-effective solution is UASB plus post treatment with aerated lagoons followed by chlorine disinfection.

6.3.3 Chauka ghat MPS

Preliminary capital costs for Chauka ghat MPS for proposed alternatives Alternative 1, 2, 3 are developed in Appendix A. O&M costs include energy costs, which are developed in Appendix A. The incremental flow for each alternative is relatively small. Therefore the economic size of rising main is the same (diameter 1600mm) in all options. Similarly, the outfall sewer to Sathwa STP remains the same for each alternative.

Table 6.7 Chauka ghat MPS: Preliminary Cost Comparison for Capacity Alternatives

(Million Rs.)

Item	Alternative 1	Alternative 2	Alternative 3
Chauka ghat PS Capacity (mld) 2030	150.1	160.1	170.1
Land Cost	4.0	4.0	4.0
Capital Cost	99.1	100.6	104.8
O&M Cost	16.0	16.3	17.4
Present Value	363.8	384.4	392.6

6.3.4 Selection of Preferred Alternative for District 1&2

The costs for Dinapur, Konia, Chauka ghat and Sathwa are combined for each alternative in Table A1 in Appendix A. The preferred alternative for District 1 and District 2 will be based on the combination that provides the lowest capital, O&M and life cycle costs.

Table 6.8 District 1 and District 2: Comprehensive Comparison of Alternatives

(Million Rs.)

Item	Alternative 1	Alternative 2	Alternative 3
Land Cost	291.0	305.0	319.0
Capital Cost Component	799.8	772.6	779.8
Annual O&M Cost Component	93.2	88.0	84.8
Life Cycle Cost	2,645.1	2,547.7	2,518.8

Alternative 3 provides the lowest O&M cost and the lowest life cycle cost. However the costs are relatively close. Therefore the decision on which alternative to adopt will depend on the following non-monetary factors: reliability of treatment process, ease of implementation, simplicity of operation, and potential for lowest operating costs. The expansion of Dinapur (Alt.1 and 2) is considered less favorable because the activated sludge process is more easily upset by lengthy power outrages that occur daily in Varanasi. It also takes a long time for the process to recover after it is upset which means that effluent quality will be poor and pollutant loads higher. The anaerobic process for UASB is more resilient to frequent power outrages, as is the post treatment by facultative aerated lagoons. Therefore Alternative 3 offers a better opportunity to reduce pollutant loadings and is selected for the Master Plan.

6.4 DESCRIPTION OF ALTERNATIVES: DISTRICT 3

This is the Assi nala catchment and areas south of the city to Ramna. UPJN has a sanctioned project to build a waste stabilization pond at Ramna. The treatment plant is intended to receive flows from Assi nala and domestic wastewater from Assi/BHU district. It is proposed to also convey flows from future service area FSA4 to Ramna. The district already has an 8 mld treatment plant at Bhagwan pur which was constructed under GAP-I. Alternatives range from augmenting the capacity at Bhagwan pur STP to a maximum of 15 mld or diverting all wastewater generated in District 3 to Ramna STP and decommissioning Bhagwan pur STP.

Three alternative flow scenarios are evaluated for Sewerage District 3:

Item	Descriptions
Alternative 4	Bhagwan pur STP augment to 15 mld
Alternative 5	Bhagwan pur STP maintain at 8 mld
Alternative 6	Bhagwan pur STP decommission

6.4.1 Influent Flow Projections

Projected flows are based on populations in Assi/BHU district and future service area FSA4 which will require sewerage at some stage between 2015 and 2030 when population density reaches a critical mass. The amount of flows diverted to Ramna STP will depend on which alternative is selected for Bhagwan pur STP.

Table 6.9 District 3: Flow Projections

(mld)

Item	2015			2030		
	Alt. 4	**Alt. 5**	**Alt. 6**	**Alt. 4**	**Alt. 5**	**Alt. 6**
Flow from District 3	39.7	39.7	39.7	45.1	45.1	45.1
Flow from DLW STP	8.0	8.0	8.0	0.0	0.0	0.0
Less amount treated at Bhagwan pur STP	-15.0	-8.0	0.0	-15.0	-8.0	0.0
Sub-total flow to Nagwa MPS	32.7	39.7	47.7	30.1	37.1	45.1
Flow from FSA-4	0.0	0.0	0.0	28.3	28.3	28.3
Total flow to Ramna STP	32.7	39.7	47.7	58.4	65.4	73.4

Alt. 4= Bhagwan pur STP 15 mld   Alt. 5=Bhagwan pur STP 8mld   Alt.6=Bhagwan pur STP 0 mld

The largest projected flow to Ramna STP is 73.4 mld which would occur by the year 2030 if Bhagwan pur is decommissioned. Additional capacity is added as a small planning margin and preliminary evaluation of various process costs is carried out for a 75 mld facility.

6.4.2 Bhagwan pur STP

Details of the treatment plant are provided in Chapter 7. For alternatives 2 and 3 it is assumed that the existing activated sludge process will be expanded to achieve the additional capacity proposed under each alternative.

A preliminary evaluation of the process for each alternative loading condition is provided in Chapter 7. The assessment is based on original process design calculations and used to identify the modifications required at the treatment plant to enable the costing and comparison of alternatives. It is projected that the strength of sewage will gradually increase to 300 mg/l over the planning horizon on the basis of reduced per capita water supply. It is therefore recommended that calculations for augmentation be based on the higher future BOD strength. This assumption corresponds with the design criteria adopted for the existing treatment plant.

Modifications that are anticipated for each alternative flow are discussed below:

- For the 15 mld alternative, one more preliminary treatment facility (i.e. inlet collection chamber, screen chamber, grid chamber) and flow measurement device should be installed because the influent wastewater quantity becomes double, which affects the removal efficiency for small particles and floating materials.
- The surface loading to the primary clarifiers remains within acceptable design criteria. However at 15 mld the weir loading rate will be too high resulting in solids overloading. Therefore, additional weir length will be required.
- Hydraulic retention time is insufficient. Hence one or two more aeration tanks will be required.
- Under present loading condition the hydraulic overflow rate for the secondary clarifier has reached the recommended upper limit. Therefore, one more clarifier should be installed.. At 15 mld the solid loading will exceed the recommended criteria even with one additional clarifier. Therefore two more clarifiers would be required.
- Even at 15 mld the solid retention time of the digester is too high. Therefore there is no need to add new digesters.

- At 15 mld the amount of digested sludge going to the sludge drying beds will exceed the existing drying bed capacity. This excess sludge cannot be absorbed by adjusting the height of beds. Therefore, several new sludge drying beds will be required.
- The flow scheme for return sludge of this STP involves bringing the secondary clarifier sludge back to the primary clarifier and excess sludge withdrawal from the later, which causes overloading on the primary clarifier and subsequent stages. Therefore the return sludge piping and pumping should be modified to allow excess sludge to convey directly from secondary clarifier to the digesters.
- The present treatment process was not originally required to meet faecal coliform criteria and has consequently no provision for disinfection. Present discharge criteria will require reduction of faecal coliform to less than 10,000 MPN/ml. There is also no space for maturation ponds. Therefore the only feasible option will be gas chlorination. The capital cost for chlorine disinfection has been included in all the alternatives.

A site plan for the augmented treatment plant is presented in the Drawing C-13 in Appendix C.
The preliminary cost implications for Bhagwan pur STP is presented in Appendix A and summarized as follows:

Table 6.10 Bhagwanpur STP: Preliminary Cost Comparison of Capacity Alternatives

(Million Rs.)

Item	Alternative 4	Alternative 5	Alternative 6
Capacity (mld)	15.0	8.0	0.0
Incremental (mld)	7.0	0.0	0.0
Land Cost	0.0	0.0	0.0
Capital Cost	18.9	0.0	140.6**
O&M Cost	5.4	2.9	-
Present Value	108.4	48.2	133.9

** includes the cost of a gravity sewer from the Bhagwan pur STP site to Ramna STP.

6.4.3 Nagwa Nala MPS

Preliminary capital costs for Nagwa nala MPS for proposed Alternatives 4, 5, 6 are developed in Appendix A. O&M costs include energy costs that are developed in Appendix A. The incremental flow for each alternative is relatively small. Therefore the economic size of rising main is the same in all options.

Table 6.11 Nagwa Nala MPS: Preliminary Cost Comparisons

(Million Rs.)

Item	Alternative 4	Alternative 5	Alternative 6
Capacity (mld)	30.1	37.1	45.1
Land Cost	2.0	2.0	2.0
Capital Cost	11.2	16.8	22.1
O&M Cost	3.9	4.8	5.8
Present Value	89.3	111.0	134.4

6.4.4 Selection of Preferred Alternative For District 3

The final selection of alternatives for District 3 will depend on the combination that provides the most attractive life cycle cost.

Table 6.12 District 3: Comprehensive Comparison of Alternatives

(Million Rs.)

Item	Alternative 4	Alternative 5	Alternative 6
Bhagwan pur STP Capacity (mld)	15.0	8.0	0.0
Land Costs	294.0	329.0	369.0
Capital Cost Component	135.9	135.6	296.2
Annual O&M Cost Component	12.8	11.6	10.2
Life Cycle Cost	619.5	631.6	798.5

Alternative 4 (Bhagwan pur STP: 15mld) provides the lowest capital cost and the lowest life cycle cost. Alternative 5 (Bhagwan pur STP: 8mld) provides the second lowest capital cost and the second lowest life cycle cost. Alternative 6 (decommission Bhagwan pur) has the lowest O&M cost but the investment cost is high because the cost of a new gravity sewer to Ramna has been included in the analysis even though this sewer would eventually be needed as a trunk sewer to convey sewage from newly developing areas around BHU.

In the long term (after 2015) Alternative 6 should be re-examined since the treatment plant will be at or near the end of its useful lifecycle and in need of major expenditure for upgrade.

The life-cycle costs for remaining Alternative 4 and 5 are relatively close. Therefore the decision on which alternative to adopt will depend on the following non-monetary factors: reliability of treatment process, ease of implementation, simplicity of operation, and potential for lowest operating costs. The expansion of Bhagwan pur is considered less favorable than adding capacity at Ramna because the activated sludge process is more easily upset by lengthy power outrages that occur daily in Varanasi. It also takes a long time for the process to recover after it is upset which means that effluent quality will be poor and pollutant loads higher. The facultative lagoons at Ramna are not dependant on power. Therefore the pollutant loadings will potentially be reduced. Therefore Alternative 6 is selected for the Master Plan.

The Master Plan recommends that the collection system (i.e. Nagwa MPS) and the treatment plant at Ramna be planned with sufficient capacity for the eventual longer term decommissioning of Bhagwan pur at the end of its useful life. This will provide system operators and planners with additional flexibility. Flows which are currently received at Bhagwan pur can be diverted via gravity sewers that will eventually be implemented in the district.

6.5 DESCRIPTION OF ALTERNATIVES: DISTRICT 4

To the west is the future service area of Lohta. Future service area FSA2 is already densely populated and at present discharges a significant pollutant load to Phulwaria nala with flow of 7.6 mld (reported by UPJN). Future service area FSA3 is at present sparsely populated and it is not economical to provide sewer reticulation. It is expected that population densities in FSA3 should reach above the 120 ppHa threshold after 2020.

Options for servicing this district include:

Option 1. Providing a separate STP for District 4; or
Option 2. Diverting all wastewater flows to the sanctioned relief sewer in sub-central district; or
Option 3. Diverting all wastewater flows to Ramna STP in District 3; or
Option 4. Tapping Phulwaria nala and diverting its dry weather flow to Sathwa STP until 2020.

6.5.1 Influent Flow Projections

Projected flows are based on populations in future service areas. The projected flows are presented as follows:

Table 6.13 District 4: Flows Projections

(mld)

Item	Year 2015	Year 2030
Flow from FSA 2	21.2	24.1
Flow from FSA 3	10.8	21.0
Total flow	32.0	45.1

6.5.2 Evaluation of Alternatives

Option 2 is rejected because the wastewater load generated by zone FSA2 is greater than the spare carrying capacity of the relief sewer. Option 3 is rejected because providing a new treatment plant in District 4 with trunk sewers following the direction of current growth will be less expensive than conveying sewage and treating it at Ramna.

It is anticipated that FSA3 will not require sewerage until after 2020. Therefore the construction of a treatment plant (option 1) would not be economically justifiable in the immediate phase. Therefore, the least cost solution for controlling pollution in the short term will be to divert wastewater flows from FSA2 to Sathwa STP. Sewerage in Lotha should be implemented as part of the second phase works after 2015. The tapping facility will by then have run through its lifecycle and can be decommissioned once trunk sewers and treatment works are implemented in district 4.

6.5.3 Lohta STP: Selection of Treatment Process

A potential 15 ha site has been identified by UPJN near Lohta village with discharge to Varuna river. Only activated sludge or FAB technology can provide a small enough footprint to fit the available site. The cost of these two options is compared along with other options.

Table 6.14 Lohta STP: Preliminary Cost Comparison of Process Alternatives

(Million Rs.)

Item	AS	FAB	AL	UASB++
Capacity (mld)	50	50	50	50
Land area for treatment process (ha)	10	3	18	18
Land Cost	40	12	70	70
Capital Cost	135	230	125	150
Annual O&M Cost	18	30	15	7
Life Cycle Cost	468	777	428	338

FAB technology has a much higher investment cost and nearly double the life cycle cost when considering O&M and land acquisition however it does have the advantage of producing stabilized sludge without the need for additional digesters and the process is much simpler to operate.

UASB++ provides the lowest life cycle cost and the lowest O&M cost. UASB++ should be implemented if sufficient land can be acquired and it is still considered cost effective at the time when it should be implemented. Effluent should be chlorinated before discharge to Varuna river.

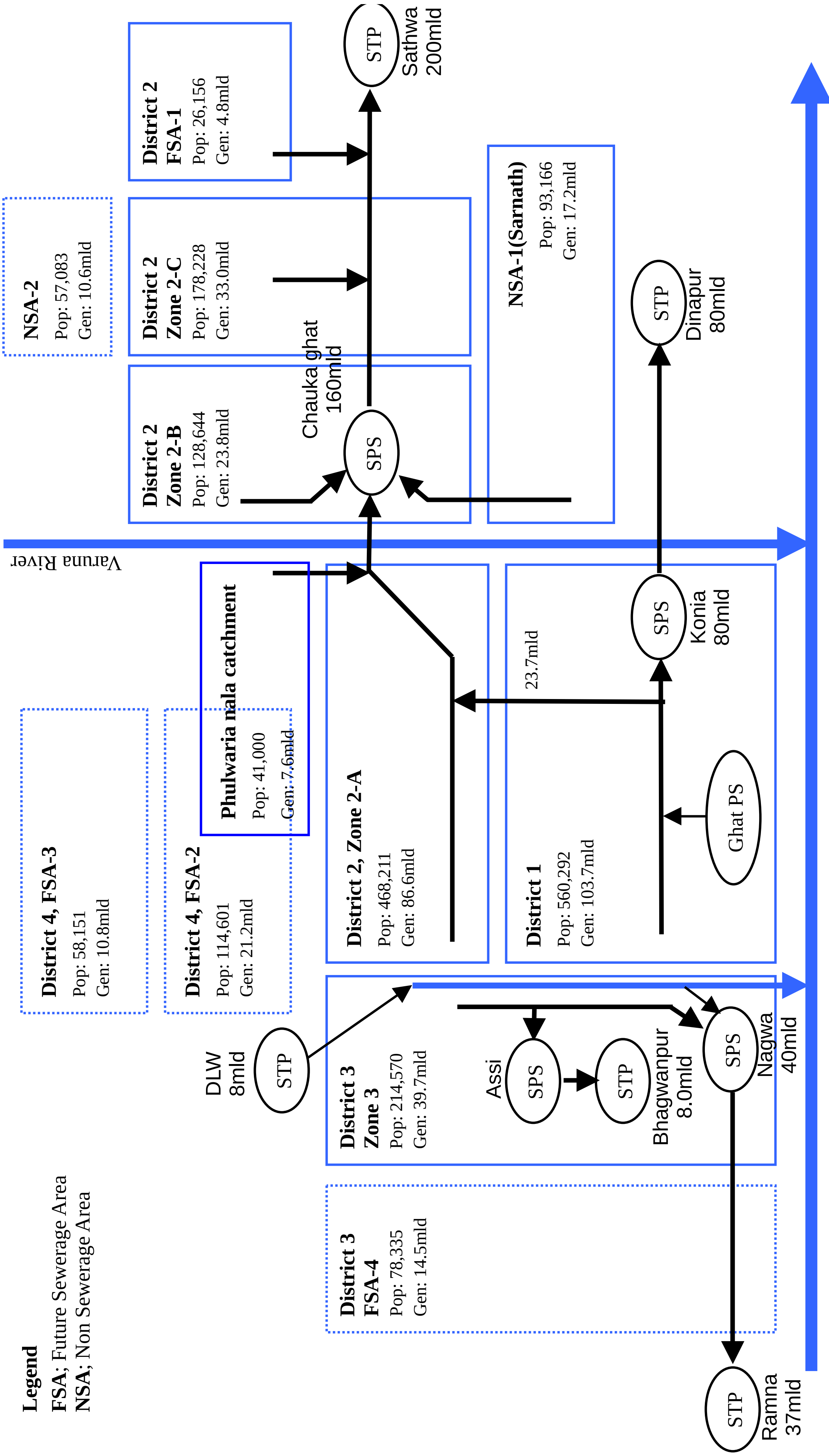


Fig 6.1 Schematic: District Wise Flow in 2015

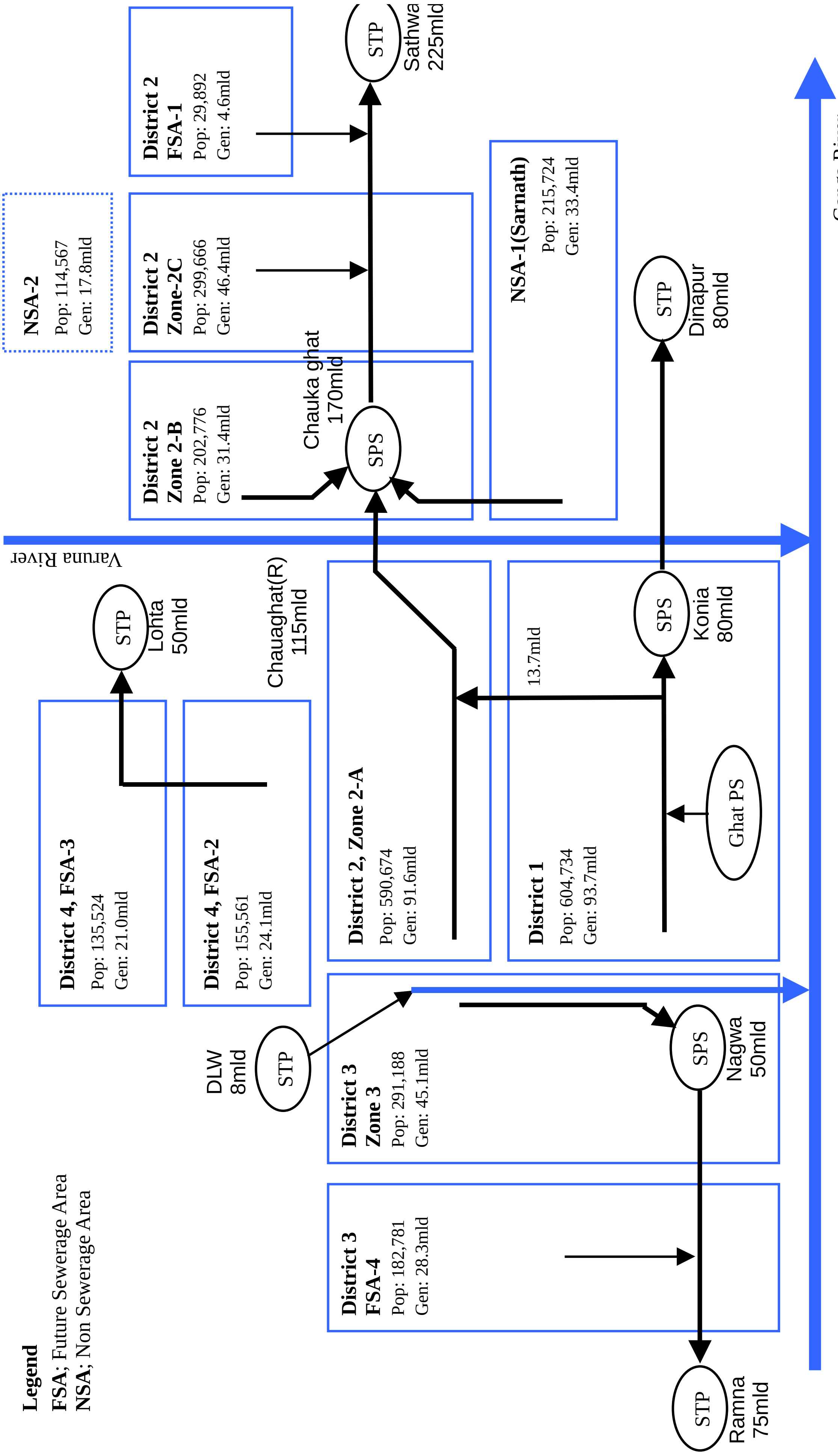


Fig 6.2 Schematic: District Wise Flow in 2030

CHAPTER 7

PROPOSED MASTER PLAN

CHAPTER 7 PROPOSED MASTER PLAN

7.1 SUMMARY

This chapter describes the collection and treatment components of the future sewerage system based on the sewerage districts identified in Chapter 5 and selection of preferred collection system configuration identified in Chapter 6. This Chapter also evaluates current capacity, identifies existing deficiencies and identifies the capacity of each component to handle projected wastewater flows over the planning period.

District wise delineation of the sewerage scheme is presented in Figure 7.1 for 2015 and Figure 7.2 for 2030. The overall sewerage scheme will consists of 4 separate Sewerage Districts each with its own treatment plant:

- District 1: City center conveying 80 mld of sewage through the existing outfall sewer to Konia MPS and existing activated sludge treatment plant at Dinapur.
- District 2: Sub central and trans-Varuna zone conveying approximately 200 mld to a UASB plant with post treatment at Sathwa. Wastewater is diverted away from the City District to relieve flows in the outfall sewer to Konia MPS
- District 3: South, Assi nala catchment, conveying 8 mld of sewage to Bhagwan pur STP and the balance of 50 mld to a sanctioned facultative waste stabilization pond at Ramna.
- District 4: Lotha District conveying 50 mld of sewage to a proposed UASB plant followed by aerated lagoons near Varuna river.

Populations, and wastewater volumes by sewerage district are presented in Planning Framework Chapter 5, Table 5.6. Sewage generation quantities have been computed considering tributary areas proposed under the Master Plan as shown on collection system drawings in Appendix C.

7.2 STORM WATER DRAINS

Locations of existing nalas/drains are shown in Figure 7.3. In ancient days Varanasi city was dotted with small ponds and inland lakes, interconnected with small streams and drains that discharged to Ganga or Varuna rivers. Over the times the ponds have disappeared and domestic sewer lines have been connected to all these open drains and as such they now carry significant sewage flow during dry weather. These drains are also a significant source of pollution during wet weather when cow dung and human wastes that accumulates during the dry season are flushed away by runoff.

Flow measurements, taken in 2000 are presented in Table 7.1 and these indicate a total wastewater flow of 240 mld. Out of the 26 nalas, 12 nalas were found to carry 180 mld of wastewater to Ganga River, while 14 nalas carry 60 mld of wastewater to Varuna river.

Under GAP-I, pump stations were implemented to divert 122mld of sewage to Dinapur and Bhagwan pur STPs. However, only 100 mld is received at the treatment plants, indicating that the collection system is not operating properly.

Nala-tapping arrangements are essential for intercepting wastewater during dry weather and reducing pollution loads. However they do not prevent pollution during wet weather. The present tapping arrangements are inadequate:

- They allow a substantial quantity of silt and debris into the sewer system which is detrimental to its life and proper functioning.
- They allow large quantities of storm water into the sewerage system which causes flooding and hydraulic overloads at treatment plants

Such nala tapping arrangements are considered as interim measures only and should be phased out gradually with the improvement in sewer coverage into all urban areas i.e. implementation of the

Master Plan. However, house connection targets for 2030 are at most 80%. Therefore there will always be some wastewater flow in the nalas. It is recommended that each tapping point be provided with screening and grit removal facilities to protect the collection system. Furthermore each tapping point should have a means of automatically regulating the inflow to the sewer system during wet weather.

7.3 GENERAL ASSESSMENT: TRUNK SEWERS

7.3.1 Description

The collection system in the old city centre dates back to the year 1917 and has remained largely unchanged except for components added during GAP-I. Primary collector sewers include two brick sewers: a main trunk sewer that starts from Assi nala and runs parallel to the bank of Ganga river to Rajghat and a second trunk sewer along Orderly Bazar road connected to the main trunk sewer at Kabir Chaura. The main trunk sewer originally discharged wastewater to the Ganga river but under GAP-I it was diverted to Konia MPS for conveyance to Dinapur STP.

Flow in the main trunk sewer is diverted to Konia by a gate located on the main trunk sewer about 250 m before the outfall. When closed it diverts the sewage flow to Konia main pumping station through a 90” (224 mm) diameter, 305m long connecting sewer. At Konia, wastewater receives preliminary treatment (screening and de-gritting) before being conveyed to Dinapur Sewage Treatment Plant. Flows in excess of Konia’s 100 mld capacity are diverted to an outfall sewer that discharges to the Ganga river at about 500 m downstream of Malviya Bridge. Flows in excess of Dinapur’s 80 mld capacity are discharged to the Varuna river after receiving preliminary treatment at Konia.

The upper end of the Orderly Bazar sewer begins on the trans-Varuna side but the portion crossing the Varuna river was destroyed when the old bridge collapsed in 1940. A new crossing was never re-constructed and as a result wastewater discharges untreated to the Varuna river. The Orderly Bazar sewer on the Cis-Varuna side was relined with GRP in 1994 under GAP-I but has not been inspected since.

Although the sewer system was originally designed as a separate system several surface drains have been diverted into it and consequently the sewerage system becomes overloaded during the rainy season.

7.3.2 Current Physical Deficiencies

A detailed survey of the trunk sewers was beyond the scope of the present Master Plan study. However the JICA Team did carry out a visual survey of the trunk sewers at random locations to get an appreciation for potential problems. The visual surveys were supplemented by discussions with Jal Sansthan and Jal Nigam. Current deficiencies include:

1) Poor maintenance: The majority of the branch sewerage system is at any time either completely blocked or its capacity is severely reduced by silt and solid waste. Sewer maintenance is restricted to emergency clearing of blockages and is given low priority.

2) Silting and surcharging: Visual surveys by UPJN and JICA Study Team indicates that upstream sections of the main trunk sewer are heavily silted. According to Jal Sansthan one reason for heavy silting is the discharge of rising mains from Ghat pumping stations that slows down the flow. Reduced capacity results in sewage overflows from manholes to surface drains during peak flow periods. Problems may also be caused by structural damage in some sections.
3) Ageing infrastructure: The existing trunk sewer system is over 75 years old and has been allowed to deteriorate to the point where rehabilitation is necessary. The Orderly

Bazaar trunk sewer was rehabilitated in 1994. The main trunk sewer and other trunk sewers have not been inspected.

4) Poor record keeping and inadequate information for planning: The limited availability of records relating to pumping stations and the sewerage system makes planning for extending services and assessing the amount of sewage presently flowing into the sewer system difficult. This also prevents effective maintenance and corrective actions.

5) Storm water and solid waste ingress to sewers: Damaged manhole,and sewer defects particularly around the nala and connections of nalas to the sewerage system have led to the increased risk of solid waste entering and blocking the system.

7.3.3 Current Capital Needs

Trunk sewers and branch sewers in the city need to be cleaned. Branch sewers that have been diverted to drains as a temporary relief from chronic blockage or surcharging should be re-instated and connected to the sewage collection system.

Drains that have been diverted directly into sewers must be rerouted to formal tapping points. These tapping points must be constructed with proper screening and grit removal facilities. Tapping points will also require some physical means of by-passing large storm water flows. The present solution of manual gates is inadequate and creates operational difficulties. JICA Study Team recommends the use of mechanical regulators at all tapping points to limit the discharge of storm water into the sewage collection system.

7.4 SEWERAGE DISTRICT 1: DINAPUR STP

7.4.1 General Description

District 1 is the central city sewerage district draining to Dinapur STP. This area includes the old city, about 1 km in breadth and 5km along the Ganga river from Assi to Rajghat. This area is covered by branch sewers connecting to the old trunk sewer and the Orderly Bazar trunk sewer. Wastewater that does not enter the sewer system follows open drains that discharge to Ghat pumping stations along the Ganga river. Densities in this area are very high and this area urgently requires reinforcement of branch sewers and household connections.

Projected flows based on populations are as follows:

- Year: 2015 Population: 560,292 Sewage load: 104 mld
- Year: 2030 Population: 604,734 Sewage load: 94 mld

Sewage from central district will be collected by the existing main trunk sewer and conveyed to Dinapur treatment plant. The main trunk sewer will be fully rehabilitated to restore its calculated design capacity. Flow of 80 mld will be pumped from Konia MPS to Dinapur STP. Flows in excess of 80 mld will be diverted to the relief trunk sewer (District 2) and conveyed to Sathwa STP.

The gate diverting sewage to Konia MPS will be rehabilitated and closed to prevent overflows to the Ganga river. It shall be fitted with electric actuators and controls to allow automatic operation of the gate in emergency by-pass situations.

The firm capacity at Konia MPS will be improved by adding a fourth line of low lift and high lift pumps. An emergency overflow will be constructed from Konia Stage 1 sump to the Varuna river to prevent surcharging of the main trunk sewer when the screw pumps are stopped.

Mechanical and electrical equipment at Ghat pumping stations will be replaced and capacities will be augmented as required. Improvements will be made to emergency power equipment.

7.4.2 Existing Main Trunk Sewer

This sub-section describes the assessment of hydraulic capacity for the city of Varanasi's main trunk sewer. The hydraulic analysis is carried out for existing and future dry weather flows to assess current capacity and deficiencies and ability to carry future wastewater flows.

(1) Current Capacity and Deficiencies

UPJN has provided a record drawing showing the results of a survey conducted (date unknown) on silting and surcharging of the main trunk sewer (Figure 7.4). This drawing indicates several problem sections especially in the upstream reaches.

Hydraulic capacity of the old trunk sewer is assessed in Table 7.2 using Manning's formula with n=0.017 for old brick sewers with silting. The maximum depth of flow equal to 0.8 of full bore. Total wastewater flow is estimated for the tributary area defined by the boundary for the Central sewerage district. It is assumed that sewers outside this boundary (for example Orderly Bazar sewer) will be connected to the new relief sewer presently being constructed by UPJN. The tributary area is then divided into sub-catchments to analyze each segment of the trunk sewer. GIS intersects the sub-catchments with ward populations to provide contributing populations for each sub-catchment. Peak flows estimated for each sub-catchment are accumulated from upstream to downstream and compared with the calculated design capacity of the pipe.

Table 7.3 Summary of Discharge in Main Trunk Sewer (without diversion)

Item	2003	2015	2030
Population	512,737	560,292	604,734
Contributing flow (lpcd)	215	185	155
Average flow (mld)	110	104	94
Peak flow (lps)	2,871	2,699	2,441
Carrying capacity (lps) for n=0.017	3,964	3,964	3,964

The calculations indicate that the main trunk sewer has sufficient carrying capacity for present and future flows generated by the central sewerage district even without diversion to District 2. However, as discussed in previous Chapter 6, Konia pump station and Dinapur STP can only cope with an average flow of 80 mld and therefore diversion to the proposed relief sewer in District 2 is planned.

Surcharging should not occur under normal operating conditions unless the flow is obstructed by heavy deposits of silt or other large objects. A review of the hydraulic profile indicates that there may be a problem when the screw pumps at Konia MPS are stopped because there is no bypass provision at Konia Stage 1. With pumps stopped, all the flow must pass through Konia sluice gate which at present is partially closed to divert flow to the MPS. Since the gate can no longer be opened it could cause the flow to back up and surcharge the trunk sewer during a power failure.

(2) Current Capital Improvement Needs

The most urgent need concerns the main trunk sewer. It urgently needs to be inspected, cleaned and if necessary rehabilitated to restore structural integrity and hydraulic capacity. Inspection and cleaning using traditional methods will be difficult given the large flow and difficult access. An engineering study is required to determine how to inspect and clean the pipe as well as to assess its condition and determine appropriate method for rehabilitation.

In future the Konia gate must be fully closed in order to divert all of the wastewater flow to Konia MPS and eliminate the overflows through the outfall sewer to Ganga river. The Konia gate is presently defunct and cannot be operated. It should be fully refurbished and automated with controls to operate in a closed position during normal conditions and open when screw pumps at Konia are stopped.

7.4.3 Existing Branch Sewers

Branch sewers in the central district are old, and poorly maintained. These sewers are often blocked by solid waste and silt. As a result they overflow to surface drains. Residents and in some cases Jal Sansthan have by-passed blocked sections by diverting branch sewers to nearby drains. If the branch sewer network was functioning properly the sewage would flow to the trunk sewer. However, in the present condition, the wastewater flows via drains towards the Ghats. This is contributing to the pollution along the Ghats and also resulting in overloading at Ghat pumping stations.

Branch sewers in the central district require immediate attention and a program for renewal and reinforcement is urgently required. Such a program should consist of the following activities:

- Street survey of all drains and sewers with specific information of direction of flow
- Preparing a detailed inventory of pipe sizes, with location maps
- Cleaning and inspection using CCTV
- Structural repairs and replacement where necessary
- Disconnecting all branch sewers from surface drains
- Structural measures to remove and prevent sources of surface runoff from entering the sewer
- New branch sewers and lateral connections to trunk sewer facilities
- Identification of all buildings that do not have connection to the sewer system
- Mandatory connection to branch sewers

7.4.4 Konia MPS and Pre-Treatment Works

Konia pump station is situated near Rajghat. It pumps wastewater from District 1 to Dinapur STP. Preliminary treatment is provided at Konia, for removal of screenings and grit.

(1) Current Capacity and Deficiencies

Flow in the main trunk sewer has been diverted to Konia by constructing a special manhole with a sluice gate to prevent flow to Ganga river. The amount of sewage diverted to Konia pumping station is controlled by opening or closing the diversion gate. At present the gate is defunct and is in the partially open position leaving some portion of the flow to the outfall at Ganga river.

The pumping station has a firm capacity of 2,316 lps with one pump out of service.

Table 7.4 Summary of Capacity at Konia Main Pumping Station

Pumping station	Installed capacity (lps)	Firm capacity (lps)	Average (mld)
Konia stage 1 - present	3 x 1158 lps = 3474	67% = 2,316	100
Konia stage 2 - present	3 x 420 = 1260 lps 3 x 740 = 2220 lps	67% = 2,320	
Konia stage 1- future	4 x 1158 lps = 4632	75% = 3,474	150
Konia stage 2 - future	4 x 420 = 1680 lps 4 x 740 = 2960 lps	75% = 3,480	

The present peak flow is approximately 2,871 lps. Therefore there is at present insufficient capacity to pump the peak hour flow when one in three units is out of service. As concluded in the evaluation of alternatives the Master Plan proposes to divert excess sewage flows to the relief sewer in District 2.

Pump station characteristics are presented in Table 7.5. Pumping is carried out in two stages with 3 screw pumps in the first stage and a battery of centrifugal pumps in the second stage. The sewage lifted by the screw pumps passes through screening and grit removal before being pumped by the second stage centrifugal pumps to Dinapur treatment plant.

The second stage pumping station has six pumps at present and adequate space to install two new pumps in future. Two common delivery headers inside the pump house have been provided. One of these headers is connected to the old 900 mm dia hume steel pipe rising main while the other is connected to the new 1200 mm dia PSC main about 2.9 km long.

Diesel generators (5 x 500 KVA) have recently been added to provide continuous operation during power failures.

(2) Current Capital Improvement Needs

The Konia diversion gate is at present open because flows exceed pump station and treatment plant capacity. When the relief sewer is in place the gate must eventually be closed to prevent sewage overflows to the Ganga river. A by-pass line will then be required at the level of the screw pumping station (stage 1) in order to prevent surcharging in the main trunk sewer should the pumps stop for any prolonged period due to lack of power supply.

UPJN has identified funding for spare parts in PFR documents for the following equipment:

- Screw pumps
- Detritor
- Mechanical screen
- Grit removal mechanism

The condition and rehabilitation needs of the pump station should be assessed in more detail.in a separate study.

7.4.5 Existing Ghat Pumping Stations

(1) Current Capacity and Deficiencies

Five pumping stations are located at various Ghats along the left bank of the Ganga river. These pumping stations collect sewage from local drains, branch sewers and small interceptor sewers installed by UPJN along the Ghats. The pumping stations lift sewage to the main trunk sewer. Details of Ghat pumping stations are presented in Table 7.6.

JICA Study Team has inspected the 5 pumping stations along the Ghats and found them to be in a poor state of repair. Although the pumps are operatable they are old and appear to lack proper maintenance and spares. Power interruptions occur daily in Varanasi from 9:30 am to 2:30 pm. Although each pumping station is equipped with a diesel generator, they are rarely operated because UPJN lacks funds for diesel fuel. Only the generators at Dr. R.P. Ghat pumping station are kept in operation because this is the most significant religious site and facilitates the largest discharge among the Ghat pumping stations. In all cases the fuel tanks are too small to provide more than 5 or 6 hours of operation.

Estimating future flow at the pump station depends on two flow components:

- Flow from sanitary sewers along the Ghats
- Flow from nalas

The catchment area contributing to each nala is generally larger than the sewer catchment area and it cannot be clearly defined. Therefore the impact of sewerage improvements in areas outside the Ghat sewer catchment cannot be predicted with any certainty. Because the Ghats are very sensitive the Master Plan has taken a conservative approach by assuming that the flow in the nalas will continue to increase in direct proportion to population growth i.e. no reduction in flow for improvements in sewerage or connection rates.

Table 7.7 Projected Flow at Ghat Sewage Pumping Stations

Pump station	Estimated flow (1) (mld)					
	2003		2015		2030	
	Avg (mld)	Peak (lps)	Avg (mld)	Peak (lps)	Avg (mld)	Peak (lps)
Harishchandra	8.0	185.0	7.0	162.0	5.9	137.0
Mansarovar	2.5	58.0	2.2	51.0	1.9	44.0
Dr. RP	25.1	581.0	21.8	505.0	18.5	428.0
Jalesan	3.8	88.0	3.3	76.0	2.8	65.0
Trilochan	7.3	169.0	6.3	146.0	5.4	125.0
Total	46.7		40.6		34.5	
Population in Ghat sewer catchment area	41,762		43,657		45,370	
Wastewater contribution within Ghat sewer catchment	9.0		8.1		7.0	
Wastewater contribution to nalas from sources outside the Ghat sewer catchment	37.7		32.5		27.5	

Source: (1) calculated by dividing measured nala flow by estimated sewer connection rate. Future flows are based on population growth assuming no improvement in connection rates.

The quantity of wastewater generated within the pumping station catchment is relatively small in proportion to the total amount received. The analysis indicates that a substantial amount of wastewater that reaches the pumping stations is being generated from areas outside the catchment (i.e. areas that should be connected to the trunk sewer). This observation leads to the important conclusion that improvements in sewerage in areas adjacent to the Ghat catchment area have the potential of greatly reducing the flows at Ghat pumping stations thereby reducing pollutant loads and pumping costs.

A comparison of estimated flows and pumping capacity is provided in Table 7.8. Present installed capacity is compared to the pumping capacity that would be required for projected peak flows. In accordance with NRCD guidelines installed capacity should be 5/4 x peak hourly flow.

Table 7.9 Summary of Required Pumping Capacity at Ghat Pumping Stations

(lps)

Pumping Stations	Installed capacity	Required installed capacity (peak x 5/4)		
		2003	2015	2030
Harishchandra	146	290	258	224
Mansarovar	173	90	81	70
Dr. RP	793	904	805	701
Jalesan	160	136	121	105
Trilochan	182	262	233	203

The analysis indicates that installed capacities at Trilochan ghat, Dr. RP ghat and Harishchandra ghat pump stations are insufficient to meet present and future peak hour pumping requirements. NRCD has sanctioned upgrades at Harishchandra ghat and Trilochan ghat pumps stations.

(2) Current capital improvement needs

Varanasi currently experiences daily power outrages that last up to 5 hours. However UPJN lacks the funds to buy diesel and cannot provide continuous operation at all stations. This results in sewage overflows along the Ghats and degraded water quality.

A number of improvements will be required at Ghat pumping stations:

- Replace old pumping equipment, motor starters and switchgear
- Augment capacity at Mansarovar ghat and Trilochan ghat SPS
- Improve/rehabilitate or provide sluice gates on incoming sewers to prevent flooding and silting of sump during high water level season
- Improve diesel generators, increase fuel storage capacity and automate start and stop functions, as well as runtime logs.

Funding should be made available to purchase diesel fuel and operate the pumps continuously. Annual energy costs are estimated at approximately Rs. 11 million (including about Rs. 5.5 million for diesel fuel).

7.4.6 80mld Dinapur STP

(1) General

This section includes information pertaining to the existing wastewater treatment plant. Data associated with the current facilities is limited because record keeping is poor. Physical processes and current loadings have been reviewed for capacity against design values. The Master Plan proposes that Dinapur STP should be optimized to treat an average flow of 80 mld.

Detailed analysis of plant processes to identify potential improvements for optimizing performance of the present treatment plants is beyond the scope of the present Master Planning study. However some general observations are made on the basis of site visits and the limited operational data provided to the Study Team. A more detailed study and review of the treatment plant should be carried out since improving treatment plant effluent can greatly reduce the overall pollutant loads to the Ganga river.

This STP is under direct control of UP Jal Nigam for operation and maintenance purposes. The work on this plant was initiated during February, 1988 and it was fully commissioned in June, 1994. The design capacity of the plant is 80mld. Facility drawings are presented in Appendix C. The current process diagram illustrates the major process units. The site plan provides an actual layout and location of the various process units. As part of the master planning process it is important to understand the components that make up the treatment works and the associated capacities of each unit.

(2) Liquid Process Units

The present wastewater treatment process consists of three overall process stages: primary treatment, roughing filters, and secondary treatment. Each phase of treatment acts as a removal mechanism for targeted pollutants in the influent wastewater stream.

Preliminary treatment is carried out at Konia pumping station. Wastewater flow enters the inlet chamber equipped with Parshall flume for flow measurement. The flow enters distribution chamber where it is divided into three equal streams. Screening at Konia is not sufficiently effective and a large amount of plastics and other small non-organic materials enter the treatment process. Addition of fine screens at Dinapur is recommended to reduce the amount of inorganic material that is finding its way into primary and secondary sludge.

The roughing filter is a high rate trickling filter that is usually provided when the influent has a large amount of industrial wastewater. This was indeed the case when the plant was initially commissioned but at present the contribution from textile dyeing has declined significantly and the plant is processing mostly domestic wastewater. The rotating mechanisms on the trickling filters experience high wear and tear and often fail.

Primary treatment is achieved by three circular primary clarifiers that operate in parallel. Clarified effluent from the primary overflows to secondary treatment, while primary sludge is removed from the bottom and conveyed to solids handling process. The current clarifiers appear to be in good condition and working efficiently.

Secondary treatment accomplishes the conversion of soluble organic material into settleable solid biomass. Organic material that does not settle in the primary clarifiers is introduced into a biological inventory of micro organisms in the secondary process where the organisms convert the organic material into cellular mass. The cellular mass is settled in final secondary clarifiers. At Dinapur secondary treatment is accomplished with activated sludge in three aeration basins using surface aerators. Each aeration basin is operated in parallel. There are three final clarifiers.

Clarified secondary effluent overflows to the sump of the effluent pump station. Treated effluent is pumped up to a discharge channel that leads to irrigating canals downstream. Treated effluent is being used for irrigating 150 acres of land of private farmers. Excess effluent is discharged into the Ganga river through a by-pass pipe. Secondary sludge is drawn off the bottom and pumped back to the primary clarifiers.

The various components of the liquid stream are listed by treatment stage in the following Table. Additionally the condition of each component has been rated poor, fair or good depending on age and condition.

Table 7.10 Major Liquid Process Components

Level	Process	Component	Condition
Head works	Inlet chamber	1 - 3.65m x 1.20m, SWD=4.20m	Good
	Flow measurement	1 - Parshall Flume, TW=1.525m, 40mld to 180mld	Fair
	Distribution chamber	1 - 2.50m x 1.56m x 5.00m	Good
Primary treatment	Primary clarifiers	3 - 28m diameter, SWD=5.00m	Good
	Trickling filters	3 - 22.5m diameter, MD=1m, course stone	Fair
Secondary treatment	Aeration tank	3 – Aeration basins 60m x 20m, SWD=3.75m	Fair
	Secondary clarifiers	3 - 40m Diameter, SWD=3.5m	Good
	Effluent lift station	6 – 27000 lpm x 12 m x 100 H.P.	Good

(3) Solids Handling Units

Sludge is produced from primary sedimentation and the generation of biological sludge from the conversion of organic materials into cellular mass.

Biological sludge is entirely recirculated to the influent flow before the primary sedimentation tanks. The combined sludge and influent suspended solids are removed from the liquid treatment process in the primary clarifiers where the solids combine and are removed by gravity forming a sludge blanket. From the primary clarifiers sludge is pumped directly to the digesters. There is no sludge thickener to remove water and concentrate the sludge prior to entering the digesters.

Sludge entering the digesters is stabilized anaerobically where volatile fraction of the sludge is converted by bacteria into methane and water. There are no secondary digesters for solid/liquid separation or storage. Water generated by the process is removed from the digestors as supernatant. Gas containing methane and CO_2 is used for the production of electricity with gas driven engine generators.

After adequate solids retention time the digested sludge is conveyed to the sludge drying beds for dewatering. The dried sludge cakes are sold for agricultural re-use generating revenues of approximately Rs. 1.24 million per year.

Table 7.11 Major Solids Handling Components

Process	Component	Condition
Digesters	3 - 29m, SWD=7.0m	Fair
Gas Holders	2 - 21m diameter, D=8.7, Volume 2500m^3	Fair
Sludge drying beds	25 – L=30m, W=30m 3 – L=30m, W=20m 1 – L=30m, W=15m	Fair
Raw Sludge Pump House	2 – 1,333 lpm x 12 m x 15 H.P.	Fair
Return Sludge Pump House	3 – 13,885 lpm x 11 m x 60 H.P	Fair
Filterate Pump House	4 – 1,165 lpm x 18.5 m x 5 H.P.	Fair
SCREW Mixers at Digester	9 – 20 H.P.	Fair

(4) Evaluation

Average monthly influent and effluent data is presented in Table 7.12 and Figure 7.5. Process design parameters are available from original process calculations. However there is insufficient operating data to compare present unit wise performance with design values.

Table 7.13 Dinapur STP: Design Criteria

Process	Parameter	Unit	Design value	Recommended
Primary clarifiers	Hydraulic overflow rate at average flow	m^3/m^2/day	35	35-50
	Weir loading at average flow	m^3/m^2/day	140.5	125
Aeration tank	HRT	(hours)	3.5	4-5
	MLSS	mg/liter	3,000	3,000-4,000
Secondary clarifier	Hydraulic overflow rate at average flow	m^3/m^2/day	15.35	15-35
	Weir loading	m^3/m/day	212.2	185
	Solids loading	Kg/m^3/day	84.4	70-140
Anaerobic sludge digesters	Minimum solids retention time at 30^{0}C	days	15	14
	Additional storage capacity	days		10-15

Actual values are monthly averages from Jan-00 to Aug-02 reported by UPJN

It is projected that the strength of sewage will gradually increase to 300 mg/l over the planning horizon on the basis of reduced per capita water supply. It is therefore recommended that expansion of the treatment plant also be based on higher future BOD strength. This assumption corresponds with the design criteria adopted for the existing treatment plant.

Influent wastewater quality appears to be within the treatment plants design parameters. However the treatment plant is hydraulically overloaded.

Table 7.14 Design Parameters versus Actual

Parameter		Design value	Actual
Flow	Peak (m^3/day)	160,000	n.a.
	Average (m^3/day)	80,000	54,000 – 98,000
	Minimum (m^3/day)	32,000	n.a.
Wastewater quality	BOD_5 (mg/l)	300	149-204
	SS (mg/l)	600	397-499
	COD (mg/l)	400	335-406
Effluent quality	BOD_5 (mg/l)	20	25-31
	SS (mg/l)	30	73-94

Effluent quality data show that BOD ranges from 13 to 77 mg/l and suspended solids from 25 to 121 mg/l. These values generally do not meet the requirements for discharge to water bodies but they do meet the requirements for discharge to agricultural irrigation.

A preliminary analysis of the process under existing and future loading conditions is provided in Table 7.15. These preliminary calculations are based on original process design calculations and used to identify the potential problems with the treatment process:

- The basins and channels have been designed to handle increased flows under the abnormal condition when one of the three lines is out of service.
- Although surface loading to the primary clarifiers is within acceptable limits the weir-loading rate is too high resulting in solids carry over. A second weir should be added to increase the total weir length.
- The secondary clarifiers are the most essential stage for final effluent quality and return of activated sludge to the aeration tank to maintain adequate MLSS levels. At present the weir-loading rate is too high resulting in solids carry over. Therefore the weir length should be increased.
- The existing digester scheme does not include any spare tank to store sludge when it cannot be discharged to drying beds. Design guidelines recommend a minimum of 15 days. The requirements for sludge digestion, storage and disposal should be studied in more detail.
- The present treatment process was not originally required to meet faecal coliform criteria and has consequently no provision for disinfection. Present discharge criteria will require reduction of fecal coliform to less than 10,000 MPN/ml. Because there is no space for maturation ponds, the only feasible option will be gas chlorination.

The presence of floating black scum and gas bubbles was observed in the primary clarifiers during visual inspection of the treatment process by the Study Team. This indicates that removal of waste sludge is inadequate, which could be another factor contributing to solids carry over and poor effluent quality. The return sludge piping and pumping should be modified to allow wasting of sludge directly from the secondary clarifier to the digesters. This will help operators in controlling the amount of sludge returned to primary to improve sludge settling characteristics and reduce sludge age to prevent anaerobic conditions

Average biogas production is reported to be between 2,000 to 2,500 m^3/day. This is much lower than the value of 12,600 m^3 identified in the design calculations. Probably it is caused in part by the reduced

BOD load. Dual fuel generators (4 x 400 kW) installed for cogeneration however are at present not cost effective and therefore only utilized as a source of stand-by power during power outrages. Problems with dual fuel generators include:

- Lack of funds for diesel fuel
- Electricity charges linked to contracted minimum load irrespective of actual consumption
- Inadequate quantity of biogas for meeting entire energy requirement of the plant
- Higher production cost using duel-fuel engine generators compared to cost of electricity supplied from the grid.

It is projected that the strength of sewage will increase to 300 mg/l over the planning horizon on the basis of reduced per capita water supply. The projected BOD load is equal to the design criteria adopted for the treatment plant. Therefore it is reasonable to expect that the treatment process can continue to provide adequate treatment if it is not hydraulically overloaded i.e. flow must be regulated to an average of 80mld.

(5) Current Capital Improvement Needs

The digesters have developed structural defects and gas escapes through cracks in the roof. The co-generation heat recovery system and sludge heating system has become defunct because the hot water coils are clogged by scale formation.

UPJN has identified the following capital improvement needs in PFR documents:

- Repair 2 digester structures
- Provide separate pipeline between digester and filtrate pump house
- Improve sludge drying beds
- Modify dual fuel engines
- Spare aerator assemblies
- Rehabilitation of trickling filter arm

The Study Team also recommends improvements to the primary and secondary overflow weirs and chlorination facilities. Since effluent is used for irrigation it will also need to de-chlorinated.

The return and waste activated sludge lines and pump stations should be modified to allow wasting of secondary sludge directly to the digesters. This will improve sludge settling in the primary tank.

Wasted sludge should be thickened before going to the digesters. Therefore a sludge thickener and modifications to sludge piping and pumping are required.

7.5 SEWERAGE DISTRICT 2: SATHWA STP

7.5.1 General Description

Wastewater from District 2 will be collected and conveyed to Sathwa STP. Sewerage District 2 is divided by the Varuna river. Zone 2A is on the cis-Varuna side west of the city centre, Zone 2B and 2C on the trans-Varuna side. The district includes a non-sewer service area NSA-1 along both sides of Narokar nala, east of the Azamgarh road, and a future sewer service area FSA-1 north of Zone 2C.

At present, wastewater that does not enter the sewer system follows natural storm water drains that discharge to the Varuna river. In this District, many new colonies have been developed but there is no sewerage system. In a few localities branch sewers were laid and have either been connected to the old trunk sewer on the cis side or to open drains.

Projected flows based on populations in future service areas contributing to Sathwa STP are as follows:

- Year: 2015 Population: 1,063,456 Sewage load: 197 mld
- Year: 2030 Population: 1,427,151 Sewage load: 221 mld

Table 7.16 Summary of Flows in District 2

Item	2015		2030	
	Flow (mld)	Population	Flow (mld)	Population
Diverted from District 1	23.7	128,051	13.7	88,419
Zone 2A	86.6	468,211	91.6	590,674
Zone 2B	23.8	128,644	31.4	202,776
NSA-1 (Narokhar Nala)	17.2	93,166	33.4	215,724
Diverted from District 4 (temporary in 2015)	7.6	41,000	-	-
Sub-total at Chauka ghat MPS	158.9	859,072	170.1	1,097,593
Zone 2C	33.0	178,228	46.4	299,666
FSA-1	4.8	26,156	4.6	29,892
Total at Sathwa STP	196.7	1,063,456	221.1	1,427,151

Sewage from Zone 2A (sub-central) will be conveyed by the relief trunk sewer (presently under construction) to Chauka ghat pumping station located on the left bank of the Varuna river. Drains discharging into Varuna river will be collected into the right bank interceptor. The Orderly Bazaar trunk sewer and several small trunk sewers that presently discharge into the Central district main trunk sewer will be diverted and connected to the relief trunk sewer.

The first part of the relieving trunk sewer is presently under construction by UPJN from Chauka ghat to Rathyatra. This section is therefore not included in capital cost estimates. The second part of the trunk sewer, from Rathyatra to Durgakund has not been sanctioned. Therefore the direct cost of Rs. 93.5 Million (estimated by UPJN in DPR) has been added to estimated cost for the Master Plan.

Sewage from Zone 2B (trans-Varuna) will be collected in gravity sewers and drains that discharge into the left bank interceptor. A pumping station will tap flows at the tail end of Narokar nala and divert to the left bank interceptor.

In year 2030, sewage from Zone 2C and FSA-1will be collected by gravity sewers to new pumping stations: Sathwa No.1 and Sathwa No.2, but in year 2015 (priority project stage), these sewage will discharge to nalas or drains.

Some sewage from catchment of Phulwaria nala located in District 4 will be tapped and diverted to the right bank interceptor in District 2 temporarily in year 2015. Because the catchment has been already urbanised and sewage is discharging to Varuna river without treatment and urgent provision is necessary.

These will lift sewage to the Sathwa outfall sewer.

Major trunk facilities for District 2 will consist of the following components:

a) Pump station at Chauka ghat on left bank of Varuna river
b) Relieving trunk sewer
c) Connection from relief sewer on right bank crossing under the river to pumping station on the left bank
d) Interceptor sewer along left and right bank of Varuna river upstream of Chauka ghat connecting to the pumping station
e) Interceptor sewer along left and right bank of Varuna river downstream of Chauka ghat also connecting to the pumping station
f) Diversion of nalas by gravity into the right and left bank Varuna interceptors
g) Diversion of Narokhar nala with pumping station and rising main to head of Varuna left bank interceptor.
h) Rising main from Chauka ghat MPS to gravity outfall sewer
i) Gravity outfall sewer to Sathwa STP
j) Sathwa SPS No.1 and No.2
k) Sathwa STP and effluent channel

7.5.2 Sanctioned Relief Sewer

(1) Current Capacity and Deficiencies

UPJN is presently constructing a relief trunk sewer in the Sub-central District. The sewer is designed to carry sewage from the sub-central catchment area and is also intended to relieve part of the flow from the existing main trunk sewer.

Carrying capacity of the relief sewer is assessed using Manning's formula with n=0.015 for aged concrete pipe. Total wastewater flow is estimated for the tributary area defined by the boundary for the Sub-central sewerage district on the cis-Varuna side. Estimated flow includes infiltration allowance. Detailed calculation sheets for the relief sewer are presented in Table 7.17. The relief sewer has a calculated peak discharge capacity of 2,555 lps. The sewer has sufficient capacity to convey wastewater flows from the sub-central district as well as flows diverted from the central core of the city.

Table 7.18 Flows in Relief Trunk Sewer

Item	2015	2030
Diverted from central (mld) Total average flow sub-central (mld)	23.7 86.6	13.7 91.6
Total average flow (mld)	110.3	105.3
Total peak flow (lps)	2,553	2,438
Peak carrying capacity (lps)	2,555	2,555

The construction of the river crossing and pumping station has not been sanctioned by NRCD. Therefore the sewer cannot be used since the outfall is lower than the Varuna river. Details on how to cross the river have yet to be worked out however it would appear to be more practical to have the pumping station on the cis-Varuna side with a rising main on the bridge crossing the river. Details will be examined during the concurrent feasibility study.

7.5.3 Proposed Trunk Sewers

Tentative alignment and sizing of proposed sewers for Zone 2A, and 2B is presented in Drawing C4, and C5. The profile drawing for interceptor sewers along left and right bank of the Varuna River is presented in Drawing C2. Carrying capacity of the new sewers have been computed in accordance with Manning's formulae with values of 'n' = 0.015 corresponding to concrete pipes. Sewage quantities identified in Table 7.19 are peak flows that the collection system has to sustain.

7.5.4 Chauka ghat MPS

The pump station is sized to handle all the flow from Zone 2A and 2B plus flows from interceptors along both sides of the Varuna river. The pumping station will cater to the following design flows:

- 2015 :160 mld :3,704 lps peak
- 2030 :170 mld :3,935 lps peak

The pumping station will be located on the Trans side of the Varuna river next to bridge abutment on the road leading to Sathwa. Twin rising mains will carry sewage under pressure to the Sathwa outfall sewer along Azamgarh road. An evaluation of required pumping station capacities is presented in Table 7.20.

The new pumping station would have the following characteristics:

- Pumps initial stage: 12 x 28,000 lpm
- Pumps ultimate stage: 12 x 30,000 lpm
- Rising main: 2 x 1,200mm dia. Length :1,800m
- Sump capacity: 1,181 m^3

7.5.5 Varuna Interceptor

A plan and profile drawing of the Varuna interceptor sewer is presented in Drawing C2 and preliminary sizing is summarized below:

Pipe crossing under Varuna river	Pipe jacking under the river bed, below scouring level - 2200 mm dia. x 400m
Rising main from Chauka ghat PS	Pre-stressed concrete pressure pipe 1400mm dia x 1650m
Gravity outfall sewer	NP4 concrete pipe - 2000 ~ 2200mm x 4500 m (Dual pipeline)
Left bank interceptor (upstream)	Size & Lengths - 500 mm dia. x 1450 m - 800 mm dia. x 1000 m - 1000 mm dia. x 1850 m - 1200 mm dia. x 400 m Name of drains intercepted by gravity - Central jail - Orderly Bazaar - Chamrautia - Khajurl Colony
Left bank interceptor (downstream)	Size & Lengths - 1400 mm x 2500 mm Drains intercepted by gravity - Banaras - Hukulganj - Nai Basti Drain intercepted with pumping station - Narokhar

Right bank interceptor (upstream)	Size & Lengths - 500 mm dia. x 4700 m Drains intercepted by gravity - Phulwaria - Sadam Bazaar - Hotel Drain - Raja Bazaar - TeliaBagh
Right bank interceptor (downstream)	Size & Lengths - 700 mm dia. x 2500 m Drains intercepted by gravity - Nakhi Ghat

7.5.6 Narokar nala SPS

The pump station is sized to handle all the flow from Narokar nala, which acts as a drain for non-sewerage area NSA-1. The pumping station will cater to the following design flows:

- 2015 : 18 mld :417 lps peak
- 2030 : 34 mld :787 lps peak

The pumping station will be located on the tran side of the Varuna river at the tail end of Narokar nala. The station will require civil works to divert nala flow during dry weather. These works will include screening and grit removal facilities. The new rising main will carry sewage under pressure to the Varuna interceptor sewer where it will flow by gravity to Chauka ghat MPS. An evaluation of required pumping station capacities is presented in Table 7.20.

The new pumping station would have the following characteristics:

- Pumps initial stage: 6 x 6,600 lpm
- Pumps ultimate stage: 10 x 6,600 lpm
- Rising main: 800mm dia. Length :1,600m
- Sump capacity: 236 m^3

7.5.7 Sathwa SPS No.1

The pump station is sized to handle the flow from sub-catchments in Zone 2C that lie to the east side of the Azamgarh Road. The pumping station will cater to the following design flows:

- 2015 :12 mld :278 lps peak
- 2030 :17 mld :394 lps peak

The new rising main will lift sewage to the Sathwa treatment plant outfall sewer. An evaluation of required pumping station capacities is presented in Table 7.20.

The new pumping station would have the following characteristics:

- Pumps initial stage: 3 x 6,000 lpm 2 x 4,500 lpm
- Pumps ultimate stage: 6 x 6,000 lpm
- Rising main: 600 mm dia. Length :100m
- Sump capacity: 118 m^3

7.5.8 Sathwa SPS No.2

The pump station is sized to handle the flow from sub-catchments in Zone 2C that lie to the west of Azamgarh Road and flows from future service area FSA-1. The pumping station will cater to the following design flows:

- 2015 :28 mld :648 lps peak
- 2030 :36 mld :833 lps peak

The new rising main will lift sewage to the Sathwa treatment plant outfall sewer. An evaluation of required pumping station capacities is presented in Table 7.20.

The new pumping station would have the following characteristics:

- Pumps initial stage: 3 x 13,200 lpm 2 x 10,500 lpm
- Pumps ultimate stage: 6 x 12,600 lpm
- Rising main: 800 mm dia. Length :100m
- Sump capacity: 250 m^3

7.5.9 Sathwa STP

Projected wastewater flows based on population projections are as follows:

- 2015 200 mld
- 2030 225 mld

UPJN has proposed an area of 300 ha near Sathwa village just east of Azamgarh road. Comparison of alternatives in chapter 6 indicates that a UASB process followed by post treatment with facultative aerated lagoons will be the most cost-effective treatment process. The treated effluent will be chlorinated and discharged into an irrigation canal located near this site. This treated effluent could be used for irrigating the crops cultivated on the downstream of this canal. Reuse of the effluent has the potential to reduce, to a minor extent, further exploitation of the ground water in the vicinity.

Total land requirements for the selected treatment process are approximately 80 ha. Availability of land has not yet been confirmed by UPJN. Final site location and the potential for effluent re-use should be investigated in more detail

7.6 SEWERAGE DISTRICT 3: RAMNA STP

7.6.1 General Description

District 3 lies mainly to the south of Assi nala but includes an area to the north that drains to Assi nala. Wastewater from the BHU campus is collected and treated at Bhagwan pur STP. Assi nala remains a significant source of pollution discharging just upstream of the bathing Ghats. UPJN has a sanctioned project to diverting dry weather wastewater flow of Assi/Nagwa nala to a new waste stabilization pond at Ramna. The Sewerage Master Plan proposes interceptor sewers along Assi nala connected to the sanctioned Nagwa pump station. New trunk sewers proposed for other parts of district 3 will carry wastewater by gravity to Ramna STP. Sewage from the BHU campus will continue to be treated at Bhagwan pur STP until it is no longer economically viable to maintain or if effluent quality cannot be improved. Wastewater flow from BHU can be conveyed by gravity to Ramna after decommissioning Bhagwan pur STP.

Projected flows based on populations in future service areas contributing to Ramna STP are as follows:

- Year: 2015 Population: 214,570 Sewage load: 40 mld
- Year: 2030 Population: 473,969 Sewage load: 75 mld

Table 7.21 Summary of Flows in District 3

Item	2015		2030	
	Flow (mld)	Population	Flow (mld)	Population
Zone 3	39.7	214,570	45.1	291,188
FSA-4			28.3	182,781
Total at Ramna STP	39.7	214,570	73.4	473,969

Major trunk facilities for the Assi/BHU district will consist of the following components:

a) Pump station at Nagwa drain (sanctioned under GAP-II and being implemented by UPJN).
b) Interceptor sewer along left and right bank of Assi/Nagwa nala
c) Lateral sewers connected to interceptor
d) Trunk sewers for gravity flow to Ramna STP
e) Gravity outfall sewer to Ramna STP
f) Existing Assi MPS pumping to BHU STP through 400 mm dia rising main

7.6.2 Proposed Trunk Sewers

Tentative alignment and sizing of proposed sewers is presented in Drawings C3 and C6. Carrying capacity of the new sewers has been computed in accordance with Manning's formulae with value of 'n' = 0.015 corresponding to concrete pipes. Sewage quantities identified in Table 7.22 are peak flows that the collection system has to sustain.

Interceptor sewers are proposed along the banks of the Assi/Nagwa nala. The intent is for these sewers to intercept all branch sewers that discharge wastewater to the nala. Small pockets of informal settlements and low lying areas along the nala may need small local lift stations to reach the interceptor depending on topographic elevations.

7.6.3 Assi/Nagwa Nala MPS

Sewage from the Assi/BHU district will be conveyed by gravity to a new interceptor sewer along Nagwa drain which will convey sewage to Nagwa pumping station.

Sanctioned under GAP-II, Nagwa nala main pumping station is designed to tap flow at the tail end of Nagwa nala and pump over 7 km to proposed Ramna waste stabilization ponds. Capacities proposed in GAP-II assume that there is no improvement in sewerage and therefore flow in the nala will increase with population growth.

Technical details of the sanctioned pumping station are as follows:

Nagwa MPS:	Design flows: - 37 mld (avg.) 856 lps (peak) 2015 - 50 mld (avg.) 1,157 lps (peak) 2030 Pumps: (2015) (proposed by UPJN) - 3 x 500 lps x 39 m head - 2 x 250 lps x 20 m head Sump: 5 minutes for avg (2030)

	- volume : 173.6 m3 - diameter: 12 m - depth : 3.7 m Invert levels : - incoming sewer : 61.9 m - pump station sump : 58.2 m
Rising Main:	Pre stressed concrete pressure pipe - 1000 mm dia. x 7,000 m

7.6.4 Bhagwan pur STP: 8mld Treatment Plant

(1) Facility Overview

This STP is under direct control of UP Jal Nigam for operation and maintenance purposes. The work on this plant was initiated during February, 1988 and it was fully commissioned in June, 1994.

This section includes information pertaining to the existing wastewater treatment plant. Data associated with the current facilities is limited because record keeping is poor. Physical processes and current loadings have been reviewed for capacity against design values. The Master Plan proposes that the process at Bhagwan pur STP should be optimized to treat an average flow of 8 to 10 mld.

Detailed analysis of plant processes to identify potential improvements for optimizing performance of the present treatment plant is beyond the scope of the present Master Planning study. However some general observations are made on the basis of site visits and the limited operational data provided to the Study Team. A more detailed study and review of the treatment plant should be carried out since improving treatment plant effluent can greatly reduce the overall pollutant loads to the Ganga river. This facility only treats a small flow but it discharges effluent directly upstream of the bathing Ghats and the water supply intake, and in its present state of disrepair and poor performance it is a serious risk to the health of all downstream users as well as a source of pollution. The Study Team has on several occasions indicated its preference for decommissioning this facility in favor of treating more flow at Ramna STP. However this proposal has not been acceptable to UPJN in the short-term, with preference given to keeping the treatment plant in operation and optimizing the process.

Facility drawings are presented in Appendix C. The current process diagram illustrates the major process units. The site plan provides an actual layout and location of the various process units. As part of the master planning process it is important to understand the components that make up the treatment works and the associated capacities of each unit.

The plant receives sewage from two pumping stations within BHU campus and from Assi pumping station. The design capacity of the plant is 8 mld.

Before start-up of GAP-I, a 1.8 mld capacity Trickling Filter was operated by BHU to treat the wastewater generated from university hospital and residential quarters. After some time it failed for lack of maintenance. Under GAP-I, this was completely renovated and made operational. It consists of primary settling, trickling filter and secondary clarifier, each in one number with a treatment capacity of 1.8 mld. It has not been operational since 1997 because housing has taken over the area to where effluent was discharged.

The Study Team visited the treatment facility many times between October-03 and May-04 but it was never in operation for two reasons:

- The digesters were undergoing structural repairs to seal cracks in the roof. UPJN reported that sludge from secondary process was being temporarily discharged to a nearby channel on the site.

- The visits coincided with times of the day when power was not available. Although diesel generators are on site they were not used presumably because UPJN lacks the funds for purchasing fuel.

The activated sludge process is seriously compromised by the daily power outrages because it Is not receiving sufficient aeration. The results achieved under the present operating conditions equal to primary sedimentation at best.

(2) Liquid Process Units

The present wastewater treatment process consists of three overall process stages: preliminary treatment, primary treatment, roughing filters, and secondary treatment. Each phase of treatment acts as a removal mechanism for targeted pollutants in the influent wastewater stream.

There are two streams of 4 mld each and the process consists of screening, primary settling, activated sludge and secondary clarifier.

Two circular primary clarifiers that operate in parallel provide primary treatment. In the primary clarifiers, not only some settleable solids but also some settleable organic loads are removed from the bottom and conveyed to solids handling process with the sludge generated from secondary clarifiers. The current clarifiers appear to be in good condition and working efficiently. Clarified effluent from the primary overflows to secondary treatment, while primary sludge is removed from the bottom and conveyed to solids handling process.

Secondary treatment accomplishes the conversion of soluble organic material into settleable biomass by utilizing metabolic mechanism of micro-organisms. The biomass is settled in final secondary clarifiers. At Bhagwan pur STP, secondary treatment is accomplished with the conventional activated sludge process in two aeration tanks using surface aerators. The settled sludge is drawn off the bottom and pumped back to the primary clarifiers. Clarified secondary effluent overflows to a drain that flows by gravity to a nala that leads to the Ganga river.

The various components of the liquid stream are listed by treatment stage in the following table. Additionally the condition of each component has been rated poor, fair or good depending on age and condition.

Table 7.23 Major Liquid Process Components

Level	Process	Component	Condition
Head Works	Inlet collection chamber	1 – 2.0m x 1.5m x 5.0m	Fair
	Screen chamber	2 – 3.0(L)m x 0.5(W)m x 1.0m(D)	Fair
	Grit chamber	2 – 7.15(L)m x 2.0(W)m x 1.3m(D)	Fair
	Flow measurement	1 – Parshall flume TW=150mm 4 mld-20 mld	Fair
Primary Treatment	Primary clarifier	2 – 14.6m diameter, SWD=2.5m	Fair
Secondary Treatment	Aeration tank	2 – 15.6m diameter, SWD=3.5m	Fair
	Secondary clarifiers	2 – 16.0m diameter, SWD=3.5m	Fair

(3) Solids Handling Units

Sludge is produced from primary sedimentation and the biological sludge from the secondary clarifiers.

Biological sludge is entirely recirculated to the influent flow before the primary sedimentation tanks. The combined sludge and influent suspended solids are removed from the liquid treatment process in the primary clarifiers where the solids combine and are removed by gravity forming a sludge blanket. From the primary clarifiers sludge is pumped directly to the digesters. There is no sludge thickener to remove water and concentrate the sludge prior to entering the digesters.

Sludge entering the digesters is stabilized anaerobically where volatile fraction of the sludge is converted by bacteria into methane and water. There are no secondary digesters for solid/liquid separation or storage. Water generated by the process is removed from the digesters as supernatant. Gas containing methane and CO_2 is used for the production of electricity with gas driven engine generators. After adequate solids retention time the digested sludge is conveyed to the sludge drying beds for dewatering.

Table 7.24 Major Solids Handling Components

Process	Component	Condition
Digesters	2 – 18.0m diameter, L.D.=8.0m	Poor
Sludge drying beds	9 – 28.0m x 12.0m	Fair

(4) Evaluation

Average monthly influent and effluent data is presented in Table 7.25 and Figure 7.6. Process design parameters are available from original process calculations. However there is insufficient operating data to compare present unit wise performance with design values.

Table 7.26 Bhagwan pur STP: Design Criteria

Process	Parameter	Unit	Design value	Recommended
Primary clarifiers	Hydraulic overflow rate at average flow	$m^3/m^2/day$	23.9	35-50
	Weir loading at average flow	$m^3/m/day$	87.2	125
Aeration tank	HRT	(hours)	4.0	4-5
	MLSS	mg/liter	3,000	3,000-4,000
Secondary clarifier	Hydraulic overflow rate at average flow	$m^3/m^2/day$	19.9	15-35
	Weir loading	$m^3/m/day$	79.6	185
	Solids loading	$kg/m^3/day$	119.4	70-140
Anaerobic sludge digesters	Minimum solids retention time at 30^0C	days	48.6	14
	Additional storage capacity	days	0	10-15

It is projected that the strength of sewage will gradually increase to 300 mg/l over the planning horizon on the basis of reduced per capita water supply. It is therefore recommended that expansion of the treatment plant also be based on higher future BOD strength. This assumption corresponds with the design criteria adopted for the existing treatment plant. Influent wastewater quality appears to be within the treatment plant design parameters. However the treatment plant is hydraulically overloaded.

Table 7.27 Design Parameters versus Actual

Parameter		Design value	Actual
Flow	Peak m^3/min	13.89	
	Average (m^3/day)	8,000	9,520 to 12,720
	Minimum m^3/min	2.78	
Wastewater quality	BOD_5 (mg/l)	300	60 to 240
	SS (mg/l)	600	66 to 350
	COD (mg/l)	400	104 to 354
Effluent quality	BOD_5 (mg/l)	20	4 to 20
	SS (mg/l)	30	19 to 26

Source: Actual values are as reported to CPCB by UPJN in *"Varanasi State of the Environment" October, 2000.*

Effluent quality data show that BOD range from 4 to 22 mg/l and suspended solids from 16 to 22 mg/l. These values generally meet the requirements for discharge to water bodies and agricultural irrigation with the exception over faecal coliform counts.

A preliminary analysis of the process under existing and future loading conditions is provided in Table 7.28. These preliminary calculations are based on original process design calculations and used to identify the potential problems with the treatment process:

- Although surface loading to the primary clarifiers is within acceptable limits the weir-loading rate is too high resulting in solids carry over. A second weir should be added to increase the total weir length.
- The hydraulic retention time in the aeration tanks is insufficient. Hence one or two more aeration tanks will be required.
- The secondary clarifiers are the most essential stage for final effluent quality and return of activated sludge to the aeration tanks to maintain adequate MLSS levels. At present the weir-loading rate is too high resulting in solids carry over. Therefore the weir length should be increased.
- The solid retention time of the digesters is too high. The digesters could be operated in two stages to achieve greater reduction in volatile solids.
- The present treatment process was not originally required to meet faecal coliform criteria and has consequently no provision for disinfection.

The presence of floating black scum and gas bubbles was observed in the primary clarifiers during visual inspection of the treatment process by the Study Team. This indicates that the process is anaerobic, probably caused by poor aeration given the lengthy power outages. Removal of waste sludge may also be inadequate, especially since the digesters are out of service.

Average biogas production is reported to be between 150 to 180 m^3/day. This is much lower than the value of 1,300 m^3/day identified in the design calculations caused in part by the reduced BOD load. Dual fuel generators (3 x 56 kW) are installed for cogeneration. However they are at present not cost effective and therefore only utilized as a source of stand-by power during power outrages. Problems with dual fuel generators include:

- Lack of funds for diesel fuel
- Electricity charges linked to contracted minimum load irrespective of actual consumption
- Inadequate quantity of biogas for meeting entire energy requirement of the plant
- Higher production cost using duel-fuel engine generators compared to cost of electricity supplied from the grid.

It is projected that the strength of sewage will increase to 300 mg/l over the planning horizon on the basis of reduced per capita water supply. The projected BOD load is equal to the design criteria adopted for the treatment plant. Therefore it is reasonable to expect that the treatment process can continue to provide adequate treatment if it is not hydraulically overloaded i.e. flow must be regulated to an average of 8 mld. Additional aeration basins are required as well as improving overflow weirs in primary and secondary clarifiers.

(5) Current capital improvement needs

The digesters have developed structural defects and gas escapes through cracks in the roof.

UPJN has identified the following capital improvement needs in PFR documents:

- Repair 2 digester structures
- Provide roughing filter with sand filtration to reduce faecal coliform in effluent
- Increase capacity of activated sludge plant
- No additional digesters or sludge drying beds
- Construction of effluent channel for trickling filter

The return and waste activated sludge lines and pump stations should be modified to allow wasting of secondary sludge directly to the digesters. This will improve sludge settling in the primary tanks.

Wasted sludge should be thickened before going to the digesters. Therefore a sludge thickener and modifications to sludge piping and pumping is required.

The effluent does not meet current discharge limits for faecal coliform. Roughing filters combined with sand filters have been proposed by UPJN but the operational feasibility of this option and the results obtained are questionable. The effluent should be chlorinated to protect public health of downstream bathers and drinking water supply intake.

7.6.5 Ramna STP

A project has been sanctioned to construct waste stabilization ponds at Ramna (capacity 37mld). The treatment system would include pre-treatment to remove grit and inorganic solids, followed by anaerobic ponds, facultative ponds and finally maturation ponds. The effluent will be finally discharged to unrestricted irrigation and to the Ganga river. Therefore faecal coliform levels should be reduced to at least 10,000 MPN or less therefore maturation ponds should be sized accordingly.

UPJN have identified a 50 ha site in their DPR. However preliminary process calculations indicate that the total land requirement for a 75 mld WSP should be about 94ha (1.25 hectare per mld) to accommodate the maturation ponds.

7.7 SEWERAGE DISTRICT 4: LOTHA STP

7.7.1 General Description

Sewage from the Lohta district will be conveyed by gravity sewers towards the village Lohta. From Lohta the outfall sewer will flow by gravity along an alignment that follows a drain heading northwest, crossing the railway line. Sewage will be lifted at the treatment plant.

Projected flows based on populations projections for the future service area are as follows:

- Year: 2015 Population: 172,752 Sewage load: 32.0 mld
- Year: 2030 Population: 291,085 Sewage load: 45.1 mld

7.7.2 Sewers

Tentative alignment and size of the future sewer network are shown in Drawing C7. Some of the sewer alignments shown in this area are along roads that do not yet exist or roads that have been proposed in the City Master Plan. Therefore the sewerage scheme will need to be revised when the detailed project is taken up. Carrying capacity of the new trunk sewers have been computed in accordance with Manning's formula with values of 'n' = 0.015 corresponding to old concrete pipes. Sewage quantities in Table 7.29 are peak flows that the collection system has to sustain.

7.7.3 Lohta STP

The proposed 15 ha site with ground elevation of about 75 m is located on the western part of Varanasi city , north of the Northern railway line near the Varuna river at Mathura Purva.

A detailed comparison of various treatment process options is presented in Appendix A and discussed in Section 6 of this report. Although UASB with post treatment by aerated lagoons is the most cost effective solution it would require at least 18 ha land and would therefore exceed the land area that is expected to be available at the location selected by UPJN. The availability of land should be confirmed by UPJN as early as possible and secured for the future.

Table 7.1 List of Existing Nala and Drain

Point of Discharge	No.	Name of Nala or Drain	Measured Flow (mld)		Type	Remarks
			1986	2000		
Ganga River	1	Nakkhi Drain	-	0.00	Open Chanel	Running almost dry
	2	Samne Ghat Drain	-	0.00	Circular Pipe	Running almost dry
	3	Assi Nala	22.00	44.50	Open Chanel	
	4	Shiwala Drain	1.00	5.50	Circular Pipe	Intercepted into main sewer
	5	Harishchandra Ghat Drain	1.50	2.50	Rectungular	Intercepted into main sewer
	6	Mansarovar Drain	2.50	2.50	Circular Pipe	Intercepted into main sewer under GAP-I
	7	Dr. R. P. Ghat Nala (Ghora Nala)	20.00	25.00	Rectungular	Intercepted into main sewer
	8	Jalesan Drain	2.75	3.75	Rectungular	Intercepted into main sewer
	9	Sankatha Ghat	-	0.30	Rectungular	Intercepted into main sewer
	10	Trilochan Ghat Drain	2.00	3.50	Rectungular	Intercepted into main sewer
	11	Telia Nala	1.00	3.00		Intercepted into main sewer under GAP-I
	12	Bhainsasur Nala	-	0.40		
	13	Rajghat Railway Nala	-	0.03	Circular Pipe	
	14	Rajghat Outfall	100.00	130.00	Circular Pipe	Intercepted into main sewer under GAP-I
Varuna River (Right Bank)	1	Phulwaria Nala	3.20	7.60	Open Chanel	
	2	Sadar Bazar Nala	0.90	2.00		
	3	Drain Of Hotels	0.20	0.20		
	4	Raja Bazar Nala	0.10	0.10		
	5	Teliabagh Nala	10.80	18.00		
	6	Nala Near Nakhi Ghta	0.10	0.10		
	7	Konia Bypass		50.00		
Varuna River (Left Bank)	8	Central Jail Nala	2.80	6.50		
	9	Orderly Bazar Nala	2.20	7.00		
	10	Chamrautia Nala	1.30	3.00		
	11	Nala Of Khajurl Colony	1.20	1.50		
	12	Banaras Nala No.5	0.80	1.00		
	13	Hukulgang Nala	0.90	2.50	Open Chanel	
	14	Nala Of Nai Basti	0.30	3.00		
	15	Narokhar Nala	-	7.50	Open Chanel	

Table 7.2 Hydraulic Capacity Calculations : Main Trunk Sewer (Page 1 of 3), 2003

Node		Contributory Population		Flow (lps)	Diversion (lps)	Design Flow (lps)	Size (inch)	Size (mm)	Length (m)	Gradient	Invert level (m)		Ground level (m)		Full pipe capacity		Design capacity		Sub Catchment	Remarks
From	To	Each	Cumulative								u/s	d/s	u/s	d/s	Velocity (m/s)	Discharge (l/s)	Velocity (m/s)	Discharge (l/s)		
1	2	30,308	30,308	188.5		188.5	30	762.0	815	2,205	70.16	69.79	78.00	76.00	0.415	189	0.473	183	2	
2	3	46,040	76,348	427.5		427.5	48	1219.2	815	1,150	69.79	69.08	76.00	74.00	0.786	918	0.896	888	1+3+18+19	Harishchandra SPS+ Mansorovar SPS
3	4			427.5		427.5	72	1828.8	525	1,940	68.50		74.00		0.793	2,083	0.904	2,016		
4	5	67,164	143,512	803.5		803.5	72	1828.8	445	1,940		68.00		74.00	0.793	2,083	0.904	2,016	4+5+17	Dr. RP SPS
5	6	57,024	200,536	1,122.8		1,122.8	84	2133.6	840	1,680	67.40	66.90	74.00	75.00	0.944	3,375	1.076	3,267	6+7+16	Jalesan SPS
6	7	34,025	234,561	1,313.3		1,313.3	90	2286.0	750	1,265	66.82		75.00		1.139	4,675	1.298	4,525	8	
7	8	93,506	328,067	1,836.9		1,836.9	90	2286.0	540	1,265		65.80		73.50	1.139	4,675	1.298	4,525	10	Trilonchan SPS
8	9	30,899	358,966	2,009.9		2,009.9	96	2438.4	950	2,715	65.52	65.17	73.50	74.00	0.812	3,792	0.926	3,671	14+15	
9	10	65,779	424,745	2,378.0		2,378.0	96	2438.4	575	2,325	65.17		74.00		0.877	4,095	1.000	3,964	9+11	
10	11	87,992	512,737	2,870.8		2,870.8	96	2438.4	680	2,325		64.63		73.50	0.877	4,095	1.000	3,964	12+13	
11	SPS		512,737	2,870.8		2,870.8	96	2438.4												

Manning's N;	0.017

Table 7.2 Hydraulic Capacity Calculations : Main Trunk Sewer (Page 2 of 3), 2015

Node		Contributory Population		Flow (lps)	Diversion (lps)	Design Flow (lps)	Size (inch)	Size (mm)	Length (m)	Gradient	Invert level (m)		Ground level (m)		Full pipe capacity		Design capacity		Sub Catchment	Remarks
From	To	Each	Cumulative								u/s	d/s	u/s	d/s	Velocity (m/s)	Discharge (l/s)	Velocity (m/s)	Discharge (l/s)		
1	2	31,196	31,196	167.0		167.0	30	762.0	815	2,205	70.16	69.79	78.00	76.00	0.415	189	0.473	183	2	
2	3	48,289	79,485	383.0		383.0	48	1219.2	815	1,150	69.79	69.08	76.00	74.00	0.786	918	0.896	888	1+3+18+19	Harishchandra SPS+ Mansorovar SPS
3	4			383.0		383.0	72	1828.8	525	1,940	68.50		74.00		0.793	2,083	0.904	2,016		
4	5	68,900	148,385	714.8		714.8	72	1828.8	445	1,940		68.00		74.00	0.793	2,083	0.904	2,016	4+5+17	Dr. RP SPS
5	6	59,149	207,534	999.9	-617.2	382.7	84	2133.6	840	1,680	67.40	66.90	74.00	75.00	0.944	3,375	1.076	3,267	6+7+16	Jalesan SPS
6	7	35,077	242,611	1,168.9	-617.2	551.7	90	2286.0	750	1,265	66.82		75.00		1.139	4,675	1.298	4,525	8	
7	8	96,735	339,346	1,634.9	-617.2	1,017.7	90	2286.0	540	1,265		65.80		73.50	1.139	4,675	1.298	4,525	10	Trilonchan SPS
8	9	32,562	371,908	1,791.7	-617.2	1,174.5	96	2438.4	950	2,715	65.52	65.17	73.50	74.00	0.812	3,792	0.926	3,671	14+15	
9	10	72,951	444,859	2,143.1	-617.2	1,525.9	96	2438.4	575	2,325	65.17		74.00		0.877	4,095	1.000	3,964	9+11	
10	11	115,433	560,292	2,699.3	-617.2	2,082.1	96	2438.4	680	2,325		64.63		73.50	0.877	4,095	1.000	3,964	12+13	
11	SPS		560,292	2,699.3	-617.2	2,082.1	96	2438.4												

	Ave	Peak	
Domestic flow	103.7	233.3	mld
Diversion to New Trunk	-23.7	-53.3	mld
Total	80.0	180.0	mld

0.0

Manning's N;	0.017

Table 7.2 Hydraulic Capacity Calculations : Main Trunk Sewer (Page 3 of 3), 2030

Node		Contributory Population		Flow (lps)	Diversion (lps)	Design Flow (lps)	Size (inch)	Size (mm)	Length (m)	Gradient	Invert level (m)		Ground level (m)		Full pipe capacity		Design capacity			Remarks
From	To	Each	Cumulative								u/s	d/s	u/s	d/s	Velocity (m/s)	Discharge (l/s)	Depth ratio d/df	Velocity (m/s)	Discharge (l/s)	
1	2	32,217	32,217	144.5		144.5	30	762.0	815	2,205	70.16	69.79	78.00	76.00	0.415	189	0.80	0.473	183	
2	3	50,253	82,470	332.8		332.8	48	1219.2	815	1,150	69.79	69.08	76.00	74.00	0.786	918	0.80	0.896	888	Harishchandra SPS+ Mansorovar SPS
3	4			332.8		332.8	72	1828.8	525	1,940	68.50		74.00		0.793	2,083	0.80	0.904	2,016	
4	5	70,650	153,120	618.1		618.1	72	1828.8	445	1,940		68.00		74.00	0.793	2,083	0.80	0.904	2,016	Dr. RP SPS
5	6	60,959	214,079	864.2	-356.8	507.4	84	2133.6	840	1,680	67.40	66.90	74.00	75.00	0.944	3,375	0.80	1.076	3,267	Jalesan SPS
6	7	35,964	250,043	1,009.4	-356.8	652.6	90	2286.0	750	1,265	66.82		75.00		1.139	4,675	0.80	1.298	4,525	
7	8	99,671	349,714	1,411.7	-356.8	1,054.9	90	2286.0	540	1,265		65.80		73.50	1.139	4,675	0.80	1.298	4,525	Trilonchan SPS
8	9	34,339	384,053	1,550.3	-356.8	1,193.5	96	2438.4	950	2,715	65.52	65.17	73.50	74.00	0.812	3,792	0.80	0.926	3,671	
9	10	79,125	463,178	1,869.5	-356.8	1,512.7	96	2438.4	575	2,325	65.17		74.00		0.877	4,095	0.80	1.000	3,964	
10	11	141,556	604,734	2,441.0	-356.8	2,084.2	96	2438.4	680	2,325		64.63		73.50	0.877	4,095	0.80	1.000	3,964	
11	SPS		604,734	2,441.0	-356.8	2,084.2	96	2438.4												

	Ave	Peak	
Domestic	93.7	210.8	mld
Diversion to New Trunk	-13.7	-30.8	mld
Total	80.0	180.0	mld

Manning's N;	0.017

Table 7.5 Konia MPS & Pre-treatment Works (100 mld)

a)	Diversion Sewer:		305.0 meters long 2286 (90") dia brick sewer (old existing)
b)	Emergency overflow at Konia High lift: 250 meters long 2200mm dia pipe.		
c)	Old Pump House:		
	- Screen chamber of 48.33.5ft with two no. manually cleaned screens.		
	- Sump of 30ft. diameter with partition wall in between.		
	- Two nos. pumps of 150 HP capacity each with head		
	- One no. pump of 150 HP with 2700 lpm discharge at 16.6m head.		
d)	First Stage Pumping	:	
	No. of Pumps	:	3 Nos.
	Type	:	Screw type
	H.P.	:	215 HP each
	Capacity	:	1158 lps each
	Head	:	8.51 meters
	RPM	:	29
	Make	:	Spans Babcock (Netherlands)
	Screens	:	2 nos. mechanically operated, 50mld capacity each Dorr-Oliver make.
			1 No. manually operated 50mld capacity.
	Detritor	:	2 nos. each of 100mld capacity with 20% over-loading capacity.
e)	Second Stage Pumping:		
	Sump Size	:	32m x 6m with partition walls
	No. of pumps	:	6 Nos.
	Type	:	Non clog horizontal centrifugal
	H.P.	:	3 Nos. 215 and 3 Nos. 150
	Capacity	:	740 lps/420 lps. Respectively
	R.P.M.		: 590 each
	Make	:	Beacon weir.
f)	Rising Main	:	1200mm dia PSC pipe 2.9 km (new)
			900mm dia hume steel pipe 2860m long (old)
g)	Switch Yard	:	Capacity 1600 KVA
			Transformers 3 Nos. 1000 KVA each.

Table 7.6 Existing Sewage Pumping Station Unit Wise Details

(1) Harishchandra Ghat SPS:

Pump House	6m dia. circular sump cum pump house. Sump floor is 6.5m below the floor of Pump House
Pumping Plants	1 No. 50 HP 5000 lpm at 24.0m head 1 No. 25 HP 2600 lpm at 13.5m head 1 No. 10 HP 1150 lpm at 9.5m head
Diesel Generating Set	1 No. of 70 KVA capacity
Rising Main	200mm dia C.I

(2) Mansarovar Ghat SPS:

Pump House	9m dia. circular sump cum pump house. Sump floor is 11.0m deep from Pump House floor.
Pumping Plants	2 Nos. 10 HP 1300 lpm at 15.0m head 3 Nos. 25 HP 2600 lpm at 21.0m head
Diesel Generating Set	1 No. of 100 KVA capacity
Rising Main	400mm dia C.I

(3) Dr. R.P. Ghat SPS:

Pump House	6.1m internal dia. sump cum pump house. Sump floor is 18.3m deep from Pump House floor.
Pumping Plants	2 Nos. 125 HP 15000 lpm at 23.0m head 2 Nos. 75 HP 8800 lpm at 22.0m head
Diesel Generating Set	3 Nos. of 160 KVA capacity
Rising Main	600mm dia C.I.

(4) Jalesan Ghat SPS:

Pump House	6.1m internal dia. sump cum pump house. Sump floor is 16.3m deep from Pump House floor. 3.65m internal dia and 16.45m deep special manhole.
Pumping Plants	2 Nos. 30 HP 3600 lpm at 20.0m head 2 Nos. 15 HP 1200 lpm at 15.0m head
Diesel Generating Set	1 No. of 70 KVA capacity
Rising Main	250mm dia C.I.

(5) Trilochan Ghat SPS:

Pump House	6.1m internal dia. sump cum pump house. Sump floor is 18.3m deep from Pump House floor. 3.65m internal dia and 18.63m deep special manhole
Pumping Plants	2 Nos. 35 HP 4100 lpm at 20.5m head 2 Nos. 12 HP 1365 lpm at 18.0m head
Diesel Generating Set	1 No. of 70 KVA capacity
Rising Main	300mm dia C.I.

(6) Assi MPS

Pump House	No details
Pumping Plants	3 Nos. 50 HP 5000 lpm at 24.0m head 1 No. 22.5 HP 3000 lpm at 15.0m head
Diesel Generating Set	1 No. of 70 KVA capacity
Rising Main	400mm dia 1940m long PSC Rising Main from Assi MPS to BHU STP

Table 7.8 Ghat Pumping Stations Analysis of Capacity

		Capacity of each pumping plant			Total pumping capacity at design head		Allowable at 5/4
		HP	Head (m)	Discharge (lp	lps	mld	lps
1 Harishchandra Ghat							
	1	50	24	5000	83.3	7.2	
	1	25	13.5	2600	43.3	3.7	
	1	10	9.5	1150	19.2	1.7	
				8750	145.8	12.6	116.7
2 Mansarovar Ghat	2	10	15	1300	43.3	3.7	
	3	25	21	2600	130.0	11.2	
				3900.0	173.3	15.0	138.7
3 RP Ghat	2	125	23	15000	500.0	43.2	
	2	75	22	8800	293.3	25.3	
				23800.0	793.3	68.5	634.7
4 Jalesan Ghat	2	30	20	3600	120.0	10.4	
	2	15	15	1200	40.0	3.5	
					160.0	13.8	128.0
5 Trilochan	2	35	20.5	4100	136.7	11.8	
	2	12.5	18	1365	45.5	3.9	
				5465.0	182.2	15.7	145.7

	Existing capacity at design			Estimated flow without sewerage improvements					
	Installed		allowable	2003		2015		2030	
	lpm	lps	lps	Avg (mld)	Peak (lps)	Avg (mld)	Peak (lps)	Avg (mld)	Peak (lps)
1 Harishchandra	8,750	146	116.7	8.0	232	7.1	206	6.2	179
2 Mansarovar	10,400	173	138.7	2.5	72	2.2	65	1.9	56
3 Dr. RP	47,600	793	634.7	25.0	723	22.3	644	19.4	560
4 Jalesan	9,600	160	128.0	3.8	109	3.3	97	2.9	84
5 Trilochan	10,930	182	145.7	7.3	210	6.5	187	5.6	162

	Existing capacity at design			Estimated flow without sewerage improvements					
	Installed		allowable	2003		2015		2030	
	lpm	lps	lps	Peak (lps)	Req'd capacity (lps)	Peak (lps)	Req'd capacity (lps)	Peak (lps)	Req'd capacity (lps)
1 Harishchandra	8,750	146	116.7	232	290	206	258	179	224
2 Mansarovar	10,400	173	138.7	72	90	65	81	56	70
3 Dr. RP	47,600	793	634.7	723	904	644	805	560	701
4 Jalesan	9,600	160	128.0	109	136	97	121	84	105
5 Trilochan	10,930	182	145.7	210	262	187	233	162	203

allowable capacity is installed/ 1.25 required capacity is peak flow x 1.25

Table 7.12 Dinapur STP Average Monthly Inflow and Effluent Characteristics

Month	Flow (mld)	Influent Sewage (Raw)			Effluent (Treated)			Overall Efficiency(%)			Remark
		BOD	COD	TSS	BOD	COD	TSS	BOD	COD	TSS	
Jan-00	83.92	167.30	348.00	438.00	24.69	73.57	79.28	85	79	82	
Feb-00	91.13	165.71	334.75	397.00	27.28	76.20	86.75	84	77	78	
Mar-00	81.34	178.00	350.96	433.56	27.92	80.29	84.52	84	77	81	
Apr-00	83.80	181.20	377.68		28.32	77.84		84	79		
May-00	72.21	181.92	386.57		28.30	84.14		84	78		
Jun-00	74.75	183.92	386.20	490.82	29.50	83.86	81.65	84	78	83	
Jul-00	70.62	180.71	384.57	441.14	30.78	91.28	82.21	83	76	81	
Aug-00	81.93	160.74	371.72	432.96	28.59	72.96	79.72	82	80	82	
Sep-00	80.00	149.23	358.00	440.07	27.69	77.07	75.70	81	78	83	
Oct-00	83.22	163.63	367.54	423.08	28.63	76.05	84.41	83	79	80	
Nov-00	78.14	161.90	371.04	428.88	30.38	75.84	85.36	81	80	80	
Dec-00	79.44	155.00	366.00	438.07	27.23	75.14	78.58	82	79	82	
Jan-01	66.20	161.78	348.88	463.29	28.00	76.85	84.37	83	78	82	
Feb-01	71.73	165.20	351.23	416.00	28.40	78.61	80.37	83	78	81	
Mar-01	77.74	169.31	363.68	441.28	28.63	81.60	89.76	83	78	80	
Apr-01	92.22	173.04	355.20	426.08	27.39	77.28	86.40	84	78	80	
May-01	82.18	191.60	379.03	455.56	29.28	81.71	87.48	85	78	81	
Jun-01	94.23	165.92	366.51	439.25	28.51	80.44	89.48	83	78	80	
Jul-01	54.01	174.13	382.13	468.68	31.03	88.41	94.20	82	77	80	
Aug-01	60.95	159.60	380.00	482.30	29.12	77.18	85.33	82	80	82	
Sep-01	63.71	174.00	386.00	499.42	31.00	93.64	100.00	82	76	80	
Oct-01	89.39	164.11	360.66	437.61	29.52	83.04	85.20	82	77	81	
Nov-01	78.16	179.00	406.33	475.00	29.77	85.88	89.29	83	79	81	
Dec-01	96.09	203.75	394.36	458.18	30.00	84.00	87.63	85	79	81	
Jan-02	67.12	171.00	352.00	483.00	30.00	87.00	91.00	82	75	81	
Feb-02	81.10	193.00	401.00	447.00	29.00	79.00	80.00	85	80	82	
Mar-02	97.49	179.00	377.00	472.00	29.00	82.00	88.00	84	78	81	
Apr-02	89.45	167.00	368.00	402.00	30.00	86.00	88.00	82	77	78	
May-02	79.32	180.00	366.00	486.00	29.00	88.00	86.00	84	76	82	
Jun-02	55.49	201.00	401.00	468.00	28.00	87.00	86.00	86	78	82	
Jul-02	72.59	178.00	380.00	470.00	28.00	79.00	76.00	84	79	84	
Aug-02	87.80	184.00	380.00	470.00	27.00	84.00	81.77	85	78	83	
AVG	78.67	173.87	371.94	450.81	28.75	81.40	85.15	83	78	81	

Actual Sewage Flow which Reached at STP Dinapur 80mld

Table 7.15 District 1 ; Dinapur STP: STP Process under Future Loading Conditions (Page 1 of 2)

	Parameter		Unit	Design Value	Existing 80 mld		Alternative1 90 mld		Alternative2 100 mld		Recommended	Metcalf &Eddy	Remarks
					without	after expansion	without	after expansion	without	after expansion			
Water quantity	Peak		m3/d	160,000	160,000	160,000	180,000	180,000	200,000	200,000			
	Average			80,000	80,000	80,000	90,000	90,000	100,000	100,000			
	Minimum			32,000	32,000	32,000	36,000	36,000	40,000	40,000			
Water quality	Influent BOD5		mg/l	300	174	174	300	300	300	300			
	Influent SS		mg/l	600	451	451	600	600	600	600			
	Effluent BOD5		mg/l	20	29	29	20	20	20	20			
	Effluent SS		mg/l	30	85	85	30	30	30	30			
Primary clarifiers	No of clarifier	Existing	No.	3	3	3	3	3	3	3			
		Expand	No.	0	0	0	0	0	0	0			
		Total	No.	3	3	3	3	3	3	3			
	Hydraulic overflow rate at average flow		$m^3/m^2/day$	35.0	34.9	34.9	39.2	39.2	43.6	43.6	35-50	30-50	
	Weir length	Existing	m	569.3	569.3	569.3	569.3	569.3	569.3	569.3			
		Expand1	m		0.0	275.2	0.0	275.2	0.0	275.2			for existing tank
		Expand2											from new tank
		Total	m	569.3	569.3	844.6	569.3	844.6	569.3	844.6			
	Weir loading at average flow		$m^3/m/day$	140.5	140.5	94.7	158.1	106.6	175.6	118.4	125(max)	125-500	
Aeration tank	No of tank	Existing	No.	3	3	3	3	3	3	3			
		Expand	No.	0	0	0	0	1	0	1			
		Total	No.	3	3	3	3	4	3	4			
	HRT		hr	3.5	4.1	4.1	3.6	4.8	3.2	4.3	4-5	3-5	
	MLSS		mg/l	2,500	2,500	2,500	2,500	2,500	2,500	2,500	3,000-4,000	1,500-4,000	
Secondary clarifier	No of clarifier	Existing	No.	3	3	3	3	3	3	3			
		Expand	No.	0	0	0	0	1	0	1			
		Total	No.	3	3	3	3	4	3	4			
	Hydraulic overflow rate at average flow +recircuration		$m^3/m^2/day$	28.1	28.1	28.1	31.8	23.9	35.3	26.5	15-35	16-28	

Table 7.15 District 1 ; Dinapur STP: STP Process under Future Loading Conditions (Page 2 of 2)

	Parameter		Unit	Design Value	Existing		Alternative1		Alternative2		Recommended	Metcalf &Eddy	Remarks
					80 mld		90 mld		100 mld				
					without	after expansion	without	after expansion	without	after expansion			
Secondary clarifier													
	Weir length	Existing	m	377.0	377.0	377.0	377.0	377.0	377.0	377.0			
		Expand1	m		0.0	367.6	0.0		0.0	367.6			for existing tank
		Expand2						125.7		248.2			from new tank
		Total	m	377.0	377.0	744.7	377.0	502.7	377.0	992.9			
	Weir loading		m^3/m/day	212.2	212.2	107.4	238.7	179.0	265.2	100.7	185(max)	-	
	Solids loading		kg/m^3/day	84.4	70.3	70.3	79.6	59.7	88.2	66.1	70-140	5-7(kg/m3/hr)	
Anearobic sludge digesters	No of digester	Existing	No.	3	3	3	3	3	3	3			
		Expand	No.	0	0	0	0	1	0	1			
		Total	No.	3	3	3	3	4	3	4			
	Minimum solids retention time at 30℃		days	15.0	23.5	23.5	13.4	18.1	12.0	16.2	14(min)	14(min)	
	Additional storage capacity		days	-	-	-	-	-	-	-	10-15	-	
Sludge drying bed	Depth of sludge		m	0.225	0.225	0.225	0.225	0.250	0.225	0.270	≦0.3		
	Required area		m2	24,195	15,283	15,283	27,338	24,318	30,482	25,136			
	Total area	Existing	m2	25,327	25,327	25,327	25,327	25,327	25,327	25,327			
		Expand	m2										
		Total	m2	25,327	25,327	25,327	25,327	25,327	25,327	25,327			
Gas holder	No of gas holder	Existing	No.	2	2	2	2	2	2	2			
		Expand	No.	0	0	0	0	0	0	0			
		Total	No.	2	2	2	2	2	2	2			
	Gas volume		m3	12,601	7,303	7,303	14,176	14,176	15,751	15,751			
	Volume of gas holder		m3	6,027	6,027	6,027	6,027	6,027	6,027	6,027			

Table 7.17 Hydraulic Capacity Calculations : Relief Sewer (Page 1 of 2), 2015

Node		Contributory Population		Design Flow (lps)	Total Flow including diversion (lps)	Size (mm)	Length (m)	Gradient	Invert level (m)		Ground level (m)		Covering (m)		Full pipe capacity		Design capacity		Sub Catchment
From	To	Each	Cumulative						u/s	d/s	u/s	d/s	u/s	d/s	Velocity (m/s)	Discharge (l/s)	Velocity (m/s)	Discharge (l/s)	
RTS-1	RTS-7	5,192	5,192	27		600	390	900	72.000	71.390	75.23	75.42	2.55	3.35	0.63	178	0.72	172	2-1
RTS-7	RTS-12	0	5,192	27		600	420	900	71.290	70.743	75.42	76.09	3.45	4.67	0.63	178	0.72	172	
RTS-12	RTS-19	24,699	29,891	135		600	540	900	70.643	69.983	76.09	77.20	4.77	6.54	0.63	178	0.72	172	2-2
RTS-19	RTS-24	0	29,891	135		700	390	1,000	69.899	69.419	77.20	77.28	6.52	7.08	0.66	254	0.75	246	
RTS-24	RTS-27	0	29,891	135		800	180	1,000	69.329	69.109	77.28	77.20	7.06	7.20	0.72	363	0.82	351	
RTS-27	RTS-30	54,687	84,578	342		900	270	1,500	69.089	68.869	77.20	76.94	7.11	7.07	0.64	405	0.73	392	2-4
RTS-30	RTS-34	0	84,578	342		1,000	420	1,500	68.769	68.429	76.94	75.09	7.07	5.56	0.68	537	0.78	520	
RTS-34	RTS-37	7,778	92,356	374		1,200	230	2,000	68.229	68.074	75.09	73.99	5.55	4.60	0.67	757	0.76	733	2-5
RTS-37	RTS-42	0	92,356	374		1,200	520	2,000	68.020	67.680	73.99	75.72	4.66	6.72	0.67	757	0.76	733	
RTS-42	RTS-47	53,154	145,510	587		1,400	450	2,200	67.480	67.195	75.12	77.03	6.11	8.30	0.71	1087	0.81	1,052	2-10
RTS-47	RTS-50	15,328	160,838	650		1,600	300	2,500	66.955	66.807	77.03	78.05	8.34	9.50	0.72	1456	0.83	1,409	2-13
RTS-50	RTS-53	31,919	192,757	779		1,600	330	2,500	66.787	66.615	78.05	77.83	9.52	9.48	0.72	1456	0.83	1,409	2-15
RTS-53	RTS-57	28,726	221,483	893		1,600	480	2,500	66.600	66.348	77.83	77.05	9.49	8.96	0.72	1456	0.83	1,409	2-17
RTS-57	RTS-64	10,181	231,664	936		1,600	720	2,500	66.248	65.840	77.05	76.86	9.06	9.28	0.72	1456	0.83	1,409	2-19
RTS-64	RTS-71	39,263	270,927	1,094		1,600	720	2,500	65.780	65.148	76.86	75.89	9.34	9.00	0.72	1456	0.83	1,409	2-21
Diversion from OTS	RTS-71	617 lps (peak) 23.7 MLD (Ave.)		617															
RTS-71	RTS-76	27,153	298,080	1,204	1,821	1,800	420	2,500	65.128	64.924	75.89	73.52	8.81	6.65	0.78	1992	0.89	1,928	2-23
RTS-76	RTS-79	31,193	329,273	1,330	1,947	2,000	240	2,500	64.724	64.588	73.52	75.03	6.63	8.27	0.84	2639	0.96	2,555	2-24
RTS-79	RTS-86	91,530	420,803	1,699	2,316	2,000	680	2,500	64.568	64.176	75.03	72.70	8.29	6.35	0.84	2639	0.96	2,555	2-26
RTS-86	SMH		420,803	1,699	2,316	2,000	250	2,500	64.126	63.986	72.70	73.16	6.40	7.00	0.84	2639	0.96	2,555	

Manning's N;	0.015

Table 7.17 Hydraulic Capacity Calculations : Relief Sewer (Page 2 of 2), 2030

Node		Contributory Population		Design Flow (lps)	Total Flow including diversion (lps)	Size (mm)	Length (m)	Gradient	Invert level (m)		Ground level (m)		Covering (m)		Full pipe capacity		Design capacity		Sub Catchment
From	To	Each	Cumulative						u/s	d/s	u/s	d/s	u/s	d/s	Velocity (m/s)	Discharge (l/s)	Velocity (m/s)	Discharge (l/s)	
RTS-1	RTS-7	6,528	6,528	36		600	390	900	72.000	71.390	75.23	75.42	2.55	3.35	0.63	178	0.72	172	2-1
RTS-7	RTS-12	0	6,528	36		600	420	900	71.290	70.743	75.42	76.09	3.45	4.67	0.63	178	0.72	172	
RTS-12	RTS-19	30,773	37,301	168		600	540	900	70.643	69.983	76.09	77.20	4.77	6.54	0.63	178	0.72	172	2-2
RTS-19	RTS-24	0	37,301	168		700	390	1,000	69.899	69.419	77.20	77.28	6.52	7.08	0.66	254	0.75	246	
RTS-24	RTS-27	0	37,301	168		800	180	1,000	69.329	69.109	77.28	77.20	7.06	7.20	0.72	363	0.82	351	
RTS-27	RTS-30	66,024	103,325	416		900	270	1,500	69.089	68.869	77.20	76.94	7.11	7.07	0.64	405	0.73	392	2-4
RTS-30	RTS-34	0	103,325	416		1,000	420	1,500	68.769	68.429	76.94	75.09	7.07	5.56	0.68	537	0.78	520	
RTS-34	RTS-37	10,110	113,435	459		1,200	230	2,000	68.229	68.074	75.09	73.99	5.55	4.60	0.67	757	0.76	733	2-5
RTS-37	RTS-42	0	113,435	459		1,200	520	2,000	68.020	67.680	73.99	75.72	4.66	6.72	0.67	757	0.76	733	
RTS-42	RTS-47	72,679	186,114	752		1,400	450	2,200	67.480	67.195	75.12	77.03	6.11	8.30	0.71	1087	0.81	1,052	2-10
RTS-47	RTS-50	19,811	205,925	830		1,600	300	2,500	66.955	66.807	77.03	78.05	8.34	9.50	0.72	1456	0.83	1,409	2-13
RTS-50	RTS-53	39,797	245,722	992		1,600	330	2,500	66.787	66.615	78.05	77.83	9.52	9.48	0.72	1456	0.83	1,409	2-15
RTS-53	RTS-57	33,039	278,761	1,125		1,600	480	2,500	66.600	66.348	77.83	77.05	9.49	8.96	0.72	1456	0.83	1,409	2-17
RTS-57	RTS-64	11,842	290,603	1,172		1,600	720	2,500	66.248	65.840	77.05	76.86	9.06	9.28	0.72	1456	0.83	1,409	2-19
RTS-64	RTS-71	57,126	347,729	1,404		1,600	720	2,500	65.780	65.148	76.86	75.89	9.34	9.00	0.72	1456	0.83	1,409	2-21
Diversion from OTS	RTS-71	357 lps (peak) 13.7 MLD (Ave.)		357															
RTS-71	RTS-76	28,710	376,439	1,519	1,876	1,800	420	2,500	65.128	64.924	75.89	73.52	8.81	6.65	0.78	1992	0.89	1,928	2-23
RTS-76	RTS-79	47,226	423,665	1,710	2,067	2,000	240	2,500	64.724	64.588	73.52	75.03	6.63	8.27	0.84	2639	0.96	2,555	2-24
RTS-79	RTS-86	98,090	521,755	2,106	2,463	2,000	680	2,500	64.568	64.176	75.03	72.70	8.29	6.35	0.84	2639	0.96	2,555	2-26
RTS-86	SMH		521,755	2,106	2,463	2,000	250	2,500	64.126	63.986	72.70	73.16	6.40	7.00	0.84	2639	0.96	2,555	

Manning's N;	0.015

Table 7.19 Hydraulic Calculation for Pipe Sizing: District 2

Node		Contributory Population		Design Flow (lps)	Total Flow including diversion (lps)	Size (mm)	Length (m)	Gradient	Invert level (m)		Ground level (m)		Covering (m)		Full pipe capacity		Design capacity		Sub Catchment	Remarks
From	To	Each	Cumulative						u/s	d/s	u/s	d/s	u/s	d/s	Velocity (m/s)	Discharge (l/s)	Velocity (m/s)	Discharge (l/s)		
RTS-1	RTS-7	6,528	6,528	36		600	390	900	72.000	71.390	75.23	75.42	2.55	3.35	0.63	178	0.72	172	2-1	
RTS-7	RTS-12	0	6,528	36		600	420	900	71.290	70.743	75.42	76.09	3.45	4.67	0.63	178	0.72	172		
RTS-12	RTS-19	30,773	37,301	168		600	540	900	70.643	69.983	76.09	77.20	4.77	6.54	0.63	178	0.72	172	2-2	
RTS-19	RTS-24	0	37,301	168		700	390	1,000	69.899	69.419	77.20	77.28	6.52	7.08	0.66	254	0.75	246		
RTS-24	RTS-27	0	37,301	168		800	180	1,000	69.329	69.109	77.28	77.20	7.06	7.20	0.72	363	0.82	351		
1	RTS-27	46,314	46,314	208		700	1,050	1,000	74.220	73.170	77.00	77.20	2.00	3.25	0.66	254	0.75	246	2-3	
RTS-27	RTS-30	19,710	103,325	416		900	270	1,500	69.089	68.869	77.20	76.94	7.11	7.07	0.64	405	0.73	392	2-4	
RTS-30	RTS-34	0	103,325	416		1,000	420	1,500	68.769	68.429	76.94	75.09	7.07	5.56	0.68	537	0.78	520		
RTS-34	RTS-37	10,110	113,435	459		1,200	230	2,000	68.229	68.074	75.09	73.99	5.55	4.60	0.67	757	0.76	733	2-5	
RTS-37	RTS-42	0	113,435	459		1,200	520	2,000	68.020	67.680	73.99	75.72	4.66	6.72	0.67	757	0.76	733		
2	4	11,780	11,780	63		500	500	700	74.920	74.020	77.50	76.60	2.00	2.00	0.63	124	0.72	120	2-6	
3	4	32,807	32,807	148		600	1,250	900	74.320	72.930	77.00	76.60	2.00	2.99	0.63	178	0.72	172	2-7	
4	RTS-42	8,219	52,806	214		700	1,100	1,000	72.830	71.730	76.60	75.72	2.99	3.21	0.66	254	0.75	246	2-8	
5	RTS-42	14,984	14,984	81		500	950	700	74.420	73.060	77.00	75.72	2.00	2.08	0.63	124	0.72	120	2-9	
RTS-42	RTS-47	4,889	186,114	752		1,400	450	2,200	67.480	67.195	75.12	77.03	6.11	8.30	0.71	1,087	0.81	1,052	2-10	
6	RTS-47	9,493	9,493	51		500	1,000	700	74.020	72.590	76.60	77.03	2.00	3.86	0.63	124	0.72	120	2-11	
7	RTS-47	8,203	8,203	45		500	680	700	73.720	72.750	76.30	77.03	2.00	3.70	0.63	124	0.72	120	2-12	
RTS-47	RTS-50	2,115	205,925	830		1,600	300	2,500	66.955	66.807	77.03	78.05	8.34	9.50	0.72	1,456	0.83	1,409	2-13	
8	RTS-50	28,446	28,446	128		500	1,450	700	74.920	72.850	77.50	78.05	2.00	4.62	0.63	124	0.72	120	2-14	
RTS-50	RTS-53	11,351	245,722	992		1,600	330	2,500	66.787	66.615	78.05	77.83	9.52	9.48	0.72	1,456	0.83	1,409	2-15	
9	RTS-53	12,216	12,216	66		500	950	700	74.920	73.560	77.50	77.83	2.00	3.69	0.63	124	0.72	120	2-16	
RTS-53	RTS-57	20,823	278,761	1,125		1,600	480	2,500	66.600	66.348	77.83	77.05	9.49	8.96	0.72	1,456	0.83	1,409	2-17	
10	RTS-57	5,036	5,036	27		500	600	700	73.920	73.060	76.50	77.05	2.00	3.41	0.63	124	0.72	120	2-18	
RTS-57	RTS-64	6,806	290,603	1,172		1,600	720	2,500	66.248	65.840	77.05	76.86	9.06	9.28	0.72	1,456	0.83	1,409	2-19	
11	RTS-64	46,421	46,421	208		700	1,600	1,000	75.220	73.620	78.00	76.86	2.00	2.46	0.66	254	0.75	246	2-20	
RTS-64	RTS-71	10,705	347,729	1,404		1,600	720	2,500	65.780	65.148	76.86	75.89	9.34	9.00	0.72	1,456	0.83	1,409	2-21	

Table 7.19 Hydraulic Calculation for Pipe Sizing: District 2

Node		Contributory Population		Design Flow (lps)	Total Flow including diversion (lps)	Size (mm)	Length (m)	Gradient	Invert level (m)		Ground level (m)		Covering (m)		Full pipe capacity		Design capacity		Sub Catchment	Remarks
From	To	Each	Cumulative						u/s	d/s	u/s	d/s	u/s	d/s	Velocity (m/s)	Discharge (l/s)	Velocity (m/s)	Discharge (l/s)		
Diversion from OTS	RTS-71	337 lps (peak) 13.7 MLD (Ave.)		357																
12	RTS-71	9,045	9,045	48		500	600	700	72.920	72.060	75.50	75.89	2.00	3.25	0.63	124	0.72	120	2-22	
RTS-71	RTS-76	19,665	376,439	1,519	1,876	1,800	420	2,500	65.128	64.924	75.89	73.52	8.81	6.65	0.78	1,992	0.89	1,928	2-23	
RTS-76	RTS-79	47,226	423,665	1,710	2,067	2,000	240	2,500	64.724	64.588	73.52	75.03	6.63	8.27	0.84	2,639	0.96	2,555	2-24	
13	RTS-79	79,313	79,313	320		900	1,050	1,500	72.730	72.030	76.50	75.03	2.77	2.00	0.64	405	0.73	392	2-25	
RTS-79	RTS-86	18,777	521,755	2,106	2,463	2,000	680	2,500	64.568	64.176	75.03	72.70	8.29	6.35	0.84	2,639	0.96	2,555	2-26	
RTS-86	SMH	0	521,755	2,106	2,463	2,000	250	2,500	64.126	63.986	72.70	73.16	6.40	7.00	0.84	2,639	0.96	2,555		
Varuna Right Bank Interceptor																				
VRI-1	SMH	20,873	20,873	93		500	4,700	700	64.92	58.21	67.50	73.16	2.00	14.37	0.63	124	0.72	120	2-27	
VRI-2	SMH	48,046	48,046	215		700	2,500	1,000	63.92	61.42	66.70	73.16	2.00	10.96	0.66	254	0.75	246	2-28	
SMH	Chauka SPS	0	590,674	2,385	2,742	2,200	400	2,500	55.00	54.84	73.16	73.10	15.79	15.89	0.90	3,402	1.02	3,293		Crossing Varuna River
Varuna Left Bank Interceptor																				
VLI-1	VLI-2	14,755	14,755	78		500	1,450	700	64.92	62.85	67.50	67.40	2.00	3.97	0.63	124	0.72	120	2B-1	
14	VLI-2	59,201	59,201	239		700	1,850	1,000	74.22	64.62	77.00	67.40	2.00	2.00	0.66	254	0.75	246	2B-2	
VLI-2	VLI-3	7,216	81,172	329		800	1,000	1,000	62.55	61.55	67.40	67.70	3.96	5.26	0.72	363	0.82	351	2B-3	
15	VLI-3	20,021	20,021	90		500	1,250	700	74.92	65.12	77.50	67.70	2.00	2.00	0.63	124	0.72	120	2B-4	
VLI-3	VLI-4	9,662	110,855	448		1,000	1,850	1,500	61.45	60.22	67.70	67.00	5.15	5.68	0.68	537	0.78	520	2B-5	
16	VLI-4	52,720	52,720	214		700	2,650	1,000	74.72	64.22	77.50	67.00	2.00	2.00	0.66	254	0.75	246	2B-6	
VLI-4	Chauka SPS		163,575	659		1,200	400	2,000	59.92	59.72	67.00	73.10	5.77	12.07	0.67	757	0.76	733		
From Salnath	VLI-5	215,724	215,724	871		800	1,200								1.73				NSA 1	Rising Main
VLI-5	VLI-6	5,452	221,176	893		1,400	1,000	2,200	63.47	63.02	67.00	67.80	2.00	3.24	0.71	1,087	0.81	1,052	2B-7	
VLI-6	Chauka SPS	33,749	254,925	1,028		1,400	1,500	2,200	63.02	62.34	67.80	73.10	3.24	9.22	0.71	1,087	0.81	1,052	2B-8	
Chauka SPS	TS-101		1,009,174	4,073	4,430	1,600	1,650		69.36	74.26	73.10	78.00	2.00	2.00	2.20					Rising Main

Table 7.19 Hydraulic Calculation for Pipe Sizing: District 2

Node		Contributory Population		Design Flow (lps)	Total Flow including diversion (lps)	Size (mm)	Length (m)	Gradient	Invert level (m)		Ground level (m)		Covering (m)		Full pipe capacity		Design capacity		Sub Catchment	Remarks
From	To	Each	Cumulative						u/s	d/s	u/s	d/s	u/s	d/s	Velocity (m/s)	Discharge (l/s)	Velocity (m/s)	Discharge (l/s)		
Trans-Varuna District																				
TS-101	TS-102	9,872	1,019,046	4,113	4,470	2,400	850	2,500	73.43	73.09	78.00	78.10	2.00	2.44	0.95	4,293	1.08	4,156	2C-1	
TS-102	TS-103	9,730	1,028,776	4,154	4,511	2,400	850	2,500	73.04	72.70	78.10	78.10	2.49	2.83	0.95	4,293	1.08	4,156	2C-2	
TS-103	TS-104	6,803	1,035,579	4,181	4,538	2,400	300	2,500	72.65	72.53	78.10	78.10	2.88	3.00	0.95	4,293	1.08	4,156	2C-3	
17	18	7,070	7,070	39		500	550	700	74.71	73.92	78.00	76.50	2.71	2.00	0.63	124	0.72	120	2C-4	
18	20	24,943	32,013	143		600	750	900	73.92	73.09	76.50	75.50	1.90	1.73	0.63	178	0.72	172	2C-5	
19	20	9,850	9,850	54		600	1,250	900	72.32	70.93	75.00	75.50	2.00	3.89	0.63	178	0.72	172	2C-6	
20	Sathwa-1 SPS	18,836	60,699	245		700	1,300	1,000	70.83	69.53	75.50	75.00	3.89	4.69	0.66	254	0.75	246	2C-7	
21	22	8,746	8,746	48		500	1,200	700	74.42	72.71	77.00	76.60	2.00	3.31	0.63	124	0.72	120	2C-8	
22	24	1,613	10,359	57		500	550	700	72.71	71.92	76.60	76.50	3.31	4.00	0.63	124	0.72	120	2C-9	
23	24	4,754	4,754	27		500	400	700	74.42	73.85	77.00	76.60	2.00	2.17	0.63	124	0.72	120	2C-10	
24	Sathwa-1 SPS	19,079	34,192	153		600	850	900	71.92	70.98	77.00	76.60	4.40	4.94	0.63	178	0.72	172	2C-11	
Sathwa-1 SPS	TS-104		94,891	383		500	1,250								1.95					Rising Main
TS-104	TS-105	1,474	1,131,944	4,570	4,927	2,400	1,100	2,500	72.48	72.04	78.10	78.20	3.05	3.59	0.95	4,293	1.08	4,156	2C-12	Dual Pipeline
28	30	35,597	35,597	160		600	1,200	900	76.75	75.42	79.90	78.10	2.47	2.00	0.63	178	0.72	172	2C-13	
29	30	22,256	22,256	100		500	1,050	700	74.42	72.92	77.00	78.10	2.00	4.60	0.63	124	0.72	120	2C-14	
30	31	12,421	70,274	284		800	1,100	1,000	72.62	71.52	78.10	79.60	4.59	7.19	0.72	363	0.82	351	2C-15	
31	35	4,106	74,380	299		800	700	1,000	71.52	70.82	79.60	78.90	7.19	7.19	0.72	363	0.82	351	2D-1	
32	33	36,195	36,195	163		600	1,650	900	75.92	74.09	78.60	78.90	2.00	4.13	0.63	178	0.72	172	2C-16	
33	35	1,908	38,103	170		700	300	1,000	73.99	73.69	78.90	78.90	4.13	4.43	0.66	254	0.75	246	2D-2	
34	35	20,048	20,048	90		500	950	700	76.02	74.66	78.60	78.90	2.00	3.66	0.63	124	0.72	120	2D-3	
35	39	3,830	136,361	551		1,200	1,500	2,000	70.32	69.57	78.90	78.50	7.27	7.62	0.67	757	0.76	733	2D-4	
36	38	40,934	40,934	183		700	1,500	1,000	75.12	73.62	77.90	77.00	2.00	2.60	0.66	254	0.75	246	2C-17	
37	38	20,419	20,419	93		500	900	700	75.52	74.23	78.10	77.00	2.00	2.19	0.63	124	0.72	120	2C-18	
38	39	9,074	70,427	284		800	1,000	1,000	73.52	72.52	77.00	77.10	2.59	3.69	0.72	363	0.82	351	2C-19	

Table 7.19 Hydraulic Calculation for Pipe Sizing: District 2

Node		Contributory Population		Design Flow (lps)	Total Flow including diversion (lps)	Size (mm)	Length (m)	Gradient	Invert level (m)		Ground level (m)		Covering (m)		Full pipe capacity		Design capacity		Sub Catchment	Remarks
From	To	Each	Cumulative						u/s	d/s	u/s	d/s	u/s	d/s	Velocity (m/s)	Discharge (l/s)	Velocity (m/s)	Discharge (l/s)		
39	Sathwa-2 SPS		206,788	835		1,400	1,100	2,200	69.37	68.87	77.10	78.20	6.20	7.80	0.71	1,087	0.81	1,052		
Sathwa-2 SPS	TS-105		206,788	835		800	100								1.66					
TS-105	Sathwa STP		1,338,732	5,405	5,762	2,200	1,400	2,500	71.84	71.28	78.20	78.20	3.99	4.55	0.90	3,402	1.02	3,293		

Manning's N;	0.015

RTS: Relief Trunk Sewer
VRI: Varuna Right Bank Interceptor
VLI: Varuna Left Bank Interceptor

SMH: Special Manhole
TS: Trunk Sewer (down stream of Chaukaghat PS)

Table 7.20 Proposed Pumping Stations

Peak (pk)	2
Average (avg)	1
Non-peak (npk)	0.5

Pump stations		Stage-I requirement 2015										
		Required capacity	Design Discharge (lps)			Proposed pumps					Rising Main	
		(lps)	pk	avg	npk	No.	head (m)	kw	lps	Total lps)	dia. (m)	length (m)
Chaukaghat MPS	P	5,556	3,704	1,852	926	12	30	210	467	5,604	2 x 1200	1,800
Sathwa no.1	P	417	278	139	69	2	10	15	100	350	600	100
						2	8	10	75			
Sathwa no.2	P	972	648	324	162	3	8	25	220	1,010	800	100
						2	8	20	175			
Nagwa nala SPS	S	1,285	856	428	214	2	20	85	500	1,500	1,100	7,000
						2	15	35	250			
Narokar Nala SPS	P	625	417	208	104	6	20	42	110	660	800	1,600

Pump stations		Ultimate requirement - 2030										
		Required capacity	Design Discharge (lps)			Proposed pumps					Rising Main	
		(lps)	pk	avg	npk	No.	head (m)	kw	lps	Total lps)	dia. (m)	length (m)
Chaukaghat MPS	P	5,903	3,935	1,968	984	12	30	210	500	6,000	2 x 1200	1,800
Sathwa no.1	P	590	394	197	98	3	10	15	100	600	600	100
						3	8	10	100			
Sathwa no.2	P	1,250	833	417	208	3	8	25	210	1,260	800	100
						3	8	20	210			
Nagwa nala SPS	S	1,736	1,157	579	289	3	20	85	500	2,000	1,100	7,000
						2	15	35	250			
Narokar Nala SPS	P	1,181	787	394	197	10	22	45	110	1,100	800	1,600

Pump stations		Design Discharge (lps)			Design Holding Time	Required sump capacity
		pk	avg	npk	(min)	2030
Chaukaghat MPS	P	3,935	1,968	984	5.0	1,181
Sathwa no.1	P	394	197	98	5.0	118
			-			
Sathwa no.2	P	833	417	208	5.0	250
			-			
Nagwa nala SPS	S	1,157	579	289	5.0	347
			-			
Narokar Nala SPS	P	787	394	197	5.0	236

Table 7.22 Hydraulic Calculation for Pipe Sizing: District 3

Node		Contributory Population		Design Flow (lps)	Size (mm)	Length (m)	Gradient	Invert level (m)		Ground level (m)		Covering (m)		Full pipe capacity		Design capacity		Sub Catchment	Remarks
From	To	Each	Cumulative					u/s	d/s	u/s	d/s	u/s	d/s	Velocity (m/s)	Discharge (l/s)	Velocity (m/s)	Discharge (l/s)		
Left Bank Interceptor																			
1	ALI-1	14,758	14,758	78	500	1,700	700	73.35	70.92	77.50	73.50	3.57	2.00	0.63	124	0.72	120	3-1	
ALI-1	ALI-2	0	14,758	78	500	150	700	70.92	70.71	73.50	74.70	2.00	3.41	0.63	124	0.72	120		
2	ALI-2	52,702	52,702	214	700	1,300	1,000	73.22	71.92	77.50	74.70	3.50	2.00	0.66	254	0.75	246	3-2	
ALI-2	ALI-3	0	67,460	272	800	130	1,000	70.41	70.28	74.70	75.00	3.40	3.83	0.72	363	0.82	351		
3	ALI-3	15,408	15,408	84	500	900	700	72.92	71.63	75.50	75.00	2.00	2.79	0.63	124	0.72	120	3-3	
ALI-3	ALI-4	11,853	94,721	383	900	1,800	1,500	70.18	68.98	75.00	73.00	3.82	3.02	0.64	405	0.73	392	3-4	
4	ALI-4	6,374	6,374	33	500	450	700	70.92	70.28	73.50	73.00	2.00	2.14	0.63	124	0.72	120	3-5	
ALI-4	Nagwa SPS	16,343	117,438	475	1,000	1,350	1,500	68.98	68.08	73.00	71.00	2.92	1.82	0.68	537	0.78	520	3-6	
Right Bank Interceptor																			
5	ARI-1	41,719	41,719	188	700	750	1,000	72.22	71.47	75.00	75.00	2.00	2.75	0.66	254	0.75	246	3-7	
ARI-1	ARI-2	16,499	58,218	234	700	2,300	1,000	71.47	69.17	75.00	72.30	2.75	2.35	0.66	254	0.75	246	3-8	
6	ARI-2	47,198	47,198	213	700	600	1,000	70.12	69.52	75.00	72.30	4.10	2.00	0.66	254	0.75	246	3-9	
ARI-2	ARI-3	13,038	118,454	479	1,000	1,200	1,500	68.97	68.17	72.30	72.00	2.23	2.73	0.68	537	0.78	520	3-10	
7	ARI-3	55,296	55,296	223	700	650	1,000	69.87	69.22	73.50	72.00	2.85	2.00	0.66	254	0.75	246	3-11	
ARI-3	Nagwa SPS	0	173,750	702	1,200	250	2,000	68.17	68.05	72.00	71.00	2.52	1.64	0.67	757	0.76	733		
From Nagwa SPS to Ramna STP																			
Nagwa SPS	8	0	291,188	1,175	1,000	2,300	-	68.82	67.82	71.00	70.00	1.08	1.08	1.50					Rising Main
8	9	52,661	343,849	1,388	1,600	1,700	2,500	66.26	65.58	70.00	71.00	2.00	3.68	0.72	1,456	0.83	1,409	3-121314	
9	11	0	343,849	1,388	1,600	1,200	2,500	65.58	65.10	71.00	72.00	3.68	5.16	0.72	1,456	0.83	1,409		

Table 7.22 Hydraulic Calculation for Pipe Sizing: District 3

Node		Contributory Population		Design Flow (lps)	Size (mm)	Length (m)	Gradient	Invert level (m)		Ground level (m)		Covering (m)		Full pipe capacity		Design capacity		Sub Catchment	Remarks
From	To	Each	Cumulative					u/s	d/s	u/s	d/s	u/s	d/s	Velocity (m/s)	Discharge (l/s)	Velocity (m/s)	Discharge (l/s)		
BHU	10																	3-00	Rising Main
10	11	79,550	79,550	322	700	4,400	2,200				72.00	1.50	1.50	0.84	323			3-15,16	Rising Main
11	Ramna STP	0	423,399	1,710	1,800	500	2,500	64.90	64.70	72.00	72.00	4.76	5.35	0.78	1,992	0.89	1,928		
12	Ramna STP	50,570	50,570	205	700	1,000	900	69.22	68.11	72.00	72.00	2.00	3.11	0.70	268	0.79	259	3-17	

Manning's N;	0.015

		Population
BHU	To Node 5	36,718
(3-18)	To Node 6	36,718
	To Node 7	36,718
	Total	110,154

Table 7.25 Bhagwanpur STP Average Monthly Inflow and Effluent Characteristics

Month	Flow	Influent Sewage (Raw)			Effluent (Treated)			Overall Efficiency(%)			Remark
	(mld)	BOD	COD	TSS	BOD	COD	TSS	BOD	COD	TSS	
Jan	12.47	98	218	185	22	48	22	78	78	88	
Feb	11.42	92	180	176	15	32	17	84	82	90	
Mar	10.20	98	176	250	18	65	20	82	63	92	
Apr	10.66	92	140	195	18	76	19	80	46		
May	11.92	102	173	230	15	52	22	85	70		
Jun	12.20	110	196	151	20	41	17	82	79	89	
Jul	14.62	96	215	164	14	54	18	85	75	89	
Aug	16.72	79	156	158	22	70	16	72	55	90	
Sep	15.62	72	150	156	12	36	19	83	76	88	
Oct	16.00	76	184	175	12	52	18	84	72	90	
Nov	16.62	97	275	182	16	83	22	84	70	88	
Dec	15.75	98	160	178	15	38	20	85	76	89	
AVG	13.68	93	179	183	17	54	19	82	70	89	

Note; The above values are monthly average fig derived from the late three years test report(1999-2001)

Table 7.28 Bhagwanpur STP: STP Process under Future Loading Conditions, District 3

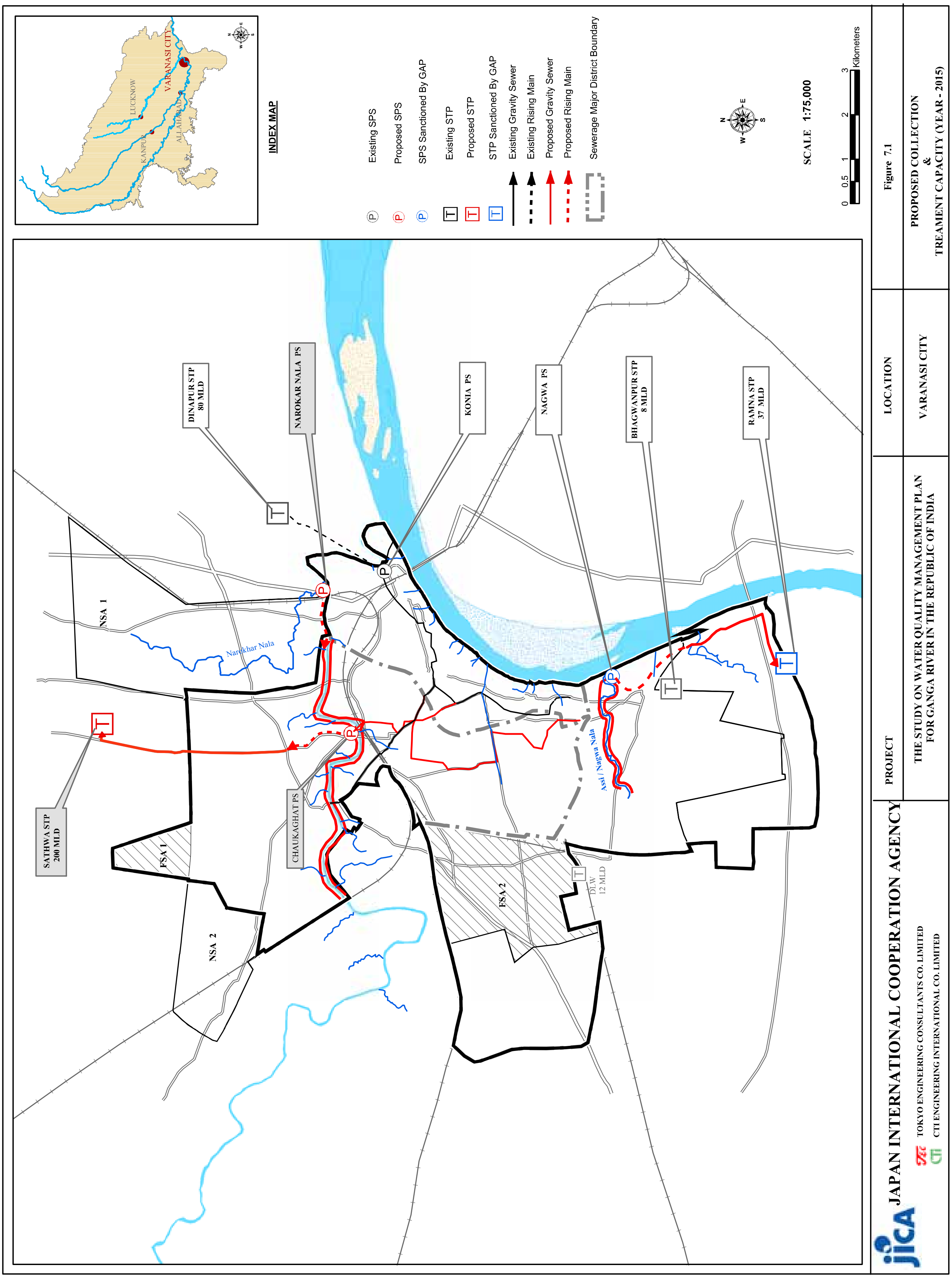
	Parameter		Unit	Design Value	CPHEEO standard	Metcalf &Eddy	Existing condition actual flow 13.7 mld			Future loading 15 mld		
							no modification	modification option 1	modification option 2	no modification	modification option 1	modification option 2
Water quantity	Peak		m3/d	20,000			34,250	34,250	34,250	37,500	37,500	37,500
	Average			8,000			13,700	13,700	13,700	15,000	15,000	15,000
	Minimum			4,000			6,850	6,850	6,850	7,500	7,500	7,500
Water quality	Influent BOD5		mg/l	300			93	93	93	300	300	300
	Influent SS		mg/l	600			183	183	183	600	600	600
	Effluent BOD5		mg/l	20			17	17	17	20	20	20
	Effluent SS		mg/l	30			19	19	19	30	30	30
Primary clarifiers	No of clarifier	Existing	No.	2			2	2	2	2	2	2
		Expand	No.	0			0	0	0	0	0	0
		Total	No.	2			2	2	2	2	2	2
	Hydraulic overflow rate at average flow		$m^3/m^2/day$	23.9	35-50	30-50	40.9	40.9	40.9	44.8	44.8	44.8
	Weir length	Existing	m	91.7			91.7	91.7	91.7	91.7	91.7	91.7
		additional	m					85.5	85.5	85.5	85.5	85.5
		Total	m	91.7			91.7	177.2	177.2	177.2	177.2	177.2
	Weir loading at average flow		$m^3/m/day$	87.2	125.0	125-500	149.3	77.3	77.3	84.6	84.6	84.6
Aeration tank	No of tank	Existing	No.	2			2	2	2	2	2	2
		additional	No.	0				1	2	0	1	2
		Total	No.	2			2	3	4	2	3	4
	HRT		hr	4.0	4-5	3-5	2.3	3.5	4.7	2.1	3.2	4.3
	MLSS		mg/l	3,000	3,000-4,000	1,500-4,000	(1,500)	(1,500)	(1,500)	3,000	3,000	3,000
Secondary clarifier	No of clarifier	Existing	No.	2			2	2	2	2	2	2
		Expand	No.	0				1	1	0	1	2
		Total	No.	2			2	3	3	2	3	4
	Hydraulic overflow rate at average flow		$m^3/m^2/day$	19.9	15-35	16-28	34.1	22.7	22.7	37.3	24.9	18.7
Secondary clarifier	Weir length	Existing	m	100.5			100.5	100.5	100.5	100.5	100.5	100.5
		additional						50.3	50.3		50.3	100.5
		Total	m	100.5			100.5	150.8	150.8	100.5	150.8	201.1
	Weir loading		$m^3/m/day$	79.6	185(max)	-	136.3	90.8	90.8	149.2	99.5	74.6
	Solids loading		$kg/m^3/day$	119.4	70-140	-7(kg/m3/hr)	102.2	68.1	68.1	223.8	149.2	111.9
Anearobic sludge digesters	No of digester	Existing	No.	2			2	2	2	2	2	2
		Expand	No.	0			0	0	0	0	0	0
		Total	No.	2			2	2	2	2	2	2
	Minimum solids retention time at 30℃		days	48.6	14(min)	14(min)	105.2	110.2	115.7	24.9	25.5	26.1
	Additional storage capacity		days	-	10-15	-	-	-	-	-	-	-
Sludge drying bed	Depth of sludge		m	0.250	≦0.3		0.225	0.250	0.250	0.225	0.300	0.300
	Required area		m2	2,678			1,314	1,145	1,108	5,725	4,231	4,169
	No of bed	Existing		9			9	9	9	9	9	9
		additional									4	4
		Total		9			9	9	9	9	13	13
	Total area	Existing	m2	3,024			3,024	3,024	3,024	3,024	3,024	3,024
		additional	m2								1,344	1,344
		Total	m2	3,024			3,024	3,024	3,024	3,024	4,368	4,368
Gas holder	No of gas holder	Existing	No.	2			2	2	2	2	2	2
		additional	No.	0			0	0	0	0	0	0
		Total	No.	2			2	2	2	2	2	2
	Gas volume		m3	333			571	571	571	625	625	625
	Volume of gas holder		m3	353			353	353	353	353	353	353

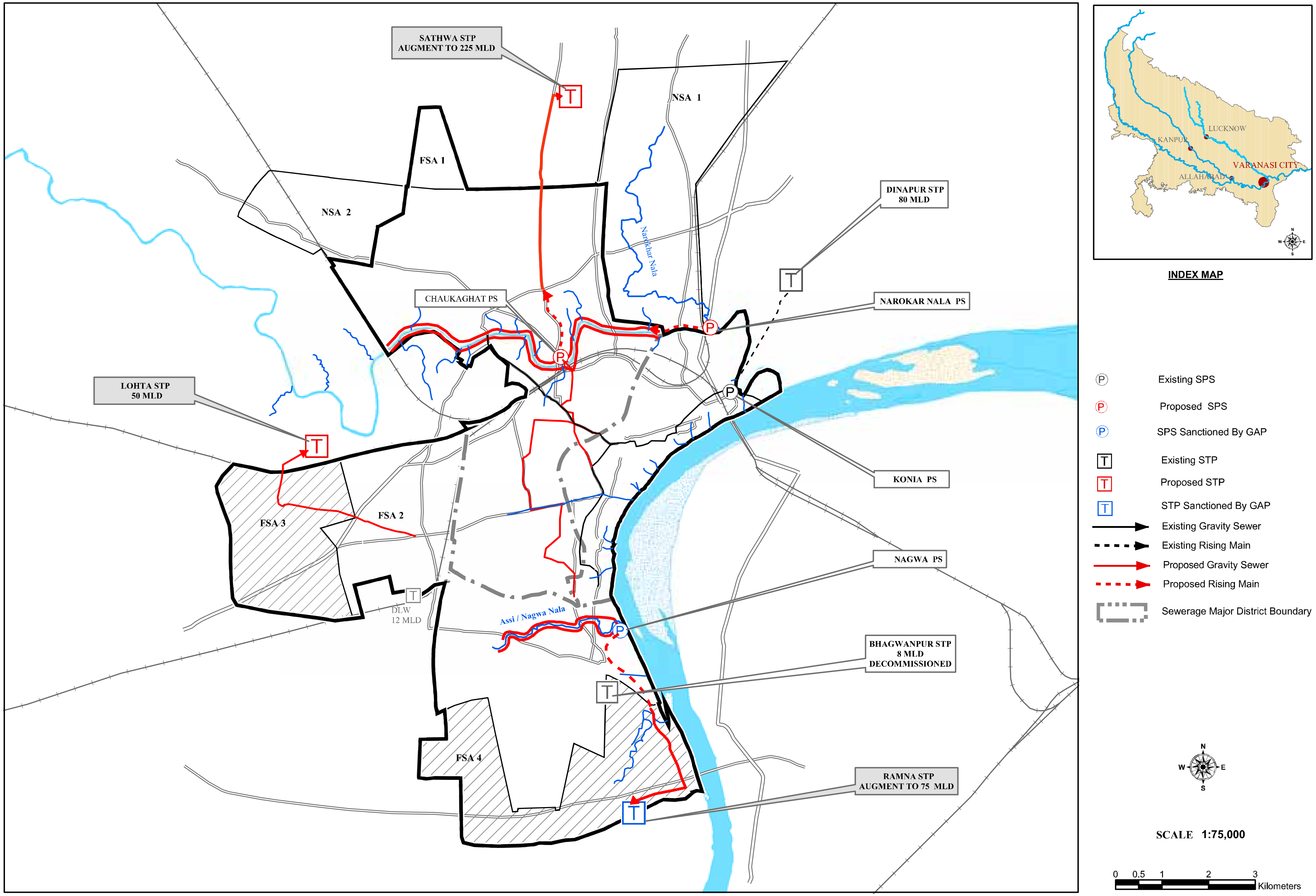
Note: Values shown in parenthesis are assumed.
Option 1 is adding 1 extra aeration tank
Option 2 is adding 2 extra aeration tanks

Table 7.29 Hydraulic Calculation for Pipe Sizing: District 4

Node		Contributory Population		Design Flow (lps)	Size (mm)	Length (m)	Gradient	Invert level (m)		Ground level (m)		Covering (m)		Full pipe capacity		Design capacity		Sub Catchment	Remarks
From	To	Each	Cumulative					u/s	d/s	u/s	d/s	u/s	d/s	Velocity (m/s)	Discharge (l/s)	Velocity (m/s)	Discharge (l/s)		
1	5	42,394	42,394	190	700	1,300	1,000	75.92	74.62	78.70	78.40	2.00	3.00	0.66	254	0.75	246	4-1	
2	3	8,366	8,366	45	500	1,000	700	73.72	76.52	75.80	78.60	1.50	1.50					4-2	Rising Main
3	5	35,126	43,492	195	700	800	1,000	75.82	75.02	78.60	78.40	2.00	2.60	0.66	254	0.75	246	4-3	
4	5	69,675	69,675	281	800	1,400	1,000	75.11	73.71	78.00	78.40	2.00	3.80	0.72	363	0.82	351	4-4	
5	9	29,141	184,702	745	1,400	1,600	2,200	73.11	72.19	78.40	75.50	3.76	1.78	0.71	1,087	0.81	1,052	4-5	
6	8	19,269	19,269	105	500	800	700	75.02	73.88	77.60	78.10	2.00	3.64	0.63	124	0.72	120	4-6	
7	8	17,694	17,694	96	500	750	700	74.72	73.65	77.30	78.10	2.00	3.87	0.63	124	0.72	120	4-7	
8	9	23,608	60,571	245	700	1,550	1,000	73.45	71.90	78.10	75.50	3.87	2.82	0.66	254	0.75	246	4-8	
9	13	224	245,497	990	1,400	100	2,200	71.20	71.15	75.50	76.00	2.77	3.31	0.71	1,087	0.81	1,052	4-9	
10	12	26,292	26,292	118	500	2,300	700	75.62	72.33	78.20	76.50	2.00	3.59	0.63	124	0.72	120	4-10	
11	12	18,776	18,776	102	500	1,200	700	75.63	73.92	78.40	76.50	2.19	2.00	0.63	124	0.72	120	4-11	
12	13	520	45,588	205	700	250	1,000	72.13	71.88	76.50	76.00	3.59	3.34	0.66	254	0.75	246	4-12	
13	Lotha STP		291,084	1,175	1,600	1,600	2,500	70.95	70.31	76.00	75.50	3.31	3.45	0.72	1,456	0.83	1,409		

Manning's N;	0.015

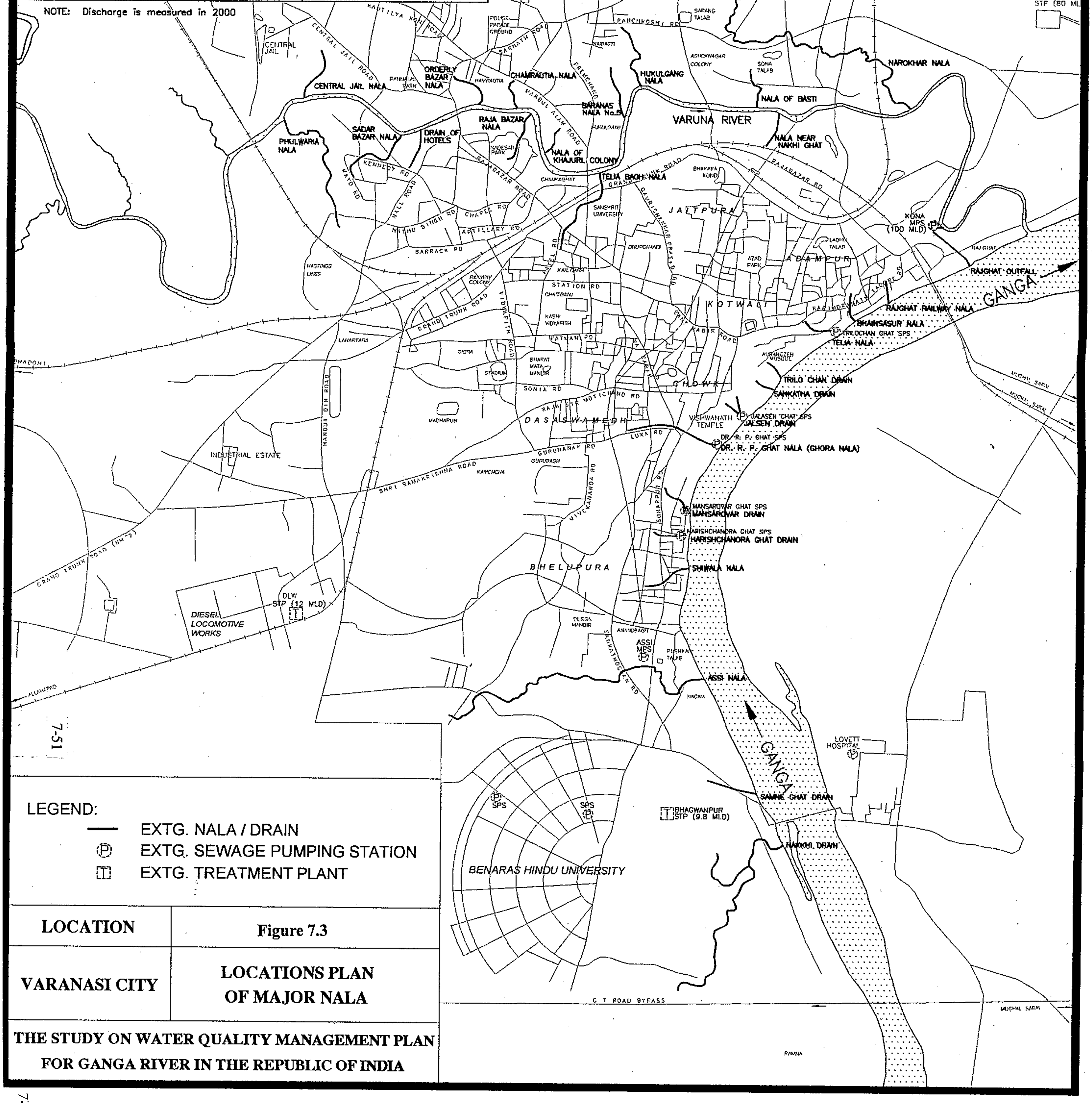

INDEX MAP
LUCKNOW
KANPUR
ALLAHABAD
VARANASI CITY
Existing SPS
Proposed SPS
SPS Sanctioned By GAP
Existing STP
Proposed STP
STP Sanctioned By GAP
Existing Gravity Sewer
Existing Rising Main
Proposed Gravity Sewer
Proposed Rising Main
Sewerage Major District Boundary
SCALE 1:75,000
0 0.5 1 2 3 Kilometers
DINAPUR STP 80 MLD
NAROKAR NALA PS
KONIA PS
NAGWA PS
BHAGWANPUR STP 8 MLD
RAMNA STP 37 MLD
SATHWA STP 200 MLD
CHAUKAGHAT PS
NSA 1
NSA 2
FSA 1
FSA 2
DLW 12 MLD
Narokhar Nala
Assi / Nagwa Nala
Figure 7.1
PROPOSED COLLECTION & TREAMENT CAPACITY (YEAR - 2015)
LOCATION
VARANASI CITY
PROJECT
THE STUDY ON WATER QUALITY MANAGEMENT PLAN FOR GANGA RIVER IN THE REPUBLIC OF INDIA
JAPAN INTERNATIONAL COOPERATION AGENCY
TOKYO ENGINEERING CONSULTANTS CO., LIMITED
CTI ENGINEERING INTERNATIONAL CO., LIMITED



JAPAN INTERNATIONAL COOPERATION AGENCY	PROJECT	LOCATION	Figure 7.2
TOKYO ENGINEERING CONSULTANTS CO. LIMITED CTI ENGINEERING INTERNATIONAL CO. LIMITED	THE STUDY ON WATER QUALITY MANAGEMENT PLAN FOR GANGA RIVER IN THE REPUBLIC OF INDIA	VARANASI CITY	PROPOSED COLLECTION & TREAMENT CAPACITY (YEAR - 2030)

	No.	NAME OF NALA	DISCHARGE (MLD)	TYPE	REMARK
GANGA RIVER	1	NAKKHI DRAIN	0.00	Open Channel	Running almost dry
	2	SAMNE GHAT DRAIN	0.00	Circular Pipe	Running almost dry
	3	ASSI NALA	44.50	Open Channel	Intercepted into main sewer
	4	SHIWALA DRAIN	5.50	Circular Pipe	Intercepted into main sewer
	5	HARISHCHANDRA GHAT DRAIN	2.50	Rectangular	Intercepted into main sewer
	6	MANSAROVAR DRAIN	2.50	Circular Pipe	Intercepted into main sewer under GAP Ph-I.
	7	DR. R. P. GHAT NALA	25.00	Rectangular	Intercepted into main sewer
	8	JALESAN DRAIN	3.75	Rectangular	Intercepted into main sewer
	9	SANKATHA GHAT	0.30	Rectangular	Intercepted into main sewer
	10	TRILOCHAN GHAT DRAIN	3.50	Rectangular	Intercepted into main sewer
	11	TELIA NALA	3.00	–	Intercepted into main sewer under GAP Ph-I.
	12	BHAINSASUR NALA	0.40	–	Intercepted into main sewer
	13	RAJGHAT RAILWAY NALA	0.03	Circular Pipe	Intercepted into main sewer
	14	RAJGHAT OUTFALL	130.00	Circular Pipe	
	15	KONIA BY-PASS	50.00	–	
VARUNA RIVER (RIGHT BANK)	16	PHULWARIA NALA	7.60	Open Channel	Proposed to intercepted and diverted to proposed sewer along the Varuna River under GAP Ph-II.
	17	SADAR BAZAR NALA	2.00	–	
	18	DRAIN OF HOTELS	0.20	–	
	19	RAJA BAZAR NALA	0.10	–	
	20	TELIABAGH NALA	18.00	–	
	21	NALA NEAR NAKHI GHTA	0.10	–	
VARUNA RIVER (LEFT BANK)	22	CENTRAL JAIL NALA	6.50	–	
	23	ORDERLY BAZAR NALA	7.00	–	
	24	CHAMRAUTIA NALA	3.00	–	
	25	NALA OF KHAJURL COLONY	1.50	–	
	26	BANARAS NALA No.5	1.00	–	
	27	HUKULGANG NALA	2.50	Open Channel	
	28	NALA OF NAI BASTI	3.00	–	
	29	NAROKHAR NALA	7.50	Open Channel	

NOTE: Discharge is measured in 2000



LEGEND:

- EXTG. NALA / DRAIN
- Ⓟ EXTG. SEWAGE PUMPING STATION
- ⌸ EXTG. TREATMENT PLANT

LOCATION	Figure 7.3
VARANASI CITY	LOCATIONS PLAN OF MAJOR NALA

THE STUDY ON WATER QUALITY MANAGEMENT PLAN FOR GANGA RIVER IN THE REPUBLIC OF INDIA

S.NO	LOCATION OF MAN HOLE	M.H. NO.	DISTANCE BETWEEN M.H.	DIA OF SEWER	DEPTH OF SILT	DEPTH OF WATER IN M.H.	TIME OF MTG.	CROSS SECTION OF MAIN SEWER	REMARKS
1	NEAR SPECIAL MAN HOLE RAJGHAT	1	113 m	2.40 m	0.05 m	1.70 m	7.0 AM		THE WORK AT [illegible] WAS BEING GOING ON, DUE TO WHICH SOME DIVERSION ARRANGEMENTS HAVE BEEN DONE TO DIVERT THE SULLAGE. SAND BAGS HAVE BEEN KEPT AT THE BOTTOM OF MAN SEWER TO KEEP THE PIPE ON IT. ON ACCOUNT OF THIS THERE IS MINOR SILTING DUE TO OBSTRUCTION OF FREE FLOW.
2	NEAR RAIL OVER BRIDGE RAJGHAT	2	120 m	2.30 m	0.05 m	[illegible]	7.40 AM		
3	NEAR RAILWAY LINE RAJGHAT	3	125 m	2.40 m	0.08 m	[illegible]	8.15 AM		
4	IN AGRICULTURE LAND BHADAU	4	105 m	2.40 m	0.[illegible] m	[illegible] m	10.0 AM		DO
5	NEAR RAILWAY COLONEY RAJGHAT	5	110 m	2.40 m	0.05 m	1.55 m	11.15 AM		DO
6	TURNING OF G.T. ROAD BHADAU	6	100 m	2.40 m	0.04 m	[illegible]	12.30 PM		[illegible]
7	IN GANGA NAGAR COLONEY BHADAU	7	168 m	2.40 m				COULD NOT BE OPENED [illegible]	
8	IN AGRICULTURE LAND BHADAU	8	135 m	2.4[illegible] m	0.05 m	1.45 m	3.00 PM		
9	INFRONT OF HOUSE NO U H 8/35 PATHAN TOALA	9	150 m	2.40 m				DO	
10	IN BACK SIDE OF HOUSE NO 35/25 ADAMPUR	10	130 m	2.40 m	0.05 m	1.34 m	7.30 AM		DO
11	INFRONT HOUSE NO 33/31 A HASANPURA	11	115 m	2.29 m	[illegible]	1.29 m	[illegible].00 AM		[illegible]
12	" " " 26/A 13 HASANPURA	12	115 m	2.29 m	0.07 m	1.08 m	[illegible] AM		[illegible]
13	" " " A 24/74 KOYALA BAZAR	13	105 m	2.28 m	0.07 m	0.78 m	12.35 PM		
14	" " " A 24/67 " " "	14	105 m	2.28 m	0.05 m	1.00 m	[illegible] PM		
15	" " N.M.P. SCHOOL MACHHODARI	15	105 m	2.29 m	0.09 m	0.95 m	7.15 AM		
16	ON ROAD AT MACHHODARI	16	105 m	2.28 m	0.20 m	0.80 m	9.30 AM		
17	IN MACHHODARI LAWN	17	100 m	2.29 m	0.30 m	0.65 m	[illegible]		IT HAS BEEN [illegible] THAT A [illegible] HAS BEEN MADE QUITE ADJACENT TO THE SEWER. IT SEEMS THAT FREE FLOW HAS BEEN OBSTRUCTED TO SOME EXTENT [illegible]
18	INFRONT OF KOTWALI VARANASI	18	516 m	2.28 m	0.47 m	1.00 m	9.00 AM		
19	ON ROAD CROSSING MAIDAGIN NEAR TEMPLE	19	1[illegible] m	2.28 m	0.09 m	1.60 m	10.30 AM		LATERAL SEWER CARRYING HUGE DISCHARGE JOINS HERE.
20	INFRONT OF BRITISH [illegible] BAGAGANE	20	[illegible]	2.13 m	[illegible]	0.81 m	[illegible]		
21	LOHATIA CROSSING [illegible]	[illegible]	190 m	2.13 m	0.35 m	0.94 m	12 [illegible] AM		
22	NEAR SHOPS OF LALLU[illegible] AND SON [illegible]PURA	22	380 m	1.98 m	0.65 m	0.60 m	11.30 AM		
23	NEAR PRINCE [illegible] AT PIYARI CROSSING	23	186 m	1.98 m	0.77 m	0.67 m	4.0 PM		
24	NAGAR MAHA[illegible] BENIA PARK	24	160 m	1.80 m	0.75 m	0.81 m	[illegible] PM		
25	NEAR WATER TANK BENIA PARK	25	228 m	1.80 m	0.76 m	0.60 m	2.0 PM		
26	SANSAR LOTTERY AGENCY NAISARAK	26	25[illegible] m	1.80 m	0.89 m	0.97 m	11.0 AM		THE MANHOLES ARE SURCHARGED AT SEVERAL PLACES DUE TO OVER SILTING OF DOWN STREAM SEWERS DURING PEAK HOURS
27	BOMBAY RADIO AGENCY GODAULIA	27	283.50 m	1.80 m	0.78 m	1.54 m	12.30 PM		DO
28	NEAR KALAWATI BHAWAN GODAULIA	28	149 m	1.20 m	0.21 m	1.65 m	10.35 AM		DO
29	NEAR KHARI KUNAWA GODAULIA	29	121 m	1.20 m	0.20 m	1.70 m	10.45 AM		"
30	NEAR RAJ ELECTRICALS RAMAPURA	[illegible]	104 m	1.20 m	0.09 m	1.85 m	11.05 AM		DO
31	NEAR DR. S.K. R[illegible] CHAUDHARY CLINIC	31	43 m	1.20 m	0.07 m	2.30 m	11.20 AM		DO
32	FRONT OF KRISHNA BLOCK WORKS	32	61 m	1.20 m	0.50 m	1.50 m	11.40 AM		DO
33	NEAR JAINARAIN INTER COLLEGE	33	114 m	1.20 m	0.15 m	1.60 m	11.50 AM		DO
34	NEAR S.S. SHISU VIDHYA MANDIR	34	86 m	1.20 m	0.38 m	1.15 m	12.05 PM		DO
35	FRONT OF REVARI TALAB PARK	[illegible]	208 m	1.20 m	0.35 m	1.05 m	12.25 PM		"
36	INFRONT OF DR. UMA GOEL CLINIC	36	161 m	1.20 m	0.38 m	0.78 m	12.35 PM		DO
37	NEAR POLICE STATION BHELUPUR	37	84 m	1.20 m	0.[illegible] m	0.55 m	12.50 PM		DO
38	IN COMPOUND [illegible] TALKIES	[illegible]	433 m	[illegible]	0.61 m	0.35 m	[illegible]		
39	ROAD CROSSING NEAR NEW COLONEY	39	158 m	1.20 m	0.60 m	0.70 m	11.50 AM		A SEWER CARRYING SULLAGE FROM NEW COLONY JOINS HERE
40	— DO	[illegible]	8 m	1.20 m	0.36 m	0.85 m	10.50 AM		
41	M/S A. R[illegible]	[illegible]	90 m	0.75 m	0.35 m	0.70 m	[illegible] PM		A SEWER CARRYING DISCHARGE FROM [illegible] JOINS [illegible] STATION [illegible]
42	NE[illegible]	[illegible]	228 m	0.76 m	0.18 m	0.45 m	[illegible]		
43	FRONT OF SRIRAM VASTRA BHANDAR SHIVALA	[illegible]	64 m	0.75 m	0.25 m	0.37 m	1.55 PM		
44	FRONT OF MATA ANANDMAI HOSPITAL	44	115 m	0.76 m	0.30 m	0.50 m	2.[illegible] PM		
45	INFRONT OF HOSPITAL [illegible] ASSI	45	257 m	0.75 m	0.30 m	0.25 m	2.15 PM		
46	INFRONT OF HOUSE OF MR. A.K. BAJAJ ADVOCATE	46	92 m	0.75 m	0.15 m	0.37 m	2.30 PM		
47	ASSI CROSSING	47	100 m	0.75 m	NIL	0.65 m	2.45 PM		THE SULLAGE FROM SEWAGE PUMPING STATION ASSI FALLS IN IT.

INDICATES — SULLAGE WITH WATER
— SILT

Figure 7.4

STATEMENT OF SHOWING SILTING IN DIFFRENT MAN HOLES OF MAIN SEWER OF VARANASI CITY

DRG NO	DRAWN BY	ASS PRO. ENGR	PRO. MANAGER
SCALE	CHECKED BY	PRO. ENGR	GENERAL MANAGER

GANGA POLLUTION CONTROLL UNIT
UTTAR PRADESH JAL NIGAM VARANASI

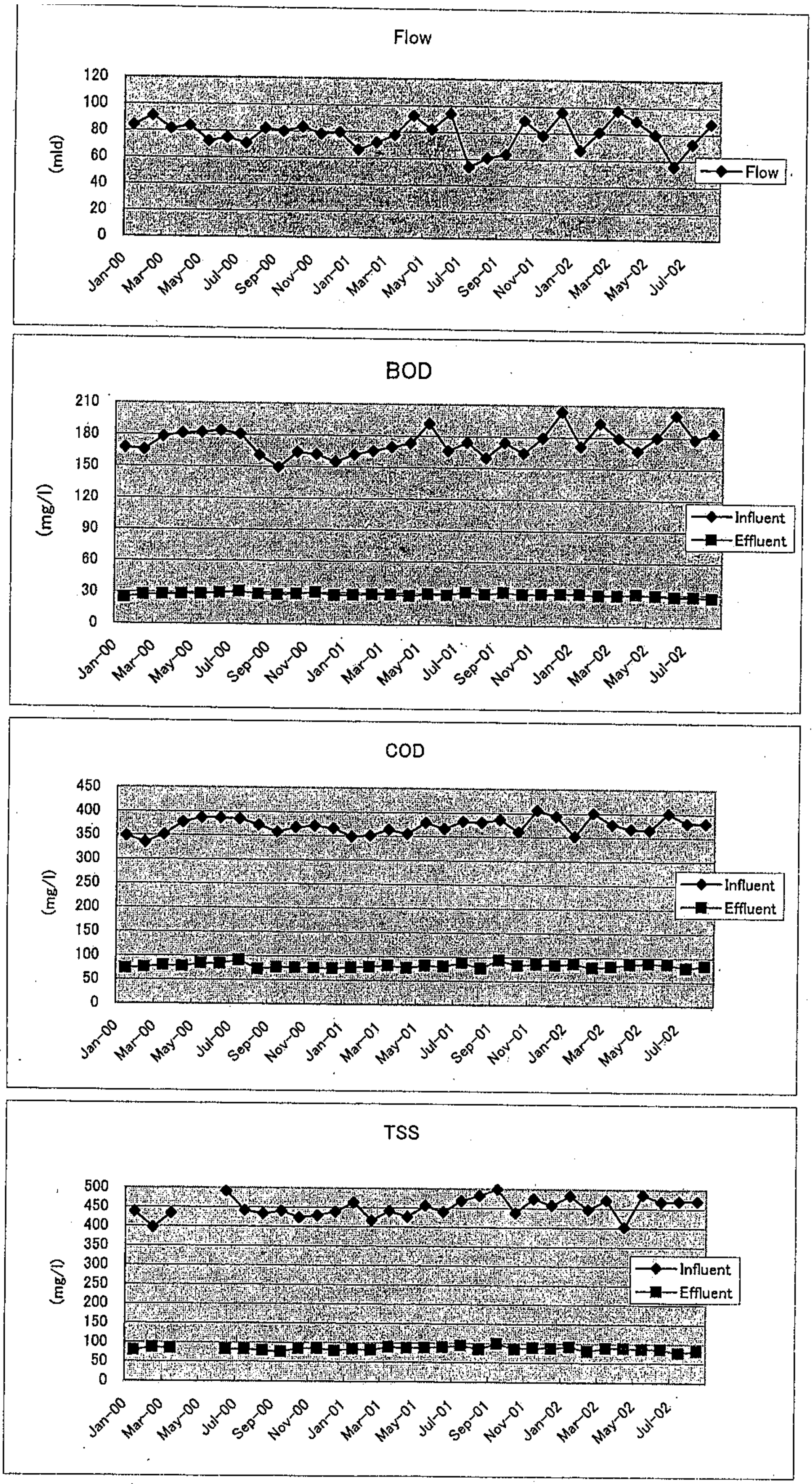


Figure 7.5 **Dinapur STP : Average Monthly Data**

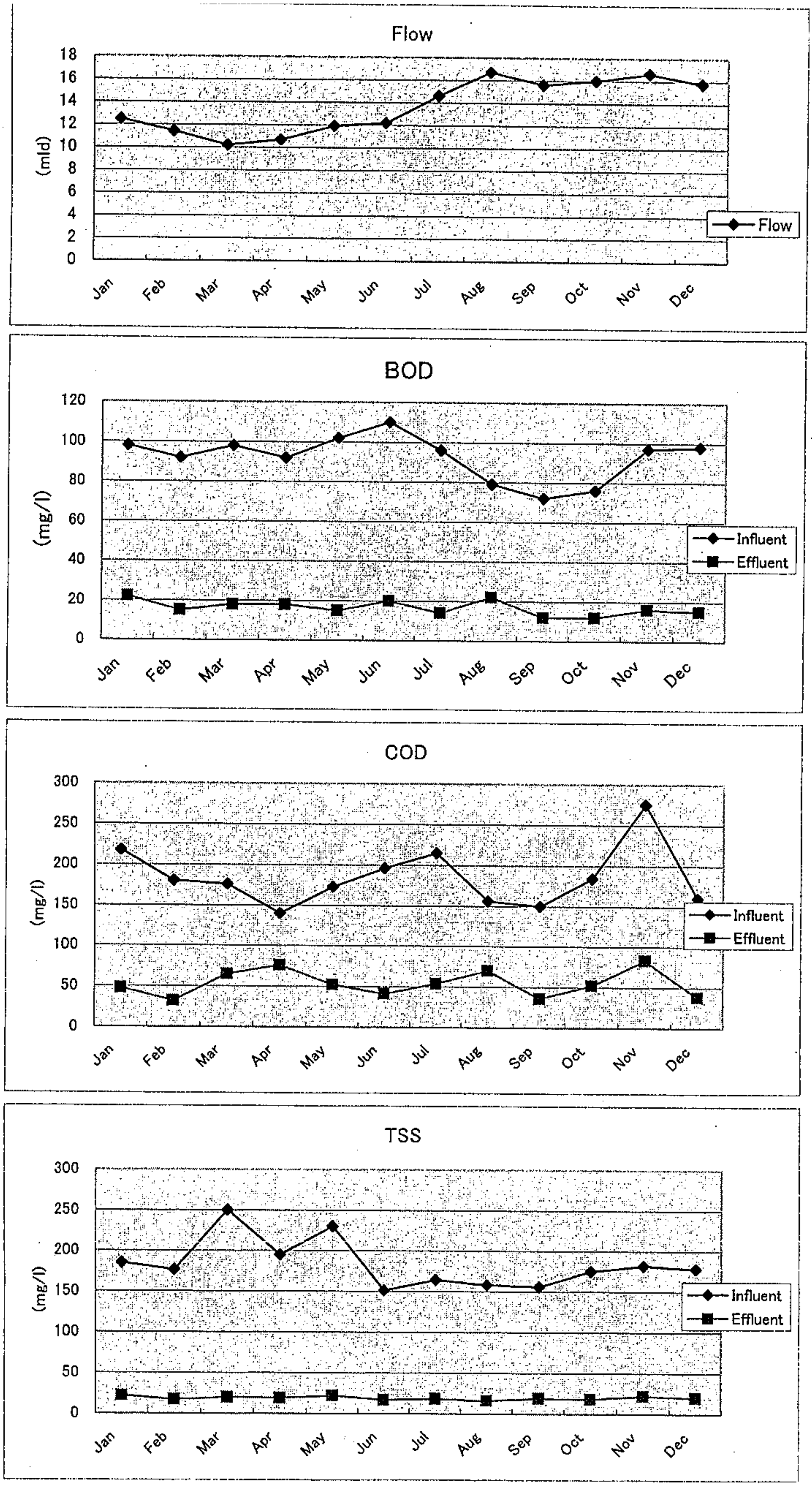


Figure 7.6 **Bhagwanpur STP : Effluent Quality Data**

CHAPTER 8

IMPLEMENTATION STRATEGY AND PHASING

CHAPTER 8 IMPLEMENTATION STRATEGY AND PHASING

A number of options were evaluated in Chapter 6 leading to the selection of a recommended plan. The details of the sewerage infrastructure, location, capacity, and type of treatment process were determined in Chapter 7. This section of the Master Plan identifies the implementation strategy and recommends priorities. It also identifies the required infrastructure components, along with implementation phases.

8.1 OVERALL STRATEGY

Sewerage will be developed gradually, with a series of interventions implemented in a phased approach. Although the time line to full build out cannot be predicted with any certainty, and may not happen within the 2030 planning horizon, it is assumed that all the improvements will take place within the planning horizon. The implementation of sewerage over the planning horizon has been divided into two stages:

- Stage I: Immediate interventions required by 2015
- Stage II: Continuing long-term development of sewerage 2016 to 2030

8.1.1 Stage I

The following projects have been identified as critical needs and should be implemented within one to five years following the adoption of the Master Plan:

- Augmentation of existing treatment works
- Construction of new treatment plants
- Interception of all drains and diversion to treatment
- Major trunk sewers and pumping stations required to service densely populated areas and convey sewage to treatment works.
- Cleaning and rehabilitation of existing sewers
- Capacity building for project implementation organization
- Capacity building of O&M organizations for sewers and treatment plant

The second part of the improvement program will focus on the development of trunk facilities as a foundation for long-term growth. Projects are aimed at extending trunk sewer facilities and increasing sewer connection rates to improve health, sanitation and living environment.

Projects in the second part of Stage I are considered a priority and should be implemented between 2011 and 2015. Projects will generally consist of:

- Reorganization of existing trunk sewers to divert sewage to new treatment works
- The extension of trunk sewers in all areas of the city that do not have adequate sewerage infrastructure
- Improving branch sewers in existing sewered areas
- Development of branch sewers in formerly unserviced areas
- An on-going program of house connections to increase amount of wastewater collected and treated
- Removing informal connections of storm drains to the sewer system
- Disconnecting informal connections of branch sewers to storm drains.
- On-going capacity building for O&M organizations

8.1.2 Stage II

Stage-II: projects implemented beyond 2015 are required to service population growth in new areas. These projects will generally include:

- Additional trunk sewers in new growth areas
- Replacement pumping equipment and/or augmentation of pumping capacity
- Augmentation of capacity at treatment plants to handle increased flows over the planning horizon
- On-going program for development of branch sewers and improving house connections ratios.

8.2 TIMING FOR IMPLEMENTATION OF SEWERAGE COMPONENTS

District wise delineation of the sewerage scheme is presented in Figure 7.1 for 2015 and Figure 7.2 for 2030. The overall scheme will consists of 4 separate sewerage Districts each with its own treatment plant:

- District 1: Central core conveying sewage to existing Dinapur STP, with diversion of sewage to relief sewer in District 2
- District 2: Sub-central and trans-Varuna areas conveying sewage to proposed Sathwa STP
- District 3: Assi/BHU area conveying sewage to proposed Ramna STP
- District 4: Future service area west of railway line conveying sewage to proposed Lohta STP

8.2.1 Treatment Plants

Wastewater generation is represented schematically in Figure 6.1 for 2015 and Figure 6.2 for 2030. Treatment plants for each District have been selected on the basis of cost comparisons and technology options for meeting required effluent standards. Capacities are for full build out conditions with an additional 5% planning allowance.

Table 8.1 Proposed Treatment Plants

(mld)

STP	District	Status	2003	2015	2030
Dinapur STP	1	E/R	80	80	80
Sathwa STP	2	P	-	200	225
Bhagwanpur STP	3	E/R	8	8	0
Ramna STP	3	S/A	-	37	75
Lohta STP	4	P	-	-	50
Total			88	325	430

STP	District	Process	Effluent Discharge	Disinfections
Dinapur STP	1	Activated sludge	Irrigation and Ganga River	Add chlorination
Sathwa STP	2	UASB++	Irrigation and Ganga River	Chlorination
Bhagwanpur STP	3	Activated sludge	Ganga River	Add chlorination
Ramna STP	3	Stabilization pond	Water body and Irrigation	Maturation ponds
Lohta STP	4	UASB++ or Aerated lagoons	Ganga River through Varuna River	Chlorination

It is recommended that the capacity at existing treatment plants will not be augmented. This is in favor of treating more flow at new treatment works which offer a more reliable method of treatment and opportunities for reuse. A number of potential improvements have been identified in Chapter 7 for existing treatment plants in order to improve effluent quality, especially in the future as organic loading increases:

- Increase weir length in primary and secondary tanks
- Provide sludge waste lines from secondary clarifiers to digesters
- Provide chlorine disinfection

8.2.2 Collection System Components

Proposed trunk sewers, pumping stations and preliminary alignments are presented in the drawings in Appendix C. The drawings also identify sewer sub-catchments used to calculate hydraulic capacity of the pipes. Contributing populations by sub-catchment are presented in Table 5.6. Hydraulic calculations for pipe sizing are presented in Table 7.19, 7.22 and 7.29 Requirements for new pumping stations are presented in Table 7.20.

Table 8.2 Phase wise Implementation of Collection System Implementation

Implementation period	Pump Stations	Trunk Sewers	Lateral and Branch Sewers
Stage I (-2015)	**District 1** - Improve and augment capacity at Konia MPS - Improve and augment capacity at Ghat SPS **District 2** - Chauka ghat MPS **District 3** - Nagwa MPS (sanctioned)	**District 1** - Rehab main trunk sewer - Rehab Konia diversion gate and close Rajghat outfall **District 2** - Relief trunk sewer - Varuna interceptor - Sathwa outfall sewer **District 3** - Assi interceptor - Ramna outfall sewer	**District 1** - All **District 2** - Sub-central **District 3** - Assi area
Stage II (2016-2030)	**District 2** - Sathwa No.1 SPS - Sathwa No.2 SPS	**District 3** - FSA 4 **District 4** - FSA 2,3	**District 1:** remainings **District 2 :** remainings **District 3 :** remainings **District 4 :** remainings

A District wise discussion for the development of collection system infrastructure is presented in the following subsections.

8.2.3 Description

(1) District 1 (Central)

Most of the existing branch sewers in the city center are overloaded, poorly maintained and do not have sufficient carrying capacity for future populations. These sewers can either be paralleled or replaced by larger pipes in areas that are congested. Furthermore many sewers are probably in poor condition and in need of cleaning or repairs.

A concentrated effort will be required to develop maps, inspect the condition and prepare a detailed inventory of the existing branch sewer network before planning for improvements.

Similarly the main trunk sewer, which is the essential backbone of the system, will need to be inspected in order to assess its physical condition, and to prepare a plan for rehabilitation. Jal Sansthan and Jal Nigam will require funding and technical assistance to carry out this sewer inspection and mapping program.

Ghat sewage pumping stations will be upgraded with new equipment with sufficient capacity to deal with future flows.

(2) District 2 (Cis and Trans Varuna)

The new relief sewer is presently under construction. However there is no outlet for the sewage; therefore the pumping station at the tail end must be constructed to lift sewage so it can at least overflow to the Varuna river in the interim while other parts of the system are constructed.. Once the relief sewer and pumping station have been constructed the process of diverting sewage into the collection system can begin. It will at first be necessary to reorganize existing lateral sewers in the district and divert them to the new relief sewer. New trunk sewers can also be constructed at this time and tied into the relief sewer.

The next step will be construction of sewerage network and facilities on the trans Varuna side. The most urgent of these will be the rising main, outfall sewer and treatment works at Sathwa. The treatment plant will begin initial operation with flows collected on the cis side. Once commissioning has been successfully completed the collection network and tapping facilities on the trans side can be implemented and connected to the outfall sewer.

(3) District 3 (Assi / BHU)

Sanctioned projects are expected to be implemented in the near future term. These include, new STP at Ramna and main pumping and tapping facilities at Nagwa/Assi nala. Trunk sewer facilities within the Assi nala drainage catchment can be implemented at a later stage since any wastewater generated in this area will naturally drain to the nala which will already be diverted. It should however be noted that increased flow in the nala must be monitored closely so that future replacement of pumping equipment can be planned in a timely manner. Future growth areas outside the Assi drainage catchment should be provided with adequate trunk sewer facilities by the respective Development Authority or developer. These trunk facilities must be connected to Ramna STP to prevent wastewater from flowing to other natural drains in the area, thus creating new sources of pollution.

8.3 PRIORITY PROJECTS

The sewerage system is required to improve sanitary conditions in the city with the goal of removing wastewater from open drains and improving water quality in water bodies. In the beginning, priority should be given to developing sewerage in areas upstream of water supply intake and the bathing Ghats.

Development of sewerage should then follow in the downstream direction with priority given to diverting sewage away from bathing Ghats and improving services in the most densely populated areas. Finally, sewerage should be implemented in new growth areas.

The timing of any sewerage development will depend on actual population growth and growth patterns. It is also essential that sewerage development be integrated with development of water supply. Installation of sewers in areas where water distribution is inadequate will lead to failure of the system.

Delayed installation of sewers in areas that have adequate water supplies will lead to discharge of sewage to drains and pollution of the environment.

Priority projects are defined as projects that should be implemented as soon as possible to achieve pollution reduction targets. Projects that have already been sanctioned are not identified because funding is in place and it is assumed they will be fully implemented in the short term.

Table 8.3 Component of Priority Project

Item	Priority
(1) Rehabilitation of Ghat Pumping Stations (District 1) - Ghat area is most densely populated area including old city, and the pollution load to Ganga river is high - Ghat Pumping Stations are decrepit, so wastewater is discharged directly to Ganga river - Fuel for generators of Ghat Pumping Stations is not enough - This rehabilitation is expected to be direct reduction of pollution load to Ganga river - Rehabilitation of five Ghat Pumping Stations	A
(2) Rehabilitation of Existing Treatment Plant and Pumping Stations (District 1) - Konia SPS - Dinapur STP	A
(3) Installation of Assi Nala Interceptors (District 3) - Assi nala is located just upstream of water intake - Assi nala is located upstream of main Ghat area, and it is main pollution source - Wastewater discharged from Assi nala to Ganga river tends to flow along left bank (near Ghats) without dilution with main Ganga river flow - This component is expected to be direct reduction of pollution load to Ganga river - Installation of Assi nala interceptor - Installation of outfall trunk sewer to Ramna STP (sanctioned) - Installation of Nagwa PS (sanctioned) - Installation of Ramna STP (sanctioned) - Rehabilitation of Bhagwanpur STP - Installation of lateral trunk sewers - Land acquisition - Branch sewers	A
(4) Resolution of Overload of Dinapur STP (District 1 and 2) - Overload of Dinapur STP causes wastewater discharge to Varuna river and Ganga river - So, new STP is necessary to complement Dinapur STP - Also, new trunk sewer is necessary to convey excess wastewater to proposed Sathwa STP - Rehabilitation of Dinapur STP and Konia PS - Rehabilitation of old trunk sewer - Installation of relief trunk sewer (downstream component, sanctioned) - Installation of rising main from Chauka ghat MPS - Installation of Chauka ghat MPS and Sathwa STP - Land acquisition - Branch sewers	A

Item	Priority
(5) Measures for Sub-Central Area (District 2) - Sub-Central area is the most densely populated area next to Central area or Ghat area, and the pollution load to Ganga river is rather high - Installation of relief trunk sewer (upstream component) - Installation of Varuna interceptor of right bank - Installation of lateral trunk sewers - Branch sewers	A
(6) Measures for Trans-Varuna Area (District 2) - Not so populated area compared to Sub-Central area, but the pollution load to Varuna river is high - Population growth rate is estimated higher than Sub-Central area - Installation of Varuna interceptor of left bank - Installation of Narokhar nala SPS, Saraiya nala SPS and Chouka ghat left bank SPS and their rising mains - Installation of lateral trunk sewers - Branch sewers	A
(7) Other Projects District 1 - Replacement of M/E of Konia SPS and Ghat SPS - Replacement of M/E of existing Dinapur STP - Branch sewers District 2 - Installation of lateral trunk sewers in Trans Varuna - Installation of Sathwa No.1 SPS and Sathwa No.2 SPS, and their rising mains - Replacement of M/E of Chauka ghat SPS - Augmentation of Sathwa STP - Branch sewers District 3 - Installation of lateral trunk sewers in Future Sewerage Area - Replacement of M/E of Nagwa nala SPS - Augmentation of Ramna STP - Branch sewers District 4 - All facilities	B

A: Works to be implemented before 2015
B: Works to be implemented before 2030

CHAPTER 9

COST ESTIMATES

CHAPTER 9 COST ESTIMATES

9.1 CAPITAL COST ESTIMATE

9.1.1 General

The total estimated direct construction costs including a 20% physical contingency for planning level estimates and land acquisition are as follows:

(Crores)

Item	Stage I	Stage II	Total
Direct Cost	426.3	369.7	796.1
Physical Contingency (20%)	85.3	73.9	159.2
Land Acquisition	32.4	27.2	59.6
Total	544.0	470.8	1,014.9

Direct cost does not include house connection cost

Summary of direct cost is presented phase wise in Table 9.1 and the breakdown of component costs is represented in the form of a pie chart in Figure 9.1.

All costs are with 2003 base prices, in Indian Rupees. Taxes and duties vary depending on the equipment or material supplied therefore these are included in the unit costs.

The estimate of investment costs has been worked out based on a phase wise implementation plan that corresponds to priorities and timeframes discussed in the report. The following costs have been included in estimated costs for project evaluation:

Item	Capital	O&M	Replacement
Existing facilities and Sanctioned projects (GAP-II)	X	O	O
Augmenting existing pump stations and treatment plants or replacing outdated equipment	O	O	O
Proposed master plan projects	O	O	O

X = not included, O = included in cost estimate

The investment costs for Stage II (2016 to 2030) include an estimate of replacement costs for mechanical/electrical equipment installed during the first phase that will have reached the end of their useful life after 15 years. The cost of sanctioned projects identified by UPJN in most recent DPRs has been adopted for calculating O&M and replacement costs of sanctioned facilities.

Total costs for the facilities identified in the Master Plan are comprised of the following items:

- Direct construction cost based on preliminary design of facilities (based on unit costs including taxes and duties) plus 10% for contractor’s profit.
- Land acquisition cost
- Engineering cost: Add 15% of direct construction cost for design and construction supervision
- Administrative costs: Add 10% of direct construction cost for centage fees related to project preparation and supervision (refer Indo-Dutch project 4% preparation + 6% admin. during construction)
- Physical contingency: add 20% to the sum of direct construction cost

9.1.2 Capital Costs for Major Sewers and Manholes

The cost estimate for laying trunk sewers and laterals has been prepared on the basis of preliminary design for Master Plan.

The estimated costs include ancillary items like excavation, reinstatement of road surfaces, provision of protection works, closed timbering, and cost of bedding. The cost per linear meter of pipe includes the cost of manholes. The cost of new trunk sewers and laterals is presented in Table 9.2.

Total length of trunk sewers and laterals is approximately 96 km. The cost of trunk sewers and laterals is estimated at Rs. 2,574 million.

9.1.3 Capital Costs for Branch Sewers

The capital cost of branch sewers has been worked out on the basis of cost per unit length of Rs.1,000/m (Jal Sansthan Allahabad) assuming 250mm diameter concrete pipe. The average length of branch sewer per hectare is 385 m/ha which has been worked out from a review of sewer drawings for typical colonies and urban areas.

The total cost of branch sewers is worked out Rs.2,524 million. The estimated cost of branch sewers includes cost of manholes, road reinstatement and other ancillary works. The estimated cost of branch sewers is presented in Table 9.3.

9.1.4 Capital Costs for House Connections

The number of house connections to be made during various project years have been assessed on the basis of number of dwellings calculated from census population and family size. The number of houses connected to the wastewater collection system will reach up to 80% by the end of phase II. The connection ratios at each phase have been identified in section 6 “planning framework”.

The unit cost of house connections is taken as Rs.7,750 /connection. This unit costs is obtained from discussions with Jal Sansthan Allahabad and costs identified in Allahabad sewerage master plan adjusted to 2003 cost base using wholesale price index. Costs for house connections are estimated for each District in Table 9.4.

9.1.5 Capital Costs for Sewage Pumping Stations

The cost of new pumping stations and upgrades to existing is estimated at Rs 1,211 million. The total capital cost of pumping stations has two major components: civil works and electro-mechanical works. The cost of each has been worked out separately as shown in Table 9.5.

The costs are worked out on the basis of cost per mld developed from a review of recent UPJN tenders and DPR cost estimates. The following formulae and costs are applied depending on the type of pump station:

Type	Civil works	Electro-mechanical	Electrical service
Submersible < 6 mld	$y = 0.1073x + 2.7675$	$y = 1.0x$	$y = 0.8x$
Submersible > 6 mld	$y = 0.1679x + 1.3616$	$y = 0.3x$	$y = 0.8x$
Centrifugal	$y = 26.958Ln(x) - 80.598$	$y = 0.2462x + 5.0009$	$y = 25.0x$

x: Design capacity in mld, y: Cost in million Rs.

The electro-mechanical costs include the cost of diesel generators. The cost of electrical service entrance assumes 11 kV, and includes an average transmission line length of 5 km.

9.1.6 Capital Costs for Rising Mains

The size and other details of rising mains have been worked out on the basis of preliminary design. All rising mains are estimated on the basis of unit cost per length for pre-stressed concrete pipe. Costs include installation, jointing, and testing, and connection to outfall sewer.

Cost details are provided in Table 9.6. The total length of new rising mains is 4.2 km and the estimated cost is Rs. 66 million.

9.1.7 Capital Costs for Treatment Plants

Capital costs of treatment plants have been worked out in Chapter 6 "Evaluation" for comparison and selection of treatment processes. Capital costs per unit mld are based on a review of treatment plants constructed under GAP and YAP presented in Supporting Report Vol. III-11. The estimated cost of treatment works is presented in Table 9.7. The total cost is Rs. 899 million. The estimated cost includes treatment units along with piping, pumping, cost of laboratory, administrative building, electrical sub-station, site development and boundary walls. The cost of dual fuel engine generators is included for treatment processes that produce methane. Costs of land acquisition have been identified separately in Table 9.8.

9.2 ANNUAL O&M COSTS

Effective operation and maintenance is essential for the success of any sewerage system. Operation and maintenance involves the following major components:

- Operation, maintenance and monitoring personnel
- Parts, equipment and machinery
- Energy costs

Total O&M costs are summarized in Table 9.10

Annual repair and maintenance costs at pumping stations are estimated as a percentage of capital costs using the following factors as adopted by UPJN:

Table 9.11 Unit Operation and Maintenance Costs

Sl.	Description of items	Economic life (years)	Annual repair and maintenance cost as % of capital cost
1	Civil structures	30	1.5
2	Pumps	15	3.0
3	Pipelines	30	0.25
4	Electrical	15	3.0
5	Diesel generators	15	3.0

Energy costs for pumping stations are calculated on the basis of electricity required to operate the pumps as calculated from the quantity and pumping head. The cost of electricity is taken as Rs. 3.1 per kWhr from the rate schedule issued by U.P. Power Corporation, August 2003. Recurring costs (excluding staff) for pumping stations are presented in Table 9.12.

Energy costs for treatment plants is worked out on the basis of unit consumption rates per mld identified in Supporting Report "Case Study of Sewage Treatment Plants. Recurring costs for treatment plants are identified in Table 9.13.

9.2.1 Staff

The number of staff required for carrying out regular operational, preventive and corrective maintenance activities can be grouped into the following categories:

- Personnel for sewer maintenance
- Personnel for sewage pumping stations
- Personnel for operation and maintenance of sewage treatment works
- Personnel for process control

Staff requirements for pump stations and treatment plants are in accordance with directives issued for GAP projects by UP Ministry for Urban Development. Annual recurring costs on staffing is based on the manpower required and salaries that have been given by UPJN Allahabad for 2002, and increased by 10% to bring them to 2003 base.

(1) Sewer Maintenance

Sewer maintenance generally involves regular inspection of all sewers, sewer cleaning operations, both preventive and corrective, and occasional repairs to manholes. Category and extent of personnel required for these activities have been worked out on the basis of quantity of work. Recommended personnel requirements for this component are presented in Table 9.14. A total of 5 gangs are recommended for Stage I and 7 gangs for Stage II.

(2) Sewage Pumping Stations

The personnel requirement for operation and maintenance of sewage pumping stations vary depending on the size of the station. Staff requirements for pump stations are presented in Table 9.15 in accordance with directives issued for GAP projects by UP Ministry for Urban Development.

(3) Sewage Treatment Plants

The personnel requirement for operation and maintenance of treatment plants vary depending on the size of the station. Staff requirements for GAP projects are determined by UP Ministry for Urban Development and presented in Table 9.16 to 9.20.

9.3 COST/IMPLEMENTATION SCHEDULE

The annual investment costs and recurring costs for implementing the Sewerage Master Plan are presented for each district in Table 9.21. The schedule of costs is based on a preliminary implementation plan and priorities discussed in previous sections. The cost breakdown of projects identified for implementation during Stage I is listed in order of priority in Table 9.22.

Table 9.1 Preliminary Capital Cost Estimate: Summary

Base year : 2003
City: Varanasi

Total

Item	Cost (Rs. million)		
	Stage I	Stage II	Total
	-2015	2016-2030	
Trunk sewers (including manholes)	1,749.04	825.04	2,574.08
Branch sewers	413.70	2,110.26	2,523.96
Pumping stations	818.50	380.10	1,198.60
Rising mains	56.43	9.86	66.29
Treatment plants	613.20	285.80	899.00
Rehabilitation of Old Trunk Sewer	612.47	0.00	612.47
Replacement of M/E assets	0.00	86.40	86.40
Sub-total	4,263.34	3,697.46	7,960.80
Physical Contingency (20%)	852.67	739.49	1,592.16
Cost of detailed engineering (15%)	639.50	554.62	1,194.12
Cost of project administration (10%) (1)	426.33	369.75	796.08
Land acquisition	324.00	272.00	596.00
Sub-total	2,242.50	1,935.86	4,178.36
Grand total	6,505.84	5,633.32	12,139.16

Direct Cost (including land acquisition)	4,587.34	3,969.46	8,556.80
House Connection	326.03	990.28	1,316.31

Note (1): 4% preparation + 6% administration during construction

Base year : 2003
City: Varanasi

District-1

Item	Cost (Rs. million)		
	Stage I	Stage II	Total
	-2015	2016-2030	
Trunk sewers (including manholes)	0.00	0.00	0.00
Branch sewers	39.34	78.69	118.03
Pumping stations	170.70	160.70	331.40
Rising mains	0.00	0.00	0.00
Treatment plants	12.00	0.00	12.00
Rehabilitation of Old Trunk Sewer	612.47	0.00	612.47
Replacement of M/E assets	0.00	86.40	86.40
Sub-total	834.51	325.79	1,160.30
Physical Contingency (20%)	166.90	65.16	232.06
Cost of detailed engineering (15%)	125.18	48.87	174.05
Cost of project administration (10%) (1)	83.45	32.58	116.03
Land acquisition	0.00	0.00	0.00
Sub-total	375.53	146.61	522.14
Grand total	1,210.04	472.40	1,682.44

House Connection	88.57	95.91	184.48

Note (1): 4% preparation + 6% administration during construction

Base year : 2003
City: Varanasi

District-2

Item	Cost (Rs. million)		
	Stage I -2015	Stage II 2016-2030	Total
Trunk sewers (including manholes)	1,494.10	448.40	1,942.50
Branch sewers	161.50	879.01	1,040.51
Pumping stations	647.80	213.10	860.90
Rising mains	56.43	9.86	66.29
Treatment plants	600.00	75.00	675.00
Rehabilitation of Old Trunk Sewer	0.00	0.00	0.00
Replacement of M/E assets	0.00	0.00	0.00
Sub-total	2,959.83	1,625.37	4,585.20
Physical Contingency (20%)	591.97	325.07	917.04
Cost of detailed engineering (15%)	443.97	243.81	687.78
Cost of project administration (10%) (1)	295.98	162.54	458.52
Land acquisition	324.00	8.00	332.00
Sub-total	1,655.92	739.42	2,395.34
Grand total	4,615.75	2,364.79	6,980.54
House Connection	126.02	537.09	663.11

Note (1): 4% preparation + 6% administration during construction

Base year : 2003
City: Varanasi

District-3

Item	Cost (Rs. million)		
	Stage I -2015	Stage II 2016-2030	Total
Trunk sewers (including manholes)	254.94	83.08	338.02
Branch sewers	212.86	561.58	774.44
Pumping stations	0.00	6.30	6.30
Rising mains	0.00	0.00	0.00
Treatment plants	1.20	60.80	62.00
Rehabilitation of Old Trunk Sewer	0.00	0.00	0.00
Replacement of M/E assets	0.00	0.00	0.00
Sub-total	469.00	711.76	1,180.76
Physical Contingency (20%)	93.80	142.35	236.15
Cost of detailed engineering (15%)	70.35	106.76	177.11
Cost of project administration (10%) (1)	46.90	71.18	118.08
Land acquisition	0.00	192.00	192.00
Sub-total	211.05	512.29	723.34
Grand total	680.05	1,224.05	1,904.10
House Connection	111.45	204.85	316.30

Note (1): 4% preparation + 6% administration during construction

Base year : 2003
City: Varanasi

District-4

Item	Cost (Rs. million)		
	Stage I -2015	Stage II 2016-2030	Total
Trunk sewers (including manholes)	0.00	293.56	293.56
Branch sewers	0.00	590.98	590.98
Pumping stations	0.00	0.00	0.00
Rising mains	0.00	0.00	0.00
Treatment plants	0.00	150.00	150.00
Rehabilitation of Old Trunk Sewer	0.00	0.00	0.00
Replacement of M/E assets	0.00	0.00	0.00
Sub-total	0.00	1,034.54	1,034.54
Physical Contingency (20%)	0.00	206.91	206.91
Cost of detailed engineering (15%)	0.00	155.18	155.18
Cost of project administration (10%) (1)	0.00	103.45	103.45
Land acquisition	0.00	72.00	72.00
Sub-total	0.00	537.54	537.54
Grand total	0.00	1,572.08	1,572.08

House Connection	0.00	152.43	152.43

Note (1): 4% preparation + 6% administration during construction

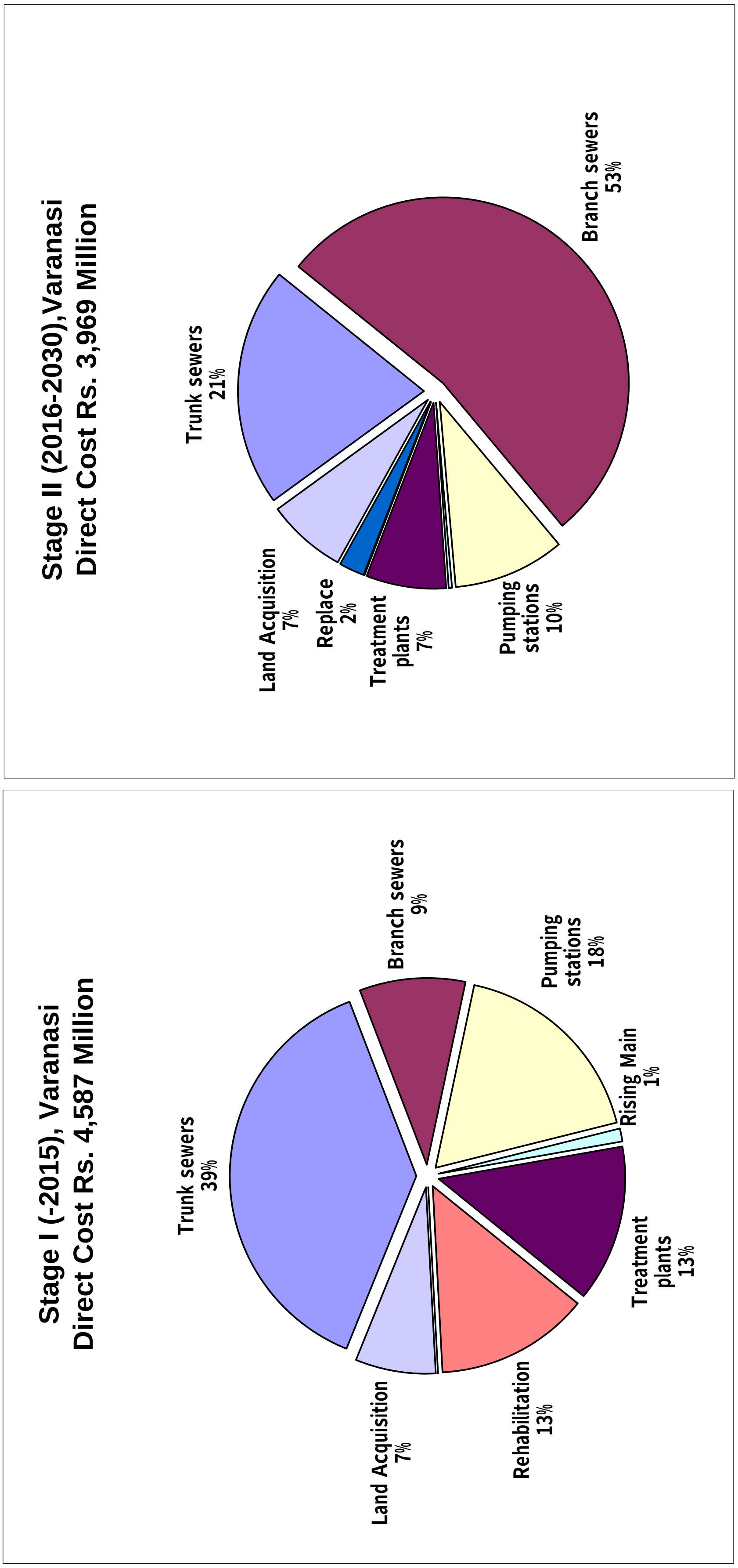


Figure 9.1 Estimated Cost of Sewerage, Breakdown of Direct Construction Cost

Table 9.2 Preliminary Capital Cost Estimate: Trunk Sewers and Laterals (Page 1 of 3)

Base year : 2003
City: Varanasi

District	Node (U/S)	Node (D/S)	Diameter (mm)	Depth	Length (m)	Unit Cost (Rs./m)	Cost (Rs. million)		
							Stage I -2015	Stage II 2016-2030	Total
District-1									
			Total				0.00	0.00	0.00
District-2									
Relief Trunk Sewer									
	RTS-1	RTS-7	600	C	390	18,557	7.24		
	RTS-7	RTS-12	600	D	420	23,532	9.88		
	RTS-12	RTS-19	600	E	540	29,250	15.80		
	RTS-19	RTS-24	700	E	390	30,132	11.75		
	RTS-24	RTS-27	800	F	180	37,539	6.76		
	RTS-27	RTS-30	900	F	270	35,991	9.72		
	RTS-30	RTS-34	1,000	E	420	31,293	13.14		
			Sub-Total		2,610		74.29	0.00	74.29
New Trunk Sewer under Varuna River (Jacking Method)									
	SMH	Chauka PS	2,200	H	400	314,000	125.60		
			Sub-Total		400		125.60	0.00	125.60
New Trunk Sewer to Sathwa STP (Connecting Trunk Sewer in Trans-Varuna District)									
	TS-101	TS-102	2,000	C	850	44,727	76.04	(Dual)	
	TS-102	TS-103	2,000	D	850	50,241	85.41	(Dual)	
	TS-103	TS-104	2,000	D	300	50,241	30.14	(Dual)	
	TS-104	TS-105	2,000	D	1,100	50,241	110.53	(Dual)	
	TS-105	Sathwa STP	2,200	E	1,400	84,072	235.40	(Dual)	
			Sub-Total		4,500		537.52	0.00	537.52
Lateral Sewers in Sub-Central Area									
	1	RTS-27	700	C	1,050	19,352	20.32		
	2	4	500	B	500	12,368	6.18		
	3	4	600	C	1,250	18,557	23.20		
	4	RTS-42	700	C	1,100	19,352	21.29		
	5	RTS-42	500	B	950	12,368	11.75		
	6	RTS-47	500	C	1,000	17,162	17.16		
	7	RTS-47	500	C	680	17,162	11.67		
	8	RTS-50	500	C	1,450	17,162	24.88		
	9	RTS-53	500	C	950	17,162	16.30		
	10	RTS-57	500	C	600	17,162	10.30		
	11	RTS-64	700	B	1,600	14,483	23.17		
	12	RTS-71	500	C	600	17,162	10.30		
	13	RTS-79	900	C	1,050	19,986	20.99		
			Sub-Total		12,780		217.51	0.00	217.51
Lateral Sewers of Varuna Inrerceptor									
	14	VLI-2	700	B	1,850	14,483	26.79		
	15	VLI-3	500	B	1,250	12,368	15.46		
	16	VLI-4	700	B	2,650	14,483	38.38		
			Sub-Total		5,750		80.63	0.00	80.63
Varuna Interceptor									
	VLI-1	VLI-2	500	C	1,450	17,162	24.88		
	VLI-2	VLI-3	800	D	1,000	25,594	25.59		
	VLI-3	VLI-4	1,000	E	1,850	31,293	57.89		
	VLI-4	Chauka SPS	1,200	G	400	47,872	19.15		
	VLI-5	VLI-6	1,400	C	1,000	28,639	28.64		
	VLI-6	Chauka SPS	1,400	F	1,500	46,120	69.18		
	VRI-1	SMH	500	F	4,700	33,594	157.89		
	VRI-2	SMH	700	E	2,500	30,132	75.33		
			Sub-Total		14,400		458.55	0.00	458.55
Lateral Sewers in Trans-Varuna Area									
	17	18	500	B	550	12,368		6.80	
	18	20	600	B	750	13,718		10.29	
	19	20	600	C	1,250	18,557		23.20	
	20	Sathwa-1 SPS	700	D	1,300	24,365		31.67	
	21	22	500	C	1,200	17,162		20.59	
	22	24	500	C	550	17,162		9.44	

Table 9.2 Preliminary Capital Cost Estimate: Trunk Sewers and Laterals (Page 2 of 3)

Base year : 2003
City: Varanasi

District	Node (U/S)	Node (D/S)	Diameter (mm)	Depth	Length (m)	Unit Cost (Rs./m)	Cost (Rs. million)		
							Stage I -2015	Stage II 2016-2030	Total
	23	24	500	B	400	12,368		4.95	
	24	Sathwa-1 SPS	600	D	850	23,532		20.00	
	28	30	600	B	1,200	13,718		16.46	
	29	30	500	C	1,050	17,162		18.02	
	30	31	800	E	1,100	31,420		34.56	
	31	35	800	F	700	37,539		26.28	
	32	33	600	C	1,650	18,557		30.62	
	33	35	700	D	300	24,365		7.31	
	34	35	500	C	950	17,162		16.30	
	35	39	1,200	F	1,500	40,323		60.48	
	36	38	700	C	1,500	19,352		29.03	
	37	38	500	B	900	12,368		11.13	
	38	39	800	C	1,000	20,541		20.54	
	39	Sathwa-2 SPS	1,400	F	1,100	46,120		50.73	
			Sub-Total		19,800		0.00	448.40	448.40
			Total		60,240		1,494.10	448.40	1,942.50
District-3 Assi Nala Interceptor									
	ALI-1	ALI-2	500	C	150	17,162	2.57		
	ALI-2	ALI-3	800	C	130	20,541	2.67		
	ALI-3	ALI-4	900	C	1,800	19,986	35.97		
	ALI-4	Nagwa SPS	1,000	C	1,350	20,996	28.34		
	ARI-1	ARI-2	700	C	2,300	19,352	44.51		
	ARI-2	ARI-3	1,000	C	1,200	20,996	25.20		
	ARI-3	Nagwa SPS	1,200	C	250	23,768	5.94		
			Sub-Total		7,180		145.20	0.00	145.20
Lateral Sewer of Assi Interceptor									
	3	ALI-3	500	B	900	12,368	11.13		
	4	ALI-4	500	B	450	12,368	5.57		
	7	ARI-3	700	C	650	19,352	12.58		
	1	ALI-1	500	C	1,700	17,162	29.18		
	5	ARI-1	700	C	750	19,352	14.51		
	6	ARI-2	700	C	600	19,352	11.61		
	2	ALI-2	700	C	1,300	19,352	25.16		
			Sub-Total		6,350		109.74	0.00	109.74
Trunk Sewer to Ramna STP									
	8	9	1,600	C	1,700	32,205	Sanctioned		
	9	11	1,600	E	1,200	43,425	Sanctioned		
	11	Ramna STP	1,800	E	500	50,114	Sanctioned		
			Sub-Total		3,400		0.00	0.00	0.00
Assi/BHU Area (FSA-4)									
	10	11	700	B	4,400	14,483		63.73	
	12	Ramna STP	700	C	1,000	19,352		19.35	
			Sub-Total		5,400		0.00	83.08	83.08
			Total		22,330		254.94	83.08	338.02
District-4 Western Area (FSA-2)									
	1	5	700	C	1,300	19,352		25.16	
	3	5	700	C	800	19,352		15.48	
	4	5	800	C	1,400	20,541		28.76	
	5	9	1,400	C	1,600	28,639		45.82	
	9	13	1,400	C	100	28,639		2.86	
	13	LothaSTP	1,600	D	1,600	37,331		59.73	
			Sub-Total		6,800		0.00	177.81	177.81

Table 9.2 Preliminary Capital Cost Estimate: Trunk Sewers and Laterals (Page 3 of 3)

Base year : 2003
City: Varanasi

District	Node (U/S)	Node (D/S)	Diameter (mm)	Depth	Length (m)	Unit Cost (Rs./m)	Cost (Rs. million)		
							Stage I -2015	Stage II 2016-2030	Total
Western Area (FSA-3)									
	6	8	500	C	800	17,162		13.73	
	7	8	500	C	750	17,162		12.87	
	8	9	700	C	1,550	19,352		30.00	
	10	12	500	C	2,300	17,162		39.47	
	11	12	500	B	1,200	12,368		14.84	
	12	13	700	C	250	19,352		4.84	
			Sub-Total		6,850		0.00	115.75	115.75
			Total		13,650		0.00	293.56	293.56
Total							1,749.04	825.04	2,574.08

Table 9.3 Preliminary Capital Cost Estimate: Branch Sewers

Base year : 2003
City: Varanasi

District/Zone	Area (ha)	Length (m)		Cost (Rs million)		
		Stage I -2015	Stage II 2016-2030	Stage I -2015	Stage II 2016-2030	Total
District -1						
Zone 1	1,022	39,348	78,694	39.34	78.69	118.03
Sub-Total				39.34	78.69	118.03
District-2						
Zone 2A	1,451	55,864	279,318	55.86	279.32	335.18
Zone 2B	686	105,644	158,466	105.64	158.47	264.11
Zone 2C	997	0	383,845	-	383.85	383.85
FSA 1	149	0	57,365	-	57.37	57.37
Sub-Total				161.50	879.01	1,040.51
District-3						
Zone 3	1,382	212,858	159,644	212.86	159.64	372.50
FSA 4	1,044	0	401,940	-	401.94	401.94
Sub-Total				212.86	561.58	774.44
District-4						
FSA 2	761	0	292,985	-	292.99	292.99
FSA 3	774	0	297,990	-	297.99	297.99
Sub-Total				-	590.98	590.98
Total	8,266			413.70	2,110.26	2,523.96

1. Average length of branch sewer per hectare taken as 385 m / ha.
2. A factor of increment in connection target in each Phase, has been used for calculation of lengths of branch sewers.
   Branch sewer length = 385 x Area (ha) x Increment in connection target (%)
3. Cost per unit length taken as Rs. 1000 / m (Jal Sansthan, Allahabad) assuming 250 mm diameter concrete pipe.

Existing and proposed branch sewer coverage

District/Zone	Year 2003	2010	2015	2030
District -1				
Zone 1	70%	75%	80%	100%
District -2				
Zone 2A	40%	45%	50%	100%
Zone 2B	0%	0%	40%	100%
Zone 2C	0%	0%	0%	100%
FSA 1	0%	0%	0%	100%
District -3				
Zone 3	30%	50%	70%	100%
FSA 4	0%	0%	0%	100%
District -4				
FSA 2	0%	0%	0%	100%
FSA 3	0%	0%	0%	100%

Table 9.4 Preliminary Capital Cost Estimate: House Connections

Base year : 2003
City: Varanasi

District/Zone	No. of households with connection				Cost (Rs. Million)		
	2003	2010	2015	2030	Stage I -2015	Stage II 2016-2030	Total
District -1							
Zone 1	41,573	47,474	53,001	65,377	88.57	95.91	184.48
Sub-toal					88.57	95.91	184.48
District-2							
Zone 2A	14,264	19,852	25,309	63,857	85.60	298.75	384.35
Zone 2B	0	2,827	5,215	13,701	40.42	65.77	106.18
Zone 2C	0	0	0	20,248	0.00	156.92	156.92
FSA 1	0	0	0	2,020	0.00	15.66	15.66
Sub-toal					126.02	537.09	663.11
District-3							
Zone 3	3,017	9,280	17,398	31,480	111.45	109.14	220.59
FSA 4	0	0	0	12,350	0.00	95.71	95.71
Sub-toal					111.45	204.85	316.30
District-4							
FSA 2	0	0	0	10,511	0.00	81.46	81.46
FSA 3	0	0	0	9,157	0.00	70.97	70.97
Sub-toal					0.00	152.43	152.43
Total					326.03	990.28	1,316.31

1. Unit cost per connection taken as Rs. 7750
2. Existing and proposed connection targets (%) have been used to calculate the Number of households with connection.
Cost = Rs. 7750 x Increase in Number of households with connection.

Population and number of households

Zone	No. of persons per household	2003		Stage I				StageII	
				Before 2010		2011-2015		2016-2030	
		Population	Total Households	Population	Total Households	Population	Total Households	Population	Total Households
District -1									
Zone1	7.4	512,737	69,289	540,477	73,037	560,292	75,715	604,734	81,721
District-2									
Zone 2A	7.4	351,848	47,547	419,726	56,720	468,211	63,272	590,674	79,821
Zone 2B	7.4	70,914	9,583	104,590	14,134	128,644	17,384	202,776	27,402
Zone 2C	7.4	97,194	13,134	144,464	19,522	178,228	24,085	299,666	40,495
FSA 1	7.4	14,946	2,020	21,485	2,903	26,156	3,535	29,892	4,039
District-3									
Zone 3	7.4	111,638	15,086	171,682	23,200	214,570	28,996	291,188	39,350
FSA 4	7.4	36,556	4,940	60,927	8,233	78,335	10,586	182,781	24,700
District-4									
FSA 2	7.4	60,292	8,148	91,972	12,429	114,601	15,487	155,561	21,022
FSA 3	7.4	19,416	2,624	42,011	5,677	58,151	7,858	135,524	18,314

1. No. of persons per household, for the city of Varanasi has been taken as 7.40.
2. Population considered here is the total population i.e. Resident + Floating.

Existing and proposed household connection targets

	Year			
	2003	2010	2015	2030
District -1				
Zone 1	60%	65%	70%	80%
District-2				
Zone 2A	30%	35%	40%	80%
Zone 2B	0%	20%	30%	50%
Zone 2C	0%	0%	0%	50%
FSA 1	0%	0%	0%	50%
District-3				
Zone 3	20%	40%	60%	80%
FSA 4	0%	0%	0%	50%
District-4				
FSA 2	0%	0%	0%	50%
FSA 3	0%	0%	0%	50%

Table 9.5 Preliminary Capital Cost Estimate: Pumping Stations

Base year : 2003
City: Varanasi

	District	Status	Type of Pump	Design capacity Average flow (mld)		Cost (Rs. million)							
				Stage I	Stage II	Electrical Service	M&E (Stage I)	M&E (Srage II)	Cost of civil Works	Misc. Road, wall, staff quarters	Total capital cost		
				-2015	2016-2030					10% of civil	Stage I Before 2010	Stage II 2016-2030	Total
New pumping stations													
Chaukaghat MPS	2	P	Centrifugal	160.0	170.0	425.0	44.4	46.9	57.9	5.8	533.0	46.9	579.9
Sathwa No.1	2	P	Submersible		26.0	20.8		7.8	5.7	0.6	0.0	34.9	34.9
Sathwa No.2	2	P	Centrifugal		35.0	87.5	5.0	13.6	15.2	1.5	0.0	117.9	117.9
Nagwa nala SPS	3	S	Centrifugal	40.0	40.0	Sanctioned	Sanctioned	12.0	Sanctioned	Sanctioned	Sanctioned		0.0
		A			10.0	0.0		3.0	3.0	0.3	0.0	6.3	6.3
Narokar Nala SPS	2	P	Centrifugal	18.0	34.0	85.0		13.4	14.5	1.4	112.8	13.4	126.2
Nala tapping	2	P							2.0		2.0		2.0
Upgrade Konia MPS													
Increase firm capacity	1	E									31.7	126.8	158.5
Construct overflow	1	E									31.5		31.5
Rehabilitate diversion gate	1	E									15.0		15.0
Rehabilitate ghat pumping stations													
Harishchandra	1	E	Centrifugal	7.1	6.2		10.0	6.5	3.8		13.8	6.5	20.3
Mansarovar	1	E	Centrifugal	2.2	1.9		10.0	5.5	1.0		11.0	5.5	16.5
Dr. RP	1	E	Centrifugal	22.3	19.4		30.0	9.8	9.0		39.0	9.8	48.8
Jalesan	1	E	Centrifugal	3.3	2.9		10.0	5.7	1.9		11.9	5.7	17.6
Trilochan	1	E	Centrifugal	6.5	5.6		10.0	6.4	6.8		16.8	6.4	23.2
Sanctioned Facility											**(Replace)**		
Nagwa nala SPS		S		40.0	40.0	100.0	14.8				114.8		

Type of pump	Costs (Rs. million)		
	M&E	Civil	Electrical Service
Centrifugal (>=30mld)	Y = 0.2462x + 5.0009	Y=26.958Ln(x) - 80.598	Y= 2.5x
Submersible (<30mld)	Y = 0.3x	y = 0.1679x + 1.3616	Y = 0.8x

	Stage I -2015	Stage II 2016-2030	Total
District-1	170.7	160.7	331.4
District-2	647.8	213.1	860.9
District-3	0.0	6.3	6.3
District-4	0.0	0.0	0.0
Total	818.5	380.1	1,198.6

Table 9.6 Preliminary Capital Cost Estimate: Rising Mains

Base year : 2003
City: Varanasi

District	Pump station	Status	Diameter (mm)	Length (m)	Type of material	Unit Cost (Rs./m)	Cost (Rs. million)		
							Stage I Before 2010	Stage II 2016-2030	Total
District-1									
	Total of District-1						0.00	0.00	0.00
District-2									
	Chaukaghat MPS	P	1,600	1,650	PSC	26,543	43.80		
	Narokar Nala SPS	P	800	1,200	DIP	10,526	12.63		
	Sathwa No.1	P	500	1,250	DIP	7,050		8.81	
	Sathwa No.2	P	800	100	DIP	10,526		1.05	
	Total of District-2						56.43	9.86	66.29
District-3									
	Nagwa SPS	S	1,000	2,300	PSC	12,727	Sanctioned		
	Total of District-3						0.00	0.00	0.00
District-4									
	Total of District-4						0.00	0.00	0.00
	Total						56.43	9.86	66.29

Table 9.7 Preliminary Capital Cost Estimate: Treatment Plants

Base year : 2003
City: Varanasi

	District	Process	Unit Cost Million Rs./mld	Status	Incremental Capacity (mld)		Civil Cost (Rs. million)		M&E Cost (Rs. million)		Cost (Rs. million)		
					Stage I -2015	Stage II 2016-2030	Stage I -2015	Stage II 2016-2030	Stage I -2015	Stage II 2016-2030	Stage I -2015	Stage II 2016-2030	Total
Dinapur STP	1	AS		E	80		80.0		80.0		12.0		12.0
Rehabilitate primary and secondary overflow weirs													
Add chlorination													
Bhagwanpur	3	AS		E	8		0.0		1.2		1.2		1.2
Rehabilitate primary and secondary overflow weirs													
Add chlorination													
Sathwa STP	2	UASB++	3.0	P	200	25	420.0	52.5	180.0	22.5	600.0	75.0	675.0
Ramna STP	3	WSP	1.6	S	37	0					Sanctioned		0.0
			1.6	A	0	38		59.6		1.2	0.0	60.8	60.8
Lohta STP	4	UASB++	3.0	P	0	50		105.0		45.0	0.0	150.0	150.0
Total											613.2	285.8	899.0

Sanctioned Facility							**(Civil)**		**(M&E)**		**(Total)**		
Ramna STP	3	WSP	1.6	S	37		41.4		17.8		59.2		

	Stage I -2015	Stage II 2016-2030	Total
District-1	12.0	0.0	12.0
District-2	600.0	75.0	675.0
District-3	1.2	60.8	62.0
District-4	0.0	150.0	150.0
Total	613.2	285.8	899.0

Table 9.8 Preliminary Capital Cost Estimate: Land Acquisition

Base year : 2003
City: Varanasi

Location	District	Process	Land Req. (ha/mld)	Status	Capacity (mld)		Land Acquisition (ha)		Rate per ha (Rs million)	Cost (Rs. million)		
					Stage I -2015	Stage II 2016-2030	Stage I -2015	Stage II 2016-2030		Stage I -2015	Stage II 2016-2030	Total
Treatment Plant												
Sathwa STP	2	UASB++	0.35	P	225		79		4	316.0		316.0
Ramna STP	3	WSP	1.25	S	37		46		4		Sanctioned	0.0
			1.25	A		38		48	4		192.0	192.0
Lohta STP	4	UASB++	0.35	P		50		18	4		72.0	72.0
Pumping Station												
Chaukaghat PS	2	-		P			1.0		4	4.0		4.0
Sathwa-1 PS	2	-		P				1.0	4		4.0	4.0
Sathwa-2 PS	2	-		P				1.0	4		4.0	4.0
Narokar Nala PS	2	-		P			1.0		4	4.0		4.0

	Stage I -2015	Stage II 2016-2030	Total
District 1	0.0	0.0	0.0
District 2	324.0	8.0	332.0
District 3	0.0	192.0	192.0
District 4	0.0	72.0	72.0
Total	324.0	272.0	596.0

Table 9.9 Replacement Cost of Existing Assets

(2) Treatment Plant

	District	Capacity (MLD)	Type	Capital cost Rs x 10^6	
				Civil	M/E
Dinapur STP	1	80	ASP	129.6	86.4
Sub Total (District 1)					86.4
Ramna STP	3	37	WSP	58.0	1.2
Sub Total (Dostrict 3)					1.2

Table 9.10 Annual Operation and Maintenance Costs: Summary

(Rs. million)

	Status	District	Stage I				Stage II			
			Maintenance	Staff	Energy	Total	Maintenance	Staff	Energy	Total
Sewer Maintenance					-				-	
District 1			3.15	0.60	-	3.75	3.93	0.60	-	4.53
District 2			18.79	0.60	-	19.39	32.06	0.90	-	32.96
District 3			6.27	0.30	-	6.57	12.72	0.45	-	13.17
District 4			-	-	-	-	8.85	0.15	-	9.00
Sub-total Sewers			28.21	1.50	-	29.71	57.56	2.10	-	59.66
Pump Stations			Stage I				Stage II			
Harishchandra	E	I	0.26	0.18	0.41	0.85	0.25	0.18	0.28	0.72
Mansarovar	E	I	0.18	0.22	0.13	0.54	0.18	0.22	0.12	0.52
Dr. RP	E	I	0.45	0.40	0.87	1.72	0.43	0.40	0.63	1.46
Jalesan	E	I	0.20	0.22	0.15	0.57	0.20	0.22	0.12	0.54
Trilochan	E	I	0.30	0.55	0.25	1.10	0.29	0.55	0.22	1.06
Konia MPS Stage I	E	I	0.96	0.85	2.01	3.83	0.96	0.85	2.01	3.83
Konia MPS Stage II	E	I	1.22	-	2.81	4.04	1.22	-	2.81	4.04
Chaukaghat MPS	P	II	2.31	0.74	10.73	13.78	2.38	0.74	17.41	20.53
Sathwa No.1 SPS	P	II	-	-	-	-	0.47	0.42	1.18	2.07
Sathwa No.2 SPS	P	II	-	-	-	-	0.64	0.53	1.22	2.39
Narokar Nala SPS	P	II	0.53	0.53	2.00	3.06	0.65	0.53	1.51	2.69
Nagwa Nala SPS	E	III	0.89	0.69	2.12	3.70	0.97	0.69	3.37	5.03
Sub-total Pump Staion			7.31	4.38	21.49	33.18		5.33	30.89	44.87
Treatment Plant			Stage I				Stage II			
Dinapur STP	E	I	5.18	7.22	18.10	30.51	5.18	7.22	18.10	30.51
Sathwa STP	P	II	15.30	5.21	16.75	37.26	17.21	5.21	18.84	41.26
Ramna STP	S	III	0.91	2.99	-	3.90	1.84	3.66	-	5.50
Bhagwanpur STP	E	III	0.52	3.83	1.81	6.16	0.52	3.83	1.81	6.16
Lotha STP	P	IV	-	-	-	-	3.83	3.88	4.19	11.89
Sub-total of Treatment Plants			21.91	19.25	36.66	77.82	28.58	23.80	42.94	95.32
Total			57.43	25.13	58.15	140.71	86.14	31.23	73.83	199.85

Table 9.12 Annual Operation and Maintenance: Pumping Stations

	Status	District	Stage I						Stage II					
			Annual Repairs			Staff	Energy	Total	Annual Repairs			Staff	Energy	Total
			M&E	Rising Main	Civil works				M&E	Rising Main	Civil works			
			3%	0.25%	1.5%				3%	0.25%	1.5%			
New Pumping Stations														
Chaukaghat MPS	P	II	1.33	0.11	0.87	0.74	10.73	13.78	1.41	0.11	0.87	0.74	17.41	20.53
Sathwa No.1 SPS	P	II	-	-	-	-	-		0.34	0.02	0.11	0.42	1.18	2.07
Sathwa No.2 SPS	P	II	-	-	-	-	-		0.41	0.00	0.23	0.53	1.22	2.39
Narokar Nala SPS	P	II	0.28	0.03	0.22	0.53	2.00	3.06	0.40	0.03	0.22	0.53	1.51	2.69
Existing Pumping Station														
Harishchandra SPS	E	I	0.20	0.00	0.06	0.18	0.41	0.85	0.20	0.00	0.06	0.18	0.28	0.72
Mansarovar SPS	E	I	0.17	0.00	0.02	0.22	0.13	0.54	0.16	0.00	0.02	0.22	0.12	0.52
Dr. RP SPS	E	I	0.31	0.00	0.14	0.40	0.87	1.72	0.29	0.00	0.14	0.40	0.63	1.46
Jalesan SPS	E	I	0.17	0.00	0.03	0.22	0.15	0.57	0.17	0.00	0.03	0.22	0.12	0.54
Trilochan SPS	E	I	0.20	0.00	0.10	0.55	0.25	1.10	0.19	0.00	0.10	0.55	0.22	1.06
Konia MPS Stage I	E	I	0.74	-	0.22	0.85	2.01	3.83	0.74	-	0.22	0.85	2.01	3.83
Konia MPS Stage II	E	I	0.74	0.26	0.22	-	2.81	4.04	0.74	0.26	0.22	-	2.81	4.04
Nagwa Nala SPS	E	III	0.45	0.07	0.37	0.69	2.12	3.70	0.52	0.07	0.37	0.69	3.37	5.03
Total			4.60	0.47	2.24	4.38	21.49	33.18	5.57	0.50	2.58	5.33	30.89	44.87

Table 9.13 Annual Operation and Maintenance: Treatment Plants

(Rs. million)

	District	Process	Stage I					Stage II				
			Annual Repairs		Staff	Energy	total	Annual Repairs		Staff	Energy	Total
			M&E 3%	Civil works 1.5%				M&E 3%	Civil works 1.5%			
Dinarpur STP	I	ASP	3.89	1.30	7.22	18.10	30.51	3.89	1.30	7.22	18.10	30.51
Sathwa STP	II	UASB++	12.60	2.70	5.21	16.75	37.26	14.18	3.04	5.21	18.84	41.26
Ramna STP	III	WSP	0.04	0.87	2.99	0.00	3.90	0.07	1.76	3.66	0.00	5.50
Bhagwanpur STP	III	ASP	0.39	0.13	3.83	1.81	6.16	0.39	0.13	3.83	1.81	6.16
Lotha STP	IV	UASB+	0.00	0.00	0.00	0.00	0.00	3.15	0.68	3.88	4.19	11.89
							77.82					95.32

Energy Cost

	District	Process	kwHr/mld	Stage I		Stage II	
				mld	kwHr/day	mld	kwHr/day
Dinarpur STP	I	ASP	200	80	16,000	80	16,000
Sathwa STP	II	UASB++	74	200	14,800	225	16,650
Ramna STP	III	WSP	0	37	0	75	0
Bhagwanpur STP	III	ASP	200	8	1,600	8	1,600
Lotha STP	IV	UASB+	74	0	0	50	3,700

Cost of electricity (Rs./kWhr):	3.1

Initial Cost for Calculating Maintenance Cost

(Rs. million)

	District	Process	Unit Cost Rs 10^6/mld	Capcity (mld)		Civil Cost		M/E Cost		Cost (Rs. million)	
				Stage I -2015	Stage II 2016-2030	Stage I -2015	Stage II 2016-2030	Stage I -2015	Stage II 2016-2030	Stage I -2015	Stage II 2016-2030
Dinarpur STP	I	ASP	2.7	80	80	86.4	86.4	129.6	129.6	216.0	216.0
Sathwa STP	II	UASB++	3.0	200	225	180.0	202.5	420.0	472.5	600.0	675.0
Ramna STP	III	WSP	1.6	37	75	58.0	117.6	1.2	2.4	59.2	120.0
Bhagwanpur STP	III	ASP	2.7	8	8	8.6	8.6	13.0	13.0	21.6	21.6
Lotha STP	IV	UASB+	3.0	0	50	0.0	45.0	0.0	105.0	0.0	150.0

Table 9.14 Staff Requirement per Sewer Cleaning Crew

Staff	No. required	Unit salaries/ month	Stage I		Stage II	
			Number of crews	Annual cost (Rs)	Number of crews	Annual cost (Rs)
Supervisor	1	5,500	5	330,000	7	462,000
Sewer inspector	1	4,500	5	270,000	7	378,000
Machine Operator	2	3,600	5	216,000	7	302,400
Helper	2	2,700	5	162,000	7	226,800
Sweeper	1	2,700	5	162,000	7	226,800
Unskilled laborer	3	2,700	5	162,000	7	226,800
Mason	1	3,300	5	198,000	7	277,200
Total				1,500,000		2,100,000

District -wise Staff Cost

	No. of Crews		Staff Cost	
	Stage I	Stage II	Stage I	Stage II
District 1	2	2	600,000	600,000
District 2	2	3	600,000	900,000
District 3	1	1.5	300,000	450,000
District 4		0.5	0	150,000
Total	5	7	1,500,000	2,100,000

Capital Cost of Trunk Sewer

	Capital Cost	
	Stage I	Stage II
District 1	0.00	0.00
District 2	1,494.10	1,942.50
District 3	254.94	338.02
District 4	0.00	293.56
Total	1,749.04	2,574.08

Capital Cost of Branch Sewer (Rs. million)

	Area (ha)	Branch Cover Area (ha)		Length per ha (m/ha)	Branch Length (m)		Initial Cost	
		Stage I	Stage II		Stage I	Stage II	Stage I	Stage II
District 1	1,022	818	1,022	385	314,930	393,470	314.93	393.47
District 2	3,283	1,000	3,283	385	385,000	1,263,955	385.00	1263.96
District 3	2,426	967	2,426	385	372,295	934,010	372.30	934.01
District 4	1,535	0	1,535	385	0	590,975	0.00	590.98
Total	8,266	2,785	8,266		1,072,225	3,182,410	1072.23	3182.41

Cost per unit length : Rs. 1,000/ha
Maintenance Cost = 1.0% of Initial Cost

	Maintenance Cost	
	Stage I	Stage II
District 1	3.15	3.93
District 2	18.79	32.06
District 3	6.27	12.72
District 4	0.00	8.85
Total	28.21	57.56

Table 9.15 Operation and Maintenance Staff: Requirements at Pumping Stations

Required Staff

S. No.	Post	Shifts	Chaukaghat MPS	Sathwa No.1	Sathwa No.2	Nagwa Nala SPS	Narokar Nala SPS	Konia MPS	Harishchandra	Mansarovar	Dr. RP	Jalesan	Trilochan
1	Junior Engineer	1	1	0.25	0.5	1	0.5	1	0.25	0.25	0.5	0.25	0.5
2	Electician	1	2	0.5	1	1.5	1	2	0.5	0.5	1	0.5	1
3	Mech. cum fitter	1	2	0.5	1	1.5	1	2	0.5	0.5	1	0.5	1
4	Pump Operator	3	1	1	1	1	1	1	1	1	1	1	1
5	Beldar	2	1	1	1	1	1	4	1	1	1	1	1
6	Sweeper	1	1	1	1	1	1	1	1	1	1	1	1

Annual Staffing Costs (in Rs.)

S. No.	Post	Chaukaghat MPS	Sathwa No.1	Sathwa No.2	Nagwa Nala SPS	Narokar Nala SPS	Konia MPS	Harishchandra	Mansarovar	Dr. RP	Jalesan	Trilochan
1	Junior Engineer	224,400	56,100	112,200	224,400	112,200	224,400	14,025	28,050	112,200	28,050	112,200
2	electrician	95,040	23,760	47,520	71,280	47,520	190,080	11,880	23,760	71,280	23,760	95,040
3	Mech. cum fitter	95,040	23,760	47,520	71,280	47,520	190,080	11,880	23,760	71,280	23,760	95,040
4	Pump Operator	213,840	213,840	213,840	213,840	213,840	71,280	71,280	71,280	71,280	71,280	71,280
5	Beldar	71,280	71,280	71,280	71,280	71,280	142,560	35,640	35,640	35,640	35,640	142,560
6	Sweeper	35,640	35,640	35,640	35,640	35,640	35,640	35,640	35,640	35,640	35,640	35,640
	TOTAL	735,240	424,380	528,000	687,720	528,000	854,040	180,345	218,130	397,320	218,130	551,760

Table 9.16 Operation and Maintenance Staff: Requirements for Dinapur STP

Activated Sludge

S. No.	Designation	Staff Requirement		Monthly Salary in Rs.	Annual wages in Rs.	
		Stage I	Stage II		Stage I	Stage II
1	Executive Engineer (Project Manager)	1	1	27,500	330,000	330,000
2	Assistant Engineer (E&M) (Asstt. Manager)	1	1	24,200	290,400	290,400
3	Assistant Engineer (Civil)	0	0	24,200	0	0
4	Junior Engineer (E&M) (Junior Manager)	6	6	19,800	1,425,600	1,425,600
5	Junior Engineer (Civil) (Junior Manager)	1	1	19,800	237,600	237,600
6	Fitter (Mech.) I Class	2	2	3,960	95,040	95,040
7	Electrician I Class	2	2	3,960	95,040	95,040
8	Fitter II Class	1	1	3,630	43,560	43,560
9	Electrician II Class	2	2	3,630	87,120	87,120
10	Gardener	2	2	3,080	73,920	73,920
11	Driver	1	1	7,700	92,400	92,400
12	Cleaner	1	1	3,080	36,960	36,960
13	Junior Accountant	1	1	11,550	138,600	138,600
14	UDC (Senior Assistant)	1	1	9,570	114,840	114,840
15	LDC/Typist (Junior Assistant)	2	2	8,360	200,640	200,640
16	Peon	2	2	6,050	145,200	145,200
17	Junior Stenographer	1	1	9,570	114,840	114,840
18	Chemist	1	1	7,700	92,400	92,400
19	Assistant Chemist	1	1	6,600	79,200	79,200
20	Lab Assistant	1	1	4,950	59,400	59,400
21	Lab Attendant	2	2	3,080	73,920	73,920
22	Sweeper	2	2	2,970	71,280	71,280
23	Weldar-cum-black smith	1	1	3,630	43,560	43,560
24	Operator	19	19	5,940	1,354,320	1,354,320
25	Labour (Beldar)	54	54	2,970	1,924,560	1,924,560
	TOTAL				7,220,400	7,220,400

Table 9.17 Operation and Maintenance Staff: Requirements for Sathwa STP

UASB + Maturation Pond

S. No.	Designation	Staff Requirement		Monthly Salary in Rs.	Annual wages in Rs.	
		Stage I	Stage II		Stage I	Stage II
1	Executive Engineer (Project Manager)			27,500	0	0
2	Assistant Engineer (E&M) (Asstt. Manager)	1	1	24,200	290,400	290,400
3	Assistant Engineer (Civil)	1	1	24,200	290,400	290,400
4	Junior Engineer (E&M) (Junior Manager)	4	4	19,800	950,400	950,400
5	Junior Engineer (Civil) (Junior Manager)	2	2	19,800	475,200	475,200
6	Fitter (Mech.) I Class	1	1	3,960	47,520	47,520
7	Electrician I Class	1	1	3,960	47,520	47,520
8	Fitter II Class	2	2	3,630	87,120	87,120
9	Electrician II Class	2	2	3,630	87,120	87,120
10	Gardener	2	2	3,080	73,920	73,920
11	Driver	1	1	7,700	92,400	92,400
12	Cleaner	1	1	3,080	36,960	36,960
13	Junior Accountant	1	1	11,550	138,600	138,600
14	UDC (Senior Assistant)	1	1	9,570	114,840	114,840
15	LDC/Typist (Junior Assistant)	2	2	8,360	200,640	200,640
16	Peon	2	2	6,050	145,200	145,200
17	Junior Stenographer			9,570	0	0
18	Chemist			7,700	0	0
19	Assistant Chemist	1	1	6,600	79,200	79,200
20	Lab Assistant	1	1	4,950	59,400	59,400
21	Lab Attendant	1	1	3,080	36,960	36,960
22	Sweeper	3	3	2,970	106,920	106,920
23	Weldar-cum-black smith			3,630	0	0
24	Operator	4	4	5,940	285,120	285,120
25	Labour (Beldar)	44	48	2,970	1,568,160	1,710,720
	TOTAL				5,214,000	5,356,560

Table 9.18 Operation and Maintenance Staff: Requirements for Bhagwanpur STP

Activated Sludge Process

S. No.	Designation	Staff Requirement		Monthly Salary in Rs.	Annual wages in Rs.	
		Stage I	Stage II		Stage I	Stage II
1	Executive Engineer (Project Manager)	0	0	27,500	0	0
2	Assistant Engineer (E&M) (Asstt. Manager)	1	1	24,200	290,400	290,400
3	Assistant Engineer (Civil)	0	0	24,200	0	0
4	Junior Engineer (E&M) (Junior Manager)	4	4	19,800	950,400	950,400
5	Junior Engineer (Civil) (Junior Manager)	0	0	19,800	0	0
6	Fitter (Mech.) I Class	1	1	3,960	47,520	47,520
7	Electrician I Class	1	1	3,960	47,520	47,520
8	Fitter II Class	0	0	3,630	0	0
9	Electrician II Class	1	1	3,630	43,560	43,560
10	Gardener	1	1	3,080	36,960	36,960
11	Driver	0	0	7,700	0	0
12	Cleaner	0	0	3,080	0	0
13	Junior Accountant	1	1	11,550	138,600	138,600
14	UDC (Senior Assistant)	1	1	9,570	114,840	114,840
15	LDC/Typist (Junior Assistant)	1	1	8,360	100,320	100,320
16	Peon	1	1	6,050	72,600	72,600
17	Junior Stenographer	0	0	9,570	0	0
18	Chemist	0	0	7,700	0	0
19	Assistant Chemist	0	0	6,600	0	0
20	Lab Assistant	1	1	4,950	59,400	59,400
21	Lab Attendant	1	1	3,080	36,960	36,960
22	Sweeper	1	1	2,970	35,640	35,640
23	Weldar-cum-black smith	0	0	3,630	0	0
24	Operator	12	12	5,940	855,360	855,360
25	Labour (Beldar)	28	28	2,970	997,920	997,920
	TOTAL				3,828,000	3,828,000

Table 9.19 Operation and Maintenance Staff: Requirements for Ramna STP

Waste Stabilisation Pond

S. No.	Designation	Staff Requirement		Monthly Salary in Rs.	Annual wages in Rs.	
		Stage I	Stage II		Stage I	Stage II
1	Executive Engineer (Project Manager)			27,500	0	0
2	Assistant Engineer (E&M) (Asstt. Manager)	1	1	24,200	290,400	290,400
3	Assistant Engineer (Civil)			24,200	0	0
4	Junior Engineer (E&M) (Junior Manager)	4	4	19,800	950,400	950,400
5	Junior Engineer (Civil) (Junior Manager)	1	1	19,800	237,600	237,600
6	Fitter (Mech.) I Class		1	3,960	0	47,520
7	Electrician I Class	1	2	3,960	47,520	95,040
8	Fitter II Class	1	1	3,630	43,560	43,560
9	Electrician II Class	1	2	3,630	43,560	87,120
10	Gardener	1	2	3,080	36,960	73,920
11	Driver		1	7,700	0	92,400
12	Cleaner		1	3,080	0	36,960
13	Junior Accountant	1	1	11,550	138,600	138,600
14	UDC (Senior Assistant)	1	1	9,570	114,840	114,840
15	LDC/Typist (Junior Assistant)	1	1	8,360	100,320	100,320
16	Peon	1	1	6,050	72,600	72,600
17	Junior Stenographer			9,570	0	0
18	Chemist			7,700	0	0
19	Assistant Chemist		1	6,600	0	79,200
20	Lab Assistant	1	1	4,950	59,400	59,400
21	Lab Attendant	1	1	3,080	36,960	36,960
22	Sweeper	1	2	2,970	35,640	71,280
23	Weldar-cum-black smith			3,630	0	0
24	Operator	4	4	5,940	285,120	285,120
25	Labour (Beldar)	14	21	2,970	498,960	748,440
	TOTAL				2,992,440	3,661,680

Table 9.20 Operation and Maintenance Staff: Requirements for Lotha STP

Aerated lagoon

S. No.	Designation	Staff Requirement		Monthly Salary in Rs.	Annual wages in Rs.	
		Stage I	Stage II		Stage I	Stage II
1	Executive Engineer (Project Manager)	0	0	27,500	0	0
2	Assistant Engineer (E&M) (Asstt. Manager)	0	1	24,200	0	290,400
3	Assistant Engineer (Civil)	0	0	24,200	0	0
4	Junior Engineer (E&M) (Junior Manager)	0	4	19,800	0	950,400
5	Junior Engineer (Civil) (Junior Manager)	0	1	19,800	0	237,600
6	Fitter (Mech.) I Class	0	1	3,960	0	47,520
7	Electrician I Class	0	2	3,960	0	95,040
8	Fitter II Class	0	1	3,630	0	43,560
9	Electrician II Class	0	2	3,630	0	87,120
10	Gardener	0	2	3,080	0	73,920
11	Driver	0	1	7,700	0	92,400
12	Cleaner	0	1	3,080	0	36,960
13	Junior Accountant	0	1	11,550	0	138,600
14	UDC (Senior Assistant)	0	1	9,570	0	114,840
15	LDC/Typist (Junior Assistant)	0	1	8,360	0	100,320
16	Peon	0	1	6,050	0	72,600
17	Junior Stenographer	0	0	9,570	0	0
18	Chemist	0	0	7,700	0	0
19	Assistant Chemist	0	1	6,600	0	79,200
20	Lab Assistant	0	1	4,950	0	59,400
21	Lab Attendant	0	1	3,080	0	36,960
22	Sweeper	0	2	2,970	0	71,280
23	Weldar-cum-black smith	0	0	3,630	0	0
24	Operator	0	4	5,940	0	285,120
25	Labour (Beldar)	0	27	2,970	0	962,280
	TOTAL				0	3,875,520

Table 9.21.1 Implementation/Investment Schedule, District 1 (Page 1 of 2)

	Stage I											Stage II							
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Direct Construction Cost																			
Trunk Sewer	102.0	102.1	102.1	102.1	102.1	102.1	(Rehabilitation)												
Branch Sewer	3.5	3.5	3.5	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Pumping Station																			
Ghat PSs (Existing)	30.8	61.7														6.8	13.6	13.5	
Konia SPS (Existing)	26.1	52.1														42.3	84.5		
Treatment Plant																			
Dinapur STP (existing)	4.0	8.0																	
Sub Total of Direct Cost	166.4	227.4	105.6	105.7	105.7	105.7	3.6	3.6	3.6	3.6	3.6	5.2	5.2	5.2	5.2	54.3	103.3	18.7	5.2
O/M Cost																			
Sewers	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Ghat SPSs	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Konia MPS	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9
Dinapur STP	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5
Sub Total of O/M	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2
Sum of Direct Cost and O/M Cost	213.4	274.4	152.6	152.7	152.7	152.7	50.6	50.6	50.6	50.6	50.6	52.4	52.4	52.4	52.4	101.5	150.5	65.9	52.4
House Connection																			
District 1	8.0	8.0	8.0	8.0	8.0	8.1	8.1	8.1	8.1	8.1	8.1	6.3	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Sub Total of House Connection	8.0	8.0	8.0	8.0	8.0	8.1	8.1	8.1	8.1	8.1	8.1	6.3	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Land Acquisition																			
District 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sub Total of Land Acquisition	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sub Total	221.4	282.4	160.6	160.7	160.7	160.8	58.7	58.7	58.7	58.7	58.7	58.7	58.8	58.8	58.8	107.9	156.9	72.3	58.8

Table 9.21.1 Implementation/Investment Schedule, District 1 (Page 2 of 2)

	Stage II							Total
	2024	2025	2026	2027	2028	2029	2030	
Direct Construction Cost								
Trunk Sewer								612.5
Branch Sewer	5.3	5.3	5.3	5.3	5.3	5.3	5.3	118.0
Pumping Station								
Ghat PSs (Existing)								126.4
Konia SPS (Existing)								205.0
Treatment Plant								
Dinapur STP (existing)							86.4	98.4
Sub Total of Direct Cost	5.3	5.3	5.3	5.3	5.3	5.3	91.7	1,160.3
O/M Cost								
Sewers	4.5	4.5	4.5	4.5	4.5	4.5	4.5	109.3
Ghat SPSs	4.3	4.3	4.3	4.3	4.3	4.3	4.3	117.3
Konia MPS	7.9	7.9	7.9	7.9	7.9	7.9	7.9	205.4
Dinapur STP	30.5	30.5	30.5	30.5	30.5	30.5	30.5	793.0
Sub Total of O/M	47.2	47.2	47.2	47.2	47.2	47.2	47.2	1,225.0
Sum of Direct Cost and O/M Cost	52.5	52.5	52.5	52.5	52.5	52.5	138.9	2,385.3
House Connection								
District 1	6.4	6.4	6.4	6.4	6.4	6.4	6.4	184.5
Sub Total of House Connection	6.4	6.4	6.4	6.4	6.4	6.4	6.4	184.5
Land Acquisition								
District 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sub Total of Land Acquisition	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sub Total	58.9	58.9	58.9	58.9	58.9	58.9	145.3	2,569.8

Table 9.21.2 Implementation/Investment Schedule, District 2 (Page 1 of 2)

	Stage I											Stage II							
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Direct Construction Cost																			
Relief Trunk Sewer				24.7	24.8	24.8													
Trunk Sewer (Across Varuna)		41.9	83.7																
Rising Main from Chauka ghat MPS			43.8									22.5							
Trunk Sewer (PS to STP)	107.5	215.0	215.0																
Varuna Interceptor	38.8	38.8	38.9	38.9	38.9	38.9	45.0	45.1	45.1	45.1	45.1								
Main Lateral																			
Sub-Central Area	36.0	36.3	36.3	36.3	36.3	36.3													
of Varuna Interceptor							16.1	16.1	16.1	16.1	16.2								
Trans-Varuna Area												89.6	89.7	89.7	89.7	89.7			
Branch Sewer																			
Sub-Central Area (Zone 2A)	5.0	5.0	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	18.6	18.6	18.6	18.6	18.6	18.6	18.6	18.6
Trans-Varuna Area (Zone 2B)	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6	10.6
Trans-Varuna Area (Zone 2C)												25.5	25.6	25.6	25.6	25.6	25.6	25.6	25.6
FSA 1												3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Treatment Plant																			
Sathwa STP	120.0	240.0	240.0									75.0							
Pumping Station																			
Chauka ghat MPS	106.6	213.2	213.2													46.9			
Naroka Nala SPS		38.2	76.5													13.4			
Sathwa No.1 PS and No.2 SPS												50.9	101.9						
Sub Total of Direct Cost	423.5	799.8	885.6	114.6	114.7	114.7	75.8	75.9	75.9	75.9	76.0	296.5	250.2	148.3	148.3	208.6	58.6	58.6	58.6
O/M Cost																			
Sewers	19.4	19.4	19.4	19.4	19.4	19.4	19.4	19.4	19.4	19.4	19.4	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0
Chauka ghat MPS				13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	20.5	20.5	20.5	20.5	20.5	20.5	20.5	20.5
Narokar Nala PS				3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Sathwa No1, No2														5.1	5.1	5.1	5.1	5.1	5.1
Sathwa STP				37.3	37.3	37.3	37.3	37.3	37.3	37.3	37.3	41.3	41.3	41.3	41.3	41.3	41.3	41.3	41.3
Sub Total of O/M	19.4	19.4	19.4	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	97.5	97.5	102.6	102.6	102.6	102.6	102.6	102.6
Sum of Direct Cost and O/M Cost	442.9	819.2	905.0	188.2	188.3	188.3	149.4	149.5	149.5	149.5	149.6	394.0	347.7	250.9	250.9	311.2	161.2	161.2	161.2
House Connection																			
Sub-Central Area (Zone 2A)	7.7	7.7	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	19.9	19.9	19.9	19.9	19.9	19.9	19.9	19.9
Trans-Varuna Area (Zone 2B)							8.0	8.1	8.1	8.1	8.1	4.3	4.3	4.4	4.4	4.4	4.4	4.4	4.4
Trans-Varuna Area (Zone 2C)												10.4	10.4	10.4	10.4	10.4	10.4	10.5	10.5
FSA 1												1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Sub Total of House Connection	7.7	7.7	7.8	7.8	7.8	7.8	15.8	15.9	15.9	15.9	15.9	35.6	35.6	35.6	35.7	35.7	35.7	35.8	35.8
Land Acquisition																			
Sathwa STP	316.0																		
Pumping Station	8.0											8.0							
Sub Total of Land Acquisition	324.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sub Total	774.6	826.9	912.8	196.0	196.1	196.1	165.2	165.4	165.4	165.4	165.5	437.6	383.3	286.5	286.6	346.9	196.9	197.0	197.0

Table 9.21.2 Implementation/Investment Schedule, District 2 (Page 2 of 2)

	Stage II							Total
	2024	2025	2026	2027	2028	2029	2030	
Direct Construction Cost								
Relief Trunk Sewer								74.3
Trunk Sewer (Across Varuna)								125.6
Trunk Sewer (Rising Main)								66.3
Trunk Sewer (PS to STP)								537.5
Varuna Interceptor								458.6
Main Lateral								
Sub-Central Area								217.5
of Varuna Interceptor								80.6
Trans-Varuna Area								448.4
Branch Sewer								
Sub-Central Area (Zone 2A)	18.6	18.6	18.6	18.6	18.7	18.7	18.7	335.2
Trans-Varuna Area (Zone 2B)	10.6	10.6	10.5	10.5	10.5	10.5	10.5	264.1
Trans-Varuna Area (Zone 2C)	25.6	25.6	25.6	25.6	25.6	25.6	25.6	383.9
FSA 1	3.8	3.8	3.8	3.8	3.9	3.9	3.9	57.3
Treatment Plant								
Sathwa STP								675.0
Pumping Station								
Chaukaghat MPS								579.9
Naroka Nala SPS								128.1
Sathwa No.1 PS and No.2 SPS								152.8
Sub Total of Direct Cost	58.6	58.6	58.5	58.5	58.7	58.7	58.7	4,585.1
O/M Cost								
Sewers	33.0	33.0	33.0	33.0	33.0	33.0	33.0	708.4
Chaukaghat PS	20.5	20.5	20.5	20.5	20.5	20.5	20.5	417.9
Narokar Nala PS	2.7	2.7	2.7	2.7	2.7	2.7	2.7	65.3
Sathwa No1, No2	5.1	5.1	5.1	5.1	5.1	5.1	5.1	66.3
Sathwa STP	41.3	41.3	41.3	41.3	41.3	41.3	41.3	917.9
Sub Total of O/M	102.6	102.6	102.6	102.6	102.6	102.6	102.6	2,175.8
Sum of Direct Cost and O/M Cost	161.2	161.2	161.1	161.1	161.3	161.3	161.3	6,760.9
House Connection								
Sub-Central Area (Zone 2A)	19.9	19.9	19.9	19.9	20.0	20.0	20.0	384.4
Trans-Varuna Area (Zone 2B)	4.4	4.4	4.4	4.4	4.4	4.4	4.4	106.2
Trans-Varuna Area (Zone 2C)	10.5	10.5	10.5	10.5	10.5	10.5	10.5	156.9
FSA 1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	15.7
Sub Total of House Connection	35.9	35.9	35.9	35.9	36.0	36.0	36.0	663.2
Land Acquisition								
Sathwa STP								316.0
Pumping Station								16.0
Sub Total of Land Acquisition	0.0	0.0	0.0	0.0	0.0	0.0	0.0	332.0
Sub Total	197.1	197.1	197.0	197.0	197.3	197.3	197.3	7,756.1

Table 9.21.3 Implementation/Investment Schedule, District3 (Page 1 of 2)

	Stage I											Stage II							
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Direct Construction Cost																			
Trunk Sewer	42.4	42.5	42.5	42.5	42.5	42.5						5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Branch Sewer	19.3	19.3	19.3	19.3	19.3	19.4	19.4	19.4	19.4	19.4	19.4	37.3	37.4	37.4	37.4	37.4	37.4	37.4	37.4
Nagwa SPS																18.3			
Bhagwanpur STP	1.2																		
Ramna STP	0.0	0.0	0.0	(sanctioned)								20.3	40.5						
Sub Total of Direct Cost	62.9	61.8	61.8	61.8	61.8	61.9	19.4	19.4	19.4	19.4	19.4	63.1	83.4	42.9	42.9	61.2	42.9	42.9	42.9
O/M Cost																			
Sewers	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.2
Nagwa SPS				3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Bhagwanpur STP	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Ramna STP				3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Sub Total of O/M	12.8	12.8	12.8	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.4	29.9	29.9	29.9	29.9	29.9	29.9	29.9	29.9
Sum of Direct Cost and O/M Cost	75.7	74.6	74.6	82.2	82.2	82.3	39.8	39.8	39.8	39.8	39.8	93.0	113.3	72.8	72.8	91.1	72.8	72.8	72.8
House Connection																			
Zone 3				13.9	13.9	13.9	13.9	13.9	14.0	14.0	14.0	7.2	7.2	7.2	7.2	7.3	7.3	7.3	7.3
FSA 4												6.3	6.3	6.3	6.4	6.4	6.4	6.4	6.4
Sub Total of House Connection				13.9	13.9	13.9	13.9	13.9	14.0	14.0	14.0	13.5	13.5	13.5	13.6	13.7	13.7	13.7	13.7
Land Acquisition																			
Ramna STP	0.0	(sanctioned)										192.0							
Sub Total of Land Acquisition	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	192.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sub Total	75.7	74.6	74.6	96.1	96.1	96.2	53.7	53.7	53.8	53.8	53.8	298.5	126.8	86.3	86.4	104.8	86.5	86.5	86.5

Table 9.21.3 Implementation/Investment Schedule, District3 (Page 2 of 2)

	Stage II							Total
	2024	2025	2026	2027	2028	2029	2030	
Direct Construction Cost								
Trunk Sewer	5.5	5.6	5.6	5.6	5.6	5.6	5.6	338.0
Branch Sewer	37.4	37.5	37.5	37.5	37.5	37.5	37.5	774.4
Nagwa SPS								18.3
Bhagwanpur STP								1.2
Ramna STP								60.8
Sub Total of Direct Cost	42.9	43.1	43.1	43.1	43.1	43.1	43.1	1,192.7
O/M Cost								
Sewers	13.2	13.2	13.2	13.2	13.2	13.2	13.2	270.6
Nagwa SPS	5.0	5.0	5.0	5.0	5.0	5.0	5.0	104.6
Bhagwanpur STP	6.2	6.2	6.2	6.2	6.2	6.2	6.2	161.2
Ramna STP	5.5	5.5	5.5	5.5	5.5	5.5	5.5	113.7
Sub Total of O/M	29.9	29.9	29.9	29.9	29.9	29.9	29.9	650.1
Sum of Direct Cost and O/M Cost	72.8	73.0	73.0	73.0	73.0	73.0	73.0	1,842.8
House Connection								
Zone 3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	220.6
FSA 4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	95.7
Sub Total of House Connection	13.7	13.7	13.7	13.7	13.7	13.7	13.7	316.3
Land Acquisition								
Ramna STP								192.0
Sub Total of Land Acquisition	0.0	0.0	0.0	0.0	0.0	0.0	0.0	192.0
Sub Total	86.5	86.7	86.7	86.7	86.7	86.7	86.7	2,351.1

Table 9.21.4 Implementation/Investment Schedule, District 4

	Stage II															Total
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	
Direct Construction Cost																
Trunk Sewer	19.5	19.5	19.5	19.5	19.5	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	19.6	293.5
Branch Sewer	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	39.4	591.0
Lotha STP	30.0	60.0	60.0													150.0
Sub Total of Direct Cost	88.9	118.9	118.9	58.9	58.9	59.0	59.0	59.0	59.0	59.0	59.0	59.0	59.0	59.0	59.0	1,034.5
O/M Cost																
Sewers	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	135.0
Lotha STP				11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	11.9	142.8
Sub Total of O/M	9.0	9.0	9.0	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	277.8
Sum of Direct Cost and O/M Cost	97.9	127.9	127.9	79.8	79.8	79.9	79.9	79.9	79.9	79.9	79.9	79.9	79.9	79.9	79.9	1,312.3
House Connection																
District 4	10.1	10.1	10.1	10.1	10.1	10.1	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	152.4
Sub Total of House Connection	10.1	10.1	10.1	10.1	10.1	10.1	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2	152.4
Land Acquisition																
Lotha STP	72.0															72.0
Sub Total of Land Acquisition	72.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	72.0
Sub Total	180.0	138.0	138.0	89.9	89.9	90.0	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	90.1	1,536.7

Table 9.22 Stage I Project - Implementation Cost

(Million Rs.)

Project	Estimated Cost	+Physical Contingency	Cumulative Cost
1. Rehabilitate Ghat PS and Main Trunk Sewer			
(a) Rehabilitation of five Ghat PS	92.5	111.0	
(b) Rehabilitation of Old Trunk Sewer	612.5	735.0	
(c) Branch Sewer in District 1	39.4	47.3	
Sub Total	744.4	893.3	893.3
2. Rehabilitate Konia MPS and Dinapur STP			
(a) Rehabilitation of Konia PS	78.2	93.8	
(b) Rehabilitation of Dinapur STP	12.0	14.4	
Sub Total	90.2	108.2	1,001.5
3. Assi Nala Interceptors to reduce flow in Nala upstream of Ghats			
(a) Installation of Assi Nala interceptor at both bank	145.2	174.2	
(b) Rehabilitation of Bhagwanpur STP	1.2	1.4	
(c) Installation of Lateral Trunk Sewers	109.7	131.7	
(d) Branch Sewer in District 3	212.9	255.5	
Sub Total	469.0	562.8	1,564.3
4. Resolution of Overload of Dinapur STP			
(a) Installation of Rising Main from Chaukaghat MPS	43.8	52.6	
(b) Installation of Outfall Trunk Sewer to Sathwa STP	663.1	795.7	
(c) Installation of Chaukaghat MPS	533.0	639.6	
(d) Land acquisition for Chaukaghat MPS	4.0	4.0	
(e) Installation of Sathwa STP	600.0	720.0	
(f) Land acquisition for Sathwa STP	316.0	316.0	
Sub Total	2,159.9	2,527.9	4,092.2
5. Sub-Central Area (District 2)			
(a) Installation of Relief Trunk Sewer (Upstream component)	74.3	89.1	
(b) Installation of Varuna Interceptor of Right Bank	233.2	279.9	
(c) Installation of Lateral Trunk Sewers	217.5	261.0	
(d) Branch Sewer in District 2	55.9	67.1	
Sub Total	580.9	697.1	4,789.3
6. Trans-Varuna Area (District 2)			
(a) Installation of Varuna Interceptor of Left Bank	225.3	270.4	
(b) Installation of Lateral Trunk Sewers	80.6	96.8	
(c) Naroka Nala SPS	114.8	137.8	
(d) Land Acquisition of Naroka Nala SPS	4.0	4.0	
(e) Installation of Rising Main of Naroka Nala	12.6	15.2	
(f) Branch Sewer in District 2	105.6	126.7	
Sub Total	543.0	651.6	5,440.9
Total	4,587.5	5,440.9	

CHAPTER 10

INITIAL ENVIRONMENTAL EXAMINATION (IEE) STUDY FOR VARANASI

CHAPTER 10 INITIAL ENVIRONMENTAL EXAMINATION (IEE) STUDY FOR VARANASI

10.1 OBJECTIVE OF THE IEE STUDY

The Initial Environmental Examination (IEE) is a very important and useful planning tool for development projects/programs at early stage. Original formulation of any projects/programs may be modified, if significant negative impact is predicted by the IEE. According to the JICA Environmental Guidelines, IEE is defined as "an examination undertaken at the outset of the development project planning stage to determine the environmental impacts that may be created by the particular project based on existing information and data."

The IEE has the following two objectives:

(1) To evaluate whether EIA is necessary for the project and, if so, to define its contents, and
(2) To examine from an environmental viewpoint, the measures for mitigating the impacts of the project, which requires environmental consideration but not a full-scale environmental impact assessment.

For the above objectives, the study on IEE has investigated (1) The existing social and natural environmental conditions of the Study area, (2) Constraints and problems for the master plan projects/programs on the water quality management for Ganga River.

10.2 METHODOLOGY OF THE IEE STUDY

10.2.1 Procedure

There are three steps for the IEE as follows.

(a) Identification of master plan projects/programs for the IEE,
(b) Survey evaluation of environmental impact at the construction or rehabilitation and the operation stage by using an environmental impact checklist, and
(c) Output of evaluation.

10.2.2 Evaluation of Environmental Elements

An environmental impact matrix is used as a checklist of environmental effects. Environmental elements of impact matrix are based on JICA Guideline including JBIC Guideline. The major components are social issues, demographic issues, economic activity, institutional and custom related issues, health and sanitary issues, and cultural asset issues as social environment, and biological and ecological issues, soil resources, land resources, hydrology, water quality and temperature, pollution and landscape as natural environment.

10.3 SURVEY AREA

The survey area is four (4) cities of Lucknow, Kanpur, Allahabad and Varanasi. This part of the Report focuses on Varanasi.

10.4 PROJECTS/PROGRAMS FOR THE IEE STUDY FOR VARANASI

(a) District I

(1) Rehabilitation of Main Trunk Sewers
(2) Rehabilitation of Five (5) Ghat Pumping Stations

(3) Rehabilitation of Konia MPS and Dinapur STP

(b) District II

(4) Construction of Sathwa STP
(5) Construction of Chauka ghat MPS
(6) Construction of Narokhar SPS
(7) Installation of Varuna river Interceptor on both banks
(8) Installation of Trunk from Chauka ghat MPS to Sathwa STP

(c) District III

(9) Augmentation of Ramna STP
(10) Augmentation of Nagwa SPS

(d) District IV

(11) Construction of Lohta STP
(12) Installation of Sewer for Main Trunk Sewer to Lohta STP

10.5 EXISTING ENVIRONMENTAL CONDITION

Varanasi city is located in the north eastern part of the India and is one of biggest cities of U.P. The Varanasi city is geographically located at $25^0$00’ to $25^0$16’ N Latitude and $82^0$50’ to $83^0$10’ E Longitude.

The Ganga river flows from south to north having the world famous Ghats on its left bank. A ridge runs almost 200m to 400m away from the western bank of Ganga and the area between the river and ridge slopes towards the Ganga river.

Varanasi is a city famous for its prominence in Hindu mythology. Varanasi had been the primordial body of two rivers, the Varuna and the Assi which are believed to have originated at the beginning of Time. The tract of land lying between them is thus known as “Varanasi” – the holiest of all Hindu pilgrimages. Varanasi sits on the banks of the sacred Ganga river, known as “Mother Ganga” to devout Hindus.

The climate of the city is tropical in nature with temperature varying from 5℃ in winter to 45℃ in summer and is more or less dry. May and June are the hottest months of the year. Dust storms and hot waves are common during summers.

The annual rainfall varies from 680 mm to 1,500 mm with large proportion of its occurring during the months of June to September. The month of October receives about 5 % of rainfall, and only 8 % of the rain occurs in remaining seven months from November to May.

The Varanasi city is situated above 80 m height from the sea level. The land is uneven and slopes from the north to south. Geologically it is situated in the alluvial Gangetic plains and mixed with clay and fine sand.

The major environmental conditions are as following.

(1) Drainage

There are 26 nalas/drains identified in Varanasi city, which carry wastewater and pollute the Ganga and Varuna rivers. Out of the 26 nalas/drains, 12 carry wastewater into Ganga river and 14 drains carry wastewater into the Varuna river.

(2) Major Sewerage System

There are three-major Sewage Treatment Plants (STP) named as Dinapur STP, Bhagwan pur STP and DLW STP. City is divided in 4 Sewerage Districts named as Central city sewerage district, Sub-central city sewerage district, Trans-Varuna sewerage district and BHU sewerage district.

(3) Ground Water Quality

In the study of existing Dinapur STP, seepage from treated sewage channel on ground water quality shows very high contamination in the ground water up to a distance of about 800 m from the STP On the other hand, at a distance of 1.0 Km to 2.5 Km there is very little or negligible contamination in the ground water.

The ground water quality around Dinapur STP shows contamination due to sewage up to a depth of about 20 m. But, deeper levels in a depth of 25 m to 60 m do not get perceptibly contaminated

(4) Influence to the Soil and Rice by Treated Sewage Irrigated

As regards, micronutrients concentration, in the soil around Dinapur STP, no appreciable change has been observed due to sewage irrigation. Even seasonal variation is observed not to make any impact.

Even though the sample volume was limited, uptake of heavy metals by paddy (rice) due to treated water irrigation was tested around Dinapur STP. The results show that there is no marked uptake of heavy metals in the rice crop.

(5) Treated Sewage Irrigation and Use of Dried Sludge

It was informed by UP Jal Nigam that treated effluent is being used for irrigating 60 ha of land of private farmers besides 4 ha of University agricultural farm and lawns of Bhagwan pur-BHU STP site. Excess effluent finds its way to Ganga river through an outfall in a nala joining the river. Digested sludge after drying is converted to manure. It is very good fertilizer for high yield. It’s Nitrogen, Phosphate and Potassium values were analysed at Regional Soil Testing Laboratory, Varanasi. The results are as follows:

Analysis Results of Dried Sludge

Item	Values Obtained	Desirable for Good Fertilizer
Nitrogen (N)	0.462 to 0.868 %	0.8 %
Phosphate (P)	8.064 to 11.648 kg/ha	20 kg/ha
Potassium (K)	56.0 to 78.4 kg/ha	80 kg/ha
pH	6.6 to 6.8	Depends on type of soil

Source: UP Jal Nigam

(6) Ghats

There are 78 pucca ghats along the Ganga river in between confluence of Assi-Ganga and Varuna-Ganga. During the flood in Ganga river silting occurs along the 7 km long stretch of ghats and also damages occur on Pucca ghats.

(7) Tourism

Varanasi is an ancient city on the bank of the holiest Ganga river. This spiritual city comprises of ghats, temples and mosques, the worth seeing places of old architecture, which attract both Indian and foreign tourists from all over the world. Some of the important places for the interest of tourists are Durga temple, Kahsi Vishwanath temple, Gyanvapi mosque, Bharat Mata temple, Tulsi Manas temple, New Vishwanath temple, Annapurna temple, Manmandir, Bharat Kala Bhawan, Alamgir mosque, Sarnath, and Ramnagar.

(8) Agriculture

An area of approximately 248,112 hectares is under cultivation in the Varanasi district. The main crops of the area are Rabi and Kharif. Among the pulses, Arhar, Chana, Mutter and Sugarcane as cash crops are predominant. Besides the above, the farming of vegetables in and around Varanasi is also taking place not only to fulfil the need of the area but also for supply to other districts, with the help of two retail and wholesale vegetable markets.

(9) Industry

Varanasi basically being a place of religious, historical and tourist importance, also enjoys the status of an important place in the production of various handicraft items like silk sarees, carpets, jari jamdani, rags, customary knitting of jamavars etc. The Varanasi sarees are famous for their uniqueness not only in India but abroad also. Out of a total of 25 hundred thousand peoples of handicraftsmen working in the country, Varanasi proudly accommodates a major portion in the tune of five hundred thousand alone.

(10) Open Space

Open spaces with recreational facilities are Azad Park, Beniya Park, Deer Park, Gandhi Park, Nadesar Park, and Pannalal Park.

10.6 EVALUATION AND CONCLUSION OF THE IEE STUDY

The Ministry of Environment and Forests (MoEF) enforced the notification in January 1994 and amended it in May 1997, April 1997, January 2000, December 2000, August 2001 and November 2001 for conducting Environmental Impact Assessment (EIA) studies which are obligatory for the establishment of certain categories of industries specified in Schedule I. The Schedule I industries include 30 categories. The appraisal committees comprising experts, Governmental official and non-government organisations (NGOs) were set up by the MoEF to scrutinise various EIAs prepared for the establishment of such industries and projects. The appraisal committees would accord an environmental clearance to the project in consultation with MoEF after scrutinising the EIA report for the proposed project. Sewerage project is not included in these industries and does not require EIA study according to the Notification.

An Initial Environmental Examination (IEE) for the proposed project components in the Master Plan for the four cities was carried out by JICA Study Team based on a JICA guideline, to briefly identify the impacts of the facilities proposed in the Sewerage Master Plans on natural and social environment. The important environmental issues are identified and the impacts are ranked as (A) strong impact, (B) medium impact, (C) not fully known, and (blank) no major impact during the construction and operation stage.

The results of the IEE to Master Plan Projects that have been planned for Varanasi city are shown in Table 10.1. The major impacts identified for the proposed facilities are related to construction and operation of sewage treatment plants as given in table below.

Impact items	**Phase**	**Spatial range**	**Time range**	**Range/ affected people**
1. Land acquisition for construction of STP	Construction	Agricultural field	Long term	Farmers
2. Income loss of agriculture due to construction of STP in agricultural field	Construction	(Social issue)	Long term	Farmers
3. Landscape and land use change	Construction	Agricultural field	Long term	Nearby villagers
4. Sludge disposal from STP	Operation	Disposal sites	Long term	Disposal sites
5. Contamination of surface water and groundwater by discharging treated effluent and seepage from STP	Operation	River, irrigation canal and groundwater	Long term	Nearby villagers
6. Contamination of soil through application of treated water and dried sludge	Operation	Agricultural field	Long term	Farmers

The proposed projects are, however, in general, environmental mitigation projects by providing sewerage system to properly dispose of municipal sewage. Therefore, the projects themselves have preferable environmental impacts on the water environment and the public health of the residents.

Table 10.1 Possible Environmental Impact Matrix for IEE

Environmental Elements / Development Scheme		Social Environment									Natural Environment								Pollution					
		Resettlement	Economic Activity	Traffic/Public Facilities	Split of Communities	Cultural Properties	Water Right/Right of Common	Public Health Condition	Solid Waste	Hazard	Topography and Geology	Soil Erosion	Groundwater	Hydrological Situation	Coastal Zone	Flora and Fauna	Local Meteorology	Landscape	Air Pollution	Water Pollution	Soil Contamination	Noise and Vibration	Ground Subsidence	Odour
Sewage Treatment Plant	**C**	B/C	B/C	C					C									B/C				C		
	O							C	C				B/C	C						B/C	B/C	C		C
Pumping Station	**C**	C		C																		C		
	O							C	C													C		
Installation of Main Trunk Sewer	**C**		C	C																		C		
	O																							
Rehabilitation of Existing Trunk sewer	**C**		C	C				C												C		C		C
	O																							

Remarks:

C: Indicates construction (rehabilitation) stage. **O**: Indicates operation stage.

A: Indicates that the development scheme is foreseen to have strong impact on the environmental element.

B: Indicates that the development scheme is foreseen to have some impact on the environmental element.

C: Indicates that the development scheme is foreseen to have minor impact on the environmental element

Balnk: indicates no impact