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-1 SEWERAGE MASTER PLAN FOR LUCKNOW CITY

JULY 2005

TOKYO ENGINEERING CONSULTANTS CO., LTD.
CTI ENGINEERING INTERNATIONAL CO., LTD.

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FINAL REPORT
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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

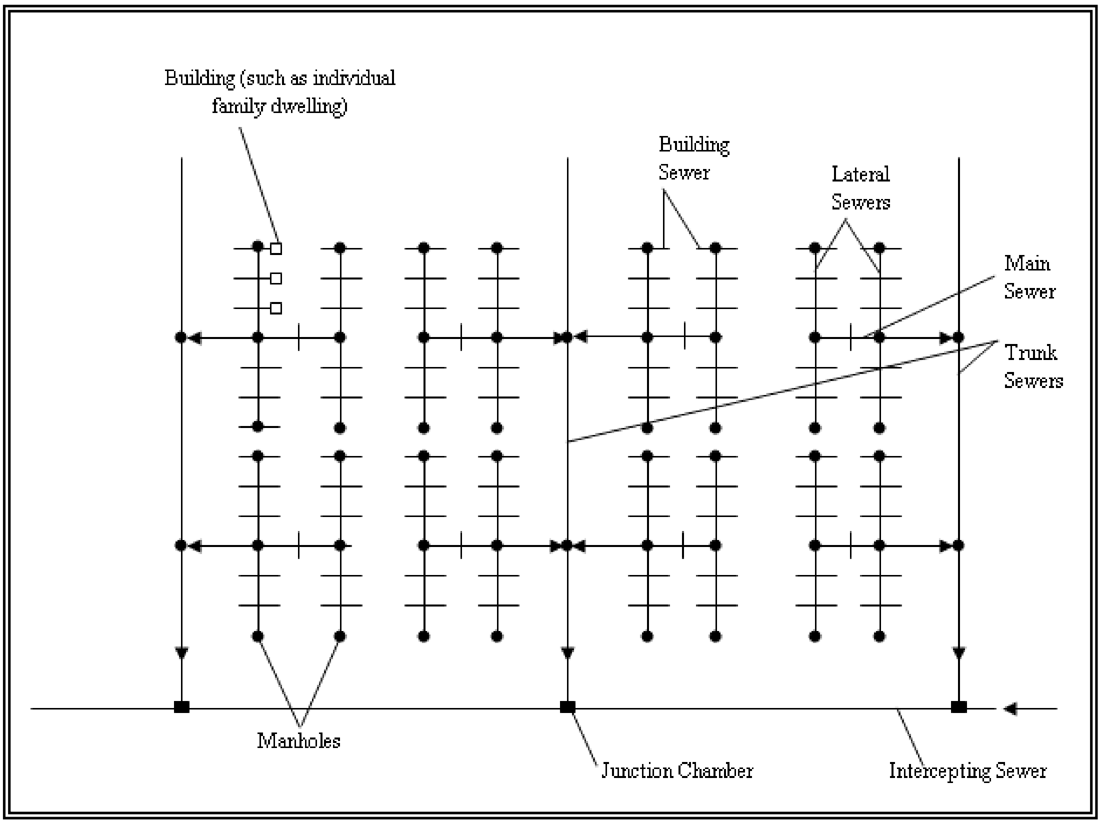
1. ***Interceptor Sewer:*** A sewer that receives flow from a number of other sewers or outlets for disposal or conveyance to a treatment plant.

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 Lucknow City. The initial stage of this study has examined prospective urban development to the year 2030, evaluated alternative sewerage projects, and selected the priority components for the Feasibility Study (FS) carried out in subsequent stages.

The methodology of this study has been to determine the least cost approach to meeting Lucknow City's sewerage and pollution control needs. This has involved the consideration of existing infrastructure and proposals by UPJN for GoAP, alternative service coverage, alternative technologies, and alternative wastewater treatment and disposal methods. A summary of relevant population, water supply and wastewater data is presented in Table 1.1.

Lucknow City's population is projected to double from 2.5 million in 2003 to 5.4 million by 2030. At present the total domestic wastewater load is about 365 mld vs. an installed treatment capacity of 42 mld. The amount of wastewater collected and diverted to treatment represents just over 10% of the total amount generated. Remaining wastewater is discharged to Gomti River through open drains. The two largest drains are GH Canal and Kukrail nala.

Water supply and sanitation services are inadequate for Lucknow’s present population. The installed raw water treatment capacity is 300 mld, while the total production from all sources is 491 mld. Distribution of water supply is higher in the central core compared to other part of the urbanized area. Production per capita in the city core is approximately 282 lpcd while in other areas it is only 147 lpcd.. Water supply is intermittent, and tube wells are becoming unreliable as the groundwater table continues to drop every year. Adverse sanitation conditions (including defecation in the open) cause increasing hazards to public health.

The sewer infrastructure is old, and poorly maintained. Many of the existing trunk sewers do not have sufficient hydraulic capacity for projected wastewater loads.

1.1.1 Need for a Sewerage Master Plan

The GAP projects and proposals have focused 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) Improving power supply
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 during lengthy power cuts.

1.2 OVERVIEW OF THE MASTER PLAN

A number of alternative district layouts have been evaluated and a recommended plan is presented in Chapter 7. The proposed sewer service areas and sewerage districts for 2030 are presented in Figure 7.3.

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 Lucknow has been divided into 4 sewerage districts. Each sewerage district having it's own sewage treatment works.

(mld)

Treatment Plants	District	Status	2003	2015	2030
Daulatganj	I	E/A	42	56	56
LDA Colony (planned)	I		-	10	14
Khwajapur	II	P	-	-	135
Kakraha	III	S	-	345	345
Mastemau	IV	P	-	100	305
Total			42	511	855

Treatment Plants	District	Process	Effluent discharge	Disinfection
Daulatganj	I	FAB	Gomti River	Chlorination
LDA Colony (planned)		FAB	Gomti River	Chlorination
Khwajapur	II	UASB++	Sai River	Chlorination
Kakraha	III	UASB++	Gomti River	Chlorination
Mastemau	IV	UASB++	Gomti River	Chlorination

E: Existing, A: Augment, S: Sanctioned, ++ post-treatment

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 sewers*:** 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 (preferably GIS based) to facilitate maintenance and future planning.

2) ***Rehabilitate existing pumping stations*:** pumping equipment is getting old and is poorly maintained. Pumps and diesel generators should be updated, and operation should be automated. 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) ***Increase treatment plant and sewer conveyance capacity*:** The existing treatment plant at Daulatganj is at present fully utilized. Part of the sewage generated on the Cis and Trans Gomti side of the river is collected in sewers but these are conveyed to the river. Remaining wastewater flow is discharged to drains that flow to the river. New treatment plants and a scheme to intercept all wastewater flows are urgently required to reduce pollutant loads to Gomti river. This intervention includes: rehabilitation of pump stations, rehabilitation of trunk sewers and lateral sewers in the city district, removing connection of branch sewers to nalas, construction of additional nala tappings and increasing the number of household connections to branch sewers.

4) ***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.

5) ***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.

Reducing the pollutant loads to water resources and improving the living environment for residents of Lucknow are important issues that can only be addressed by appropriate sanitation and sewerage interventions. These long-term goals can be met by 2030 if sufficient resources are allocated to the construction of sewage treatment plants and wastewater collection systems.

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 of new 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	626.0	1,277.8	1,903.8
Physical Contingency (20%)	125.2	255.6	380.8
Land Acquisition	43.8	19.6	63.4
Total	795.0	1,553.0	2,348.0

The cost breakdown of projects identified for implementation during Stage I is listed in order of priority in Table 1.2.

1.4 SELECTION OF PRIORITY PROJECTS FOR FEASIBILITY STUDY

A list of all infrastructure projects identified in the Master Plan is shown in Table 1.3. 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 have been included in the scope of the subsequent 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.

Priority projects: selected for detailed investigations in subsequent studies are listed as follows:

1) Feasibility of proposed trunk sewers, and pump stations. Confirm and survey proposed alignments, confirm topography, location and invert levels of connecting lateral sewers. Confirm catchment area, projected flow, determine size of pipes and develop profile drawings. If necessary adjust conceptual trunk sewer layout based on topographic surveys. Confirm site of proposed pumping stations and develop preliminary designs.

District III (Trans Gomti side)
Rising main from Mohan Meakin PS to TG pumping station

District IV (Cis Gomti side)
Cis Gomti relief sewer
Sultanpur Road trunk sewer
Martin Purwa main pumping station and rising main

2) Field survey of existing pumping stations: CGPS and TGPS to determine the physical condition of existing mechanical, electrical equipment, rising mains and sumps. Identify repair or replacement needs. Determine future flows, required size of replacement pumps, sumps and new rising mains if required.

3) Inspect condition of existing TG and CG trunk sewers and prepare a plan with costs for rehabilitation.

4) Feasibility of Mastemau treatment plant for District IV. Confirm and survey site, method of treatment, method of disposal for effluent and sludge. Develop preliminary design for STP including influent pumping station. Investigate feasibility of discharging to irrigation or wetlands.

Table 1.1 Project Data Sheet, Lucknow

Population		**2003**	**2015**	**2030**
Municipal		2,365,389	3,048,255	4,172,976
(Core Area)		793,729	922,551	1,086,280
(Other)		1,571,660	2,125,704	3,086,696
Outside municipal boundary		98,085	557,332	1,251,713
Floating		-	-	-
Total		2,463,474	3,605,587	5,424,689

Water Supply		**2,003**	**2015**	**2033**
Population served by municipal system		2,598,000	3,859,000	5,363,000
Demand (UPJN estimates)	mld	447	664	924
Water supply treatment capacity				
Existing	mld	300	300	300
Proposed	mld		364	664
Total	mld	300	664	964
Water sources				
Municipal-river	mld	241	664	924
Municipal-wells	mld	193	-	-
Private	mld	47	47	47
Other	mld	10	10	10
Total	mld	491	721	981

Wastewater		**2003**	**2015**	**2030**
Population in sewer service area		325,530	2,732,594	5,424,689
Population connected to sewer		243,930	1,223,079	4,080,732
Percentage of total population		10%	34%	75%
Wastewater return rate per capita (core)	lpcd	220	190	155
Wastewater return rate per capita (other)	lpcd	115	135	155
Total wastewater generated	mld	367	537	841
Amount intercepted	mld	42	519	841
Treatment capacity				
Existing	mld	42	42	42
Sanctioned	mld		345	345
Proposed	mld		124	468
Total	mld	42	511	855

Table 1.2 Stage I Project - Implementation Cost

(Million Rs.)

Project	Estimated Cost	+Physical Contingency	Cumulative Cost
1. District IV CIS Gomti Relief Sewer, Sultan road Trunk Sewer and STP			
(a) CIS Gomti Releif Trunk Sewer	432.5	519.0	
(b) Sultan Road Trunk Sewer	759.0	910.8	
(c) Martin Purwa SPS	714.8	857.7	
(d) CGPS	142.1	170.5	
(e) MPS at Mastemau STP	873.1	1,047.7	
(f) Rising Main of Martin Purwa SPS	23.6	28.3	
(g) Mastemau STP	364.4	437.3	
(h) Land Acquisition of STP	438.0	438.0	
(i) Branch Sewers	1,581.4	1,897.7	
Sub Total	5,328.8	6,307.0	6,307.0
2. District III			
(a) Gomti Nagar Trunk Sewer	169.6	203.5	
(b) Rising Main of Mohan Meakin PS	42.1	50.5	
(i) Branch Sewers	1,157.1	1,388.5	
Sub Total	1,368.8	1,642.5	7,949.5
Total	6,697.6	7,949.5	

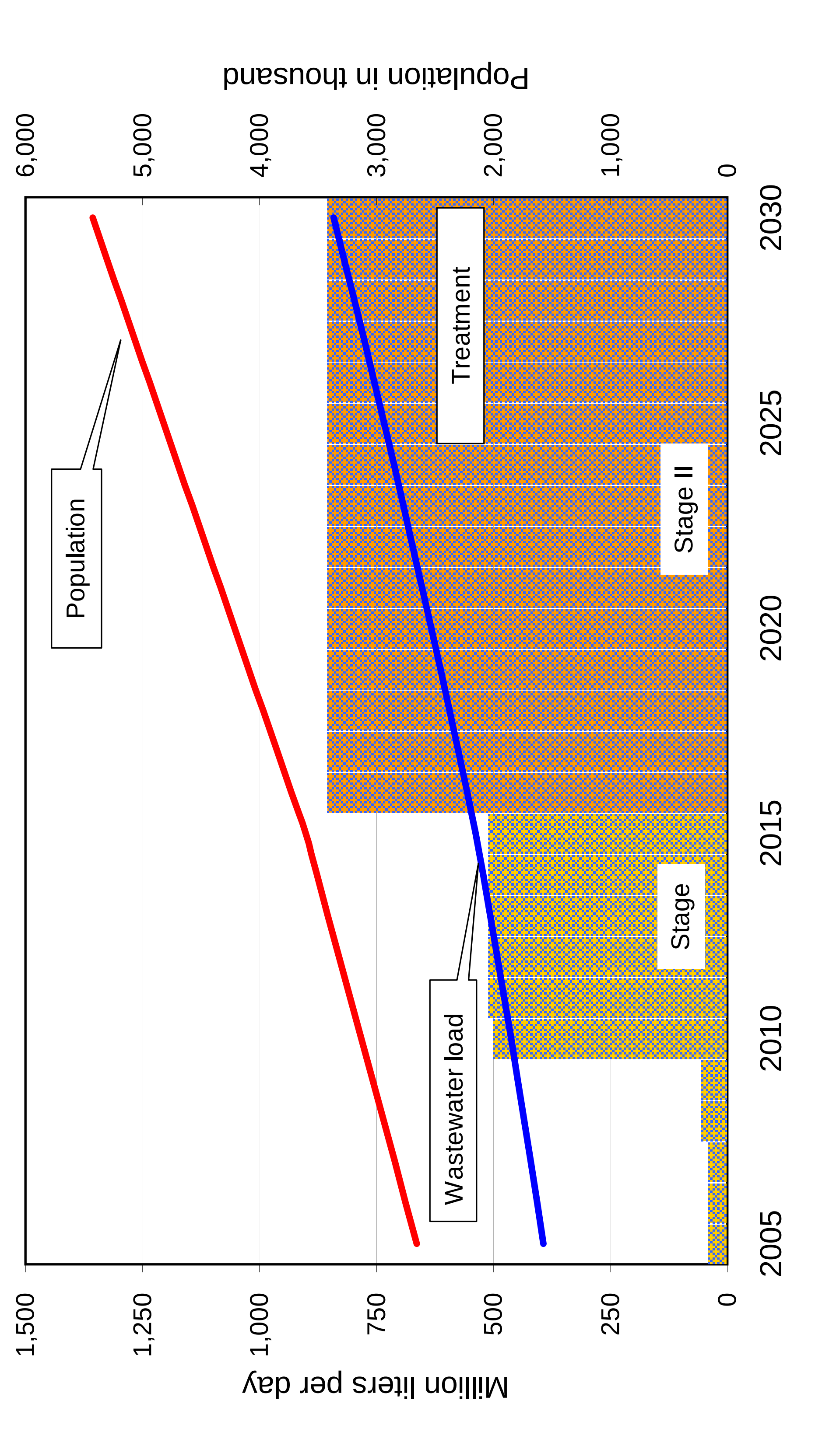


Figure 1.1 Lucknow
Sewerage Master Plan : Treatment capacity

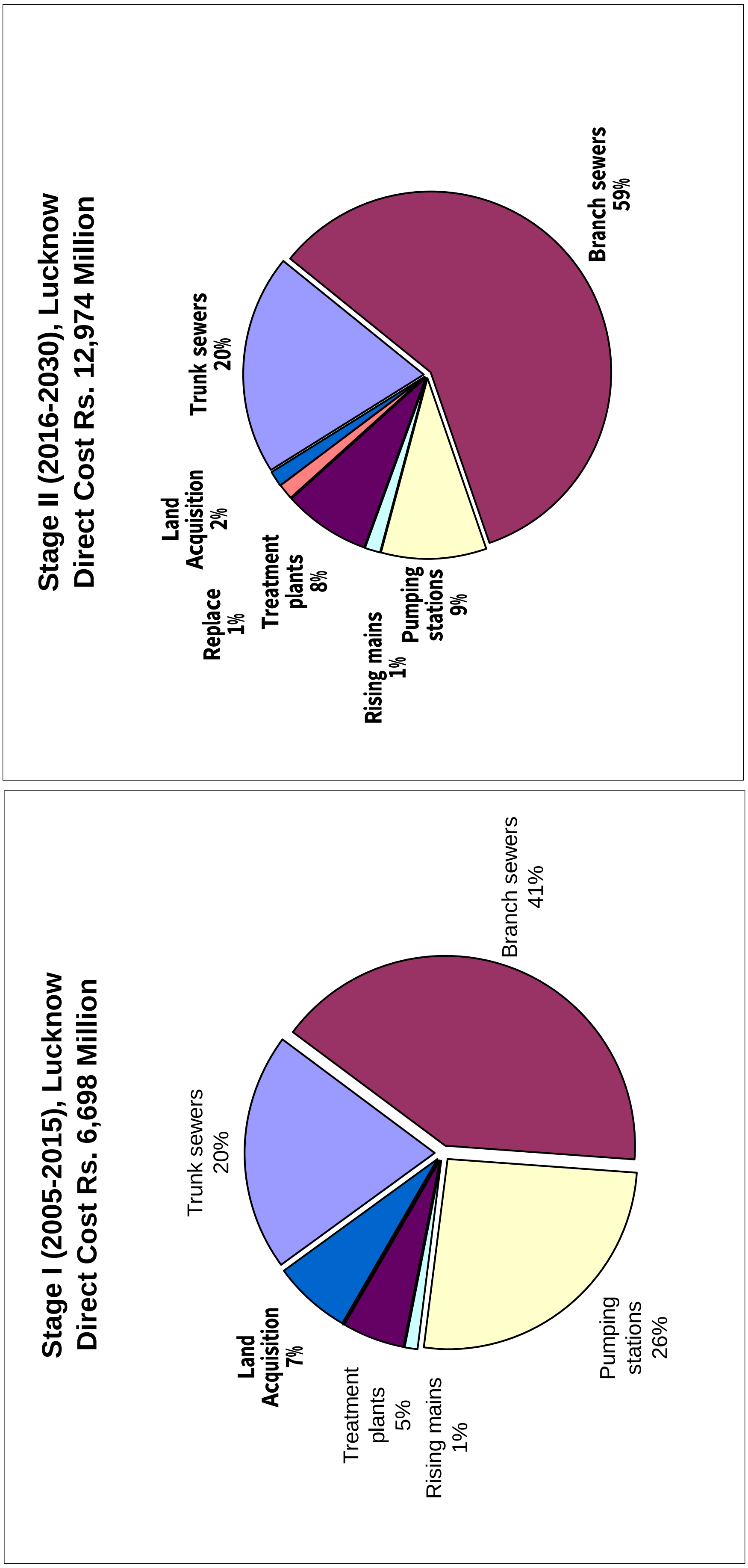


Figure 1.2 Estimated Cost of Sewerage, Breakdown of Direct Construction Cost

CHAPTER 2

INTRODUCTION

CHAPTER 2 INTRODUCTION

2.1 PRESENT WASTEWATER SYSTEMS

The city of Lucknow's wastewater collection and treatment facilities include a collection system and one wastewater treatment plant at Daulatganj with 42 mld capacity. Approximate geographical sewerage coverage, as estimated by the 1995 sewerage master plan, is depicted in Figure 2.1. The densely populated areas are already partly serviced with coverage ratios ranging from 50% to just above 70%. Coverage is between 30 and 50% on the Trans-side for a large area along the river and on the Cis-side for a large area west of Pata Nala.

The total amount of wastewater measured in 2003 (influent to STP plus flow in drains and sewer outfalls) was about 341 mld.

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 river. 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 nala interception & diversion pumping stations and the treatment plant. Jal Sansthan is responsible for maintenance sewage pumping stations, trunk sewers, lateral sewers and collection of revenue from house connections.

2.2 REVIEW OF EXISTING INFORMATION

The following background information regarding the city of Lucknow's wastewater collection and treatment system were provided to the JICA study team:

- Influent and effluent wastewater characteristics for Daulatganj FAB treatment plant
- UPJN – Nala flow measurements 2003 and 2004, and revised estimates for 2004, 2019, 2034.
- UPJN – Brief note on Pollution Control of River Gomti, March 2002.
- UPJN – Revised Project Feasibility Report (PFR) 2001-2002 for GoAP-II proposals
- UPJN – Gomti Action Plan Detailed Project Report (DPR), Sept. 2002
  - Vol. I – Phase II of Gomti Action Plan
  - Vol. II – Interception & Diversion of China Bazar Drain
  - Vol. III – Interception & Diversion of Laplace Drain
  - Vol. V – Interception & Diversion of La-Martiniere & Jiamau Drain
  - Vol. VI – Interception & Diversion of G.H. Canal Drain
  - Vol. VII – Interception & Diversion of Maheshganj Drain
  - Vol. VIII – Interception & Diversion of Rooppur Khadra Drain
  - Vol. X – Interception & Diversion of Daliganj No.1 Drain
  - Vol. XII – Interception & Diversion of Arts College Drain
  - Vol. XIII – Interception & Diversion of Hanuman Setu Nala
  - Vol. XIV – Interception & Diversion of T.G.P.S Drain
  - Vol. XV – Remaining Part of Kukrail from Bypass to MPS at Guari Culvert
  - Vol. XXI – Main Sewage Pumping Station at Guari Culvert
  - Vol. XXII – 345 mld UASB STP at Kakraha
  - Vol. XXIII – Sewage Treatment Plant Waste Stabilization Pond at Kakraha
  - Vol. XXVI – Interception & Diversion of Kedarnath Drain
- UPJN "Feasibility Report & Forecast of Cost for Augmentation of River Gomti (by SS Feeder Canal) including proposal for III Water Works at Gomti Nagar, Lucknow" Estimate No.3/2002-2003.
- Census data 2001 for wards administered by Lucknow Municipal Corporation

- Urban Environmental Services Master Plan for Lucknow (1996-2021):
  - Vol.1 – Urban Environmental Services Master Plan for Lucknow 1996-2021
  - Vol.2 – Engineering & Environmental Management Option Paper Appendices
  - Vol. 3 – Engineering Design, Costing and Supporting Data
  - Vol. 4 – Solid Waste Management
  - Vol. 5 – Infrastructure Deficiency Analysis
  - Vol. 6 – Water Quality Modeling
  - Vol. 7 – Unaccounted for Water Operation and Maintenance of Sewerage & Drainage Systems Initial Environmental Screening
  - Vol. 11 – Technical Papers
  - Vol. 12 – Report on Economic Appraisal
  - Vol. 13–Socio-Economic Segmentation in Lucknow, Population Projections and Household Service Arrangements, Summary of Findings from Study in Select Catchments

2.2.1 Previous Studies and Proposals

The Gomti Action Plan Phase I (GoAP I) was launched in 1993 under the Ganga Action Plan Phase-II. Three main cities, namely Lucknow, Sultanpur and Jaunpur where initially included in the project but works for Lucknow City where taken up by Overseas Development Administration (ODA) Govt. of UK now known as DFID (Department for International Development). The ODA intended to fund the Lucknow Project in two phases but assistance was withdrawn after the first phase. Works completed in the first phase were:

- cleaning and inspection of existing trunk and lateral sewers
- interception and diversion of Ghaughat drain
- preparation of Master Plan for phase II works
- partial rehabilitation of sewers after inspection

The master plan was prepared in 1996 for the design horizon to 2021. The location of trunk sewers, pumping stations and size of treatment facilities are identified in Drawing B1 Appendix B. The sewerage scheme consisted mainly of intercepting open drains at the tail end and diverting into the sewer system. Flow projections were provided for each major drain based on populations located within the natural catchment. These flow projections have since been used and updated by UPJN for their action plan.

In the year 2000 some priority projects were completed by UPJN under instructions from NRCD. These works included:

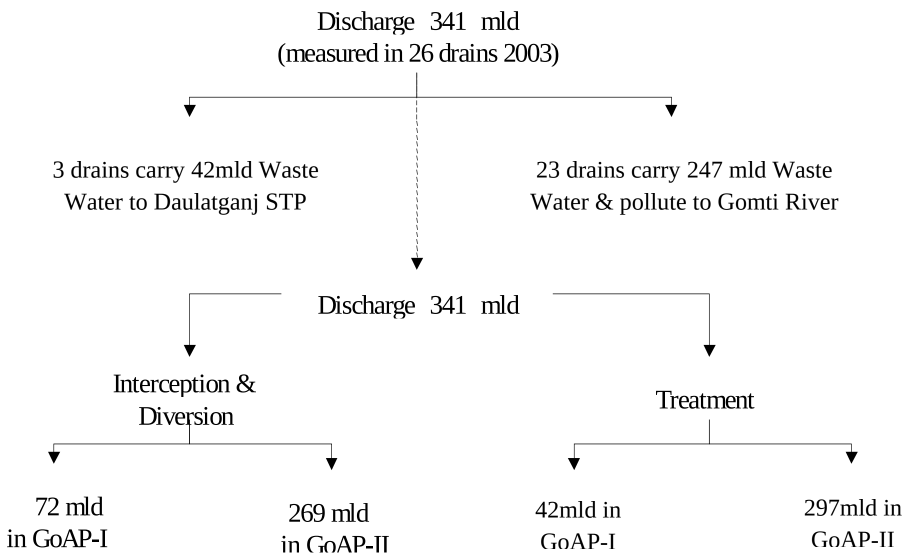
- 42 mld wastewater treatment plant at Daulatganj using FAB
- Interception of drains and conveyance to Daulatganj STP: Nagaria Nala, Sakarta Nala A&B and Pata Nala.
- Interception of drains into CG Trunk Sewer: Wazirganj Nala and Ghasiari Mandi Nala

Other works identified in the master plan have not been implemented to date.

2.2.2 Summary of Gomti Action Plan

Gomti Action Plan (GoAP) phase I has resulted in the interception and treatment of only about 11% of total present wastewater flows as shown in Table 2.1. Therefore pollution levels in the Gomti River remain high.

The GoAP phase II is aimed at intercepting and treating the remaining flows along the Gomti River. Works proposed by UPJN and sanctioned for The GoAP phase II are presented in Drawing B2 and details copied from the DPR are presented in Table 2.2.



Source: flows measured by UPJN

Figure 2.2 Flows intercepted under GoAP-I

The proposals contained in DPR provide useful information for the present master planning effort Projects implemented under GoAP I have not provided the intended improvements in water quality because there are still many large drains that have not been diverted. The weakest links in the existing scheme are the pumping stations. At present sewage overflows occur at these stations during power failures. Although emergency power generators are provided, the operating authority (UPJN) has insufficient funds for the purchase of diesel fuel. Furthermore, some of the nala tapping stations have insufficient capacity to deal with dry weather flows which have increased beyond the quantities predicted.

Under GoAP-II, UPJN has proposed several new diversion and treatment works to reduce the amounts of sewage flowing to the Gomti. It is noted, however, that the proposals do not provide a comprehensive plan for the development of a sewerage system that is needed to prevent increased flows in nalas and further degradation of the environment. Most notable is the absence of timeframes for the development of new facilities and budgets for maintenance, rehabilitation or replacement of existing facilities.

The GoAP projects consist solely of tapping nalas at the tail end and diverting to the existing Cis and Trans Gomti Trunk Sewer either by gravity or by pumping. The plan is based on the premise that the main trunk sewers (Cis and Trans side of Gomti River) have sufficient carrying capacity. Unfortunately the hydraulic capacity of the trunk sewers is much less than previously calculated. It will therefore be necessary to relieve wastewater flows in both main trunk sewers before proceeding with proposed tapping projects.

2.3 INFRASTRUCTURE MANAGEMENT ISSUES

A comprehensive proposal is required for providing adequate sewerage systems to improve sanitary conditions and reduce the impact on water quality of receiving streams. 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:

In 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 nala and connections of nala 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 location where drains have been diverted. Storm water overloads the sewer system and causes overflows to the river. 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

Table 2.1 Details of Pollution Control Schemes under Gomti Action Plan at Lucknow (as of August 2002)

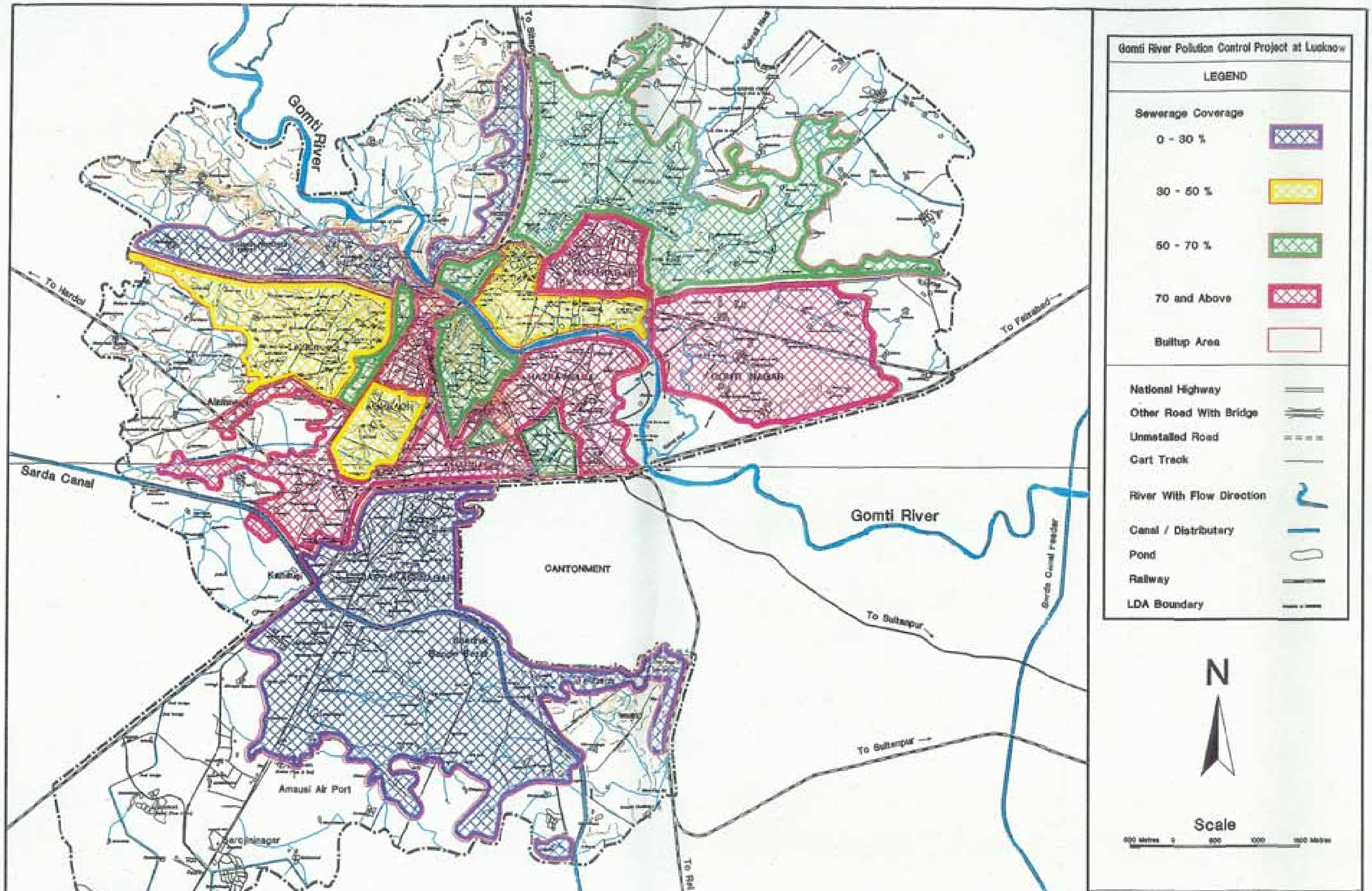
Sl. No.	Name of Scheme	No. and Name of Nala Tapped	Details of Works Proposed	Discharge in mld		Type of Treatment	Estimated Cost (in Lakh)	Remarks
				2004	2034			
A	**Pollution Control Scheme Executed (or in progress)**							
1	Interception and Diversion of Nagaria Drain	One, Nagaria Drain	Sump Well - 39.00 KL Pumping Plants -3 x 42 lps -2 x 18 lps Rising Main 350mm / 1000m	2.40	8.30	--	190	completed
2	Interception and Diversion of Sarkata Drain	One, Sarkata Drain	Sump Well - 192.00 KL Pumping Plants - 5 x 175 lps Rising Main - 800mm / 410m	29.84	45.20	--	301	completed
3	Interception and Diversion of Pata Drain	One, Pata Drain	Sump Well - 82.00 KL Pumping Plants - 2 x 60 lps -3 x 130 lps Rising Main - 600mm / 2400m	9.94	14.75	--	379	completed
4	Interception and Diversion of Wazirganj Drain	One, Waziraganj Drain	Sump Well - 152.00 KL Pumping Plants - 5 x 120 lps Rising Main - 600mm / 20.0m	17.17	36.15	--	177	completed
5	Interception and Diversion of Ghasiyari Mandi Drain	One, Ghasiyari Mandi Drain	Sump Well - 90.00 KL Pumping Plants - 5 x 80 lps Rising Main - 450mm / 70.0m	11.38	15.69	--	163	completed
6	Diversion of City Sewage upto Kukrail IPS (through Rising Main)		Rising Main 400mm / 415m 500mm / 820m 900mm / 1600m 1600mm / 1800m	--	--	Table 9-14	Operation & Maintenance Costs: Treatment Plant	not yet started
7	Interception and Diversion of Kukrail Drain		Sump Well - 1662.30 KL Pumping Plants - 6 x 1155 lps Rising Main - 1800mm / 1750m	41.47	84.12	--	2,791	not yet started
8	Construction of S.T.P. at Daulatganj (FAB Technology)		STP - 42mld	--	--	FAB	1,483	completed
9	Generating Set		Installation of Genset - 4 Nos.	--	--	--	157	
10	Land Acquisition		Land Acquisition for STP - 5.26 Hact.	--	--	--	274	
						TOTAL - A	**5,915**	

Sl. No.	Name of Scheme	No. and Name of Nala Tapped	Details of Works Proposed	Discharge in mld		Type of Treatment	Estimated Cost (in Lakh)	Remarks
				2004	2034			
B	**Pollution Control Scheme to be Executed by UP Jal Nigam**							
11	Interception and Diversion of NER D/S Drain	One, NER D/S Drain	Sump Well - KL Pumping Plants - 5 Nos. 8 lps Rising Main - 150mm / 45m	0.93	1.21	--	110	sanctioned
12	Interception and Diversion of China Bazar Drain	One, China Bazar Drain	Sump Well - 21.15 KL Pumping Plants -3 x 42 lp -2 x 10 lps	2.89	3.82	--	142	sanctioned
13	Interception and Diversion of Laplace Drain	One, Laplace Drain	Sump Well - 18.00 KL Pumping Plants -3 x 40 lps -2 x 18 lps Rising Main - 200mm / 200m	2.82	3.67	--	153	sanctioned
14	Interception and Diversion of Jopling Road Drain	One, Jopling Road Drain	Sump Well - KL Pumping Plants -3 x 20 lps -2 x 12.5 lps Rising Main - 200mm / 1000m	1.49	1.83	--	144	sanctioned
15	Interception and Diversion of Lamartiniere & Jiamau Drain	Two, Lamartiniere Drain, Jiamau Drain	Sump Well - 11.25 KL Pumping Plants -3 x 30 lps -2 x 15 lps Rising Main - 250mm / 1250m Sewer Line - 300mm / 750m	2.05	3.03	--	233	sanctioned
16	Interception and Diversion of GH Canal Drain	Three, G.H. Canal Lamartiniere Drain Jiamau Drain	Sump Well - 768.00 KL Pumping Plants -4 x 1533 lps -2 x 900 lps Rising Main-1400mm / 2x900mm	104.79	154.97	--	3,453	sanctioned
17	Interception and Diversion of Maheshganj Drain	One, Maheshganj	Sewer Line - 450mm / 1500m	0.60	1.52	--	110	sanctioned
18	Interception and Diversion of Roop Pur Khadra Drain	One, Roop Pur Khara Drain	Sump Well - 22.50 KL Pumping Plants -3 x 40 lps -2 x 13 lps Rising Main - 300mm / 1560m	0.72	1.31	--	159	sanctioned

Sl. No.	Name of Scheme	No. and Name of Nala Tapped	Details of Works Proposed	Discharge in mld		Type of Treatment	Estimated Cost (in Lakh)	Remarks
				2004	2034			
19	Interception and Diversion of Mohan Meakin Drain	One, Mohan Meakin Drain	Sump Well - 46.15 KL Pumping Plants -3 x 82 lps -2 x 41 lps Rising Main - 400mm / 800m	4.84	5.99	--	215	sanctioned
20	Interception and Diversion of Daliganj No. 1 Drain	One, Daliganj No. 1 Drain	Sump Well - 143.00 KL Pumping Plants -3 x 222 lps -2 x 136 lps Rising Main - 800mm / 180m	10.22	20.70	--	328	sanctioned
21	Interception and Diversion of Daliganj No. 2 Drain	One, Daliganj No. 2 Drain	Sewer - 450mm / 20.0m	1.51	2.07	--	18	sanctioned
22	Interception and Diversion of Art College Drain	One, Arts College Drain	Sewer - 350mm / 410m	0.72	1.30	--	16	sanctioned
23	Interception and Diversion of Hanuman Setu Drain	One, Hanuman Setu Drain	Sump Well - 7.84 KL Pumping Plants - 3 x 14 lps -2 x 6 lps Rising Main - 150mm / 50m	0.72	1.31	--	110	sanctioned
24	Interception and Diversion of TGPS Drain	One, TGPS Drain	Sewer - 400mm / 37.50m	1.51	2.07	--	51	sanctioned
25	Interception and Diversion of Nishatganj Drain	One, Nishatganj Drain	Open Drain - 1.4 x 2.3m	1.42	2.07	--	83	sanctioned
26	Interception and Diversion of Kedar Nath Drain	One, Kedar Nath Drain	Sewer - 500mm / 400m	3.02	4.14	--	79	sanctioned
27	Interception and Diversion of Baba Ka Purwa Drain	One, Baba Ka Pura Drain	Sump Well - 11.00 KL Pumping Plants -3 x 20.5 lps -2 x 8.5 lps Rising Main - 200mm / 1200m	1.09	1.68	--	191	sanctioned
28	rehabilitation of Existing Sewers and Laying of New Sewers		Sewer Line - 2100mm / 850m - 600mm / 1300m - 450mm / 630m	--	--	--	619	sanctioned
29	Kukrail Rising Main from Byepass Road to MPS at Gwari Culvert		Rising Main - 1800mm / 3890m	--	--	--	1,210	sanctioned
30	Rising Main from MPS at Gwari Culvert to STP at Kakraha		Rising Main - 2100mm / 4100m	--	--	--	1,496	sanctioned

Sl. No.	Name of Scheme	No. and Name of Nala Tapped	Details of Works Proposed	Discharge in mld		Type of Treatment	Estimated Cost (in Lakh)	Remarks
				2004	2034			
31	M.P.S. at Gwari Culvert		Sump Well - 2430.60 KL Pumping Plants - 6 x 1700 lps	--	--	--	3,293	sanctioned
32	STP (UASB at Kakraha)		STP - 345mld	--	--	UASB	11,484	sanctioned
33	STP (WSP at Kakraha)		STP - 25mld	--	--	WSP	720	sanctioned
34	Rehabilitation of SPS		Rehabilitation of Existing SPS	--	--	--	647	sanctioned
35	Genset for Kukrail Drain		Genset - 2 x 1500 KVA	--	--	--	2,312	sanctioned
36	Land Acquisition		Acquisition of Land for STP and MPS	--	--	--	1,419	sanctioned
			TOTAL - B				**28,795**	

Source: UPJN Brief note on JICA team visit to Lucknow October 2002



ESTIMATED GEOGRAPHICAL SEWERAGE COVERAGE

FIGURE 2.1

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 Lucknow, understand their spatial distribution, and then develop population growth and distribution scenarios.

The city of Lucknow has a cultural heritage and history that is inter-twined with its political and administrative importance. Its good regional and national connectivity by road, rail, and air makes it an easily accessible location, encouraging commercial growth and trade activities. It has also continued to provide employment opportunities in the administrative, services, educational, and tourism sectors.

In this project study the detailed analysis of the Lucknow region has been focussed on the municipal extents 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.

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.

Table 3.1 Decadal Population and Growth Rate of Lucknow Urban Area

Year	Lucknow Urban Area Population	Urban Area Growth Rates	Lucknow City Population	City Growth Rates
1901	256,239		256,239	-
1911	252,114	-1.6%	252,114	-1.6%
1921	240,566	-4.6%	240,566	-4.6%
1931	274,659	14.2%	251,057	4.38
1941	387,177	41.0%	361,294	43.89
1951	496,861	28.3%	459,484	27.18
1961	655,673	32.0%	615,523	33.96
1971	813,982	24.1%	774,644	25.85
1981	1,007,604	23.8%	947,990	22.38
1991	1,669,204	65.7%	1,619,116	70.79
2001	2,266,933	35.8%	2,207,340	36.33

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 Lucknow. Comparing this population distribution with a visual interpretation of the satellite imagery helped better characterize the urban development pattern into patches of varying population density levels. This approach helped assess the urban development character of the city in the face of limitations of time and resources under this project.

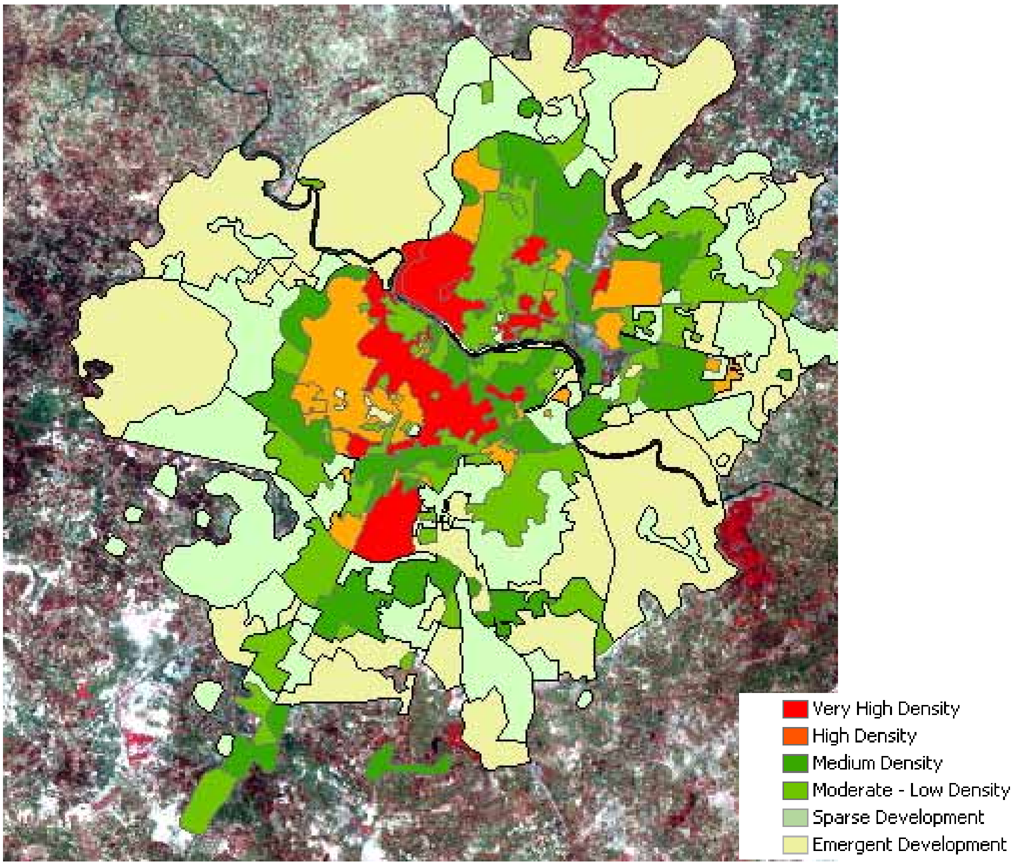


Figure 3.1 Satellite Imagery Interpretation for Development Density

3.3 POPULATION GROWTH PROJECTIONS

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

To establish the growth rates, available data on past decadal growth rates was analyzed. During the period from 1941 to 1981, the growth rate averaged 24% per decade (equivalent to a compounded annual average growth rate of 2.2%). The period of 1981 to 1991 saw a decadal growth rate of 66%. This aberrantly high growth for 1981 - 1991 is attributed in part to the changed urban extents and the inclusion of surrounding land areas into the Lucknow City census extents.

Based on the master-plan report, different statistical methods were used to project the population growth. These are shown in the table below. It has further been elaborated in the master plan that the average growth projections have been adopted for the document. This population, inclusive of an estimated 60,000 persons for the cantonment area, projects the 2021 population as 40,00,000 persons.

Table 3.2 Master Plan Projections

Item	2006	2011	2016	2021
Geometric	2,682,190	3,021,162	3,534,760	4,135,669
Arithmetic	2,501,000	2,795,000	3,089,000	3,383,000
Incremental	2,607,791	3,081,366	3,640,942	4,382,137
Average	2,563,660	2,965,843	3,421,567	3,940,269

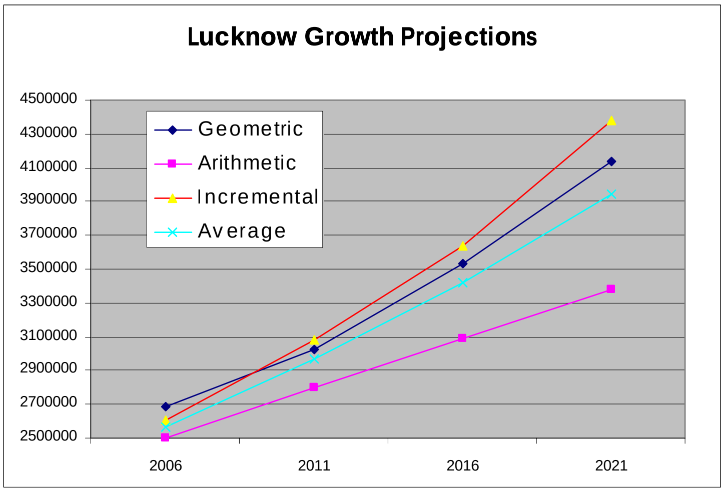


Figure 3.2 Graph: Growth Projections

Using the 1981-1991 data as background, and based on the graphical trend method, the Lucknow 2021 master plan projects a population growth rate of 50% for the period 1991 – 2001, 32% for 2001 – 2011, and 29% for the period 2011 – 2021. Reviewing this information in the context of the 2001 census, we find that the actual growth rate for 1991 – 2001 was 35.8%. Applying this growth rate, and statistically projecting successive decadal growth rates, the anticipated growth rates are expected to trend further lower than that estimated in the master-plan. However, again following the practice of attempting to place higher margins of safety in estimation, the attempt in this study has been to target population numbers similar to those projected in the master-plan, adjusting them marginally based on modeling of growth rates. Based on this approach, the study forecasts growth rates based on 2001 census data, for successive decades to be higher than master-plan rates.

Table 3.3 Population Growth Projections

Year	City Pop	Growth Rate	Source
2001	2,266,933	35.8%	Census Dept. Figures
2011	3,041,105	34.2%	Study Projections
2011	3,026,000	33.5%*	Master plan Projections
2021	4,019,809	32.2%	Study Projections
2021	4,000,000	32.2%	Master plan Projections
2031	5,215,379**	29.7%	Study Projections

* Growth rate adjusted to meet expected population numbers as provided in Master Plan

** The final numbers used in the study are based on detailed ward-wise analysis and are projected for the target year 2030. This final number is given in the table appended at the end of this chapter. This final number is higher than the number initially projected.

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. This detailed table with ward wise population estimates for 2003 and forecasts for 2015 and 2030 have been included in the end of this chapter.

It is a logical progression then to expect the exercise of population forecasts to be complemented with a spatial distribution of the population and a forecast of the increased extents of urbanization which will encompass the forecast 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 Lucknow is marked by distinct urban areas. Dominant in its growth are the historical city core and the busy Hazratganj area. The Gomti river acts as a central linear landmark of the city, and as opposed to Varanasi, where development across the Varuna river has been relatively slower, here the trans-Gomti areas are well developed and flourishing.

With growth drawn in all radiating directions of the city, the Cantonment has gradually emerged as having a more central location rather than peripheral. The limitations to urban spread of Lucknow around the cantonment are being overcome by the creation of a ring-road, that passes along the south-eastern edge of the cantonment, across relatively low-lying areas, to connect with the trans-Gomti traffic movement patterns. The intervening open space has already been targeted for development by the Lucknow Development Authority and new housing colonies are already in progress on the south-eastern and eastern side of the City.

Figure 3.3 Municipal Extents and Peri-Urban Areas

With institutional development along the northern and north-western extremities of the city, additional growth catalysts are seen in this region as well. The nature of development here is however likely to be different from that in the south-eastern part of the city. Moving along the Kanpur road, development has skipped across the limitations of the Amausi airport development restrictions to stretch along the highway towards Kanpur. Recognizing that the growth is multi-directional, the satellite imagery analysis was used to identify the peri-urban development areas in all directions.

3.4.2 Defining Growth Characteristics

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

Table 3.4 Growth Characteristics Defined

Category	Description	Decadal Growth Rate		
		2001-2011	2011-2021	2021-2031
B	Growth Directed By Catalysts	120%	80%	60%
F	Outer Area	50%	65%	75%
P	Proximal to Core	40%	20%	5%
C	Core Area	5%	4%	3%
D	Low Growth/ Dead Area for Growth/ Not to be included in Sewerage Estimates	0 to 1%	0 to 1%	0 to 1%
Avg	Background Average Growth Rate	25%	22%	20%

* 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 Lucknow, the improving infrastructure is evidently one of the most important catalyst for growth and equi-directional urban growth of the city.

Major catalysts for growth in Lucknow remain its multiple employment sources and its importance as an administrative seat. The improvements in the National Highway connecting the city with the surrounding regions and an improved internal road network, along with the proposals for the Light Rail Transport system in the city are seen as major catalysts for continued growth of Lucknow. With the relatively higher demand of real estate, improving transportation systems, and presence of major developers such as the Sahara Group are likely to continue to drive growth rates of Lucknow higher than that of other cities within this study.

At the same time however, the national trends of some slowdown in the urban growth of large cities are likely to be evidenced in Lucknow as well, supporting slower decadal growth rates in the future.

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.

The limited time on this project did not allow for detailed ground truthing and assessment of the actual development density across the entire city. Consequently the inputs of local agencies was essential in validating the existing conditions. Tremendous support in carefully reviewing this information was received from the office of the TCPO in Lucknow.

3.4.5 Population Projections by Ward

Table 3.5 gives the finalized ward-wise population figures and the overall summaries of population for each of the years of consideration under this study.

Table 3.5 Ward Wise Population Projection (Page 1 of 2)

Ward Id	Ward Name	Ward Character	Population 2001	Population Density 2001	Population 2003	Population Density 2003	Population 2015	Population Density 2015	Population 2030	Population Density 2030
1	Ibrahimpur Ward	B	20,236	59	22,090	65	37,376	110	72,125	212
2	Kharika Ward	B	22,521	154	23,914	164	34,281	235	53,772	368
3	Raja Bijli Pasi Ward	F	17,765	44	18,864	47	27,438	68	45,451	113
4	Sarojani Nagar Ward	F	42,083	45	44,686	48	64,997	70	107,667	116
5	Shaheed Bhagat Singh Ward	F	22,870	50	24,285	53	35,322	78	58,512	129
6	Guru Gobind Singh Ward	P	16,339	89	17,476	95	25,792	140	40,456	220
7	Sharda Nagar Ward	B	23,006	53	25,114	58	42,492	98	81,998	189
8	Tilak Nagar Ward	C	23,963	550	24,198	555	25,460	584	26,615	611
9	Faizullahganj Ward	F	33,431	45	35,499	47	51,634	69	85,532	114
10	Nishatganj	C	22,328	511	22,632	518	24,175	553	25,271	578
11	Vikramaditya Ward	P	17,423	92	18,636	98	27,091	143	40,155	212
12	Vidya Devi Ward	F	56,563	552	57,118	558	60,098	587	62,822	613
13	Murli Nagar Ward	C	13,704	605	13,838	611	14,504	641	14,941	660
14	Janki Puram Ward	F	35,028	99	37,195	105	53,319	150	83,634	235
15	Lal kuwan Ward	C	14,537	577	14,680	582	15,445	613	16,146	641
16	Hind Nagar Ward	F	29,644	82	31,478	87	45,124	125	70,779	196
17	Haiderganj Ward	F	25,684	62	27,273	66	39,669	96	65,711	159
18	Rajeev Gandhi Nagar Ward	C	47,280	104	49,438	109	64,618	142	90,306	199
19	Jai Prakash Nagar Ward	P	12,365	139	13,130	148	18,540	209	27,480	309
20	Chinhat Ward	B	16,739	36	18,272	39	30,917	66	59,661	127
21	Ambedkar Nagar Ward	P	34,166	206	35,725	215	45,938	277	60,388	364
22	Ram Mohan Rai Ward	C	22,632	168	24,032	178	33,406	248	46,686	346
23	Babu Kunj Bihari Lal Ward	P	22,963	248	24,011	260	30,875	334	40,587	439
24	Ramji Lal Nagar Ward	P	10,455	183	11,102	194	15,432	270	21,567	377
25	Rani Laxmi Bai Ward	C	13,113	192	13,924	204	19,042	280	25,031	367
26	Madhavpur Ward	F	17,009	50	18,061	53	26,270	77	43,517	127
27	Mahakavi Jai Shankar Prasad Wa	P	19,146	146	20,330	155	28,707	218	42,550	324
28	Indira Priyadarshini Ward	F	8,727	42	9,267	45	13,479	65	22,328	108
29	Geeta Palli Ward	P	27,288	236	28,533	247	36,691	318	48,231	418
30	Om Nagar Ward	P	11,671	198	12,393	210	16,948	287	22,279	377
31	Mahatma Gandhi Ward	C	14,791	140	15,466	147	20,215	192	28,251	268
32	Jagdish Chandra Bose Ward	C	18,006	279	18,516	287	21,512	333	24,818	384
33	Rafi Ahmad Kidwai Nagar Ward	P	34,575	63	36,982	67	54,579	99	85,610	156
34	Mahanagar Ward	P	19,185	142	20,372	151	28,766	214	42,637	316
35	GuruNanak Nagar Ward	F	15,401	215	16,354	228	23,092	322	34,227	477
36	Balakganj Ward	F	19,450	22	20,653	23	30,040	34	49,762	56
37	Shankarpurva Ward	F	34,221	268	35,783	281	46,770	367	65,363	512
38	Lalalajpatrai Ward	P	20,567	330	21,150	340	24,571	395	28,348	455
39	Mallahi Tola Ward	P	27,020	280	28,253	293	36,330	376	47,757	495
40	Lohia Nagar Ward	P	24,187	447	24,652	455	27,336	505	30,255	559
41	Hussainabad Ward	P	25,462	182	27,037	193	37,583	269	52,524	376
42	Hazratganj Ward	C	11,616	150	12,146	157	15,876	205	22,187	287
43	Triveni Nagar Ward	P	32,071	114	34,303	122	49,868	178	73,915	264
44	Begum Hazratmahal Ward	P	10,770	70	11,520	75	17,001	110	26,667	173
45	Mankameshwar Mandir Ward	P	25,790	382	26,521	393	30,811	457	35,546	527
46	Ram Tirath Ward	C	10,218	317	10,508	326	12,207	378	14,083	436
47	Rajendra Nagar Ward	C	14,275	288	14,680	296	17,054	344	19,675	397
48	Daliganj Ward	C	13,969	266	14,365	274	16,689	318	19,253	367
49	Jal Sansthan Ward	C	10,349	356	10,548	363	11,696	402	12,946	445
50	Babu Banarsi Das Nagar Ward	C	16,330	437	16,552	443	17,817	477	19,170	513
51	Bajrangbali Mandir Ward	P	18,738	150	19,897	160	28,095	226	41,644	334
52	Labour Colony Ward	C	20,054	187	21,295	199	29,121	272	38,281	357
53	Keshari Khera Ward	F	25,371	88	26,940	93	38,619	134	60,577	210
54	Peer Jalil Ward	C	10,510	188	11,160	199	15,262	272	20,062	358
55	Maithilisharan Gupt Ward	P	25,751	133	27,344	141	38,610	200	57,230	296
56	Sardar Patel Nagar Ward	P	13,418	198	14,248	210	19,485	287	25,613	377
57	Chandganj Kala Ward	P	12,216	166	12,972	176	18,316	249	27,149	369
58	Babu Jagjeevan Ram Ward	P	33,995	314	35,547	329	45,709	423	60,085	555
59	Mashakganj Ward	C	13,976	999	14,004	1,001	14,172	1,013	14,385	1,028
60	Ashok Azad Ward	P	12,281	252	12,841	264	16,513	339	21,706	446
61	Colvin College Ward	P	18,513	195	19,658	207	26,883	283	35,339	372
62	Golaganj Ward	C	13,756	608	13,891	614	14,559	644	14,998	663
63	Alam Nagar Ward	F	27,151	43	28,831	45	41,934	66	69,464	109
64	Chitraguptnagar	P	34,962	150	37,125	160	52,421	225	77,700	334
65	Aminabad Ward	C	12,161	401	12,395	409	13,744	453	15,212	501
66	Bhartendu Harishchandra Ward	P	18,006	100	19,259	107	27,998	156	41,499	231
67	Yadunath Saanyaal Ward	C	13,313	585	13,444	591	14,145	622	14,786	650
68	Gautam Buddha Ward	C	10,628	451	10,773	457	11,596	492	12,477	530
69	Ayodhya Das Ward	P	26,422	446	26,930	454	29,862	504	33,051	557

Table 3.5 Ward Wise Population Projection (Page 2 of 2)

Ward Id	Ward Name	Ward Character	Population 2001	Population Density 2001	Population 2003	Population Density 2003	Population 2015	Population Density 2015	Population 2030	Population Density 2030
70	Netaji Subhash Chandra Bose Wa	C	15,222	181	16,164	192	22,468	267	31,400	374
71	Sadat Ganj Ward	P	25,805	190	27,401	202	37,472	276	49,259	363
72	Aliganj Ward	P	21,426	140	22,751	149	32,126	210	47,618	312
73	Ismailganj Ward	F	36,909	141	38,594	148	51,241	196	75,951	291
74	Aish Bagh Ward	C	13,589	404	13,851	412	15,358	456	16,998	505
75	Harideen Rai Ward	P	27,398	338	28,175	347	32,732	404	37,763	466
76	Molviganj Ward	C	15,581	905	15,612	907	15,800	918	16,037	931
77	Wazirganj Ward	C	17,639	352	17,978	359	19,935	398	22,065	440
78	Hussainganj Ward	C	10,946	464	11,095	470	11,943	506	12,850	545
79	Gomti Nagar Ward	P	22,328	152	23,709	161	33,478	227	49,622	337
80	Nazarbagh Ward	C	15,420	751	15,511	755	16,009	779	16,492	803
81	Shivaji Marg Ward	C	9,869	426	10,003	431	10,768	464	11,586	500
82	Bashiratganj Ward	C	14,661	444	14,861	450	15,996	484	17,211	521
83	Maulana Kalbe Aabid Marg Ward	C	28,711	496	29,102	503	31,086	537	32,495	562
84	Daulatganj Ward	P	26,723	269	27,943	282	35,931	362	47,232	476
85	Motilal Nehru Nagar Ward	C	15,215	306	15,646	315	18,177	366	20,971	422
86	Lal Bahadur Shastri Ward	P	39,669	156	42,123	166	59,479	234	88,161	347
87	Gardhi Peer Khan Ward	P	29,723	237	31,080	248	39,965	318	52,535	418
88	Paper Mill Colony Ward	P	8,439	117	9,026	125	13,122	181	19,450	269
89	Ganeshganj Ward	C	10,749	538	10,854	543	11,421	571	11,938	597
90	Asharfabad Ward	C	15,255	370	15,549	377	17,241	418	19,082	462
91	Yahiyaganj Ward	C	19,361	517	19,625	524	20,963	560	21,913	585
92	Kashmiri Mohalla Ward	C	14,736	349	15,020	356	16,654	395	18,433	437
93	Nirala Nagar Ward	P	6,784	72	7,256	77	10,709	113	16,798	177
94	Bhawaniganj Ward	C	21,117	925	21,159	927	21,413	938	21,735	952
95	Acharya Narendra Dev Ward	C	14,334	1,118	14,363	1,120	14,535	1,134	14,753	1,151
96	Indra Nagar Ward	P	22,850	134	24,263	142	34,261	200	50,782	297
97	Vivekanandpuri Ward	P	14,693	217	15,364	227	19,756	292	25,970	384
98	Chandrabhanu Gupt Ward	C	10,722	358	10,928	365	12,118	405	13,412	448
99	Malviya Nagar Ward	P	13,941	236	14,577	247	18,745	317	24,640	417
100	Sewa Gram Stadium Ward	C	13,637	239	14,259	250	18,336	321	24,103	422
101	Abdul Hamid Ward	C	8,419	1,115	8,436	1,117	8,537	1,130	8,665	1,147
102	Sheetla Devi Ward	C	19,618	425	19,885	431	21,405	464	23,030	499
103	Kadam Rasool Ward	C	18,181	276	18,696	283	21,721	329	25,059	380
104	Amberganj Ward	P	24,595	400	25,292	411	29,383	478	33,899	551
105	Chowk Ward	C	13,312	246	13,920	257	17,899	330	23,529	434
106	BazarKalaji Ward	C	15,143	658	15,233	662	15,721	684	16,195	704
107	kuvar Jyoti Prasad Ward	P	30,105	319	31,479	333	40,478	428	53,210	563
108	Raja Bajar Ward	C	12,265	565	12,385	571	13,031	600	13,622	628
109	Rajajipuram Ward	P	11,650	155	12,371	165	17,468	233	25,891	345
110	Kundari Rakabganj Ward	C	20,446	418	20,839	426	23,108	472	25,576	523
111	Cantonment	D	59,593	79	60,740	81	68,100	90	78,566	104
Totals for Municipal Wards			2,266,933		2,365,389		3,048,255		4,172,976	
121	Area1		na	na	3,553	5	63,949	90	124,345	175
122	Area2		na	na	16,424	25	55,842	85	108,398	165
123	Area3		na	na	4,116	8	46,303	90	84,889	165
124	Area4		na	na	5,574	8	62,711	90	114,970	165
125	Area6		na	na	7,874	12	32,809	50	82,023	125
126	Area7		na	na	9,798	12	61,237	75	134,721	165
127	Area8		na	na	6,486	12	48,649	90	94,595	175
128	Area9		na	na	11,696	25	46,783	100	105,262	225
129	Area10		na	na	9,869	15	29,607	45	82,241	125
130	Area11		na	na	2,927	5	20,487	35	73,166	125
131	Area12		na	na	6,921	10	31,145	45	86,513	125
132	Area13		na	na	12,847	10	57,813	45	160,591	125
	Peri-Urban Areas				98,085		557,332		1,251,713	
	Urban Area Populations				2,463,474		3,605,587		5,424,689	

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. In addition, Lucknow Development Authority has constructed several large housing colonies that have their own independent water supply systems that are not maintained by Jal Sansthan.

The main source of raw water for the municipal piped water supply system is the Gomti River. Intake of water from the river in 2003 was about 250 mld (approximately 50% of the total water supplied). Raw water from the Gomti is taken to two treatment works, I at Aishbagh and II at Balaganj, where it is treated using chemical and physical clarification followed by rapid sand filtration. Present treatment capacity is 300 mld.

In 2003, approximately 195 mld was extracted from 350 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 an unknown amount of water. Hand pumps provide 52 mld in places of water scarcity.

Table 4.1 Total Municipal Water Production

Municipal Supply District	Production Capacity (mld)			
	Gomti River	Tube wells	Hand pumps	Total
A	208	56	21	285
B-E	33	137	30	200
Cantonment	3	2	1	6
Total	247	195	52	491

** Production figures reported by Jal Sansthan

4.2 QUANTITY OF WATER SUPPLIED AND CONSUMED

At present, the population of Lucknow is 2,365,389 residents. Estimated water production from municipal supplies is 490 mld.

Table 4.2 Estimated Per Capita Water Consumption (2003)

Water supply District	A (core area)	B to E
Population served	1,009,013	1,356,344
Production Capacity (mld)	285	200
Less leakage losses estimated at 15%	248	174
Per Capita Consumption (lpcd)	246	128

Including institutional/commercial consumers but excluding private supplies.

4.3 WATER SUPPLY PROBLEMS THAT AFFECT THE DEVELOPMENT OF SEWERAGE

The following water supply deficiencies have been identified in the water supply master plan and by UPJN.

4.3.1 Insufficient Water Resources

As reported by UPJN in their feasibility report the minimum discharge of River Gomti is 553.88 mld and only 266 mld can be abstracted for water supply. UPJN has reported that groundwater sources are becoming unreliable because the water table is dropping every year and as a result many tube wells are failing. UPJN has developed a plan for diverting water from the Sharda Sahayak canal to augment raw water available for treatment and distribution.

4.3.2 Power Outrages

Vital components like raw water pumping, equipments in Treatment Works, clear water pumping, tube well pumps in the water supply system are dependent exclusively on power supply for their operation. Power Outrages hence leads to severe dislocation and damage to the system operation as well as operational schedule.

4.3.3 Unaccounted for Water

Large quantity of water is lost through the system due to leakages in pipeline and appurtenances as well as due to unaccounted for water consumption. A pilot study conducted in a small area, of the city during the previous master plan identified about 40% of water is lost in the system. The component of UFW associated with leakage is estimated at approximately 15%.

4.3.4 Deficiency in System Provision

The availability of water in some areas is inadequate. With the result some people have installed their own pumping sets to draw water from distribution lines or bore wells. In summer months the crisis of water deepens to such an extent that people have to take water from hand pumps. District Administration has to arrange for new Hand Pumps every summer as immediate relief measure. Sometimes water is required to be distributed even by means of tankers.

There is problem of shortage and inadequate distribution system in the old areas of the city. Some pipe lines are very old and need replacement. Due to increase in population, existing lines have become inadequate in some pockets of the old area and need reorganization.

The new areas of the city are experiencing rapid construction activities. In these area there is shortage of source, storage and distribution lines. There are many storages, zonal reservoirs / pumping stations in operation but they are not sufficient. Such deficient system provisions lead to poor level of supply to consumers.

4.4 MASTER PLAN FOR IMPROVED WATER SUPPLY

The implementation of additional treatment capacity and strengthening of the distribution is essential to support the development of sewerage systems.

In 1997, UPJN prepared a Master Plan for augmenting water resources and improving water supply distribution to the year 2035. The plan is based on a per capita water demand of 150 lpcd + 15% UFW and the following populations and water demand estimates:

Table 4.3 Water Demand Estimates: UPJN

Item	2005	2020	2035
Population	2,598,000	3,859,000	5,363,000
Water demand (mld)	447	664	924

The plan calls for augmenting the River Gomti, with 325 m^3/s of water from the Sharda Sahayak Canal and construction of a third water works in Gomti Nagar. The canal would discharge water to the Gomti River at a place U/S of the new bridge near Gaughat.

Under the proposed plan the municipal water supply system in Lucknow city would be divided into 5 distribution Districts as shown in Figure 4.1 each with its own zonal pumping stations and reservoirs to ensure an equitable distribution of water.

The five service Districts are:

- City Service District : District ‘A’ (Old City Area)
- North Service District : District ‘B’ (Trans Gomti West to Kukrail Nala)
- East Service District : District ‘C’ (Trans Gomti East to Kukrail Nala)
- South Service District : District ‘D’ (South to N.E. Railway Track)
- Cantt. Area : District ‘E’

District A:
The ultimate demand of this district is 252 mld which can be met by the existing discharge of river Gomti. Existing water works can provide water to this district up to design year.

District B:
The ultimate demand of this district is 166 mld (68 m3/s). For this 80 Cusec raw water will be required from river/canal. Extension of existing water works at Balaganj is proposed for this district.

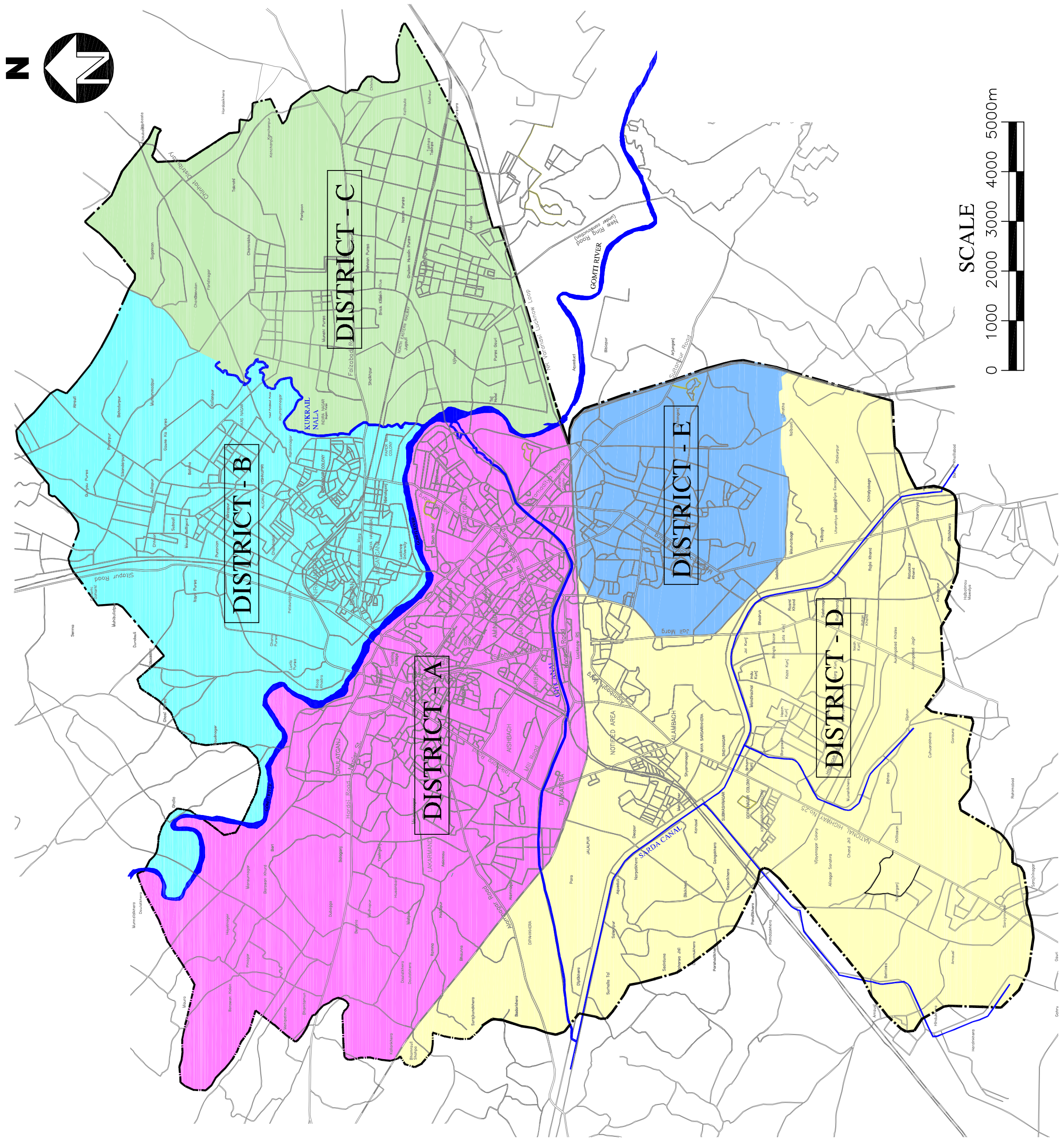
District C:
The ultimate demand of this district is 242 mld water, for this demand we need 293 mld (120 m3/s) water from river / canal. For this district a new water works is proposed near Chinhat lake in Gomti Nagar, for which 120 m^3/s raw water will be taken from the Sharda Sahayak Feeder Canal at km. 140.78.

District D:
The ultimate demand of this district is 255 mld water. For this demand we need 309 mld (125 m3/s) water from river / canal. For this district extension of Balaganj water works is proposed.

District E:
The district is Cantonment Area. The ultimate demand of this district is 9 mld water, this demand will be fulfilled by the Aishbagh Water Works.
The following new water supply works are proposed by UPJN with a design horizon of 2020:

Table 4.4 Proposed Phase I Water Supply Improvement Works (Rs. in Lakh)

Sl. No.	Proposed Work	Amount
1	Construction of Head Works on S.S. Feeder Canal.	84.00
2 (a)	Construction of RCC conduit of 2400 mm dia for gravity main from S.S. Feeder Canal at 140.8 to Gomti river near new bridge U/S of Gaughat at Lucknow. For 130 cusecs. Total length 20 Kms.	4,600.00
(b)	Crossing of National Highway, railway track and other roads and drains etc.	20.00
3	Training work at mixing point for 130 cusecs at Gomti River near new bridge U/S of Gaughat at Lucknow	13.00
4	Construction of presetling tank including cost of all pipes, gates etc. complete near head works for 190 mld (80 cusecs)	64.00
5	Raw water gravity main from pre settling tank to 3rd W/W sedimentation tank. By 1800 mm dia PSC pipe in length of 10 km.	1,800.00
6	Development of Chinhat lake as per estimate.	312.50
7	Construction of sump cum pump house at III W/W, to lift raw water from lake to the sedimentation tank during SS Feeder closing period for 172 mld flow (18 m dia and 3 m clear depth)	127.00
8	Raw Water Pumping Plants (for 172 mld)	258.00
9	Treatment Plant including settling tank, filtration plant, clear water reservoir and disinfection and other appurtenant works including pumping plants for clear water. i. Civil Works ii. Mechanical Works	 2,808.00 1,092.00
10	Clear Water Feeder Main for different zones of following sizes. 800 mm dia D.I. 600 mm dia D.I. 500 mm dia D.I	 800.00 880.00 400.00
11	Construction of boundary wall, staff quarter, lab, office and other works.	398.00
12	Acquisition of land & compensation	1,820.00
13	Electric sub station and power connection for III water works	600.00
14	Detailed survey, design and appraisal etc. @ 2.5%	401.91
15	Material storage and handling charges @ 1.5%	241.15
	BASIC COST OF WORK	16,719.56



JAPAN INTERNATIONAL COOPERATION AGENCY

TOKYO ENGINEERING CONSULTANTS CO., LTD.

CTI ENGINEERING INTERNATIONAL CO., LTD.

PROJECT	LOCATION	FIGURE 4.1
THE STUDY ON WATER QUALITY MANAGEMENT PLAN FOR GANGA RIVER IN THE REPUBLIC OF INDIA	LUCKNOW CITY	MUNICIPAL WATER SUPPLY EXISTING AND PROPOSED

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 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 considerable over the short term. In Lucknow 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.

Based on engineering experience the JICA study team has included planning capacity when sizing main trunk facilities and treatment plants by assuming a 100% connection ratio.

Future capital improvements such as expansion of treatment plants or augmentation of capacity at pumping stations 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 Lucknow 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.
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.

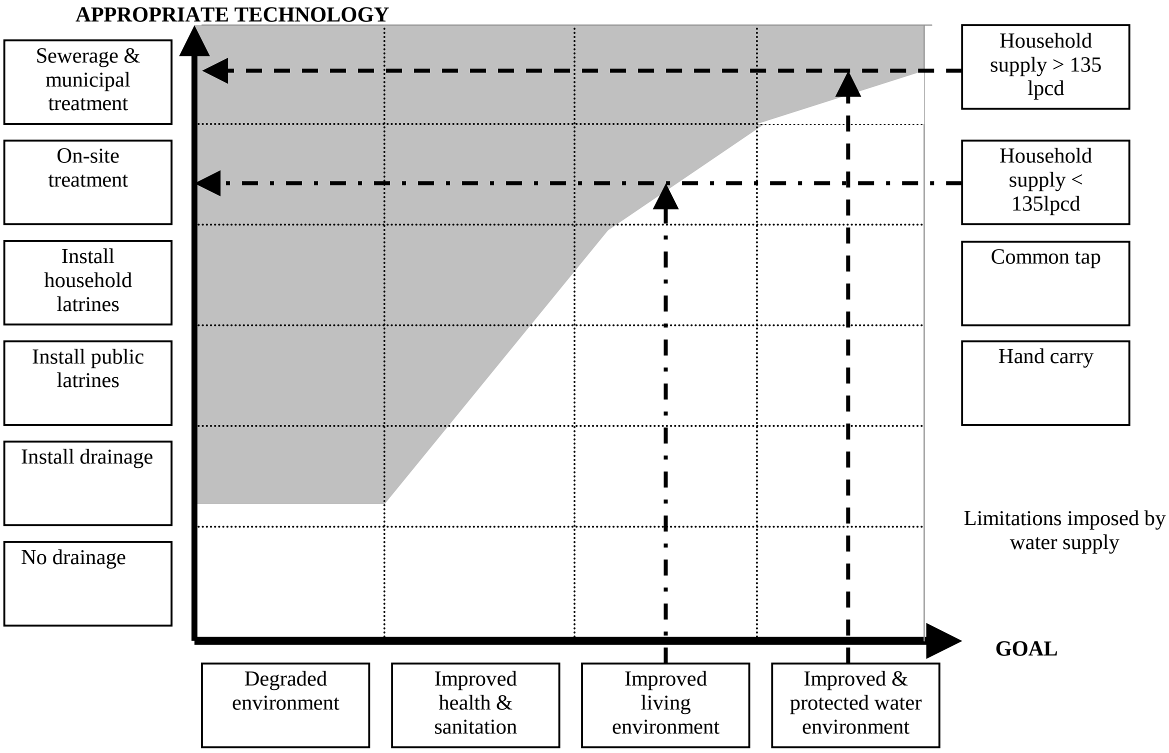


Figure 5.1 Goal and Level of Service Matrix

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.

A summary of the goals, levels of service and stepwise implementation approach proposed for each district/area is presented Table 5.1:

Table 5.1 Step-wise Progression to Sewerage Development in Lucknow

Goal	District I	District II	District III	District IV	FSA
Protecting water environment	Sewerage and off-site treatment	Sewerage and off-site treatment	Sewerage and off-site treatment	Sewerage and off-site treatment	Future sewerage and off-site treatment
Improving living environment		On-site treatment			On-site treatment
Improved health and sanitation					
Present situation	30–50% sewerage coverage Medium population densities	Mostly un-sewered Medium population densities	50-70% sewerage coverage densely populated	50-70% sewerage coverage densely populated	No sewerage, low population densities future growth potential

SEWERAGE DEVELOPMENT STRATEGY

Development of sewerage will, wherever possible, be integrated with the existing GoAP 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 service 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 that 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 by issuing 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

Regulating municipal and/or private sludge collection services through licensing and manifest system to ensure proper disposal

5.5 SEWER SERVICE AREAS AND POPULATIONS

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 2021. 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.

5.5.1 Surface Water Drainage Catchments

The previous sewerage master plan divided the Municipal Corporation of Lucknow into eight major drainage catchments, as follows:

A : Cis-Gomti	E : Kukrail Nala
B : TRANS-Gomti	F : Gomti Nagar
C : Nagaria Nala	G : Loni Nala
D : GH Canal	H: Sai catchment (a further tributary of the Gomti)

The sewerage district boundaries are generally fixed primarily on the basis of topographical features, development patterns and land use. As for the surface water drainage catchments, these are fixed especially on the basis of topographical features. In Lucknow city, there is no detailed topographic map that show the city boundary and contour lines. Therefore these drainage boundaries are used to define the sewerage catchments under this Master Plan. The drainage catchments are plotted in Drawing B3 and described below.

A: CIS-Gomti
This catchment, the core area of the city, drains into the Gomti river and extends from the Sarkata nala to Joppling Road nala. This is the only fully defined catchment in drainage terms since all the other catchments have administrative and not drainage boundaries. The boundaries of this catchment are the Nagaria nala catchment to the west, the Gomti in north-east and the GH canal catchment in smooth.

B: TRANS-Gomti
This catchment, the core area of the city north of the Gomti river, drains into the Gomti River and extends from the city boundary to the Kukrail nala. The boundaries are the city administrative boundary to the north and west, the Gomti river and Kukrail nala.

C: GH Canal
This catchment represents the man made Nawab Ghaziuddin Haidar canal. It extends from the Gomti river in the east and extends across the city past the Sharda canal in the west. While the catchment area to the north is not extensive, a large area is drained south of the railway track and at its upstream extremities. The boundaries are Cisis Gomti catchment in the north, Loni nala catchment to the east, the Sharda Canal to the south and the administrative boundary to the west.

D: Nagaria Nala
This catchment is important because it enters the Gomti river just upstream of the Gaughat water supply intake. It also includes further catchments upstream of the nala itself, together with the small catchments between the Sarkata nala and Gaughat intake. The boundaries are the city administrative boundary to the west, the Gomti river to the north, the Sarkata nala to the east and the GH canal catchment to the south.

E: Kukrail Nala
This nala catchment extends further out of the city boundary and includes the Kukrail protected forest to the north. The boundaries are the TRANS Gomti catchment to the west, the city boundary to the north and Gomti Nagar catchment in the east.

F: Gomti Nagar
This catchment represents the extreme eastern part of the city north of the Gomti river. It has as its boundaries the Kukrail nala catchment to the west and the city boundary for the remainder. The railway track represents the southern man-made boundary.

G: Loni Nala
The Loni nala catchment includes the small catchment on the Gomti river downstream of the GH Canal. It includes a major part of the Cantonment. Its boundaries are the GH canal catchment to the north, the Gomti river to the east, the city boundary to the west and the Sharda canal to the south.

H: Sai catchment
This catchment represents the extreme southern part of the city. The boundaries are the Loni Nala catchment to the east and the city boundary to the south and west and Sharda Canal to the north.

5.5.2 Proposed Sewerage Districts

A number of alternative layouts were evaluated in the previous master plan and short list of options was produced. Options that involved locating treatment plants upstream of the city were rejected. The recommended option consisted of 3 STPs: one on each side of the Gomti River located downstream of the city and one south of the airport. The recommended alternative has been re-examined and refined under the present Master Plan.

Three alternative sewerage layouts have been evaluated and a recommended plan is presented in Figures 7.1 and 7.2. Section 7 of the Master Plan. The present Master Plan has grouped the eight natural drainage catchments into 4 major sewerage districts each served by a treatment plant.

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 Gomti River 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.

5.5.3 Future Sewer Service Areas

Future Service areas outside the current Municipal Corporation limit are as follows:
District I

- FSA 131 is located in the west of Kallankhera area, just outside the current Municipal Corporation limit and extends in a narrow band along its northern and southern axis. Wastewater generated in this area tends to flow northeast towards Gomti River. Population projections indicate that densities in this area will be greater than 120 person per hectare by the year 2030, therefore, this area is designated as a future service area in District I.

District II

- FSA 127 is south of Sitalkhera, just outside the current Municipal Corporation limit. Wastewater generated in this area tends to flow southwest into local small drains that eventually join larger streams draining into Sai River. Population projections indicate that densities in this area will be greater than 120 persons per hectare by the year 2030; therefore, this area is designated as a future service area in District II.

- FSA 128 covers the southernmost part of Lucknow City, just outside the current Municipal Corporation limit. Population projections indicate that densities in this area will be greater than 120 persons per hectare by the year 2030; therefore, this area is designated as a future service area in District II.

- FSA 129/130 are south of the crossing of GH Canal and Sharda Canal, just outside the current Municipal Corporation limit. Wastewater generated in this area tends to flow southeast towards Sai river. Population projections indicate that densities in this area will be greater than 120 persons per hectare by the year 2030; therefore, these areas are designated as future service areas in District II.

District III

- FSA 121 is south of Gomti Nagar, on the south side of the Varanasi-Lucknow Loop railway line just outside the current Municipal Corporation limits. Wastewater generated in this area tends to flow southwest towards Gomti River. Population projections indicate that densities in this area will be greater than 120 persons per hectare by the year 2030; therefore, this area is designated as a future service area in District III.

- FSA 132 is the largest future service area at the Cis-side covering 1285 ha, and it is northwest of the Ghosi Purwa area, just outside the current Municipal Corporation limit. Wastewater generated in this area tends to flow southeast towards Gomti River. Population projections indicate that densities in this area will be greater than 120 persons per hectare by the year 2030; therefore, this area is designated as a future service area in District III.

- FSA 122/126 cover the northernmost part of Lucknow City, just outside the current Municipal Corporation limit. Wastewater generated in this area tends to flow southeast towards Kukrail nala. Population projections indicate that densities in this area will be greater than 120 persons per hectare by the year 2030; therefore, these areas are designated as future service areas in District III.

- FSA 125 is northeast of Gomti Nagar, just outside the current Municipal Corporation limit. Wastewater generated in this area tends to flow southwest towards Gomti River. Population projections indicate that densities in this area will be greater than 120 persons per hectare by the year 2030; therefore, this area is designated as a future service area in District III.

District IV

- FSA123/124 are east of Lilamatha, just outside the current Municipal Corporation limit. Wastewater generated in this area tends to flow northeast towards Gomti River. Population projections indicate that densities in this area will be greater than 120 persons per hectare by the year 2030; therefore, these areas are designated as future service areas in District IV.

- FSA 133 is a small pocket just west of the crossing of GH Canal and Sharda Canal outside the current Municipal Corporation limit. Wastewater generated in this area tends to flow east towards GH Canal. Population projections indicate that densities in this area will be greater than 120 persons per hectare by the year 2030; therefore, this area is designated as a future service area in District IV.

5.5.4 Populations Served

Table 5.2 Populations and Sewer Service Areas

Sewer Service Areas	Area	2003	2015	2030
Within Municipality	(ha)	Population	Population	Population
District I	3,354	162,178	221,243	323,766
District II	5,280	251,472	346,804	535,052
District III	9,567	819,532	1,107,512	1,593,952
District IV	8,592	1,132,207	1,372,696	1,720,206
Sub-total	26,793	2,365,389	3,048,255	4,172,976
Future service areas				
District I	692	6,921	31,145	86,513
District II	2,036	29,901	137,987	328,343
District III	4,125	50,496	271,648	610,077
District IV	1,427	10,767	116,552	226,780
Sub-total	8,280	98,085	557,332	1,251,713
Total	35,073	2,463,474	3,605,587	5,424,689

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. Unfortunately the amount of water consumed per capita is not well documented because there are no water meters and many households have installed private tube wells.

The Manual on Water Supply and Treatment (Ministry of Urban Development, New Delhi, May 1999) recommends the following values for planning municipal water supply systems for domestic and non-domestic purposes:

Table 5.3 Guideline Values for Future Per Capita Water Supply

	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 of water for commercial, institutional and minor industries. However, the bulk supply to such establishments should be assessed separately with proper justification

Based on production figures reported by Jal Sansthan the present estimated per capita consumption is approximately 246 lpcd in the central core and 128 lpcd or less in other areas. The JICA study team recommends using both values for planning sewerage in order to provide a more realistic estimate of wastewater volumes for phase I projects. However, in accordance with planning guidelines, the per capita rate of 150 lpcd is adopted for the design horizon of 2030.

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

Table 5.4 Assumed Per Capita Water Supply for Sewerage Master Plan (lpcd)

Water consumption	Core area			Other areas		
	lpcd	UFW	Total	lpcd	UFW	Total
2003	246	15%	283	128	15%	147
2015	200	15%	230	140	15%	161
2030	150	15%	173.5	150	15%	173.5

The core area is defined by water supply District A, located between Gomti River and GH canal. The per capita water production is expected to decrease in the core area and increase in other areas because planned improvements will result in a more equitable distribution of resources to other parts of the city.

The allowance for UFW is in accordance with Indian guidelines for planning water supply systems. It is much lower than actual and 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 5.5 Per Capita Wastewater Generation Rates

Core area	2003	2015	2030
Per capita water consumption (lpcd)	283	230	173.5
Return factor	0.70	0.75	0.80
Per capita wastewater discharge (lpcd)	198	172.5	139
+10% infiltration allowance	218 (say 220)	190	153 (say 155)

Other Areas	2003	2015	2030
Per capita water consumption (lpcd)	147	161	173.5
Return factor	0.70	0.75	0.80
Per capita wastewater discharge (lpcd)	103	121	139
+10% infiltration allowance	113 (say 115)	133 (say 135)	153 (say 155)

The wastewater return factors are within the range of 0.7 and 0.8 in the "Manual on Sewerage and Sewage Treatment (Ministry of Urban Development, December 1993). A 10% allowance is included for groundwater infiltration. The return ratio is estimated by comparing total water production to measured wastewater flows as follows: total measured wastewater flow 341 mld ÷ total water supply production 491 mld = 0.7.

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 whereby it is expected that a higher percentage of the population will be able to use flush toilets. Therefore the return factor will increase gradually from 0.7 to 0.8 to reflect larger amounts of wastewater from improved sanitation facilities and water supply conditions.

5.8 PREDICTED WASTEWATER QUANTITY

5.8.1 Total Wastewater Quantity

The population for each sewered and non-sewered area is multiplied by per capita contribution to obtain estimated wastewater flow. The sewage generated by sewerage district and by tributary area for the years 2003, 2015 and 2030 are summarized in Table 5.6 below.

Table 5.6 Projected Total Wastewater Production (mld)

Sewer Service Areas	2003	2015	2030
Within Municipality			
District I	18.7	29.9	50.1
District II	28.9	46.9	82.9
District III	94.1	149.3	246.9
District IV	212.1	236.0	266.6
Sub-total	353.7	462.1	646.6
Future service areas			
District I	0.8	4.2	13.4

District II	3.5	18.6	51.0
District III	5.8	36.6	94.5
District IV	1.1	15.7	35.1
Sub-total	11.2	75.2	194.0
Total	364.9	537.2	840.6

5.8.2 Sewer Connection Ratios

The number of households connected to sewers at present is unknown but thought to be relatively high in sewer-covered areas. However, a comparison between the total amount of wastewater produced to total amount measured in open drains indicates that only 10 to 15% of the sewage is actually reaching trunk sewers. This indicates a serious problem at the branch sewer level.

The Master Plan identifies a number of trunk sewers 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 required 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 repair to restore existing systems.

Table 5.7 Existing and Proposed Sewer Connection Targets

Sewer Service Areas	2010	2015	2030
District I	0%	0%	80%
District II	0%	0%	50%
District III	40%	60%	80%
District IV	30%	50%	80%

Note: the connection of ratio for district II is less than 80% because it is less populated and will begin development of sewerage at a later stage.

5.9 WASTEWATER TREATMENT PLANT DESIGN

5.9.1 Wastewater Characteristics

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 Biochemical 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 Daulatganj STP and CGPS sewer outfall were also measured.

Table 5.8 Summary of Measured Wastewater Characteristics

Parameter		Nalas			Sewer		
	units	Kukrail	GH Canal	Ghasiyari Mandi	Wazirganj	CGPS outfall	Daulatganj STPInlet
BOD	mg/l	75	80	72	106	154	125
COD	mg/	140	180	176	262	300	320
TSS	mg/	70	147	75	234	190	592
pH		7.3	7.3	7.1	7.0	7.1	7.5
Temp.	^{0}C	30	30	30	30	30	

Source: JICA study team, measurements taken May 7 to June 18, 2003.

Measured values in nalas do not reflect typical wastewater values. Generally the BOD is weaker than expected, probably because bio-solids are retained in soak pits or septic tanks, and sewage is diluted by some base flow in the nala.

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.

Table 5.9 Theoretical Wastewater Strength

Parameter	Unit	2015	2030
Core area			
Per capita wastewater	lpcd	190	155
BOD	mg/l	236	290
TSS	mg/l	472	580
Non core areas			
Per capita wastewater	lpcd	135	155
BOD	mg/l	333	290
TSS	mg/l	666	580

The values actually measured at the treatment plant and sewer outfall are much weaker. The dilute wastewater can be easily be explained by 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 presented in Table 5.10.

5.10 TREATMENT EFFLUENT 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 20^0C)	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
Sulphide	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 EFFLUENT DISCHARGE ALTERNATIVES

In general the cost estimates have assumed that STP effluent will be discharged to nearby rivers. However, one could consider the use of STP effluent for irrigation in agriculture. This would in most cases require an effluent pumping station in most locations. Information on required pump capacity and effluent distribution facilities is not available since the master plan didn't include survey of the proposed treatment plant or potential irrigation sites,

5.11.1 Unrestricted Irrigation

Unrestricted irrigation, that is, the irrigation of crops having direct contact with humans, either by uncooked consumption or other contact like recreational use (sport fields, parks), is subjected to effluent FC counts lower than a value of 10,000 per 100ml, according to NRCD standard. The WHO guideline for unrestricted irrigation is 1,000/100ml.

As pointed out in the next paragraph, the application of maturation ponds is the only practicable alternative for the removal of pathogens unless chlorine is used.

5.11.2 Restricted Irrigation

Although the health risks of restricted irrigation will be lower, compared to unrestricted irrigation, they will still remain. Furthermore, it will be difficult to enforced that effluent will only be used for restricted irrigation. Therefore the same standards should be applied to restricted irrigation and suitable post treatment will be required.

5.12 CHOICE OF TREATMENT TECHNOLOGY

5.12.1 General

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 Supporting Report. "Case Study on Sewage Treatment Plants" (Vol. III-11). 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 tertiary treatment to reduce faecal coliform:

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

5.12.2 Post Treatment Options for UASB Technology

The Up flow 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 Lagoon

(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 bio film 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 to 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 of rate of 1 m3/m2/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 hectare (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 FC levels remain higher than allowable:

- TSS : 20-30 mg/l
- BOD : 10-15 mg/l
- Sulphides : 0 mg/l
- FC count : aprox. 100,000 MPN/100 ml

(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 320,000m^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
FC count	:	aprox. 10,000 to 100,000 MPN/100 ml.

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 varies depending on the season.

(3) Overall Comparison of Post Treatment Options:

Criteria	Trickling filter	Aerated lagoon
Land	2	1
Investment cost	2	1
O&M	2	1
Effluent	1	2
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.

5.12.3 Unit Rates Applied in the Calculation of Treatment Costs

Land requirements and cost criteria used for comparison of options in the Master Plan are presented in Table 5.13.

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

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	AL	0.35	2.5	0.50 (20%)	2.00 (80%)	0.30
Aerated Lagoon + Maturation Ponds	AL+	0.75	3.2	0.64 (20%)	2.56 (80%)	0.32
Activated Sludge + Chlorine Disinfection	AS	0.20	2.7	1.08 (40%)	1.62 (60%)	0.36
Activated Sludge + Maturation Ponds	AS+	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
+ includes chlorine disinfection
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. Maturation ponds are added to other treatment processes if the life cycle cost is attractive and sufficient land is available.

5.13 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.

Sewers

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 pipe:	Manning's equation	$V = 1/n\ R^{2/3}\ S^{1/2}$,
	Roughness factor	n= 0.015 old concrete 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 pipe:	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

Pumping Stations:

Peak factor:	2.0 for large stations
Sump detention times:	
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 PF
	2 pumps each with capacity for the non-PF
At critical stations:	50% standby capacity at peak hour
	100% standby capacity at non-pe

Table 5.10 Calculated Future Wastewater Strength

		Condition	Ratio	BOD (mg)	
				Respective	Composite
District I	2015	Sewered	0%	237	83
		Via Nalas	100%	83	
	2030	Sewered	80%	290	249
		Via Nalas	20%	83	
District II	2015	Sewered	0%	237	83
		Via Nalas	100%	83	
	2030	Sewered	50%	290	187
		Via Nalas	50%	83	
District III	2015	Sewered	60%	237	175
		Via Nalas	40%	83	
	2030	Sewered	80%	290	249
		Via Nalas	20%	83	
District IV	2015	Sewered	50%	237	160
		Via Nalas	50%	83	
	2030	Sewered	80%	290	249
		Via Nalas	20%	83	

Calculated Future Westawater Strength

		2003	2015	2030
Per capita wastewater	lcpd	220	190	155
Per capita BOD loading	g/d	45	45	45
BOD	mg/l	205	237	290

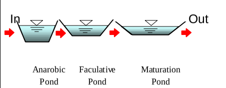
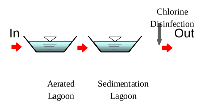
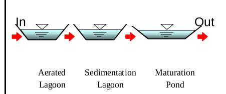
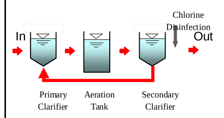
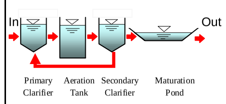
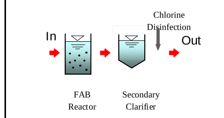
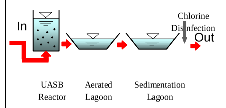
Measured Nala BOD Strength

Name of Nala	BOD(mg/l)
Kukrail Nala	75
GH Canal	80
Ghasiyari Mandi Nala	72
Wazirganj Nala	106
Average	83

District wise Overall Connecting Rate

	Year	Population	Connecting Rate	Pop. Connected	Overall Rate
District I	2015	252,388	0%	0	0%
	2030	410,278	80%	328,222	80%
District II	2015	484,792	0%	0	0%
	2030	863,396	50%	431,698	50%
District III	2015	1,379,160	60%	827,496	60%
	2030	2,204,029	80%	1,763,223	80%
District IV	2015	1,489,248	50%	744,624	50%
	2030	1,946,986	80%	1,557,589	80%

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	5.5	9.5	0.5	4.5	0.2	4.3
		Anarobic Pond(1d) +Faculative Pond(7d) +Maturation Pond(6d)	Aerated Lagoon(3.5d) +Sedimentation Lagoon(2d) +Chlorine Disinfection	Aerated Lagoon(3.5d) +Sedimentation Lagoon(2d) +Maturation Pond(4d)	Primary Clarifier(4hr) +Aeration Tank(4hr) +Secondary Clarifier(4hr) +Chlorine Disinfection	Primary Clarifier(4hr) +Aeration Tank(4hr) +Secondary Clarifier(4hr) +Maturation Pond(4d)	FAB reactor(2hr) +Secondary Clarifier(2hr) +Chlorine Disinfection	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.

CHAPTER 6

EVALUATION OF ALTERNATIVES

CHAPTER 6 EVALUATION OF ALTERNATIVES

6.1 SUMMARY

Projected wastewater flows of 855 mld far exceed the present treatment capacity of 42 mld. It will therefore be necessary to build new treatment plants. The location of these treatment plants must be within reasonable proximity to the service area to minimize conveyance costs.

Three alternative layouts, presented in Figures 6.1 to 6.3, have been evaluated in order to arrive at the most appropriate system design.

Each alternative has implications for the collection system, the sizing of pumping stations and capacity of new treatments plants. Conceptual development of the collection system and treatment plant requirements for each alternative is discussed and evaluated in the following sub-sections.

Alternative layouts are first screened through a qualitative evaluation using criteria such as reliability of operation, availability of land, ease of construction, and potential impact on water quality and downstream users. Alternatives that appear to be impractical, too difficult to construct, or potentially too costly to operate or maintain are screened out.

The key focus for evaluating the remaining alternatives involves comparison of the estimated capital cost, and O&M costs to determine the least cost solution. Cost comparisons are based on populations and sewage generated for each sub-catchment, pumping capacities, energy requirements for pumping, size and length of sewers and rising mains, land requirements and costs for treatment plants. Cost comparison tables for selected alternatives are presented in this volume in Appendix A.

6.2 DESCRIPTION OF ALTERNATIVE LAYOUTS

Three alternatives are identified with an understanding of the following constraints:

- The existing treatment plant at Daulatganj can be augmented to a maximum of 56 mld in the future.
- The STP proposed at Kakraha has a sanctioned capacity of 370 mld (345 UASB + 25 WSP) and land acquisition of 120 ha. The DPR indicates that provision will be made for a future expansion up to 545 mld.
- The STP at Hardoi Road, L.D.A. Colony has a planned capacity of 14 mld in initial stage.
- A section of the 1200 mm diameter rising main from CGPS has already been laid on the Nishat ganj bridge.
- The option of locating treatment plants upstream of the water supply intake is rejected on the grounds that it poses a health risk.
- The Cis-Gomti Trunk Sewer has a maximum carrying capacity of 1,900 lps
- The Trans-Gomti Trunk Sewer has a maximum carrying capacity of 300 lps.

All three alternatives are designed to carry total projected sewage load of 855 mld in the horizon year 2030. Khwajapur STP, STP at Hardoi Road LDA Colony and Daulatganj STP are common to all alternatives. Khwajapur STP is required to treat a projected load of 135 mld in 2030 from areas south of the Sharda canal. STP at Hardoi Road LDA Colony has been planned to treat 14mld of wastewater. Daulatganj STP is required to treat a projected load of 56 mld in 2030 from areas west of Sarkata nala. A brief description of each alternative is provided in the following paragraphs.

***Alternative I* (3 STPs):** is presented schematically in Figure 6.1. This alternative is similar to the Gomti Action Plan concept. Daulatganj STP, with total capacity of 56 mld in 2030, treats sewage from north west of the city including Hardoi Rd, Nagarian nala, Sarkata nala and Pata nala. Kakraha STP with a capacity of 650 mld in 2030 would treat sewage from Cis-Gomti including GH canal and Trans-Gomti including Gomti Nagar.

***Alternative II* (4 STPs):** presented in Figure 6.2. Kakraha STP with a capacity of 520 mld in 2030 would take sewage from part of the central core of Cis Gomti including GH canal and Trans Gomti including Gomti Nagar. A relief sewer in the central Cis-Gomti area would divert 130 mld of sewage to Mastemau STP.

***Alternative III* (4 STPs):** presented in Figure 6.3. This alternative is similar to alternative II except all sewage from Cis-Gomti side is treated at Mastemau STP with capacity of 305 mld. Kakraha with capacity of 345 mld would treat all sewage generated on the TRANS-Gomti side.

6.3 QUALITATIVE COMPARISON OF ALTERNATIVES

This subsection of the report provides a qualitative comparison of alternatives. The relative merits of each alternative are discussed in the following paragraphs.

6.3.1 Evaluation Criteria

A series of factors are developed to provide qualitative evaluation for plan alternatives. These factors are:

- *Reliability* – The potential for mechanical and electrical failure of the system must be minimized by reducing the number of pumping stations and selecting treatment processes that can meet effluent criteria even under adverse operating conditions.
- *Compatibility* – All new options must be compatible with the existing system in order to minimize disruption and cost.
- *Implementability* – the plan must minimize construction costs and have the ability to be phased into connection with the existing system. This allows for ease of construction and reduces the overall financial burden.
- *Environmental impact* – treatment plant locations and selection of processes must reduce the impact on water quality. Outfalls should not be located upstream of raw water supply intakes or within close proximity of religious bathing sites.
- *Stability of treatment processes* – Processes that are easily upset by prolonged and frequent power outages (e.g. activated sludge) are less favorable because they will not easily recover and have the potential to produce poor quality effluent day after day resulting in high pollutant loads. Alternatives that allow for more robust treatment processes such as waste stabilization ponds or aerated lagoons are more favorable.
- *Flexibility* – The plan should consider the ability to expand for future increased flows and be able to meet effluent criteria and potential future regulations.

6.3.2 Evaluation of Alternatives

Each plan alternative is ranked using the qualitative criteria discussed above. A ranking of 1 to 3 is given with 3 being the least favorable.

Table 6.1 Qualitative Ranking of Sewerage Alternatives

Item	ALT I	ALT II	ALT III
Operational Reliability	3	2	1
Compatibility	3	1	2
Implementability	3	1	2
Potential Impact on Downstream Users	3	2	1
Stability of Treatment Process	1	3	2
Flexibility	3	2	1
Total	16	11	9
Overall Ranking	**3**	**2**	**1**

1 = most favorable 3= least favorable

Alternative I:

- This alternative requires a lesser number of pumping stations and treatment plants than the other alternatives; however, a major upgrade of pumping and treatment capacity would be required at GH Canal Pumping Station, Guari Main Pumping Station and Kakraha STP.
- This alternative requires a significant cost for construction of rising main across the Gomti River from GH Canal Pumping Station.
- Sufficient land may not be available at Kakraha STP.
- The catchment area is very large and a single sewage treatment plant may become more difficult to operate with the increased load; besides, the outfall sewer to the treatment plant would be much larger.

Alternative I is not recommended on the grounds that:

- There is insufficient land available at Kakraha for a 650 mld treatment plant.
- The Cis Gomti Trunk Sewer and the Trans Gomti Trunk Sewer do not have sufficient carrying capacity for future flows. These trunk sewers run through very congested areas and it would not be possible to lay a second trunk sewer along side the existing. It would also not be possible to install a deeper interceptor in this location.

Alternative II:

- This alternative requires a new treatment plant at Mastemau to treat wastewater of Cis Gomti area, except for part of the core city area and Arjunganj-Telibagh area.
- This alternative requires less treatment capacity at Kakraha STP than alternative I; however, a major upgrade of land and treatment capacity would be required.
- A new pumping station at Martin Purwa will receive sewage only from the new CIS Gomti Relief Sewer area.
- Land is available at Mastemau; therefore, there is flexibility for future expansion as the city grows beyond 2030.

Alternative III

- This alternative requires a new treatment plant at Mastemau to treat all wastewaters of CIS Gomti area, GH Canal area and Arjunganj-Telibagh area, so that this alternative requires more treatment capacity at Mastemau than Alternative II.
- This alternative makes use of sanctioned capacity at Kakraha STP with no additional land requirements.

- A new pumping station at Martin Purwa will treat sewage from existing Cis Gomti Trunk Sewer area, new Cis Gomti Relief Sewer area and GH Canal area, so that this alternative requires more pumping at Martin Purwa than Alternative II.
- Sewage from CG Pumping Station is proposed to be conveyed to the new Cis Gomti Relief Sewer by either a rising main or a connecting sewer; likewise, the sewage from GH Canal Pumping Station will be pumped to the new pumping station at Martin Purwa as well as the flow in GH canal will be intercepted in the Cis Gomti Relief sewer by gravity, i.e., this alternative will not require rising main across the Gomti River.

Alternative I is the least favourable. Furthermore it may not be feasible to build a single large treatment plant at Kakraha since land availability has been identified as a problem issue by UPJN in their DPR for the treatment plant. The other two alternatives are relatively close therefore a cost comparison between Alt II and Alt III has been done for making a final selection.

6.4 SELECTION OF TREATMENT PROCESS

The type of treatment process for the proposed treatment plants has been selected before proceeding with a cost comparison of the alternative sewerage layouts for the various districts. The preliminary selection of a treatment processes is based on comparison of life cycle costs for various treatment processes that could be used to meet effluent criteria. Land requirements and costs are based on a survey of existing installations provided under GAP and YAP and typical values reported in literature. In the case of UASB installations it is assumed that post treatment will be achieved by adding aerated lagoons to meet discharge criteria for BOD and sulphide and a 3 day retention period to reduce faecal coliform count.

Detailed cost calculations for each treatment plant are presented in Appendix A. The following treatment capacities have been identified for the year 2030 based on population and wastewater generated by sewerage district.

Table 6.2 Treatment Capacities for Comparison of Alternatives

Treatment Plants	Status	Existing or sanctioned capacity (mld)	Alt II	Alt III
Daulatganj STP	A	42 : FAB	56	56
Kakraha STP	S	345:UASB + 25:WSP	520	345
STP at Hardoi Road LDA Colony	PL	14 : FAB (Initial stage)	14	14
Mastemau STP	P		130	305
Khwajapur STP	P		135	135
Total			855	855

A = Augment existing, P = Proposed, E = Existing, S = Sanctioned, PL = Planned

The following abbreviations and assumptions have been used in the cost comparison tables that are presented in the following sub-sections:

- WSP: Waste Stabilization Pond, including Maturation Ponds;
- AL: Facultative Aerated Lagoon;
- AS: Activated Sludge
- FAB: Fluidised Aerated Bed
- UASB: Up flow Anaerobic Sludge Blanket
- + Indicates additional maturation ponds, sized for minimum 3 day retention time
- ++ indicates post treatment provided by aerated lagoons.

- Land costs: 40 lahks per ha (reported by UPJN at Varanasi at Workshop on Feb 17 2004)
- Land area: taken from NRCD guidelines and review of existing STPs implemented under GAP/YAP
- Capital and O&M costs taken from a review of STPs implemented under GAP
- Present value based on 5% interest and 30 year life with replacement of mechanical equipment after 15 years

6.4.1 Kakraha STP

UPJN has already sanctioned a project to construct a 345 mld UASB and a 25 mld Waste Stabilization Pond. It is however the opinion of the Study Team that neither option is really suitable. The Waste Stabilization Pond requires very large land area for treatment of a relatively small portion of the flow. The proposed UASB with final polishing pond will not meet discharge standards set by NRCD and therefore post treatment will ultimately be necessary. However there is no such provision in the current DPR. Post treatment using Aerated Lagoons is recommended and it will be incumbent on UPJN to obtain sufficient land.

6.4.2 Mastemau STP

The cost comparison of process alternatives indicates that UASB plus Aerated Lagoon offers the lowest life cycle cost. Waste stabilization Ponds offer the lowest O&M cost however the land requirement is significant and it is doubtful that such a large site can be obtained. Therefore the Master Plan adopts UASB for preliminary cost comparison of alternatives.

Table 6.3 Mastemau STP: Preliminary Cost Comparison of Process Alternatives

Cost (Rs. million)	WSP	AL	AL+	AS	AS+	UASB++
Alternative II 130 mld						
Land area for treatment process (ha)	163	46	98	26	78	46
Land cost	650	182	390	104	312	182
Capital cost	208	325	416	351	412	390
Annual O&M	8	39	42	47	49	17
Life cycle cost (including land)	980	1,138	1,477	1,242	1,581	888
Alternative III 305 mld						
Land area for treatment process (ha)	381	107	229	61	183	107
Land cost	1,525	427	915	244	732	427
Capital cost	488	763	976	824	1,037	915
Annual O&M	18	92	98	110	116	40
Life cycle cost (including land)	2,299	2,669	3,465	2,914	3,709	2,084

6.4.3 Pumping Stations

Conveyance costs for trunk sewers are calculated for each layout. The carrying capacity (and size) of the gravity trunk sewers have been computed in accordance with Manning's formulae with values of 'n' = 0.015 corresponding to concrete pipe. Flows in each segment are peak flows, based on contributing populations. Conveyance costs include the costs of pumping where the invert depth of gravity sewer exceeds 10m. Pumping costs are also included at the head of treatment plants where the incoming flow is by gravity sewer.

Table 6.4 Capacity of Pumping Stations for Comparison of Alternatives (mld)

Pump Stations	Status	Existing or sanctioned capacity	Alt II	Alt III
TGPS	E	62	51	51
CGPS	E	172	51	51
Kukrail No.1	S	320	284	234
GH Canal	S	158	125	125
Guari	S	478	498	323
Martin Purwa	P	-	72	246

The size and length of rising main is different for each alternative; therefore, the energy costs will also be affected. Preliminary selection of rising mains is based on calculations presented in Appendix A for determining the most economical solution when considering energy costs, supply and installation of pre-stressed concrete pipes, cost of pumps and annual maintenance costs.

For the Kukrail No.1 Pumping Station, Alternative III requires less pumping capacity than Alternative II. This is because the pumping station in Alternative III will receive sewage only from the newly proposed Kukrail Nala Interceptor on the left bank sewer and TG Pumping Station, while the pumping station in Alternative II will receive flows form the CG Pumping Station in addition to previously mentioned

Similarly, the required pumping capacity of Alternative III for the Guari Main Pumping Station is much less than that of Alternative II. This is because the pumping station in Alternative III is to receive sewage from the Trans Gomti area only, while the pumping station in Alternative II is to receive sewage from the CG Pumping Station and GH Canal pumping station in addition to sewage from the Trans Gomti area.

There is a large difference between the pumping capacities of Alternative III and Alternative II for the Martin Purwa Main Pumping Station. Alternative III requires more pumping capacity than Alternative II because the pumping station in Alternative III is to receive sewage from the whole Cis Gomti area including those from the CG Pumping Station and the GH Canal Pumping Station. On the other hand, in the case of Alternative II, sewage flows from the Cis Gomti area do not include sewage from the catchments of CG Pumping Station and GH Canal Pumping Station.

The difference of pumping capacities between the existing or sanctioned and the required capacities under the alternatives is further described in Chapter 7.

6.5 COST COMPARISON AND SELECTION OF PREFERED ALTERNATIVE

The relative investment costs and operating costs of Alternatives II and III are compared. Components that are common to both alternatives are not included in the cost comparison. Components that are included are shown schematically in Figures 6.4 for ALT II and Figure 6.5 for ALT III. These include:

Trans Gomti	Cis Gomti
▪ TGPS rising main ▪ Kuktail no.1 PS, rising main ▪ Guari MPS and rising main ▪ Kakraha STP	▪ CGPS rising main ▪ CG relief sewer ▪ GH canal PS and rising main ▪ Martin Purwa MPS and rising main ▪ Sultanpur Road trunk sewer ▪ Mastemau STP

A comparison of investment and O&M costs for treatment and pumping Alternatives II and III is summarized in Table 6.6 and presented in more detail in Appendix A.

Alternative III has a slightly higher present value cost but a lower annual operating and maintenance cost. ALT III also provides more flexibility for future growth and expansion at both treatment plants. Lower O&M costs and operational flexibility have been identified as key parameters in the selection of alternative III by UPJN. Therefore the Master Plan adopts Alternative III as the preferred solution for configuring the future sewerage network.

Table 6.5 Preliminary Cost Comparisons of Alternatives II & III

Investment Costs (Rs. million)	ALT-II	ALT-III
Land	910	910
Capital costs		
Treatment works	2,037.6	2,103.7
Pumping stations	1,373.3	1,285.4
Rising mains	619.9	645.6
Trunk sewers	692.1	1,103.1
Sub-Total	4,722.9	5,137.8
Annual O&M (1)		
Pump stations	98.88	73.38
Treatment works	90.05	97.03
Sub-Total	188.93	170.41
Life cycle cost (2)	8,960.1	9,029.9

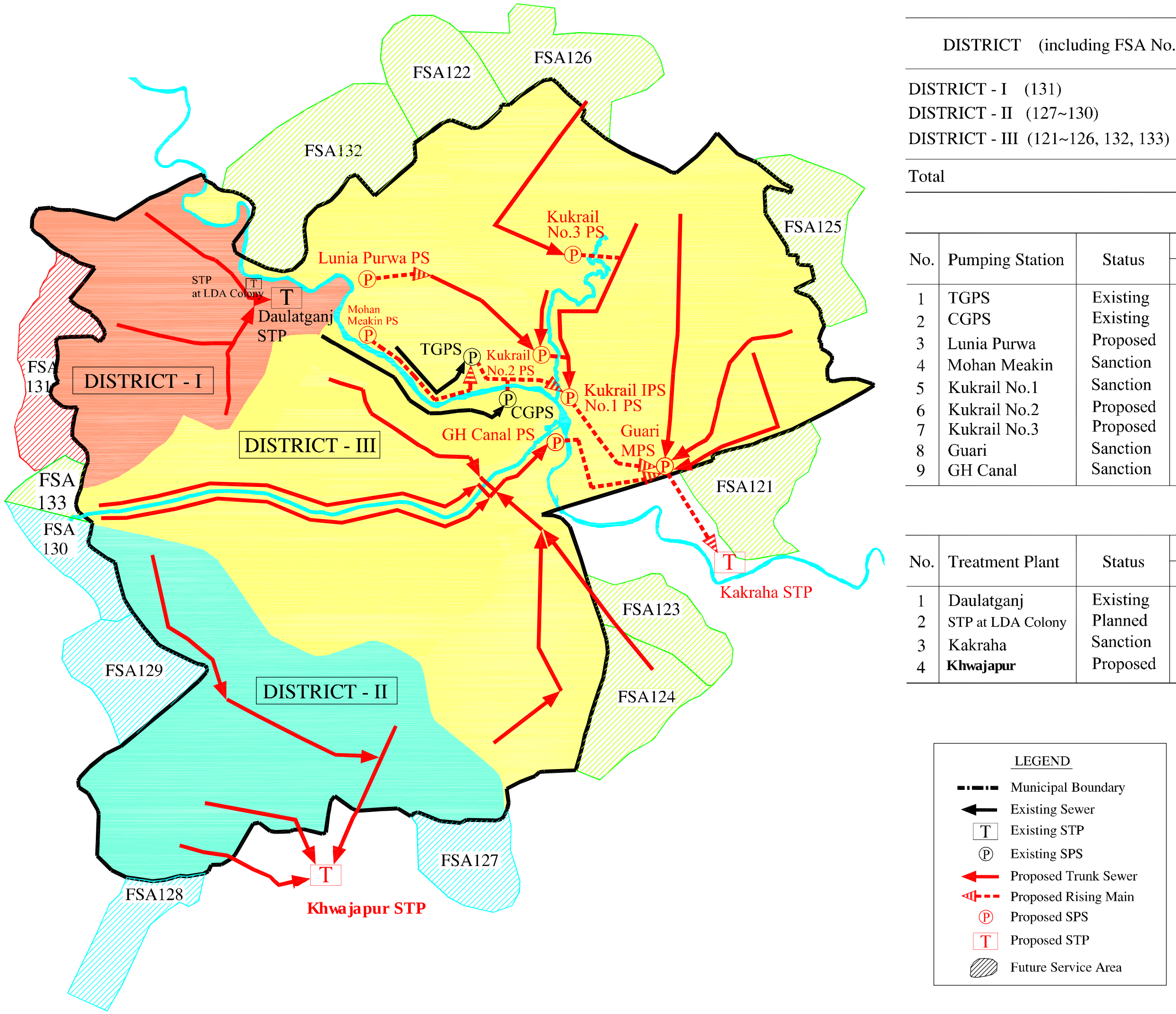
(1) Includes energy costs
(2) At 5% interest, 30 year life, and replacement of M&E components after 15 years

ALTERNATIVE - 1

DISTRICT (including FSA No.)	Population			Wastewater Generation (MLD)		
	2003	2015	2030	2003	2015	2030
DISTRICT - I (131)	169,099	252,388	410,278	19.44	34.13	63.59
DISTRICT - II (127~130)	281,373	484,792	863,396	32.31	65.49	133.83
DISTRICT - III (121~126, 132, 133)	2,013,002	2,868,408	4,151,015	313.11	437.62	643.40
Total	2,463,474	3,605,587	5,424,689	364.87	537.24	840.82

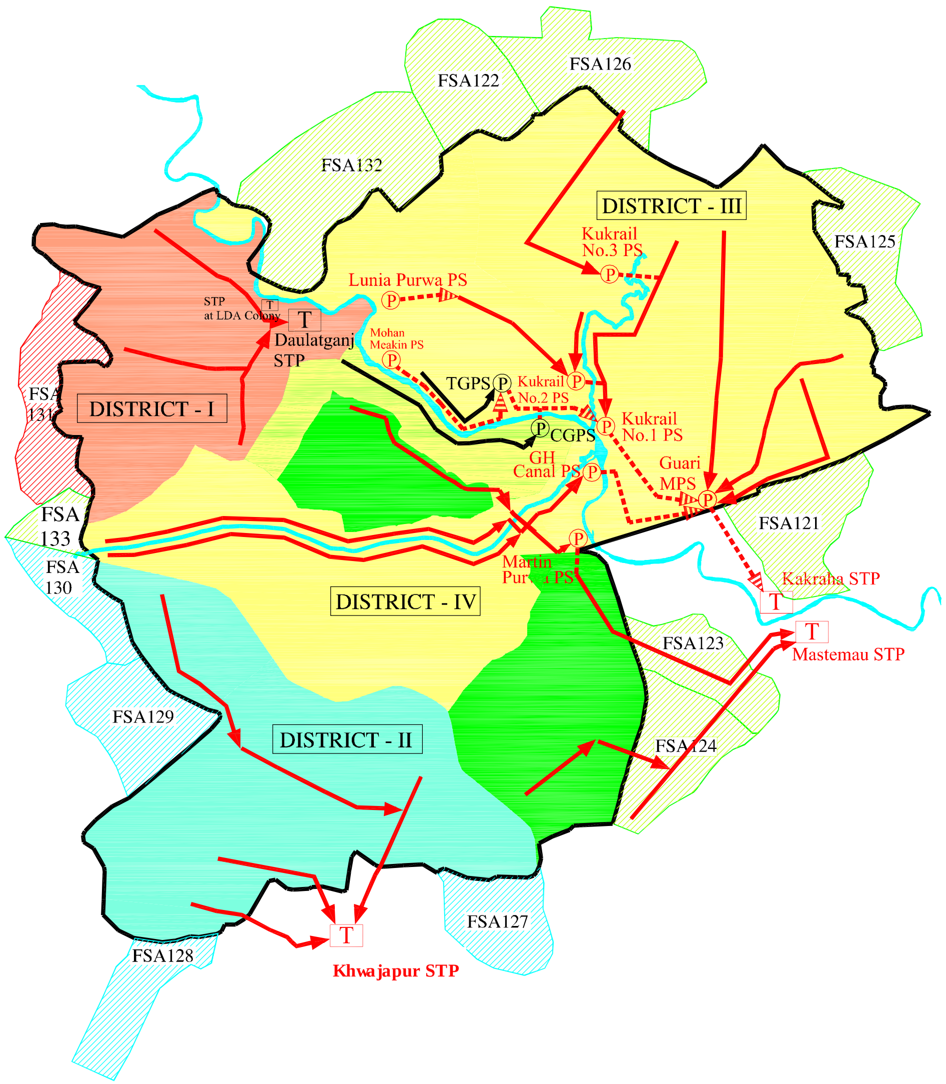
No.	Pumping Station	Status	Capacity (MLD)		Remark
			2015	2030	
1	TGPS	Existing	35	51	+ Daliganj No.1
2	CGPS	Existing	50	51	
3	Lunia Purwa	Proposed	12	33	
4	Mohan Meakin	Sanction	19	28	
5	Kukrail No.1	Sanction	180	284	+ TGPS +CGPS + Kukrail No.2&No.3
6	Kukrail No.2	Proposed	28	60	+ Lunia Purwa
7	Kukrail No.3	Proposed	50	93	
8	Guari	Sanction	429	574	+ Kukrail No.1 + GH Canal
9	GH Canal	Sanction	203	252	

No.	Treatment Plant	Status	Capacity (MLD)		Remark
			2015	2030	
1	Daulatganj	Existing	56	56	District - I
2	STP at LDA Colony	Planned	10	14	District - I
3	Kakraha	Sanction	440	650	District - III
4	**Khwajapur**	Proposed	70	135	District - II



JAPAN INTERNATIONAL COOPERATION AGENCY
TOKYO ENGINEERING CONSULTANTS CO., LTD.
CTI ENGINEERING INTERNATIONAL CO., LTD.

PROJECT	LOCATION	FIGURE 6.1
THE STUDY ON WATER QUALITY MANAGEMENT PLAN FOR GANGA RIVER IN THE REPUBLIC OF INDIA	LUCKNOW CITY	SEWER LAYOUT ALTERNATIVE - I

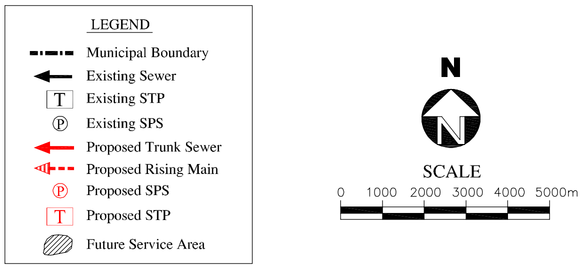


ALTERNATIVE - 2

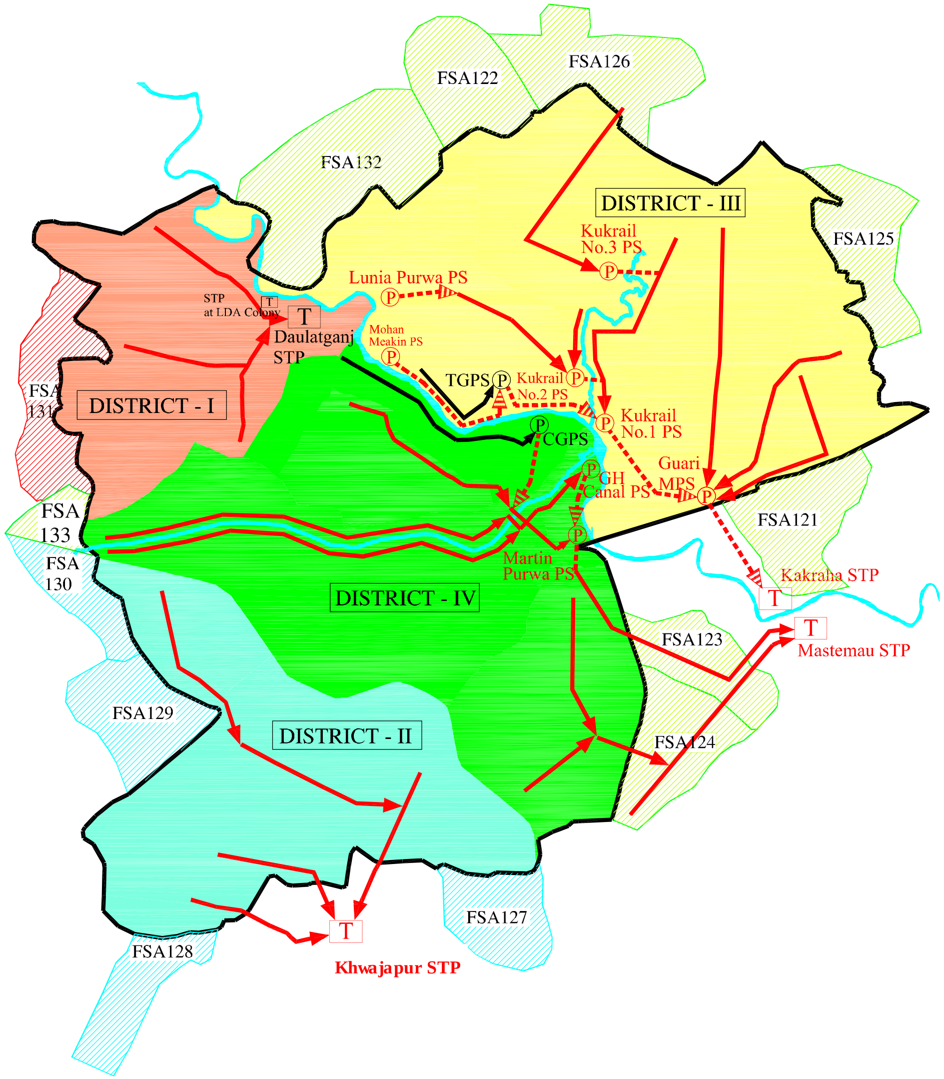
DISTRICT (including FSA No.)	Population			Wastewater Generation (MLD)		
	2003	2015	2030	2003	2015	2030
DISTRICT - I (131)	169,099	252,388	410,278	19.44	34.13	63.59
DISTRICT - II (127~130)	281,373	484,792	863,396	32.31	65.49	133.83
DISTRICT - III (121, 122, 125, 126, 132, 133)	1,543,477	2,235,366	3,331,934	219.97	329.18	516.42
DISTRICT - IV (123, 124)	469,525	633,042	819,082	93.14	108.43	126.98
Total	2,463,474	3,605,587	5,424,689	364.87	537.24	840.82

No.	Pumping Station	Status	Capacity (MLD)		Remark
			2015	2030	
1	TGPS	Existing	35	51	+ Daliganj No.1
2	CGPS	Existing	50	51	
3	Lunia Purwa	Proposed	12	33	
4	Mohan Meakin	Sanction	19	28	
5	Kukrail No.1	Sanction	180	284	+ TGPS + CGPS + Kukrail No.2&No.3
6	Kukrail No.2	Proposed	28	59	+ Lunia Purwa
7	Kukrail No.3	Proposed	50	93	
8	Guari	Sanction	321	498	+ Kukrail No.1 + GH Canal
9	GH Canal	Sanction	94	125	
10	Martin Purwa	Proposed	80	72	

No.	Treatment Plant	Status	Capacity (MLD)		Remark
			2015	2030	
1	Daulatganj	Existing	56	56	District - I
2	STP at LDA Colony	Planned	10	14	District - I
3	Kakraha	Sanction	330	520	District - III
4	**Khwajapur**	Proposed	70	140	District - II
5	Mastemau	Proposed	110	130	District - IV



JAPAN INTERNATIONAL COOPERATION AGENCY	PROJECT	LOCATION	FIGURE 6.2
TOKYO ENGINEERING CONSULTANTS CO., LTD. CTI ENGINEERING INTERNATIONAL CO., LTD.	THE STUDY ON WATER QUALITY MANAGEMENT PLAN FOR GANGA RIVER IN THE REPUBLIC OF INDIA	LUCKNOW CITY	SEWER LAYOUT ALTERNATIVE - II



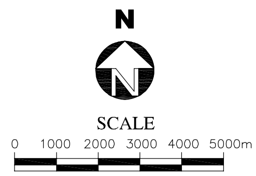
ALTERNATIVE - 3

DISTRICT (including FSA No.)	Population 2003	Population 2015	Population 2030	Wastewater Generation (MLD) 2003	Wastewater Generation (MLD) 2015	Wastewater Generation (MLD) 2030
DISTRICT - I (131)	169,099	252,388	410,279	19.44	34.13	63.59
DISTRICT - II (127~130)	281,373	484,791	863,395	32.31	65.49	133.83
DISTRICT - III (121, 122, 125, 126, 132)	870,028	1,379,160	2,204,029	99.88	185.93	341.62
DISTRICT - IV (123, 124, 133)	1,142,974	1,489,248	1,946,986	213.24	251.69	301.78
Total	2,463,474	3,605,587	5,424,689	364.87	537.24	840.82

No.	Pumping Station	Status	Capacity (MLD) 2015	Capacity (MLD) 2030	Remark
1	TGPS	Existing	35	51	
2	CGPS	Existing	50	51	
3	Lunia Purwa	Proposed	12	33	
4	Mohan Meakin	Sanction	19	28	
5	Kukrail No.1	Sanction	130	234	+ TGPS
6	Kukrail No.2	Proposed	28	59	+ Lunia Purwa + Daliganj No.1
7	Kukrail No.3	Proposed	50	93	
8	Guari	Sanction	178	323	+ Kukrail No.1 + No.2 + No.3
9	GH Canal	Sanction	94	125	
10	Martin Purwa	Proposed	223	246	+ CGPS + GH Canal

No.	Treatment Plant	Status	Capacity (MLD) 2015	Capacity (MLD) 2030	Remark
1	Daulatganj	Existing	56	56	District - I
2	STP at LDA Colony	Planned	10	14	District - I
3	Kakraha	Sanction	190	345	District - III
4	**Khwajapur**	Proposed	70	135	District - II
5	Mastemau	Proposed	255	305	District - IV

LEGEND
- Municipal Boundary
- Existing Sewer
- Existing STP
- Existing SPS
- Proposed Trunk Sewer
- Proposed Rising Main
- Proposed SPS
- Proposed STP
- Future Service Area



JAPAN INTERNATIONAL COOPERATION AGENCY TOKYO ENGINEERING CONSULTANTS CO., LTD. CTI ENGINEERING INTERNATIONAL CO., LTD.	PROJECT THE STUDY ON WATER QUALITY MANAGEMENT PLAN FOR GANGA RIVER IN THE REPUBLIC OF INDIA	LOCATION LUCKNOW CITY	FIGURE 6.3 SEWER LAYOUT ALTERNATIVE - III

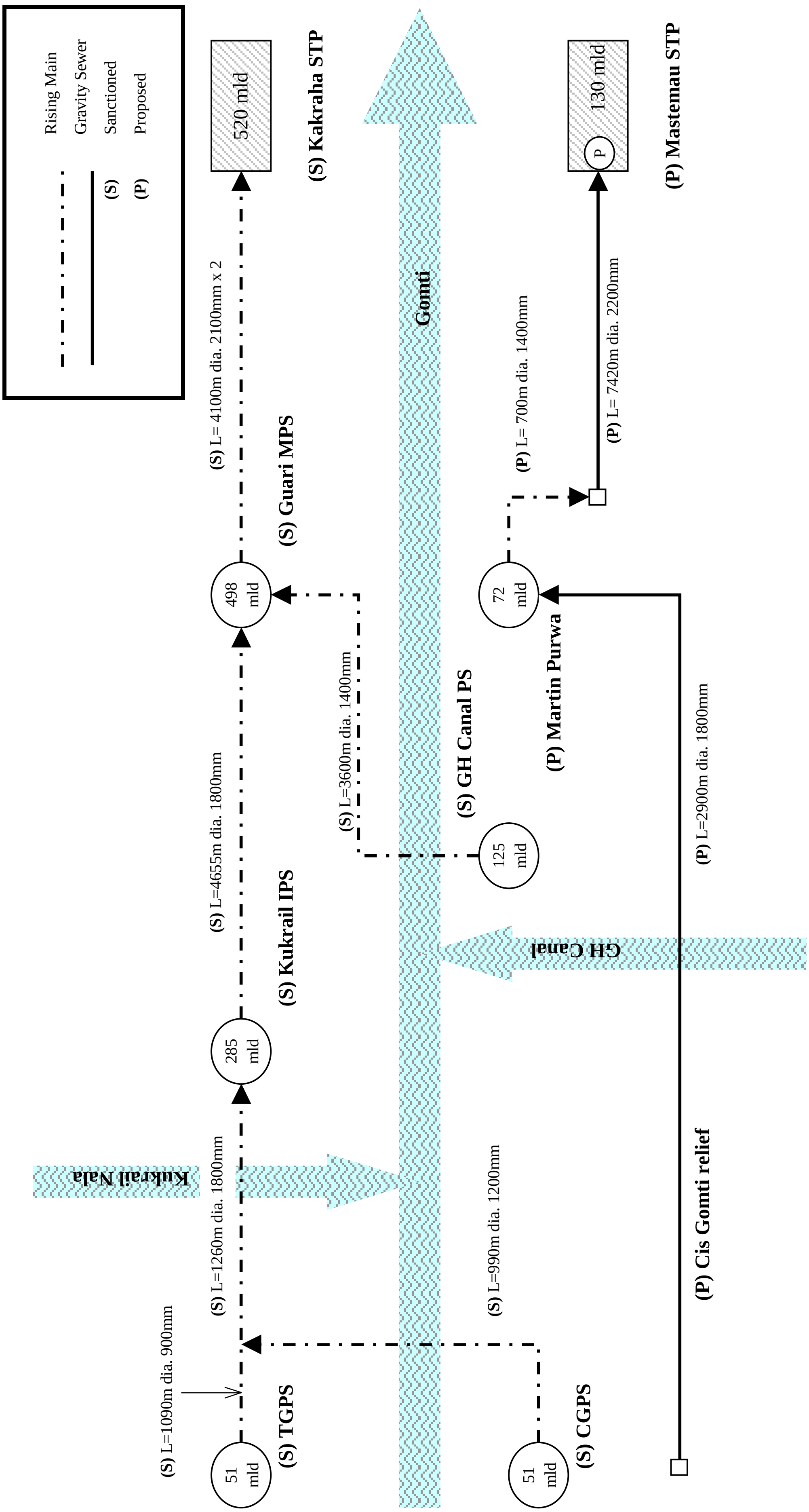


Figure 6.4 Schematic Diagram Alternative II (2030)

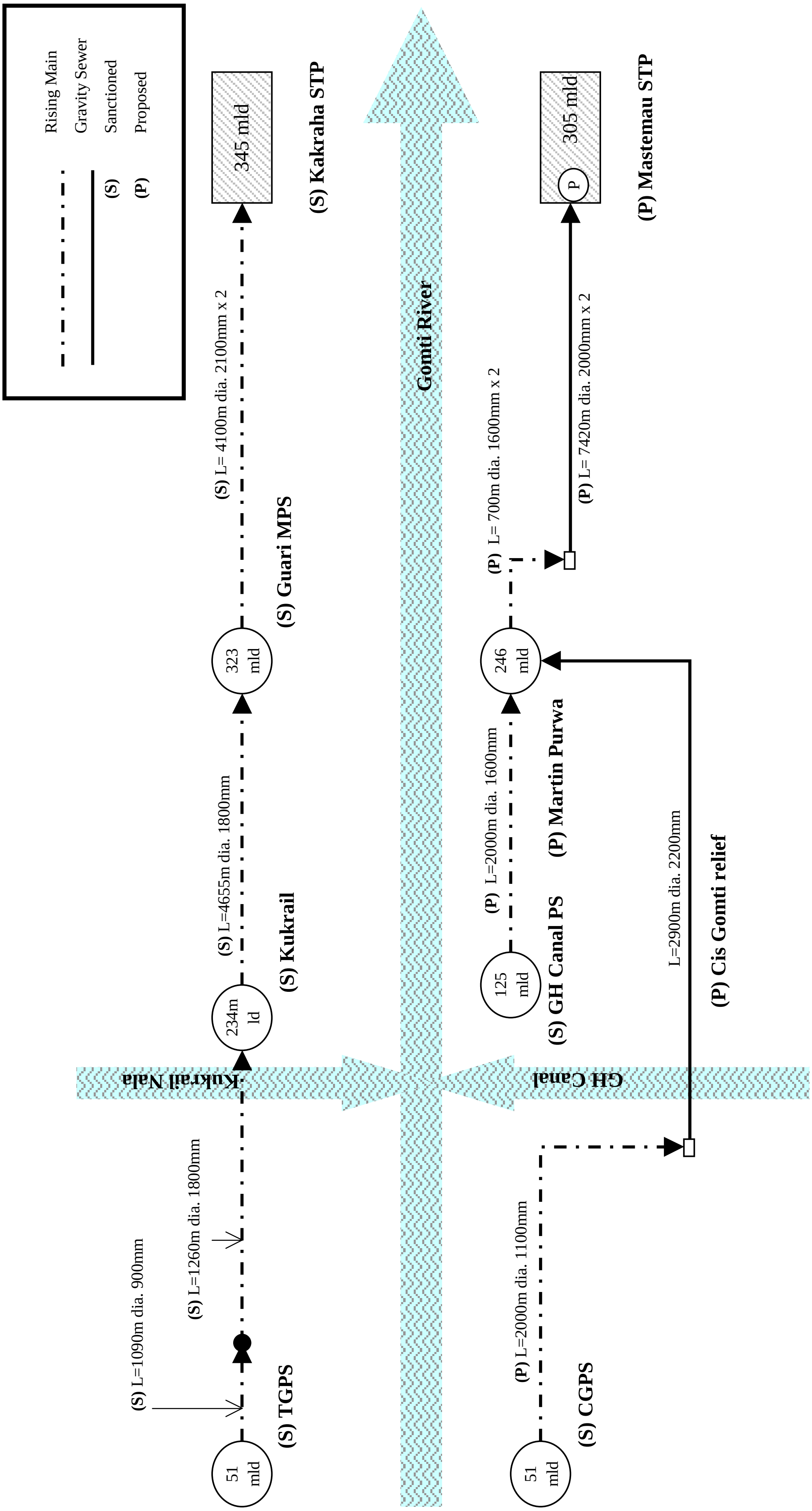


Figure 6.5 Schematic Diagram Alternative III (2030)