Ganga River Basin Management Plan-2015

Volume 11: Thematic Studies – Managing Pollution Load

Centre for Ganga River Basin Management and Studies
Indian Institute of Technology Kanpur

VOLUME 11 OF 12

NATIONAL MISSION FOR CLEAN GANGA (NMCG)

NMCG is the implementation wing of National Ganga Council which was setup in October 2016 under the River Ganga Authority order 2016. Initially NMCG was registered as a society on 12th August 2011 under the Societies Registration Act 1860. It acted as implementation arm of National Ganga River Basin Authority (NGRBA) which was constituted under the provisions of the Environment (Protection) Act (EPA) 1986. NGRBA has since been dissolved with effect from the 7th October 2016, consequent to constitution of National Council for Rejuvenation, Protection and Management of River Ganga (referred to as National Ganga Council).

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cGanga is a think tank formed under the aegis of NMCG, and one of its stated objectives is to make India a world leader in river and water science. The Centre is headquartered at IIT Kanpur and has representation from most leading science and technological institutes of the country. cGanga's mandate is to serve as think-tank in implementation and dynamic evolution of Ganga River Basin Management Plan (GRBMP) prepared by the Consortium of 7 IITs. In addition to this it is also responsible for introducing new technologies, innovations and solutions into India.

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ACKNOWLEDGEMENT

This document is a collective effort of a number of experts, institutions and organisations, in particular those who were instrumental in preparing the Ganga River Basin Management Plan which was submitted to the Government of India in 2015. Contributions to the photographs and images for this vision document by individuals are gratefully acknowledged.

SUGGESTED CITATION

GRBMP by cGanga and NMCG

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GANGA RIVER BASIN MANAGEMENT PLAN - 2015

Volume 11: Thematic Studies – Managing Pollution Load

12 VOLUMES

Ganga river in
Himalayas mountains

Guidelines for the Preparation of Urban River Management Plan (URMP)

for all Class I Towns in Ganga River Basin

GRBMP : Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay | IIT Delhi | IIT Guwahati | IIT Kanpur | IIT Kharagpur | IIT Madras | IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRB EMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. Lists of persons who are members of the concerned thematic groups and those who have taken lead in preparing this report are given on the reverse side.

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Contents

1. Urban River Management Plans (URMPs)

Almost all class I towns on Ganga River Basin (GRB) are situated beside (or very close to) river Ganga or its tributaries. The untreated and treated sewage from almost all such towns flow either directly or indirectly into these rivers. Further in towns situated beside rivers, the riverbank is a part of the urban landscape, which is often used for dumping solid waste, open defecation and other undesirable activities.

Prevention and management of the above adverse impacts on river and riverbanks in class I towns in the GRB constitute an important component of the Ganga River Basin Management Plan (GRBMP). It is proposed that URMPs be prepared for all class I towns of the GRB to systematically tackle the above issues through micro-level (town-wise) planning.

It is envisaged that an URMP will have a planning horizon of 25 years and will essentially be a compendium of all 'actions' to be undertaken during this time for comprehensive, 1) riverbank management and 2) wastewater management in the town. Once the URMP for a particular town is in place, investments can be made in various projects in a systematic and targeted manner for implementation of the URMP. Preparation of URMPs is thus essential for all class I towns in the Ganga River Basin (GRB).

2. Salient Features of Proposed URMPs

All towns in the GRB with population greater than 100,000 at present (2011 census), i.e., class I towns, must compulsorily prepare an 'Urban River Management Plan (URMP) which addresses the following issues.

1. Removal of encroachments and land acquisition for riverbank beautification and related development works.

2. Restriction/banning of certain activities on the riverbank or in the river, viz., open defecation, disposal of solid waste, washing of clothes, wallowing of cattle, throwing of floral offerings, disposal of corpses, routine bathing (as opposed to ritual bathing), etc.

3. Development/restoration of the riverbank area, i.e., construction / restoration of ghats, provision of public baths and toilets, construction of walkways, parks, other public spaces, access roads, commercial establishments, etc.

4. Prevention of the discharge of treated and untreated sewage into the river through construction of sewers and 'nala' diversion works.

5. Pumping and other infrastructure for conveyance of collected / diverted sewage to sewage treatment plants and construction / renovation of sewage treatment plants capable of treating the sewage to tertiary levels.

6. Reuse of tertiary treated sewage within the town or elsewhere for industrial, irrigation, horticultural, non-potable domestic and commercial uses, groundwater recharge, etc.

7. Disposal of sludge generated due to sewage treatment in an acceptable manner and reuse of sludge and sludge-derived products, i.e., manure, compost, etc. within the town and/or elsewhere.

URMPs for all class I towns along the river Ganga or its tributaries, viz., **Kanpur URMP**, **Allahabad URMP**, etc. when taken together, shall constitute a Regional URMP, viz., **Ganga Regional URMP**, **Yamuna Regional URMP**, etc. All regional URMP in the Ganga basin, when taken together, shall constitute the **Ganga Basin URMP**.

3. Preparation of URMPs

- URMPs should be prepared immediately (within 6 – 12 months) for all Class I towns in the Ganga River Basin, i.e., towns with population greater than 100,000 at present (2011 census).
- Preparation of URMPs will be the responsibility of the individual towns. The state governments and NGRBA shall extend all possible help (including financial and technical assistance wherever necessary) to the ULBs for the preparation of URMPs.
- For many cities, most of the data/information required for preparation of the URMPs may be available in city master plans, city development plans, city sanitation plans, and from other sources. In such cases, URMP can be prepared in much less time, mostly utilizing secondary data. In general, primary data collection is to be minimized and only resorted to when no relevant secondary data is available.
- The planning horizon in the URMP should be 25 years, i.e., 2013-2038.
- A typical URMP should have two parts; a) relevant secondary and primary information and data presented in both electronic and hardcopy form, and b) a listing and associated descriptions of 'actionable' items, i.e., areas in which projects need to be undertaken, as determined on the basis of the collected information/data.
- For each of the 'actionable' items, several 'work packages' must be specified in the URMP. Proper sequencing of all 'work packages' over the plan horizon should be suggested in the URMP. The 'work packages' must be specified such that completion of all 'work packages' over the plan horizon shall result in the objectives of URMP being completely fulfilled.
- The 'work packages' must be specified in sufficient details such that detailed project reports (DPRs) can be prepared based on these 'work packages' as and when required and put up for funding from various sources.
- URMPs must be prepared by all Class I towns within six months to one year as per guidelines outlined in this report.
- The URMPs prepared as per guidelines specified in this report will be submitted to NGRBA for vetting and final approval. An expert standing committee will be set up by NGRBA for this purpose.
- After finalization of URMPs, DPRs based on 'work packages' specified in URMPs shall only be eligible for funding by NGRBA.

- ULBs will have the option of amending the URMPs any time during the planning horizon of 2013-2038, through addition/modifications to the original plan. However, any such amendments must be vetted by the expert standing committee constituted for the vetting and approval of URMPs.

Immediate Actions Required:

1. *The list of towns for which URMPs needs to be prepared should be identified and the respective ULBs instructed accordingly regarding preparation of URMPs.*

2. *A workshop must be organized with concerned ULBs as participants, where the requirements, importance and desired contents of URMPs are to be explained.*

Important Points:

1. *All Class I towns in the GRB shall necessarily prepare an URMP within the next 6 – 12 months.*
2. *An expert standing committee will be set up for NGRBA for vetting and approving the URMPs.*
3. *The DPRs prepared based on 'actionable' items in URMPs shall only be eligible for future funding by NGRBA.*

4. Components of URMPs

A URMP should have 'actionable' items to ensure that the riverbank in the town is cleaned, developed and beautified such that it is easily accessible to the citizens as a public space suitable for various spiritual, religious, recreational, socio-cultural and other outdoor activities. Further, 'actionable' items to ensure prevention of the discharge of treated or untreated sewage into the river (either directly or indirectly) and 'actionable items' to ensure that treated sewage is reused / recycled should also be a part of the URMP. Main components of the URMP are described as follows.

4.1. Removal of Encroachments and Land Acquisition

Main Objective:

All public land on the riverbank needs to be cleared from encroachments and constant vigil must be kept to ensure that it is not re-encroached. Some of this land may be made available for riverbank beautification and development projects.

Information Required:

- Digital map of the river and riverbank area under consideration, clearly showing the land use patterns, land ownership and areas encroached.
- Survey of the various encroached areas, including population, and livelihood of the people.

Actionable Items:

Item 4.1.1: Removal of encroachments from the riverbanks. Compensation, resettlement and rehabilitation issues for population affected by the removal of encroachments.

Item 4.1.2: Assignment of land for riverbank beautification and development projects.

4.2. Restriction / Banning of Undesirable Activities

Main Objective:

Certain undesirable activities like, open defecation, disposal of solid waste, dhobi ghats, etc. should eventually be banned in both public and private lands on the riverbank. Certain undesirable activities like washing of clothes, wallowing of cattle, throwing of floral offerings, disposal of corpses, routine bathing, etc. must be discouraged, and hence severely restricted in both public and private lands on the riverbank.

Information Required:

- Digital map of the concerned area showing areas where, a) open defecation and b) solid waste dumping is prevalent.
- Digital map of the concerned area showing areas where, a) 'dhobi ghats', b) washing of clothes and routine bathing, c) wallowing of cattle, d) throwing of floral offerings, e) disposal of corpses, and f) other undesirable activities that are prevalent.

Actionable Items:

Item 4.2.1: Banning of open defecation in the concerned area. Provision of portable/zero-discharge toilet facilities in the area.

Item 4.2.2: Banning of the disposal of solid waste on the riverbank. Alternate arrangements for riverbank solid-waste disposal.

Item 4.2.3: Removal of 'Dhobi Ghats'. Providing alternate arrangements/structures for large-scale washing of clothes.

Item 4.2.4: Restriction on routine bathing and washing of clothes. Alternate arrangements for bathing, such as provision of bath houses with complete treatment and/or recycle/reuse of gray water.

Item 4.2.5: Restriction on wallowing of cattle. Arrangements for the removal of dairies from the concerned area.

Item 4.2.6: Banning disposal of un-burnt / half-burnt corpses from cremation ghats into rivers. All such corpses to be cremated (if required, free of charge) in electric crematoriums provided for this purpose.

Item 4.2.7: Restriction on disposal of floral offerings in riverbanks and into the river. Alternate arrangements, such as composting/ vermi-composting or other arrangements to be made.

4.3. Riverbank Beautification and Development

Main Objective:

Some land on the riverbank to be made available for riverfront beautification and development/restoration initiatives such as, construction of walkways, parks, other public spaces, access roads, commercial establishments, etc. Existing structures on the riverbanks such as, ghats, important places of worship, monuments of historical significance, etc. should be restored/rehabilitated.

Information Required:

- Digital map of the concerned areas where riverbank beautification and development projects are to be undertaken.
- Information regarding the status of the land in areas identified above, whether encroached, etc.

Actionable Items:

Item 4.3.1: Construction/renovation of access roads and parking for the concerned area earmarked for riverfront development.

Item 4.3.2: Development/re-development of areas designated as public spaces such as, walkways, parks, important places of worship, areas of historical significance, etc.

Item 4.3.3: Development/re-development of areas earmarked for commercial establishments.

4.4. Sewage Collection and Diversion Works

Main Objective:

Provisioning for all sewage generated in the town to be collected through underground sewage system. Further, provisioning for diversion of all sewage flowing into the river through, i) large and small 'nalas', and ii) sewers, to sewage treatment plants.

Data Requirement:

Full information regarding present water supply and sewage generation along with status of sewage collection, treatment and disposal is required in digital form in the GIS platform. Data should pertain to (but not limited to) the following points.

1. Map of the town clearly showing the location of the town with respect to nearby surface water bodies and other major geographical features.
2. Map showing various wards of the town, current population in each ward, and expected population in each ward by 2035.
3. Map showing sources of domestic water supply for the town, a) location of surface water intake structures and water treatment plants, b) locations of deep tube wells, c) location of shallow tube-wells, and c) other sources.
4. Current quantity of water supplied from, a) water treatment plants, b) deep tube wells, c) shallow tube-wells, d) other sources, and expected water supply from these and other sources by 2035.

5. Map showing the present network of sewers in the town. Also, current sewage flows in trunk sewers, location of 'nalas', sewage flow in 'nalas' and the expected sewage flows in 2035 if no further action is taken.
6. Map showing locations of current sewage pumping stations, 'nala' tapping works, and sewage treatment plants.
7. Map showing locations where sewage, either treated or untreated is discharged into surface water bodies.

Actionable Items:

Item 4.4.1: Construction/renovation of main sewers, branch sewers, laterals and house connections for collection of sewage from individual households. In the long term, sewage from all households, including slum areas must be collected by the underground sewer system.

Item 4.4.2: Construction/renovation of trunk sewers in a phased manner for the conveyance of the sewage to the sewage treatment plant. In the long-term, all sewage generated in the town must be collected and conveyed to sewage treatment plants.

Item 4.4.3: Construction/renovation of intercepting sewers for diverting the flow of small 'nalas'/drains into the sewer system. All sewage flowing in small 'nalas'/drains must be diverted to the underground sewer system. This is a short-medium term solution, which will hopefully become redundant once a comprehensive sewage collection system is developed for the whole town.

Item 4.4.4: Construction/renovation of 'nala'/drain tapping works for diverting discharges of large 'nalas'/drains to the sewer system. All sewage flowing in large 'nalas'/drains to be diverted from rivers and other surface water bodies and into sewers or directly to sewage treatment plants. This is a short-medium term solution, which will hopefully become redundant once a comprehensive sewage collection system is developed for the whole town.

4.5. Sewage Pumping Stations and Sewage Treatment Plants

Main Objective:

Sewage collected through the sewer system or diverted from rivers should be collected in sump wells and pumped to existing or new sewage treatment plants (STPs). Construction of new STPs and pumping stations and renovation of existing STPs and existing pumping stations is necessary for this purpose.

In case of newly proposed STPs, the ultimate capacity of the STP should be worked out as per population projections over the next 25 years and land for the STP must be acquired accordingly. However, the actual construction of the STP must be done in phases, with the initial size approximately restricted to the wastewater flow currently available (i.e., collected) for treatment. As and when wastewater collection increases, corresponding additional treatment capacity may be added in modular fashion, until the ultimate capacity is reached.

There must also be a provision for the construction of new STPs in a decentralized manner at multiple locations in the town, i.e., wherever sufficient quantities of collected sewage is available.

Existing STPs to be renovated, but only to the extent of the current availability of sewage at the STP. Further renovation to be planned in modular fashion as and when availability of sewage increases.

All new/renovated sewage treatment plants must be designed to treat sewage up to tertiary levels (see Report No. 003_GBP_IIT_EQP_S&R_02), such that it can be reused for various purposes. The sludge generated through sewage treatment must be, i) disposed in an acceptable manner, ii) further processed to obtain sludge-derived products, viz., compost, manure, electricity, etc. to be used locally or otherwise.

Data Requirement:

1. Map of the town showing the locations of the existing sewage treatment plants, installed capacity and the sewage quantity actually treated.
2. Information regarding technology adopted for sewage treatment and performance of the existing sewage treatment plants.
3. Information regarding production of sludge and sludge-derived products, i.e., electricity, manure, compost, etc., from existing sewage treatment plants.

Actionable Items:

Item 4.5.1: Construction/renovation of sewage pumping stations for conveying sewage flowing in trunk sewers and large 'nalas' to sewage treatment plants. Capacity for pumping all sewage generated to sewage treatment plants must be created.

Item 4.5.2: Construction of new STPs, clearly showing the area of the town from which sewage will be diverted to the STP. All sewage generated in the town to be diverted to new or existing STPs.

Item 4.5.3: Renovation of existing STPs, clearly showing the area of the town from which sewage will be diverted to the STP. All sewage generated in the town to be diverted to new or existing STPs.

4.6 Storage, Transport and Reuse Infrastructure for Treated Water and Sludge

Main Objective:

The long-term objective is that treated sewage should be stored in reservoirs and conveyed through canals or pipelines for reuse within the city or elsewhere for industrial, irrigation, horticultural, non-contact/non-potable domestic and commercial uses, groundwater recharge, etc.

Data Requirement:

1. Map of the town showing the locations of the existing ponds, reservoirs and canals/nalas/small rivers which can be used for storage and conveyance of treated sewage.
2. Analysis regarding the reuse potential of treated sewage for industrial, horticultural and non-contact/non-potable commercial uses or for irrigation purposes in the town or elsewhere. Plan regarding how the entire treated sewage can be reused.
3. Analysis regarding reuse potential of sludge and sludge-derived products, i.e., compost, manure, etc. in the city and surrounding rural area. Plan regarding safe disposal and reuse of all sludge and sludge-derived products.
4. Map showing existing depressions/low lying areas/wetlands in the city or in the surrounding areas which can be used for storage of treated sewage.
5. Map showing possible alignments of storm water drains, canals, etc., for conveyance of treated sewage for various reuse purposes.
6. Map showing areas where treated sewage can be used for groundwater recharge.

Actionable Items:

Item 4.6.1: Renovation of existing surface water bodies in the town/surrounding rural area for storage of treated sewage and groundwater recharge.

Item 4.6.2: Construction of surface water bodies in the town/surrounding area for storage and groundwater recharge of treated sewage.

Item 4.6.3: Construction/renovation of pipelines/open channels for conveyance of treated sewage, 1) to storage structures, 2) from storage structures to reuse points in the town and elsewhere.

Item 4.6.4: Production and use of sludge-derived products, i.e., manure, compost, etc. in the town or in other areas.

5. Implementation of URMPs

5.1. Work Packages and DPRs

As mentioned earlier, several 'work packages' will be specified in the URMP for every 'actionable' item. These 'work packages' will be proposed in a phased manner for gradual implementation of the URMP. The proposed work packages specified in URMPs must have sufficient details such that DPRs can be prepared based on these 'work packages' by the ULBs as and when funding becomes available.

5.2. Funding Sources

As far as external funding is concerned, NGRBA will be the nodal agency for making funds available to ULBs for the implementation of the URMPs in a phased manner over the 25 year time horizon. Funding may be made available through NGRBA for this purpose from several ministries, with MoEF, MoUD and MoWR being the major contributors. Depending on the nature of the project to be funded, any of the above or other ministries may choose to provide funding for a particular project.

The suggested funding priority of MoEF should be as follows,

1. Work packages based on 'actionable' Items 4.4.2 – 4.4.4 concerning sewage diversion works and 'actionable' items 4.5.1 – 4.5.3 concerning sewage pumping stations and sewage treatment plants.
2. Work packages based on 'actionable' items 4.2.1 – 4.2.7 concerning the banning of undesirable activities in the river and in the riverbank.
3. Work packages based on 'actionable' items 4.6.1 - 4.6.4 concerning infrastructure for storage, conveyance and reuse of treated water and use of sludge and sludge-derived products.
4. Work packages based on 'actionable' items 4.1.1 – 4.1.2 concerning removal of encroachments and land acquisition for riverbank beautification and development.
5. Work packages based on 'actionable' items 4.3.1 – 4.3.3 concerning riverbank beautification and development.
6. Work packages based on 'actionable' item 4.4.1 concerning construction of main sewers, branch sewers, laterals and house connections for collection of sewage from individual households.

The suggested funding priority of MoUD should be as follows,

1. Work packages based on 'actionable' item 4.4.1 concerning construction of main sewers, branch sewers, laterals and house connections for collection of sewage from individual households.
2. Work packages based on 'actionable' Items 4.4.2 – 4.4.4 concerning sewage diversion works and 'actionable' items 4.5.1 – 4.5.3 concerning sewage pumping stations and sewage treatment plants.
3. Work packages based on 'actionable' items 4.1.1 – 4.1.2 concerning removal of encroachments and land acquisition for riverbank beautification and development.
4. Work packages based on 'actionable' items 4.2.1 – 4.2.7 concerning the banning of undesirable activities in the river and in the riverbank.

5. Work packages based on 'actionable' items 4.3.1 – 4.3.3 concerning riverbank beautification and development.
6. Work packages based on 'actionable' items 4.6.1 - 4.6.4 concerning infrastructure for storage, conveyance and reuse of treated water and use of sludge and sludge-derived products.

The suggested funding priority of MoWR should be as follows,

1. Work packages based on 'actionable' items 4.6.1 - 4.6.3 concerning infrastructure for storage, conveyance and reuse of treated water.
2. Work packages based on 'actionable' items 4.1.1 – 4.1.2 concerning removal of encroachments and land acquisition for riverbank beautification and development.
3. Work packages based on 'actionable' items 4.2.1 – 4.2.7 concerning the banning of undesirable activities in the river and in the riverbank.

In addition, the ULBs should try to fund at least some 'work packages' in the URMP through internal accruals (i.e., local tax and other local revenue), especially in the later stages of the plan horizon of 25 years. Some 'work packages' may also be implemented through the involvement of private parties using the Public-Private-Participation (PPP) model.

'Work Packages' which can potentially be funded by ULBs using local resources or through PPP model include,

- Funding for the work packages under 'actionable' item 4.4.1 concerning construction of main sewers, branch sewers, laterals and house connections for collection of sewage from individual households.
- Funding for the work packages under 'actionable' items' 4.1.1 – 4.1.2 concerning removal of encroachments and land acquisition for riverbank beautification and development.
- Funding for the work packages under 'Actionable Items' 4.3.1 – 4.3.3 concerning riverbank beautification and development.
- Funding for work packages under 'actionable' items 4.6.3 and 4.6.4.

6. Why URMPs are Essential

As mentioned earlier, for each of the 'actionable' items, several 'work packages' will be specified in the URMP. The 'work packages' must be specified such that completion of all 'work packages' over the plan horizon shall result in the objectives of URMP being completely fulfilled. The 'work packages' specified in an URMP thus constitute a compendium of all 'projects' to be completed in a town in the plan horizon for comprehensive riverbank and wastewater management.

Once this kind of detailed micro-level (town-wise) information is available, DPRs based on the 'work packages' can be solicited from or submitted by ULBs to various agencies, including NGRBA for funding and implementation. Even ULBs by themselves can initiate some projects based on internal accruals or through the PPP model.

Further, a readily available record of projects completed, ongoing and not yet sanctioned can be kept for each town. Proper phasing of various projects in a town will be possible. The progress of various towns towards completion of objectives of the URMPs will also be readily available.

Once the URMPs are in place, the quantum of work to be done over the next 25 years in the GRB for achieving the goals for URMPs will be known. Based on this information, yearly funding requirements towards URMPs implementation can be readily computed and a 25 year plan of funding requirements can also be made.

At the present time, many projects on riverbank and wastewater management in various towns are being sanctioned by various ministries under various programmes (e.g., GAP I, GAP II, JNNURM, etc.), with the general objective of improvement of the state of rivers in the GRB. However, in the absence of URMPs, it appears that the micro-level planning that is required for obtaining the optimal benefits from such projects is not in place.

6.1. URMPs vs Other City-Specific Development Plans

For some towns of the GRB, one or more city-specific development plans, i.e., city master plans, city development plans, city sanitation plans, etc. prepared by various agencies may already be available. It is thus possible that some of the 'actionable' items in the URMPs may already have been included in one or more of these plans in some form or other.

It must however be emphasized that city-specific development plans mentioned above are 'city-centric', i.e., their main objective is the development in the town and not necessarily the prevention and management of adverse impacts to the river bank and the river. Hence 'actionable' items related to riverbank management, wastewater management and treated sewage recycling/reuse in a town are often either, 1) not included, or, 2) included with insufficient emphasis and detail, in the above city-centric plans.

In contrast, the proposed URMP is a river-centric plan, whose main purpose is the delineation of a roadmap for prevention and management of adverse impacts on river bank and the river from adjoining urban centers.

To further emphasize the points made above, the type of projects sanctioned under, 1) a typical city sanitation plan (CSP), 2) proposed under URMP, and 3) currently funded by MoEF (as per revised DPR guidelines) were compared (see Appendix 1). Based on this comparison, it is clear that a CSP does not include many projects necessary for comprehensive riverbank management, wastewater management and treated sewage recycling/reuse that are necessary for prevention and management of adverse impacts on river bank and the river from adjoining urban centers.

Further, it is clear that there is a nearly complete overlap between projects currently being sanctioned by MoEF (as per revised DPR guidelines) and those proposed under URMPs (the exceptions being projects concerning reuse/recycle of treated sewage, which are given more emphasis under URMP). Preparation of URMPs will thus provide the underlying planning structure that is required for obtaining the optimal benefits from implementation of such projects.

Under the circumstances, it is clear that the micro-level (town specific) planning that is essential for preparing a roadmap for effective prevention and management of adverse impacts on riverbank and the river from adjoining urban centers can only be achieved through preparation of URMPs for all Class I towns of the GRB.

Appendix 1

Items concerning Urban River Management included in City Sanitation Plan, Proposed URMP and Revised DPR Guidelines

Topics/Items	Included in CSP	Included in URMP	Included in Revised DPR Guidelines
River Front Development			
Approach platforms and steps leading to river	X	√	√
Changing rooms for male and female	X	√	√
Toilet, washroom and drinking water facilities at ghats	X	√	√
Sitting facilities for people	X	√	√
Lighting and landscaping of area	X	√	√
Construction of walkways, parks and parking lots	X	√	√
Commercial establishments and activities	X	√	√
Platform for cultural and recreational programs	X	√	√
Removal of encroachments and land acquisition	X	√	X
Improvement of small ghats	X	√	√
Restoration of important places of worship and monuments of historical significance	X	√	X

Appendix 1 (Continued)

Items concerning Urban River Management included in City Sanitation Plan, Proposed URMP and Revised DPR Guidelines

Topics/Items	Included in CSP	Included in URMP	Included in Revised DPR Guidelines
Restriction/Banning of Undesirable Activities (Non-point Pollution Sources) and Alternative Arrangements			
Open defecation	√	√	√
Provision of portable/zero discharge toilet at household/community levels	√	√	√
Manual scavenging	√	√	X
Prevention of dumping of MSW on or near the riverbank	X	√	√
Dhobi ghats	X	√	√
Routine bathing	X	√	X
Bath houses with treatment and recycle/reuse of gray water	X	√	X
Wallowing of cattle	X	√	√
Floral offerings	X	√	X
Washing vehicles in river	X	√	√
Disposal of carcass/dead bodies	X	√	√
Disposal of corpses from burning ghats/crematoria	X	√	√
Removal of dairies	X	√	√

Appendix 1 (Continued)

Items concerning Urban River Management included in City Sanitation Plan, Proposed URMP and Revised DPR Guidelines

Topics/Items	Included in CSP	Included in URMP	Included in Revised DPR Guidelines
Strom Water & Sewage Collection, Diversion, Pumping, Treatment, Recycle and Reuse			
Management of storm water and drainage	√	√√	√
Septic tank	√	√√	√
Human excreta management	√	√√	X
Black wastewater treatment and disposal	√	√	X
Gray water treatment and disposal	√	√	X
Gray water treatment and recycle/reuse	X	√	X
Construction of main, branch, trunk and lateral sewers	√	√	√
Construction of intercepting sewers	X	√	√
Nala tapping	X	√	√
Sewage pumping stations	√	√	√
Rising main	√	√	√
Sewage treatment plants (STPs)	√	√	√
Extension/Renovation of existing STPs	√	√	√
Decentralized treatment	√	√	√
In-situ sewage treatment through bioremediation	X	√√	√

Appendix 1 (Continued)

Items concerning Urban River Management included in City Sanitation Plan, Proposed URMP and Revised DPR Guidelines

Topics/Items	Included in CSP	Included in URMP	Included in Revised DPR Guidelines
Strom Water & Sewage Collection, Diversion, Pumping, Treatment, Recycle and Reuse			
Prevention of treated and untreated sewage discharged into river	X	√	X
Tertiary treatment of sewage	X	√	√
Treated sewage effluent recycle/reuse	√	√	√
Construction of surface storage reservoir and surface water bodies for recycle/reuse	X	√	X
Canal and pipelines for reuse of treated sewage	X	√	X
Renovation of existing surface water bodies	√	√	X
Sludge treatment and management	√	√	√
Use of sludge-derived products	X	√	√
Public-private-partnership (PPP)/BOT financing model	√	√	√
O&M of sewerage schemes	X	√	√

Appendix 1 (Continued)

Items concerning Urban River Management included in City Sanitation Plan, Proposed URMP and Revised DPR Guidelines

Topics/Items	Included in CSP	Included in URMP	Included in Revised DPR Guidelines
Solid Waste Management			
Solid Waste Management	√	√√	X
Riverbank Solid Waste Management	X	√	√
Afforestation			
Along the river banks	X	√	√
Campuses of STPs, pumping stations and effluent channel	X	√	√
Pathways and areas around crematoria	X	√	√
Around bathing ghats	X	√	√
Around community toilet complexes	X	√	√
Open spaces belonging to ULBs	X	√	√
Public Participation and Awareness			
Public participation	√	√√	√
Public awareness	√	√√	√
Capacity Building	√	X	√

Note: *'√√' indicates not included in URMP, but will be included in other reports of GRBMP*

Sewage Treatment in Class I Towns:

Recommendations and Guidelines

GRBMP : Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay	IIT Delhi	IIT Guwahati	IIT Kanpur	IIT Kharagpur	IIT Madras	IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRB EMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. Lists of persons who are members of the concerned thematic groups and those who have taken lead in preparing this report are given on the reverse side.

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Contents

1. General

Sewage is a major point source of pollution. The target of "Nirmal Dhara" i.e. unpolluted flow can be achieved if discharge of pollutants in the river channel is completely stopped. Also, sewage can be viewed as a source of water that can be used for various beneficial uses including ground water recharge through surface storage of treated water and/or rain/flood water in an unlined reservoir. This may also help achieving "Aviral Dhara".

In order to reduce substantial expenditure on long distance conveyance of sewage as well as treated water for recycling, decentralized treatment of sewage is advisable. As a good practice, many small sewage treatment plants (STP) should be built rather than a few of very large capacity. All new developments must build in water recycling and zero liquid discharge systems. Fresh water intake should be restricted only to direct human-contact beneficial uses of water. For all other uses properly treated sewage/wastewater should be used wherever sufficient quantity of sewage is available as source water for such purposes. All new community sanitation systems must adopt recycling of treated water for flushing and completely isolate fecal matter until it is converted into safe and usable organic manure. The concept of decentralized treatment systems and water/wastewater management will be covered in detail in subsequent reports.

2. Selection of Appropriate Sewage Treatment Technology

Item 4.5.2 in Guidelines for the Preparation of Urban River Management Plan (URMP) for all Class I Towns in Ganga River Basin (Report No. 002_GBP_IIT_EQP_S&R_01) concerns with sewage treatment plant. One of the most challenging aspects of a sustainable sewage treatment system (either centralized or decentralized) design is the analysis and selection of the treatment processes and technologies capable of meeting the requirements. The process is to be selected based on required quality of treated water. While treatment costs are important, other factors should also be given due consideration. For instance, effluent quality, process complexity, process reliability, environmental issues and land requirements should be evaluated and weighted against cost considerations. Important considerations for selection of sewage treatment processes are given in Table 1.

Table 1: Sewage Treatment Process Selection Considerations

Consideration	Goal
Quality of Treated Sewage	Production of treated water of stipulated quality without interruption
Power requirement	Reduce energy consumption
Land required	Minimize land requirement
Capital Cost of Plant	Optimum utilization of capital
Operation & Maintenance costs	Lower recurring expenditure
Maintenance requirement	Simple and reliable
Operator attention	Easy to understand procedures
Reliability	Consistent delivery of treated sewage
Resource Recovery	Production of quality water and manure
Load Fluctuations	Withstand variations in organic and hydraulic loads

3. Treatment Chain

All sewage treatment plants should follow a process chain depending upon the technology chosen and the treatment capacity. In general, treatment is to be done in three stages as per the flow sheet presented in Figure 1.

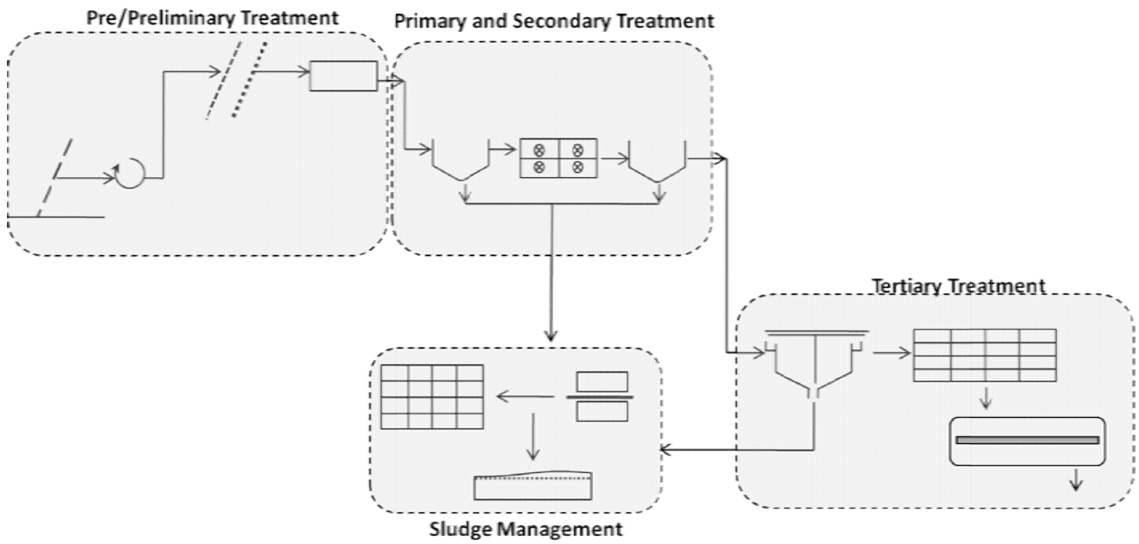

Figure 1: Process Chain for Sewage Treatment

Specifications and treatment objectives at each stage of treatment are as follows.

Stage I Preliminary Treatment:

a) Three Stage Screening: - 25 mm bar racks (before pumping)
- 12 mm bar racks
- 5 mm mesh (< 2 mm mesh for Membrane Bio Reactor, MBR)

b) Aerated Grit Chamber if following unit operation is aerobic and Normal Grit Chamber if following unit operation is anaerobic.

Expected effluent quality after preliminary treatment:

- No floating materials including polythene bags, small pouches, etc.
- Proper collection and disposal of screening and grit.

Stage II Primary and/or Secondary Treatment: Many options are available for second stage treatment. These options can be grouped into following three categories.

a) Pond Based Systems or
b) Activated Sludge Process (ASP) and its Modifications or equivalent systems including but not limited to SBR, UASB followed by ASP, ASP operated on Extended Aeration mode (EA-ASP), ASP with Biological Nutrient Removal (ASP+BNR), and MBBR or
c) Membrane Bio Reactor (MBR)

Expected effluent quality after primary and secondary treatment:

- BOD < 30 mg/L
- SS < 20 mg/L
- Nitrified effluent

A brief description of various technological options available for secondary treatment are presented in Appendix I. EA-ASP, ASP+BNR are considered to be variations of ASP and produce more or less same quality effluent (particularly when tertiary treatment is adopted after secondary treatment) and have approximately same treatment plant footprint. The treatment cost is also of the same order and hence are not considered to be distinctly different than ASP.

Stage III Tertiary Treatment: Coagulation-flocculation-settling followed by filtration and disinfection is generally recommended. Other processes could be selected on the basis of land availability, cost considerations, O&M cost, reuse option, compatibility issues in case of up-gradation of existing plants, etc. However, disinfection operation should invariably be included. Expected effluent quality after tertiary treatment:

- BOD < 10 mg/L
- SS < 5 mg/L
- Phosphate < 0.5 mg/L
- MPN of fecal coliforms < 23/ 100 mL

Where sewage flows are low and/or land can be spared without compromising on other developmental objectives or agriculture, waste stabilization ponds followed by constructed wetland can be adopted without coagulation-flocculation-settling.

4. Cost of Treatment and Land Requirement

Comprehensive analysis of capital cost, operation and maintenance costs, reinvestment cost, energy cost and land requirement based on data obtained from various STPs in the Ganga river basin and elsewhere in India has been done. This analysis has been summarized in Figure 2 as linkage between the treatment cost (`/KL as in 2010) and the required footprint of the treatment plant (m^2/MLD) for various suggested technological options. For a particular desired effluent quality, the technological option with higher treatment cost will generally require lower treatment plant footprint, and vice versa.

5. Decision Matrix

The selection of a process requires analysis of all factors, not just treatment costs. In order to provide additional factors for the final considerations, key parameters need to be evaluated and weighed as shown in the Exhibit 1 to reach a final recommendation. The matrix attributes are ranked as Low, Medium, High and Very High recognizing that differences between processes are relative, and often, the result of commonly accepted observations. The column entitled “Typical Capacity Range” is added to illustrate the range in which the treatment plants based on specific processes have been built so far in the country should not be construed as showing technological limitations, nor to affirm that plants outside that range do not exist. The ranges simply indicate most frequently found sizes. A comparison of treatment costs and evaluation of various technologies for sewage treatment in India is presented in Table 2.

In general it is accepted worldwide that the technologies which are deemed to be appropriate have to be qualified through application of a rigorous framework underscoring the performance expectations as well as the choice should be concurrent with the socio-economic acceptability.

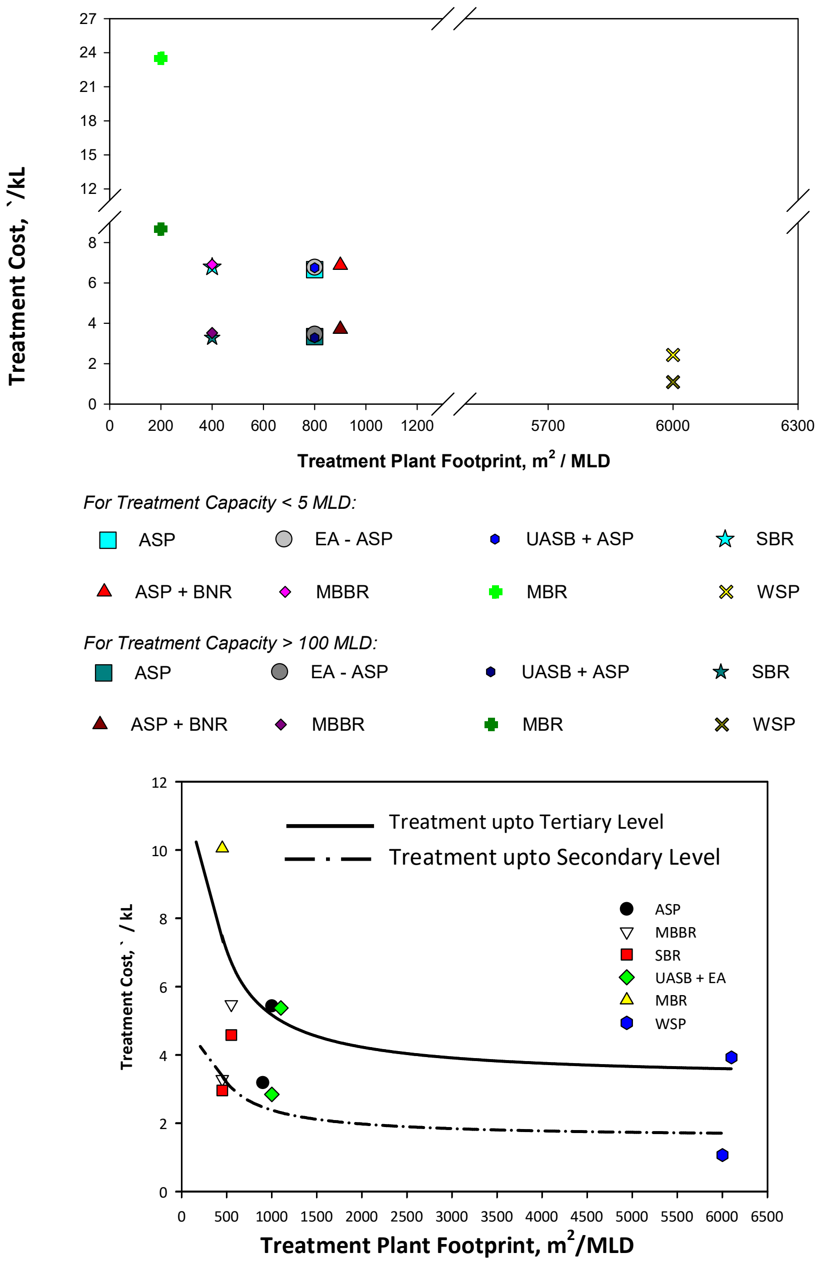

Figure 2: Treatment Cost (as in 2010) and Corresponding Plant Footprint for various Secondary Treatment Options

Table 2: Comparison of Treatment Costs of Various Technologies for Sewage Treatment in India

S. No.	Assessment Parameter/Technology	ASP[*,a]	MBBR[*,c]	SBR[*,a]	UASB+EA[*,b]	MBR[*,a]	WSP[**,b]
1.0	**Performance after Secondary Treatment**						
1.1	**Effluent BOD**, *mg/L*	<20	<30	<10	<20	<5	<40
1.2	**Effluent SS**, *mg/L*	<30	<30	<10	<30	<5	<100
1.3	**Faecal coliform removal**, *log unit*	upto 2<3	upto 2<3	upto 3<4	upto 2<3	upto 5<6	upto 2<3
1.4	**T-N Removal Efficiency**, *%*	10-20	10-20	70-80	10-20	70-80	10-20
2.0	**Performance After Tertiary Treatment**						
2.1	**Effluent BOD**, *mg/L*	<10	<10	<10	<10	<10	<10
2.2	**Effluent SS**, *mg/L*	<5	<5	<5	<5	<5	<5
2.3	**Effluent NH_3N**, *mg/L*	<1	<1	<1	<1	<1	<1
2.4	**Effluent TP**, *mg/L*	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
2.5	**Effluent Total Coliforms**, *MPN/100 mL*	10	10	10	10	10	10
3.0	**Capital cost**						
3.1	**Average Capital Cost (Secondary Treatment)**, ₹ *Lacs/MLD*	68.00	68.00	75.00	68.00	300.00	23.00
3.2	**Average Capital Cost (Tertiary Treatment)**, ₹ *Lacs/MLD*	40.00	40.00	40.00	40.00		40.00
3.3	**Total Capital Cost (Secondary + Tertiary)** ₹ *Lacs/MLD*	**108.00**	**108.00**	**115.00**	**108.00**	**300.00**	**63.00**
3.4	**Civil Works**, *% of total capital costs*	60.00	40.00	30.00	65.00	20.00	90.00
3.5	**E & M Works**, *% of total capital costs*	40.00	60.00	70.00	35.00	80.00	10.00
4.0	**Area Requirements**						
4.1	**Average Area**, *m^2 per MLD* *Secondary Treatment + Secondary Sludge Handling*	900.00	450.00	450.00	1000.00	450.00	6000.00
4.2	**Average Area**, *m^2 per MLD* *Tertiary Treatment + Tertiary Sludge Handling*	100.00	100.00	100.00	100.00	0.00	100.00
4.3	**Total Area, *m^2 per MLD*** *Secondary + Tertiary Treatment*	**1000.00**	**550.00**	**550.00**	**1100.00**	**450.00**	**6100.00**

Sludge Treatment: *** Thickener + Centrifuge; ** Drying**

Process Type : **[a] Aerobic; [b] Anaerobic-Aerobic; [c] Anoxic/Anaerobic-Aerobic**

S. No.	Assessment Parameter/Technology	ASP[*,a]	MBBR[*,c]	SBR[*,a]	UASB+ASP[*,b]	MBR[*,a]	WSP[**,b]
5.0	**Operation & Maintenance Costs**						
5.1	**Energy Costs (Per MLD)**						
5.1.1	**Avg. Technology Power Requirement**, *kWh/d/MLD* *Secondary Treatment + Secondary Sludge Handling*	180.00	220.00	150.00	120.00	300.00	2.00
5.1.2	**Avg. Technology Power Requirement**, *kWh/d/MLD* *Tertiary Treatment + Tertiary Sludge Handling*	1.00	1.00	1.00	1.00	1.00	1.00
5.1.3	**Avg. Non-Technology Power Req.**, *kWh/d/MLD* *Secondary Treatment*	4.50	2.50	2.50	4.50	2.50	2.50
5.1.4	**Avg. Non-Technology Power Req.**, *kWh/d /MLD* *Tertiary Treatment*	0.20	0.20	0.20	0.20		0.20
5.1.5	**Total Daily Power Requirement (avg.)**, *kWh/d /MLD*	185.70	223.70	153.70	125.70	302.50	5.70
5.1.6	**Daily Power Cost (@` 6.0 per KWh)**, *` /MLD/h* *(Including Standby power cost)*	46.43	55.93	38.43	31.43	75.93	1.43
5.1.7	**Yearly Power Cost**, *` lacs pa/MLD*	**4.07**	**4.90**	**3.37**	**2.75**	**6.65**	**0.49**
5.2	**Repairs cost (Per MLD)**						
5.2.1	**Civil Works per Annum**, *as % of Civil Works Cost*	3.00	3.00	3.00	3.00		3.00
5.2.2	**E&M Works**, *as % of E&M Works Cost*	1.00	1.00	1.00	1.00		1.00
5.2.3	**Civil Works Maintenance**, *` Lacs pa /MLD*	1.94	1.30	1.04	2.11		1.70
5.2.4	**E & M Works Maintenance**, *`. Lacs pa*/MLD	0.43	0.65	0.81	0.38		0.06
5.2.5	**Annual repairs costs**, *` Lacs pa/MLD*	**2.38**	**1.94**	**1.84**	**2.48**		**1.76**
5.3	**Chemical Cost (Per MLD)**						
5.3.1	**Recurring Chemical/Polymer Costs**, *` Lacs pa/MLD* *Secondary Treatment*	0.40	0.40	0.40	0.40		0.00
5.3.2	**Recurring Chemical**, *` Lacs pa/MLD* *(Alum, Chlorine, Polymer) Costs, Tertiary Treatment*	4.00	4.00	2.00	5.00		6.00
5.3.3	**Other Chemical Cost**, *` Lacs pa/MLD*	0.90	0.90	0.90	0.90		1.20
5.3.4	**Total Chemical Cost**, *` Lacs pa/MLD*	**5.30**	**5.30**	**3.30**	**6.30**		**7.20**
5.4	**Manpower Cost (Assuming 50 MLD Plant)**						
5.4.1	**Manager**, `. pa (1 No.)	3.60	3.60	3.60	3.60		3.60
5.4.2	**Chemist/Engineer**, *` pa (1 No.)*	3.60	3.60	3.60	3.60		3.60
5.4.3	**Operators**, *` Pa (@ ` 12000 pm)*	8.64	5.76	4.32	8.64		4.32
5.4.4	**Skilled technicians**, *` pa (@ ` 10000 pm)*	7.20	4.80	3.60	7.20		1.20
5.4.5	**Unskilled personnel**, *` pa (@ ` 7000 pm)*	5.04	2.88	2.16	5.04		8.64
5.4.6	**Total Salary Costs,** *` Lacs pa*	28.08	20.64	17.28	28.08		21.36
5.4.7	**Benefits (50% of total salary)**, *` Lacs pa*	14.04	10.32	8.64	14.04		10.68
5.4.8	**Salary + Benefits**, *` Lacs pa*	**42.12**	**30.96**	**25.92**	**42.12**		**32.04**
5.4.9	**Total annual O&M costs,** *` Lacs pa*	**629.26**	**638.11**	**451.22**	**618.96**	**832.55**	**504.86**

S. No.	Assessment Parameter/Technology	ASP[*,a]	MBBR[*,c]	SBR[*,a]	UASB+EA[*,b]	MBR[*,a]	WSP[**,b]
6.0	**NPV (2010) of Capital + O&M Cost for 15 years, ` *Lacs***	**14838.92**	**14971.67**	**12518.32**	**14684.42**	**27488.27**	**10722.96**
	Present (2010) Treatment Cost, paisa/L	**0.54**	**0.55**	**0.46**	**0.54**	**1.00**	**0.39**
7.0	**Average Capital Cost, `. Lacs/MLD** *upto Secondary Treatment*	**68.00**	**68.00**	**75.00**	**68.00**		**23.00**
7.1	**Yearly Power Cost,** ` *lacs pa/MLD* *upto Secondary Treatment*	4.04	4.87	3.34	2.73		0.10
7.2	**Annual Repairs Cost**, ` *Lacs pa/MLD* *upto Secondary Treatment*	1.50	1.22	1.16	1.56		1.11
7.3	**Annual Chemical Cost**, `*Lacs pa/MLD* *upto Secondary Treatment*	0.85	0.85	0.85	0.85		0.60
7.4	**Manpower Cost**, ` *Lacs pa* *for 50 mld plant upto secondary treatment*	33.70	24.77	20.74	33.70		25.63
7.5	**Total Annual O&M Costs,** ` *Lacs pa* *upto Secondary Treatment*	**353.02**	**372.11**	**288.15**	**290.72**		**116.09**
7.6	**NPV (2010) of Capital + O&M Cost for 15 years**, ` *Lacs* *upto Secondary Treatment*	**8695.35**	**8981.58**	**8072.24**	**7760.85**		**2891.39**
7.7	Present (2010) Treatment Cost, *paisa / L* *upto Secondary Treatment*	**0.32**	**0.33**	**0.29**	**0.28**		**0.11**

Sludge Treatment: *** Thickener + Centrifuge; ** Drying**

Process Type : **[a] Aerobic; [b] Anaerobic-Aerobic; [c] Anoxic/Anaerobic-Aerobic**

1. No Sludge Drying Beds. However can be provided to cater 25 % of sludge dewatering under emergency conditions
2. No FPU after UASB, only Extended Aeration (EA Process)
3. UASB not Recommended for influent SO_4> 25 mg/L
4. No Biological Phosphorus Removal, Coagulants are necessary
5. No Energy Recovery system recommended only if BOD <250 mg/L
6. Less than 5h HRT MBBR is not acceptable
7. Less than 14 h HRT SBR is not acceptable for plants with peak factor 2.5
8. Repair + Chemical + Manpower Cost of MBR is `. 500 Lac per 50 MLD
9. O&M of MBR includes all chemical (Cleaning, Polymer etc.,) cost
10. Capital cost of MBR includes membrane replacement cost for 15 years
11. All WSP,s should have mechanical pretreatment works (All types of screens & Grit chambers)
12. SBR data is based on data collected from working Indian SBR with bio selector, OUR control, RAS, Nitrogen removal
13. Manpower cost is assumed to be 20 percent less for treatment only upto secondary stage

ASP : Activated Sludge Process
MBBR : Moving Bed Biological Reactor
SBR : Sequential Batch Reactor
UASB : Upflow Anaerobic Sludge Blanket
EA : Extended Aeration
MBR : Membrane Bio Reactor
WSP : Waste Stabilization Pond

Exhibit 1: Assessment of Technology Options for Sewage Treatment in the Ganga River Basin

Criteria	ASP	UASB+ASP	SBR	MBBR	MBR	WSP
Performance in Terms of Quality of Treated Sewage						
Potential of Meeting the RAPs TSS, BOD, and COD Discharge Standards	High	High	Very High	Very High	Very High	Medium
Potential of Total / Faecal Coliform Removal	High	High	Very High	Very High	Very High	Low
Potential of DO in Effluent	High	High	High	High	High	High
Potential for Low Initial/Immediate Oxygen Demand	Very High	Very High	Very High	Very High	Very High	Very High
Potential for Nitrogen Removal (Nitrification-Denitrification)	Low	Low	Very High	Medium	Medium	Low
Potential for Phosphorous Removal	Low	Low	Very High	Medium	Medium	Low
Performance Reliability	Very High	Medium	Medium	High	Very High	Medium
Impact of Effluent Discharge						
Potential of No Adverse Impact on Land	Medium	Medium	High	High	Very High	High
Potential of No Adverse Impact on Surface Waters	High	High	High	High	Very High	High
Potential of No Adverse Impact on Ground Waters	High	High	High	High	Very High	Medium
Potential for Economically Viable Resource Generation						
Manure / Soil Conditioner	Medium	Medium	Medium	Medium	Low	Low
Fuel	High	Medium	Low	Low	Low	Low
Economically Viable Electricity Generation/Energy Recovery	Very High	High	Low	Low	Low	Low
Food	Medium	Low	Low	Low	Low	Low
Impact of STP						
Potential of No Adverse Impacts on Health of STP Staff/Locals	Medium	Low	High	High	High	Medium
Potential of No Adverse Impacts on Surrounding Building/Properties	High	Medium	High	High	High	Very High
Potential of Low Energy Requirement	Medium	Medium	Medium	Medium	Low	Very High
Potential of Low Land Requirement	High	Medium	High	High	Very High	Low
Potential of Low Capital Cost	Medium	Medium	Medium	Medium	Low	Very High
Potential of Low Recurring Cost	Medium	Medium	Medium	Medium	Low	High
Potential of Low Reinvestment Cost	Medium	Medium	Medium	Medium	Low	High
Potential of Low Level of Skill in Operation	High	Medium	High	Low	Low	Very High
Potential of Low Level of Skill in Maintenance	High	Very High	High	Medium	Low	Very High
Track Record	Very High	High	High	Low	Low	Medium
Typical Capacity Range, MLD	All Flows	All Flows	All Flows	Smaller	Smaller	All Flows

Low | Medium | High | Very High

ASP : Activated Sludge Process
MBBR : Moving Bed Biological Reactor
SBR : Sequential Batch Reactor
UASB : Upflow Anaerobic Sludge Blanket
EA : Extended Aeration
MBR : Membrane Bio Reactor
WSP : Waste Stabilization Pond

6. Sludge Management

The sludge dewatering should be done using thickener followed by filter press or centrifuge or any other equivalent mechanical device. Sludge drying beds (SDB) should be provided for emergency only. SDBs should be designed only for 25% of the sludge generated from primary and secondary processes. The compressed sludge should be converted into good quality manure using composting and/or vermi-composting processes. Energy generation through anaerobic digestion of sludges in the form of biogas and subsequent conversion to electrical energy as of now is viable only when sewage BOD > 250 mg/L. Single fuel engines should be used for conversion of biogas to electrical energy. Hazardous sludge, if any should be disposed of as per the prevailing regulations.

7. Flow Measurement

Flow measuring devices should be installed after the Stage I Treatment as well as at the outlet of the sewage treatment plant. These flow devices should be of properly calibrated V notch with arrangements for automatic measurement of head. Additional electronic or other type of flow meters may also be installed. Arrangements should be made for real time display of measured (both current and monthly cumulative) flows at prominent places.

8. Bioassay Test

The bioassay test is gaining importance in wastewater treatment plant design and operation as the whole effluent toxicity (WET) test. This test uses a standard species of aquatic life forms (like fish, algae) as a surrogate to measure the effect of the effluent on the receiving stream. The flow-through method employing continuous sampling is recommended for on-site tests.

- Flow rate (retention time): For a flow-through system, the USEPA Manual for Acute Toxicity Test of Effluents (USEPA, 2002) specifies that the flow rate through the proportional dilutor must provide for a minimum of five 90% replacements of water volume in each test chamber every 24 h (i.e. a retention time of 4.8 h) (see Figure 3). This replacement rate should provide sufficient flow to maintain an adequate concentration of dissolved oxygen (DO). This implies a maximum HRT of 5.3 h (i.e. 0.9V/Q = 4.8) for a flow-through system. Therefore, a flow-through pond with a maximum HRT of 5 h for 100% exposure is recommended for bioassay test of tertiary-treated effluent.
- Total flow requirement: 10% of the flow (subjected to maximum 1 MLD) is required to pass through the bioassay pond.

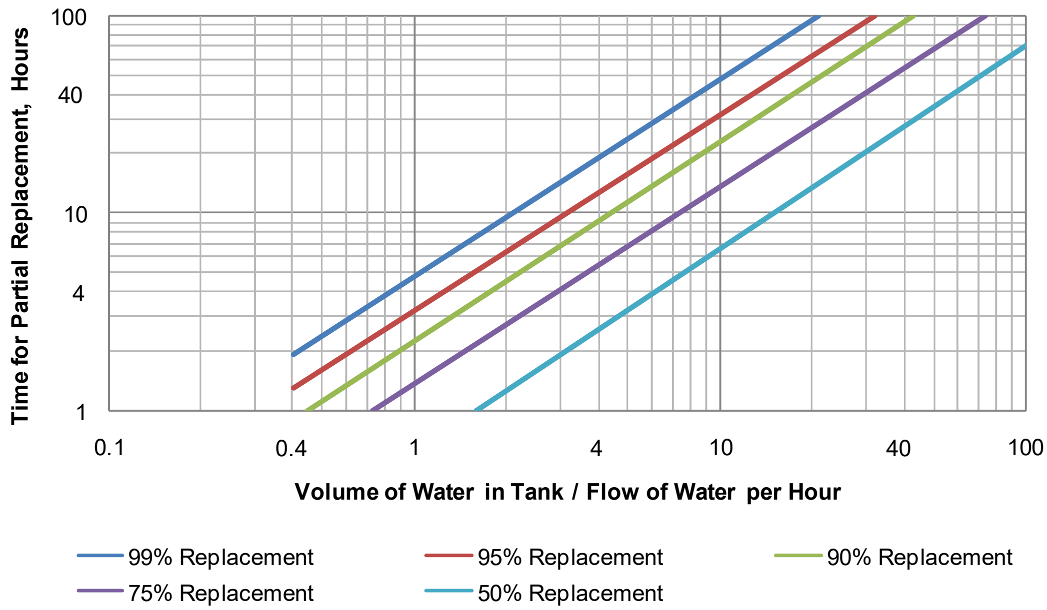

Figure 3: Approximate times required to replace water in test chambers in flow-through tests (For Example: For a chamber containing 4 L, with a flow of 2 L/h, the above graph indicates that 90% of the water would be replaced every 4.8 h. The same time period, such as hours, must be used on both axes, and the same unit of volume, such as liters, must be used for both volume and flow (Adapted from USEPA, 2002)

- Depth of flow-through system or pond: The depth of the flow-through bioassay pond should be within 1.5 to 2.5 m based on an equivalent system of wastewater-fed fish pond (aquaculture) (Costa-Pierce, 1998; Hoan and Edwards, 2005).
- Test organisms: In the bioassay pond, locally found fish, algae and daphnia should be inhabited in the bioassay pond. USEPA (2002) and APHA *et al*. (1995) have recommended following freshwater fish species when fish is the preferred form of aquatic life/test organism:

  1. *Oncorhynchus mykiss* (rainbow trout) and Salvelinus fontinalis (brook trout)
  2. *Pimephales promelas* (fathead minnow)
  3. *Lepomis macrochirus* (Bluegill sunfish)
  4. *Ictalurus punctatus* (Channel catfish)

  Based on above, following equivalent fish species are recommended under Indian conditions.

  1. *Puntias stigma*
  2. *Puntias sophore*
  3. *Anabas*
  4. *Chela bacalia*
  5. *Puntias ticto* and
  6. *Colisa faciatus*

Other freshwater fish species like *Gambusia affinis* (mosquito fish) can also be considered. *Daphnia pulex* and *D. magna* (daphnids), *Selenastrum sp*., *Scenedesmus aculeala*, *Scenedesmus guadacanda* are also recommended similar to the recommendations made by USEPA (2002) for bioassay test.

- Stocking density and number of test organisms: For flow-through tests, the live weight of test organisms in the system must not exceed 7.0 g/L (i.e. 7.0 kg/m^3) of volume at l5°C, or 2.5 g/L (i.e. 2.5 kg/m^3) at 25°C (USEPA, 2002). A minimum of 20 organisms of a given species are required for the test.
- Feeding requirement: Considering the bioassay of tertiary-treated sewage effluent and fish as the preferred form of aquatic life/test organism, 32% protein feed at 1% of the stocking biomass/d in two daily slots (preferably morning and evening) with a floating system need to be fed (Costa-Pierce, 1998). The feeding regime for fish mentioned in USEPA (2002) can also be adopted.
- Aeration and oxygen requirements: Sufficient DO (4.0 mg/L for warm water species and 6.0 mg/L for cold water species) should be maintained in the pond for proper environment for test organisms. The DO depletion is not a problem in case of a flow-through system because aeration occurs as the water pass through the system. If DO decreases to a level that would be a source of additional stress, the turnover rate of the water volume must be increased (i.e. the HRT of the system must be decreased) sufficiently to maintain acceptable DO levels (USEPA, 2002). Alternatively fountain or cascade aeration arrangements may be provided.
- Requirement of Dechlorination: Dechlorinated effluent only should be passed through the bioassay pond. If the effluent from the STP is chlorinated, the total residual chlorine in the effluent should be non-detectable after dechlorination.
- Bioassay test acceptability criterion: No mortality (100% survival) of test organisms under any condition.

Salient Features of Recommended STPs

- Continuous measurement of flow at the inlet and outlet
- Excellent preliminary treatment
- Treatment up to tertiary level
- Online bioassay test
- Designed and built as modular units
- Pumping and STPs to be taken together for contracting/bidding

9. Justification for Recommending Tertiary Treatment and Zero Liquid Discharge

The trends in water quality of river Ganga based on the past 25 years of data on more than 70 station spread over entire course of the river reveals that coliform and fecal coliform levels are of main concern (refer Report No 023_GBP_IIT_EQP_ANL_01 Ver 1_June 2012). Further, this report reveals that for control of coliforms, disinfection of treated wastewater is essential. However, no disinfection method is found to be effective in reducing coliform levels from secondarily treated wastewater. As such it is essential to have tertiary treatment for any disinfection method to be very effective (refer Report No 023_GBP_IIT_EQP_ANL_01 Ver 1_June 2012). Also, tertiary treatment of wastewater improves chances of reuse and recycle, and hence recovering the expenditure on sewage treatment. There are many examples of reuse and recycle of treated wastewater world wide as well as in India (refer Report No 012_GBP_IIT_EQP_SOA_01 Ver 1_June 2011). Considering this it is recommended that sewage be treated to tertiary level and reused instead of discharging into the river in a time bound manner to reduce abstraction of river water and exploitation of ground water.

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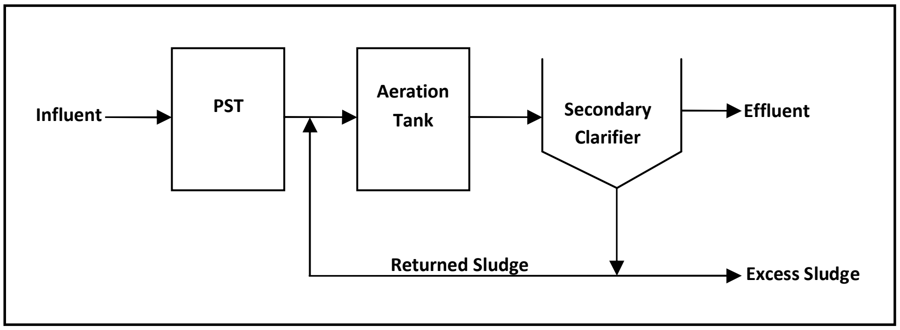
Appendix I: Exhibits on Options for Secondary Treatment

Exhibit 1: ASP - Conventional Activated Sludge Process



Schematic Diagram of a Conventional Activated Sludge Process

Activated Sludge Process (ASP) is a suspended growth aerobic process. It is provided with primary clarifier to reduce the organic load in biological reactor (aeration basin). About 40% of organic load is intercepted in primary clarifier in the form of sludge, decreasing the loading in the aeration tank. Detention period in aeration tank is maintained between 4-6 h. After aeration tank, the mixed liquor is sent to secondary clarification where sludge and liquid are separated. A major portion of the sludge is re-circulated and excess sludge is sent to a digester.

Sludge generated in primary clarifier and excess sludge from secondary clarifier are not matured, digestion of such sludge is essential before disposal. In anaerobic sludge digestion, such sludge produces biogas which can be used for power generation by gas engines. Generated power can be used for operation of plant.

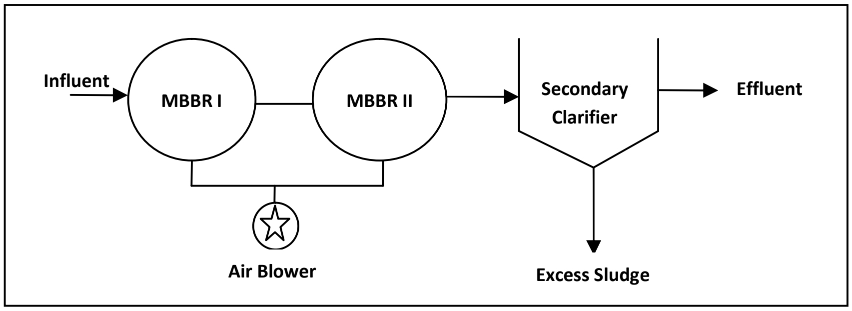
Merits

- Good process flexibility
- Reliable operation
- Proven track record in all plant sizes
- Less land requirements
- Low odor emission
- Energy production
- Ability to withstand nominal changes in water characteristics

Demerits

- High energy consumption
- Skilled operators needed
- Uninterrupted power supply is required
- Requires sludge digestion and drying
- Less nutrient removal

Exhibit 2: MBBR - Moving Bed Biofilm Reactor



Schematic Diagram of a Moving Bed Bio-Reactor

Moving Bed Biofilm Reactor is an aerobic attached biological growth process. It does not require primary clarifier and sludge recirculation. Raw sewage, after screening and de-gritting, is fed to the biological reactor. In the reactor, floating plastic media is provided which remains in suspension. Biological mass is generated on the surface of the media. Attached biological mass consumes organic matter for their metabolism. Excess biological mass leaves the surface of media and it is settled in clarifier. Usually a detention time of 5 to 12 h is provided in the reactors.

MBBR were initially used for small sewage flow rates and because of less space requirement. In large plant, media quantity is very high and it requires long shut down period for plant maintenance. In fact, it may not be successful for large capacity plants. Moreover the plastic media is patented and not available in the open market, leading to single supplier conditions which limit or deny price competition. In addition, due to very less detention time and other engineering factors, functional Moving Bed Biofilm Reactor in India do not produce acceptable quality effluent.

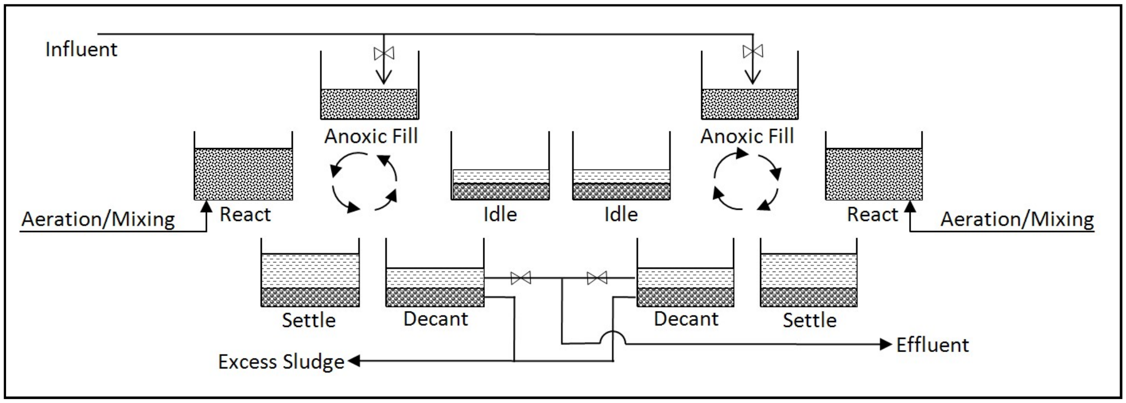
Merits

- Moving Bed Biofilm Reactor needs less space since there is no primary clarifier and detention period in reactor is generally 4-5 h.
- Ability to withstand shock load with equalization tank option
- High operator oversight is not required

Demerits

- High operating cost due to large power requirements
- Not much experience available with larger capacity plants (>1.5 MLD)
- Skilled operators needed
- No energy production
- Effluent quality not up to the mark in India
- Much less nutrient removal
- Designed criteria not well established

Exhibit 3: SBR - Sequencing Batch Reactor



Schematic Diagram of a Sequencing Batch Reactor (A Continuous Process "In Batch")

It is a fill-and-draw batch aerobic suspended growth (Activated Sludge) process incorporating all the features of extended aeration plant. After screening and de-gritting, sewage is fed to the batch reactor. Reactor operation takes place in certain sequence in cyclic order and in each cycle, following operations are involved

- Anoxic Filling tank
- Aeration
- Sedimentation/clarification
- Decantation
- Sludge withdrawal

A number of large-scale plants exist around the world with several years of continuous operation. In India also, there are large scale plants operating efficiently since more than a year. Hundreds of full-scale plants operated on Sequencing Batch Reactor Technology are under successful operation in Japan. Some parts are patented and not available in the open market, leading to single supplier conditions which limit or deny price competition.

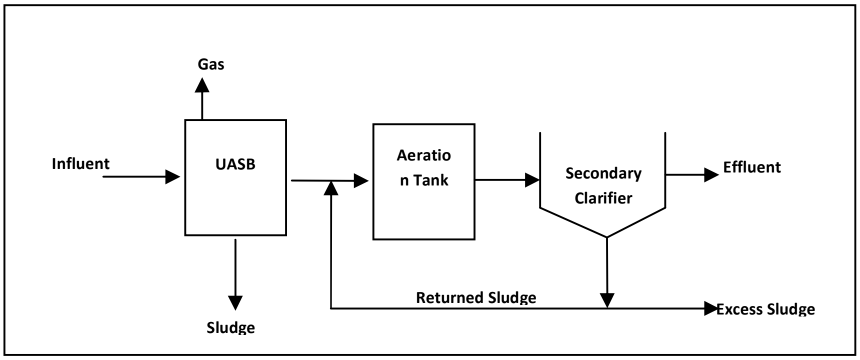
Merits

- Excellent effluent quality
- Smaller footprint because of absence of primary, secondary clarifiers and digester
- Recent track record available in large applications in India also
- Biological nutrient (N&P) removal
- High degree of coliform removal
- Less chlorine dosing required for post disinfection
- Ability to withstand hydraulic and organic shock loads

Demerits

- Comparatively high energy consumption
- To achieve high efficiency, complete automation is required
- Highly skilled operators needed
- No energy production
- Uninterrupted power supply required

Exhibit 4: UASB+ASP - Upflow Anaerobic Sludge Blanket Followed by Activated Sludge Process



Schematic Diagram of an Upflow Anaerobic Sludge Blanket Process followed by ASP

It is an anaerobic process in which influent wastewater is distributed at the bottom of the UASB reactor and travels in an up-flow mode through the sludge blanket. Critical components of UASB design are the influent distribution system, the gas-liquid-solid separator (GLSS) and effluent withdrawal design. Compared to other anaerobic processes, UASB allows the use of high hydraulic loading.

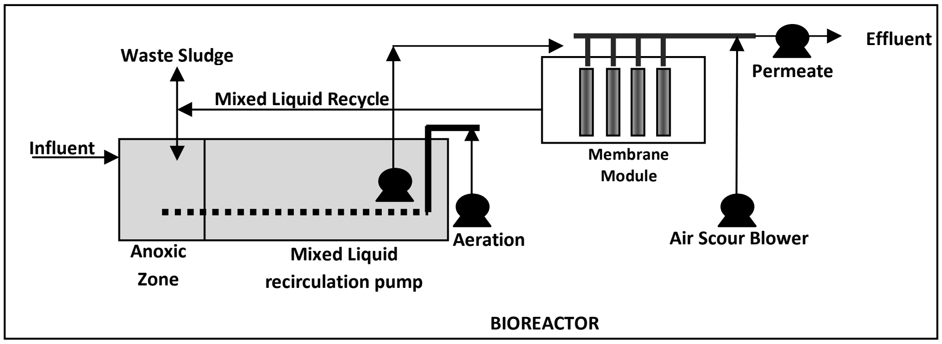
Merits

- Relatively simple operation and maintenance
- No external energy requirement and hence less vulnerable to power cuts
- No primary treatment required
- Energy production possible but generally not achieved
- Low sludge production
- No special care or seeding required after interrupted operations
- Can absorb hydraulic and organic shock loading

Demerits

- Post treatment required to meet the effluent standard
- Anoxic effluent exerts high oxygen demand
- Large Land requirement
- More man-power require for O&M
- Effluent quality is not up to the mark and poor fecal and total coliform removal
- Foul smell and corrosion problems around STP area
- High chlorine dosing required for disinfection.
- Less nutrient removal

Exhibit 5: MBR - Membrane Bioreactor



Schematic Diagram of a Membrane Bioreactor

It is a biological reactor with a suspended biomass. The solid-liquid separation in membrane bioreactor is achieved by a microfiltration membrane with pore sizes ranging from 0.1 to 0. 4 µm. No secondary clarifier is used and has the ability to operate at high MLSS concentrations. Membranes are patented and not available in the open market, leading to single supplier conditions which limit or deny price competition.

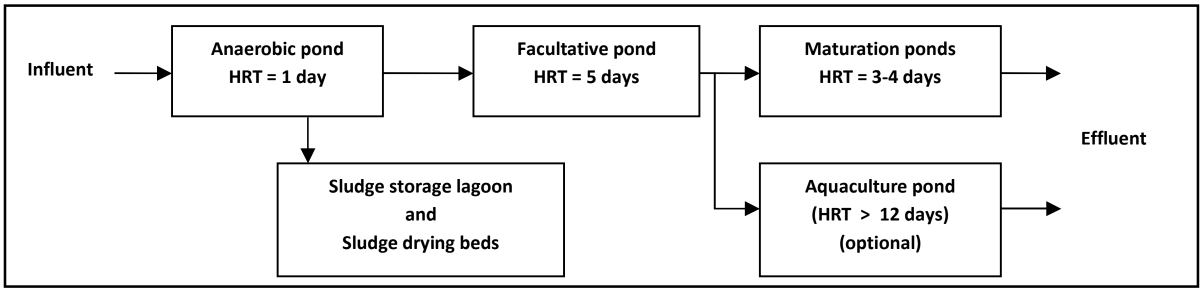
Merits

- Low hydraulic retention time and hence low foot print (area) requirement
- Less sludge production
- High quality effluent in terms of low turbidity, TSS, BOD and bacteria
- Stabilized sludge
- Ability to absorb shock loads

Demerits

- High construction cost
- Very high operation cost
- Periodic cleaning and replacement of membranes
- High membrane cost
- High automation
- Fouling of membrane
- No energy production

Exhibit 6: WSP - Waste Stabilization Pond (Combination of Anaerobic and Aerobic Pond)



Schematic Diagram of a Waste Stabilization Pond

Sewage is treated in a series of earthen ponds. Initially after screening and de-gritting it is fed to an anaerobic pond for initial pretreatment; depth of anaerobic pond is usually 3 to 3.5 m; as a result the lower section of pond does not get oxygen and an anaerobic condition is developed. BOD reduction takes place by anaerobic metabolism and gases like ammonia and hydrogen sulphide are produced creating odor problems. After reduction of BOD by 40% it enters the facultative/aerobic pond, which is normally 1 - 1.5 m in depth. Lesser depth allows continuous oxygen diffusion from atmosphere; in addition algae in the pond also produces oxygen.

Though BOD at the outlet remains within the range, sometimes the effluent has green color due to presence of algae. The algae growth can contribute to the deterioration of effluent quality (higher total suspended solids) from time to time. Moreover, coliforms removal is also in 1-2 log order. The operating cost of a waste stabilization pond is minimum, mostly related to the cost of cleaning the pond once in two to three years. A waste stabilization pond requires a very large land area and it is normally used for small capacity plant, especially where barren land is available.

Merits

- Simple to construct and operate and maintain
- Low operating and maintenance cost
- Self sufficiency, ecological balance, and economic viability is greater
- Possible recovery of the complete resources
- Good ability to withstand hydraulic and organic load fluctuations

Demerits

- Requires extremely large areas
- Large evaporation loss of water
- If liner is breached, groundwater is impacted
- Effluent quality may vary with seasons
- No energy production
- Comparatively inferior quality of effluent
- Less nutrient removal
- High chlorine dosing for disinfection
- Odor and vector nuisance
- Loss of valuable greenhouse gases to the atmosphere

Exhibit 7: CW - Constructed Wetlands

Wetlands are natural processes similar to stabilization ponds. Wetlands are shallow ponds comprising of submerged plants and floating islands of marshy species. Natural forces including chemical, physical, biological and solar is involved in the process to achieve wastewater treatment. Thick mats of vegetation trap suspend solids and biological process takes place at the roots of the plants. It produces the desired quality of treated sewage but land requirement is very high, though it is less compared to waste stabilization pond. Running cost is comparatively low.

Wetland process have not yet established compared to other processes. There are two types of systems; surface and subsurface distribution of sewage. The type of vegetation grown varies, in some cases there is regular tree cutting and plantation as a part of maintenance work. Plants like Typha, Phragamites, Kattail can be used in India. Another type of wetlands use a plant called duckweed for treatment. This weed has a very fast metabolic rate and absorbs pollutants very quickly.

Merits

- Simple to construct and operate and maintain
- Low operating and maintenance cost
- Self sufficiency, ecological balance, and economic viability is greater
- Possibility of complete resource recovery
- Good ability to withstand hydraulic and organic load fluctuations

Demerits

- Requires large area
- Large evaporation loss of water
- Not easy to recover from massive upset
- If liner is breached, groundwater is impacted
- Effluent quality may vary with seasons
- No energy production
- No nutrient removal
- Odor and vector nuisance
- Loss of valuable greenhouse gases to the atmosphere

Guidelines for Implementation of
Sewage Collection, Diversion, Pumping, Treatment, and Reuse (Sewage CDPTR) Infrastructure in Class I Towns

GRBMP : Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay | IIT Delhi | IIT Guwahati | IIT Kanpur | IIT Kharagpur | IIT Madras | IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRB EMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. Lists of persons who are members of the concerned thematic groups and those who have taken lead in preparing this report are given on the reverse side.

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Contents

1. Introduction

Two important objectives of Ganga River Basin Environment Management Plan (GRB EMP) are the restoration of, 1) 'Nirmal' dhara and 2) 'Aviral' dhara in all the rivers of the Ganga River Basin (GRB). This report specifically addresses the construction, operation and maintenance of the sewage collection, diversion, pumping, treatment and reuse (CDPTR) infrastructure in Class 1 towns of GRB to achieve the objectives of GRB EMP. The steps recommended in this report will lead to partial restoration of 'Nirmal' dhara in the rivers of the Ganga basin. The question of restoration of 'Aviral' dhara is largely outside the scope of this report, though it is thought that restoration of 'Nirmal' dhara will indirectly help in the restoration of 'Aviral' dhara also.

2. Sewage CDPTR Infrastructure Proposed Under URMPs

In future, sewage collection, diversion, pumping, treatment and reuse (CDPTR) infrastructure in Class 1 towns of Ganga River Basin (GRB) must be constructed strictly according to DPRs prepared based on 'work packages' specified under relevant 'actionable' items (see sections 4.4, 4.5 and 4.6 of Report No. 002_GBP_IIT_EQP_S&R_02) in the URMPs prepared for these towns.

The relevant 'actionable' items for this purpose (also specified in Report No. 002_GBP_IIT_EQP_S&R_02) are the following,

Item 4.4.1: Construction of main sewers, branch sewers, laterals and house connections for collection of sewage from individual households. In the long term, sewage from all households, including slum areas must be collected by the underground sewer system.

Item 4.4.2: Construction of trunk sewers in a phased manner for the conveyance of the sewage to the sewage treatment plant. In the long-term, all sewage generated in the town must be collected and conveyed to sewage treatment plants.

Item 4.4.3: Construction of intercepting sewers for diverting the flow of small 'nalas'/drains into the sewer system. All sewage flowing in small 'nalas'/drains must be diverted to the underground sewer system. This is a short-medium term solution, which will hopefully become redundant once a comprehensive sewage collection system is developed for the whole town.

Item 4.4.4: 'Nala'/drain tapping works for diverting discharges of large 'nalas'/drains to the sewer system. All sewage flowing in large 'nalas'/drains to be diverted from rivers and other surface water bodies and into sewers or directly to sewage treatment plants. This is a short-medium term solution, which will hopefully become redundant once a comprehensive sewage collection system is developed for the whole town.

Item 4.5.1: Construction of sewage pumping stations for conveying sewage flowing in trunk sewers and large 'nalas' to sewage treatment plants. Capacity for pumping all sewage generated in the town to sewage treatment plants must be created.

Item 4.5.2: Construction of new STPs, clearly showing the area of the town from which sewage will be diverted to the STP. All sewage generated in the town to be diverted to new or existing STPs.

Item 4.6.1: Renovation of existing surface water bodies in the town/surrounding rural area for storage of treated sewage and groundwater recharge.

Item 4.6.2: Construction of surface water bodies in the town/surrounding area for storage and groundwater recharge of treated sewage.

Item 4.6.3: Construction of pipelines/open channels for conveyance of treated sewage, 1) to storage structures, 2) from storage structures to reuse points in the town and elsewhere.

Item 4.6.4: Production and use of sludge-derived products, i.e., manure, compost, etc. in the town or in other areas.

Further,

1. Sewage treatment plants sanctioned by NGRBA for Class I towns in the GRB shall provide tertiary level treatment broadly using the technological options (or their equivalent) specified in Report No. 003_GBP_IIT_EQP_S&R_02.
2. The required treated water quality should be as specified in Report No. 003_GBP_IIT_EQP_S&R_02, irrespective of standards specified elsewhere. This is essential for improving the bacteriological and other water quality parameters of the river water in various rivers of the Ganga Basin.

3. Long-Term Vision

As stated by the IIT consortium in various forums, it is strongly felt that the restoration of 'Nirmal' dhara in all rivers of the GRB will require, among other actions, the following steps in the medium to long term (within next 25 years) concerning sewage CDPTR infrastructure in Class 1 towns of GRB,

1. Complete stoppage of the discharge of sewage, either treated or un-treated, from Class 1 towns in GRB into all rivers of the GRB.

2. All sewage generated in Class I towns of GRB must be collected and treated up to tertiary level (treatment guidelines for tertiary treatment specified elsewhere (IIT Report 003_GBP_IIT_EQP_S&R_02); Effluent Standards: BOD < 10 mg/L; SS < 5 mg/L; fully nitrified effluent; P < 0.5 mg/L; FC < 10/100 mL)

3. The tertiary treated water should be reused for various purposes, i.e., industrial, irrigation, horticultural, non-contact/non-potable domestic uses, groundwater recharge through surface storages and subsequent infiltration into the ground water, etc.

   Note: However, in exceptional cases, discharge of tertiary treated sewage into the river may be allowed only on short-term basis, i.e., until the required water reuse/recycling infrastructure is put in place.

4. Sewage CDPTR Infrastructure: Current Status

Ideally, all sewage generated in Class 1 towns of GRB should be collected through the underground sewer network and conveyed to sewage treatment plants for treatment followed by proper disposal or reuse. This is a necessary (if not sufficient) condition for improvement in the overall river water quality in all rivers of GRB. The current status and deficiencies in the sewage CDPTR infrastructure in various Class 1 towns of the GRB is summarized as follows.

1. The sewer network is not present in many towns. In other towns, the sewer network is only present in certain areas, with many new localities, unauthorized colonies and slum clusters having no sewer network.
2. The sewage generated in areas with no sewer network is discharged in surface drains and 'nalas'. Even in areas with sewer network, many houses are not connected to the network for a variety of reasons. The sewage from these houses is also discharged in surface drains and 'nalas'.
3. Sewage collected by the sewer network is often not conveyed to the treatment plant due to a variety of reasons, i) lack of and/or malfunctioning of sewage pumping infrastructure, ii) choked or broken sewers, or iii) lack of capacity for sewage treatment. Under such circumstances, the sewage is diverted into 'nalas' or is discharged into surface water bodies.
4. The sewage flowing in 'nalas' mostly discharged into surface water bodies without any treatment.
5. In some cases, the sewage flowing in 'nalas' is diverted to sewage treatment plant for treatment. Such diversion is often ineffective due to, i) lack of/malfunctioning of sewage pumping infrastructure due the various reasons, and ii) insufficient sewage pumping capacity.
6. In some towns, sewage treatment capacity is often much less than the amount of sewage generated.
7. In other cases, the existing sewage treatment capacity is often under-utilized due to the lack of and/or malfunctioning of the pumping infrastructure and choking/blocking of sewers required for conveying the sewage to treatment plant.

8. Sewage treatment plants often do not work properly due to erratic electricity supply and poor operation and maintenance and other associated causes. Thus untreated/partially treated sewage is often discharged from the treatment plants.
9. Sludge produced during sewage treatment is often not disposed in an acceptable manner. Sludge is often used as fertilizer in an unscientific manner with consequent occupational and other health hazards. Sludge/sludge derived products utilization infrastructure in not in place.
10. In most cases, there is no treated sewage reuse infrastructure. In some cases, treated and untreated sewage is used for irrigation purposes, mostly in an unscientific manner and with consequent occupational and other health hazards.

5. Sewage CDPTR Infrastructure: Current Initiatives

Construction, operation and maintenance of sewage CDPTR infrastructure in all Class 1 towns of the GRB is the responsibility of respective elected urban local bodies (ULBs). It is normally expected that the expenditure on above services will be recovered by the ULBs from the residents of the town through the levying of local taxes.

However, due to financial constraints, most ULBs in Class 1 towns of GRB are unable and/or unwilling to invest significant resources for construction, operation and maintenance of sewage CDPTR infrastructure. Nonetheless, over the years, the central and state governments have invested significant amounts of resources under GAP-I, GAP-II, other river action plans (RAPs) and other urban renewal projects for the creation of sewage CDPTR infrastructure in many towns of the GRB.

Funding was initially made available for projects included under 'actionable' items 4.4.2 (construction of trunk sewers), 4.4.3 (construction of intercepting sewers), 4.4.4 (construction of 'nala' tapping works), 4.5.1 (construction of sewage pumping stations) and 4.5.2 (construction of sewage treatment plants) in the proposed URMPs (see Report No. 002_GBP_IIT_EQP_S&R_02). However, sewage treatment plants ('actionable' item 4.5.2 in proposed URMPs) were funded to treat sewage only up to the secondary (and not tertiary) level.

Initially, no funding was sanctioned for development of sewer networks ('actionable' item 4.4.1 in proposed URMPs), as this was considered to have only indirect impact on river water quality. However, this restriction was somewhat relaxed in later stages of various RAPs. Central funding for development of sewer networks ('actionable' item 4.4.1 in proposed URMPs) was however always available from other sources, e.g., JNNURM and other related projects funded by MoUD and other agencies.

Almost no funding for projects included under 'actionable' items 4.6.1 (restoration of existing surface water bodies), 'actionable' items 4.6.2 (construction of new surface water bodies), 'actionable' items 4.6.3 (conveyance systems for treated sewage) and 'actionable' items 4.6.4 (production and use of sludge-derived products) under proposed

URMPs (see Report No. 002_GBP_IIT_EQP_S&R_02) was made available, since reuse of treated sewage and use of sludge-derived products was rarely emphasized in GAP-I, GAP-II and other RAPs.

The funding and implementation pattern for most projects involving sewage CDPTR supported by MoEF (through NRCD) was as follows.

1. The land for the project was provided by the ULBs/State Governments.
2. The capital cost of the project was provided (as per current practice) by the central and state governments in 70 : 30 ratio.
3. Project DPR was prepared and the project implemented by government agencies like UP Jal Nigam (UPJN).
4. After commissioning, operation and maintenance for a stipulated period, the infrastructure is handed over to ULB. Subsequent operation and maintenance of the infrastructure was the responsibility of the ULB.

Despite the above initiatives, the present scenario vis-à-vis sewage CDPTR in almost all towns of the Ganga river basin, even after implementation of works under GAP-I, GAP-II, other RAPs and other related urban renewal projects, still presents a discouraging picture. Large quantities of partially treated and untreated sewage continue to be discharged into the rivers of GRB. This gives the rivers an unwholesome appearance and the average citizen is unconvinced of positive impact, if any, of the considerable investment made over the years for cleaning the rivers.

Several assessments of GAP-I, GAP-II and other river action plans (RAPs) over the years have shown only marginal improvement, if any, in the river water quality in terms of BOD concentration. The DO values are also above the desired minimum in most stretches. However, total and fecal coliform concentrations in the river are above the desired values in most stretches.

5.1 Sewage CDPTR Infrastructure: Analysis of Current Scenario

The main deficiencies in the funding model adopted in GAP I, GAP II and other RAPs for the creation of sewage CDPTR infrastructure were the following,

1. ULBs were not closely involved in project planning and implementation. There was no public participation/involvement in project planning and implementation stages.
2. State governments were often late in releasing their share of the project cost resulting in delayed project implementation and cost overruns.
3. Despite written assurances at the project approval stage, ULBs were often unwilling to take over the operation and maintenance of the created infrastructure, citing their lack of expertise and lack of funds.
4. Uninterrupted electricity supply was not ensured for the pumping stations and sewage treatment plants, leading to constant disruptions and sub-optimal performance.

5. DG sets provided for operation of pumping stations during power cuts were mostly non-operational.
6. Performance monitoring of the completed projects was not done in an objective and systematic basis, and effective action was not taken to improve the performance of the created infrastructure based on such monitoring. Public participation/ involvement in project monitoring was minimal.
7. In many cases, due to the lack of regular maintenance, and lack of allocated funds, the created infrastructure deteriorated at a rapid rate and became non-operational very quickly.
8. The sewage treatment plant capacity was often underutilized, since sewage conveyance and pumping infrastructure was either non-existent or was not functioning properly.
9. Adopted sludge management practices were insufficient for safe and secure management of solid residues arising from sewage treatment operations.

The net effect of the above factors was that in most cases, the benefits of the creation of sewage CDPTR infrastructure, as envisaged during project planning was never realized.

Based on the analysis of the current funding and implementation scenario for sewage CDPTR infrastructure as presented above, the main issues that appear to have prevented proper functioning of sewage CDPTR infrastructure have been listed as follows.

1. Deficiencies in the operation and maintenance of the created infrastructure, often due to lack of resources.
2. Lack of involvement of ULBs and general public in project planning and implementation.
3. Lack of assured electricity supply for the operation of pumping stations and sewage treatment plants.
4. Deficiencies in the monitoring of the performance of the created infrastructure and lack of action to improve performance based on performance monitoring reports.

In addition there has been a general lack of strategic approach, i.e., examination of a spectrum of solutions such as decentralized sewage treatment, regional sewage treatment plants shared by various ULBs, reuse potential of treated sewage, etc.

The responsibility of operation and maintenance of sewage diversion and treatment infrastructure constructed through central and state funds lies with the ULBs. However, ULBs have time and again expressed reluctance in taking up the operation and maintenance of the sewage CDPTR infrastructure citing, i) lack of funds, and ii) lack of expertise. It is contended that in addition to the above reasons, another important reason for this reluctance of ULBs is the lack of motivation. Following points are made to support this contention.

- Operation and maintenance of sewage diversion, pumping and treatment infrastructure is a very low priority item for ULBs.
- Most ULBs would like to have an efficient underground sewage collection infrastructure, such that sewage is removed from the city efficiently. However, most ULBs will have no qualms in discharging this sewage to rivers, even without treatment. Sewage diversion, pumping and treatment does not provide any direct benefits to the residents of a town.
- Sewage treatment before disposal of the treated sewage into the river does result in the improvement of river water quality, but only downstream of the town. Hence it is not of direct benefit to the town.
- It is thus not unreasonable to assume that ULBs would prefer to spend their scarce resources for other development works which directly and immediately benefit the residents of the town, e.g., improvement of roads and other traffic infrastructure, water supply, drainage and sewer system, solid waste collection, etc.
- Indeed, over the last two decades, though the income of some ULBs have gone up, but almost no funds have been invested by these ULBs for creation or up-gradation of sewage diversion, pumping or treatments works, while local investment on other infrastructure services, like roads, water supply, sewers, drainage, solid waste collection, etc., have increased.
- Repeated interventions by MoEF (through NRCD) and even the courts (including the apex court) have been largely unsuccessful in compelling the ULBs to invest adequate funds and show motivation for the creation, operation and maintenance of sewage diversion, pumping and treatment infrastructure.

Considering the above points, it is impractical to envisage a scenario where the operation and maintenance of sewage CDPTR infrastructure can be done in an efficient manner, if the sole responsibility for these activities lies with the ULBs.

6. Sewage CDPTR Infrastructure: Proposed Changes

Funding is required for both construction and operation and maintenance of the required sewage CDPTR infrastructure in all Class 1 towns of GRB. Implementation of the required projects should be as per proposed URMPs to be prepared for each Class 1 town of the GRB. In other words, implementation of 'work packages' under 'actionable' items 4.4.1 – 4.4.4, 4.5.1 - 4.5.2 and 4.6.1 – 4.6.4 of the URMPs is required for creation of the required sewage CDPTR infrastructure.

Funding is required for both construction and operation and maintenance phases of various projects. At present, the construction costs of various projects are largely paid by the central and state governments, while operation and maintenance is largely being done by ULBs. It is now proposed that the above funding model be changed, primarily through the involvement of independent private/public sector agencies, through Design-Build-Finance-Operate Model (DBFO Model) or Public-Private-Partnership (PPP Model).

The private/public sector agencies will participate in project financing and in project conception, design, construction and operation and maintenance phases of some types of projects.

The suggested funding sources for various 'actionable items' concerning sewage CDPTR infrastructure is summarized below,

Item	Brief Description	Funding	
		Construction	**Operation and Maintenance**
4.4.1:	Sewer network	NGRBA (through MoEF, MoUD), State and Local resources	Mostly using local resources, with occasional funding from State government and NGRBA (MoUD)
4.4.2:	Trunk sewers	NGRBA (through MoEF, MoUD), State resources	Mostly using local resources, with occasional funding from State government, NGRBA (MoEF, MoUD)
4.4.3:	Intercepting sewers	NGRBA (through MoEF, MoUD), State resources	Mostly using local resources, with occasional funding from State government, NGRBA (MoEF, MoUD)
4.4.4:	'Nala' tapping works	NGRBA (through MoEF, MoUD), State resources	Mostly using local resources, with occasional funding from State government, NGRBA (MoEF, MoUD)
4.5.1:	Sewage pumping stations	NGRBA (through MoEF, MoUD) and State resources, using DBFO model of funding	Initially by NGRBA (MoEF, MoUD) through DBFO model, later using local resources (preferably through DBFO model)
4.5.2:	Sewage treatment plants		
4.6.1:	Renovation of surface water storage structures	NGRBA (through MoEF, MoUD, MoWR) and State resources	Mostly through local resources, with occasional funding from state government and NGRBA (MoEF, MoWR)
4.6.2:	New surface water storage structures	NGRBA (through MoEF, MoUD, MoRD) and State resources	Mostly through local resources, with occasional funding from state government and NGRBA (MoEF, MoWR)
4.6.3:	Treated water conveyance	NGRBA (through MoEF, MoWR, MoRD), State resources, Local resources, Private funds through PPP model	NGRBA (through MoEF, MoWR, MoRD), State resources, Local resources, Private funds through PPP model
4.6.4:	Sludge management and sludge-derived products	NGRBA (through MoEF, MoRD), State resources, Local resources, Private funds through PPP model	NGRBA (through MoEF, MoRD), State resources, Local resources, Private funds through PPP model

6.1 Sewage Pumping and Treatment: Proposed Changes

One of the major proposed changes is the introduction of the DBFO model for encouraging the participation of independent private /government agencies in providing sewage pumping and treatment services ('actionable' items 4.5.1 and 4.5.2 in proposed URPs) in Class I towns of GRB.

For this purpose it is necessary that for the sake of river Ganga, which has been declared a 'National River', the central and state governments not only fund the entire construction, but also the operation and maintenance costs for the sewage pumping and treatment infrastructure ('actionable' items 4.5.1 and 4.5.2 in proposed URMPs) for a certain period of time after commissioning of the infrastructure. The time period as defined above should ideally be 15 years, though a lower period of time (at least 5 years) may also be considered. This proposal is based on the following points.

1. Creation and efficient operation of sewage pumping and treatment infrastructure ('actionable' items 4.5.1 and 4.5.2 in proposed URMPs), will, in the medium to long term, result in the prevention of the discharge of treated and untreated sewage into the rivers of the GRB from Class 1 towns. This is a necessary condition for improvement of the river water quality in all rivers of the GRB. In addition, visible defilement of rivers of the GRB through the discharge of millions of liters of untreated and treated sewage per day will stop. Such developments are highly desirable and hence may be considered as a 'public good'. 'Public goods' are often funded by central and state governments in various sectors, (e.g., National Parks, NREGA, mid day meal scheme in primary schools, etc.) without considering the monetary returns/revenue generated from such actions.

2. Central and state governments are already funding the entire capital cost of sewage pumping and treatment infrastructure. In new projects, operation and maintenance costs are also being paid for 5 years. As per the present proposal, the central and state governments will continue to make payments for operation and maintenance of the created infrastructure for a period of at least 5 years after commissioning. It is further suggested that the duration of payments for operation and maintenance of the sewage pumping and treatment infrastructure by central and state governments be extended beyond five years. Ideally, such payments should continue for 15 years after commissioning of the infrastructure, though any lesser period of extension beyond 5 years is also welcome.

3. It may be argued that payment by central and state governments for both capital and operation and maintenance costs of sewage diversion, pumping and treatment infrastructure in towns of the Ganga river basin violates the 'polluter pays' principle. It lets the 'polluter' i.e., the ULBs completely avoid paying for cleaning the pollution it causes. However, it may also be argued that while the 'polluter pays' principle should be strictly applied to profit-making industrial units, application of this principle to ULBs, which are not profit-making and often under great financial stress can be considered in a more sympathetic manner. Even under the present proposal, ULBs will be making various 'in kind' contributions to facilitate the creation, operation and maintenance of sewage diversion, pumping and treatment infrastructure and will take over the responsibility for the operation and maintenance of the created infrastructure after the initial period of payments by the central and state governments for operation and maintenance is over.

4. As envisaged in this report, sewage is to be treated to the tertiary (treatment guidelines for tertiary treatment specified elsewhere (IIT Report 003_GBP_IIT_EQP_S&R_02); effluent standards: BOD < 10 mg/L; SS < 5 mg/L; fully nitrified; P < 0.5 mg/L; FC < 10/100 mL) level. The treated effluent must be (in the medium to long term) reused for various non-potable purposes, irrigation or ground water recharge (see 'actionable' items 4.6.1 – 4.6.3 in proposed URMPs). This reuse will reduce the consumption of fresh water, which would otherwise be obtained by exploiting ground water or from the existing surface water resources. Hence in effect, the investment in the creation and operation of sewage diversion, pumping and treatment infrastructure will actually augment the water resources in the Ganga river basin, ensuring which is an important component of the GRB EMP.

It is proposed that sewage pumping and treatment infrastructure ('actionable' items 4.5.1 and 4.5.2 in proposed URMPs) be constructed through the participation of independent private/public agencies using the DBFO Model. The ULB will appoint a service provider (private or public company) from a list of companies empanelled for this purpose for the project planning, design, construction, and operation and maintenance of the created infrastructure over a pre-defined (i.e., 5 – 15 years after commissioning) contact period. The DPR prepared by the service provider (as per relevant 'work packages' specified in URMPs) will be vetted by the ULB and State Government and submitted to NGRBA for approval. Once approved by the NGRBA, the project implementation will be done by the service provider under the supervision of the ULB. Initial investment for creation of the infrastructure will be made by the service provider through equity infusion or debt. No payments will be made to the service provider during the construction period of the infrastructure. After commissioning, the service provider will be paid by the ULB in annuities over the contact period. Payments to the service provider will be made by the ULB after ensuring compliance of the service provider with contract conditions. Funds for payment to the service provider will be made available to the ULB by the central and state governments throughout the contract period.

7. Design-Build-Finance-Operate (DBFO) Model

Funding for sewage pumping and treatment infrastructure ('actionable' items 4.5.1 and 4.5.2 in proposed URMPs) should be done by the DBFO model. The essential components of the proposed DBFO model are the following,

- Scope of the sewage pumping and treatment infrastructure to be constructed in a town is finalized through consultation of the associated 'work packages' specified in the relevant URMP (see Report 002_GBP_IIT_EQP_S&R_01) and subsequent discussions amongst ULB, state government and NGRBA.
- The period of the operation and maintenance contract (5 – 15 years post-commissioning) to be offered to the service provider to be decided through mutual consultations.
- The entire land for building the facility is identified by the ULB. Obtaining the associated clearances required for construction of the facility on this land is also the responsibility of the ULB. No project will be sanctioned by the NGRBA if this clearance is not in place. The actual construction of the facility must however, occur in phases as the quantity of sewage available for treatment increases.
- Bids to be invited from empanelled service providers using the two bid system. The agency submitting the lowest financial bid is selected amongst the bids that are technically sound as per prescribed criteria.
- Detailed DPR prepared by the service provider and submitted to ULB. After vetting by ULB and concerned State Government, the DPR is submitted for the approval of NGRBA.
- Once the DPR is approved, the identified land is leased to the service provider at a nominal rate by the ULB for the duration of the contract period (i.e., construction period followed by 5 - 15 years duration after commissioning).
- The service provider builds, and then maintains and operates the facility for the contact period (i.e., 5 - 15 years) after commissioning.
- Responsibility for the arrangement of uninterrupted power supply for the facility is with the service provider.
- The service provider and ULB will have joint rights (as stipulated in the contract) for the commercial exploitation of the products, i.e., treated water, sludge and sludge-derived products generated through sewage treatment. A special purpose vehicle (SPV) may be set up for this purpose by the service provider and ULB using the PPP model (see 'actionable' items 4.6.1 – 4.6.4 in the URMPs).
- Any treated sewage, sludge, etc. discharged from the sewage treatment facility during the contract period to be disposed of by the service provider in a safe manner and as per provisions of the contract.
- The facility reverts back to the ULB after the end of the contract period (construction period followed by 5 - 15 years duration after commissioning) unless the contract duration is extended.

- Any liabilities arising out of site contamination during the construction period and contract period for operation of the facilities by the service provider lie with the service provider, even after conclusion of the contract period.

In the above model, the income to the service provider will be from two sources,

- Payment made to the service provider in the form of annuities. The expected amount of annual payments (for each year of operation after commissioning) will be clearly specified in the contract. However, the actual annual payments shall be linked to the quantity of treated sewage (of specified quality) produced by the service provider in that year.
- Profit (if any), from commercial exploitation of resources generated through sewage treatment, i.e., sale of treated water, sludge and sludge-derived products, as per provisions specified in the contract.

In return, the service provider is expected to invest the entire funds required for initial creation of the sewage pumping and treatment infrastructure as per the approved DPR and also take care of operation and maintenance of the facility through the operation and maintenance contract period (i.e., 5 - 15 years after commissioning).

Funds will be made available by the state and central governments for annual payment to the service provider throughout the contract period. The contract between the ULB and service provider will be guaranteed by the state government and counter guaranteed by the central government. Alternatively, some other mechanism can be put in place such that the service provider is assured of payment as per the contract. This kind of guarantee is necessary for the private operator for raising funds from the market (loan component) of the initial capital investment.

Payments will however be released each year to the service provider only after verification that the essential contract terms regarding both quantity and quality of sewage treated and disposal of treatment residues is satisfied. Suitable penalty clauses will be included in the contract in case of non-compliance by the service provider.

The DBFO model for construction, operation and maintenance of sewage pumping and treatment infrastructure, as proposed above, has been designed to overcome the drawbacks of the current project funding and implementation practices discussed earlier. The advantages of this model are as follows.

- Proper operation and maintenance of the created infrastructure after commissioning is assured over the contract period (i.e., 5 – 15 years after commissioning) with the service provider.
- The service provider will be interested in maintaining and operating the facilities throughout the contract period, because that is how the equity invested in the project by the service provider may be recouped and profits made.

- Depending on the mutually agreed contract terms, the annuity payments made to the service provider may be sufficient to ensure profits. However, even under these circumstances, the service provider will still be interested in creating a market for treated water, sludge and sludge-derived products obtained through treatment of sewage, since additional profits could be made through this option.
- If the contract terms do not ensure sufficient profits to the service provider only through the annuity payments, the service provider will be compelled to create a market for treated water, sludge and sludge-derived products obtained through treatment of sewage, since income through this option are then essential to ensure sufficient returns on the investment made by the service provider.
- ULBs are likely to help the service provider in creating a market for the treated sewage, sludge and sludge-derived products, since part of the profit from sale of such product will accrue to ULBs. Also, operation and maintenance of the created infrastructure beyond the contract period with the service provider will partially/wholly be sustained through income generated by ULB through this route.
- ULBs will be closely involved in the supervision of project planning and implementation and also will be responsible for project monitoring. This will inculcate a sense of ownership in ULBs for the developed infrastructure. ULBs will be indirectly answerable for operation and maintenance of project facilities since annual payments will be made to the operator by the ULBs.
- Since the payments to be made by the central and state governments for a particular project are spread over the contract in this model, the yearly outgo for a particular project will be lower. This will allow allocation of the yearly NGRBA budget simultaneously for many projects. A concerted effort for river cleaning will be possible and the results of such efforts will be plainly visible in a few years.

8. Compliance, legal implications and regulatory issues

ULBs are ultimately responsible for compliance with the effluent quality standards, though the sewage treatment plants will be operated by the service provider. As is the case now, ULBs can be taken to the court for non-compliance with the prevailing standards for effluent discharge. However, with the proposed model, ULBs also have the power to ensure compliance, since monitoring of the treatment plant performance and also the payment to the service provider will be made on the recommendations of ULB. The model proposed above envisages the following scenario,

i. ULBs will make certain quantities of sewage available at certain pre-determined points, i.e., terminal manholes, sump-wells or 'nala' tapping works. The quantity of sewage available may increase with time and will be specified in the contract.

ii. The service provider is responsible for construction, operation and maintenance of pump houses for conveyance of the sewage through pumping in a continuous, reliable and fail-safe manner (see 'actionable' item 4.5.1 in proposed URMPs).

Penalty clauses will be incorporated in the contact to ensure that the service provider diverts the contracted amount of sewage consistently and with high reliability.

iii. Prevailing sewage characteristics will be determined through composite sampling at the pre-determined sewage uptake points as described above. Maximum expected variation in sewage characteristics expected over the contract period will be specified in the contract.

iv. The diverted sewage will be taken to sewage treatment plant for tertiary level treatment. Treatment guidelines are specified elsewhere (Report No. 003_GBP_IIT_EQP_S&R_02). Effluent standards will be the following: BOD < 10 mg/L; SS < 5 mg/L; fully nitrified effluent; P < 0.5 mg/L; FC < 10/100 mL; bioassay test. These standards will be specified in the contact and will not change during the contract period.

v. Previously specified and guaranteed annual payments will be made to the service provider based on the amount of treated water of the specified quality delivered at certain pre-determined points specified in the contract.

vi. It is expected that a robust market for the treated water, and sludge-derived products will be developed through the joint efforts of the service provider and ULB during the initial contract period (i.e., initial 5 – 15 years after commissioning, when the central and state governments reimburse the ULB for operation and maintenance costs). Income generated from such activities will enable the ULBs to operate and maintain the created infrastructure in the period beyond the initial contact period with the service provider.

Recommendations and Actions Required:

1. *Henceforth, all new sewage treatment plants and associated sewage pumping stations ('actionable' items 4.5.1 and 4.5.2 in proposed URMPs) should be constructed and managed together, i.e., by the same agency using the DBFO model.*
2. *The sewage pumping and treatment infrastructure should be built in a modular fashion such that the pumping and treatment capacity is approximately the same as the actual sewage collected/available.*
3. *All new sewage treatment plants sanctioned by the NGRBA should require treatment up to tertiary level (as specified in Report 003_GBP_IIT_EQP_S&R 02) and should be funded by the DBFO model as specified in this report.*
4. *As per the proposed DBFO Model, payments will be made to the service provider in annuities spread over the contract period during the operation and maintenance phase of the project. The payments will be linked to the actual amount of treated sewage (of specified quality) produced by the service provider.*
5. *All necessary clearances, permissions, etc. required by NGRBA for funding of sewage pumping stations and treatment plants using the DBFO model should be obtained.*
6. *The process of empanelment of reputed service providers interested in participating in construction, operation and maintenance of sewage treatment plants through the DBFO route should be started.*

9. DBFO Model: Public Monitoring

In order for the DBFO model as proposed above to work and give the desired results, monitoring of the project by the members of general public, NGOs and other Civil Society Organizations (CSOs) is also necessary. These organizations can be used for project monitoring in the following ways.

- One of the major objectives for the creation of sewage diversion and treatment infrastructure is to ensure that ultimately no sewage either treated or untreated flows into the river. NGOs/CSOs can be given the task of monitoring that this is indeed the case.

- Another objective for the creation of sewage diversion and treatment infrastructure is to ensure that all sewage is treated to the tertiary level (treatment guidelines for tertiary treatment specified elsewhere (IIT Report 003_GBP_IIT_EQP_S&R_02); effluent standards: BOD < 10 mg/L; SS < 5 mg/L; fully nitrified; P < 0.5 mg/L; FC < 10/100 mL) and hence is suitable for reuse. The treated sewage may be diverted to a reservoir which may in turn be developed as a picnic spot open to the general public. The monitoring is to be done through public participation (e.g. committee of eminent citizens and communication through mass media on daily basis). This will put pressure on the ULB and service provider to ensure efficient sewage treatment.

- Multi-media social awareness campaigns can be carried out by various CSOs to inform the general public about the initiatives taken for cleaning the river etc. in their town. This will raise the general awareness and put pressure on the authorities to operate and maintain the facilities in an efficient manner.

The proposals for public monitoring of the sewage diversion, pumping and treatment infrastructure given in this section are preliminary in nature. A detailed plan for public monitoring will be developed in accordance with the relevant sections of the Water (Prevention and Control) Act after extensive discussions with NGOs and other CSOs and submitted to NGRBA in due course of time.

Review of Wastewater Reuse Projects Worldwide

Collation of Selected International Case Studies and Experiences

GRBMP : Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay | IIT Delhi | IIT Guwahati | IIT Kanpur | IIT Kharagpur | IIT Madras | IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRBMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRB EMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. Lists of persons who have contributed directly and those who have taken lead in preparing this report is given on the reverse side.

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Contents

1. Introduction

The increasing demand for water in combination with frequent drought periods, even in areas traditionally rich in water resources, puts at risk the sustainability of current living standards. In industrialized countries, widespread shortage of water is caused due to contamination of ground and surface water by industrial effluents, and agricultural chemicals. In many developing countries, industrial pollution is less common, though they are severe near large urban centers. However, untreated or partially-treated sewage poses an acute water pollution problem that causes low water availability. Global trends such as urbanization and migration have increased the demand for water, food and energy. Development of human societies is heavily dependent upon availability of water with suitable quality and in adequate quantities, for a variety of uses ranging from domestic to industrial supplies. Moreover, the forecasts for water availability are quite dire and water scarcity is endemic in most parts of the world. This emphasizes the need for water scarcity solutions and water quality protection from pollution. It is in this context, the Agenda 21 adopted by the United Nations Conference on Environment and Development, popularly known as the "Earth Summit" of Rio de Janeiro, 1992, identified protection and management of freshwater resources from contamination as one of the priority issue, that has to be urgently dealt with to achieve global environmentally sustainable development.

The need for increased water requirement for the growing population in the new century is generally assumed, without considering whether available water resources could meet these needs in a sustainable manner. The question about from where the extra water is to come, has led to a scrutiny of present water use strategies. A second look at strategies has thrown a picture of making rational use of already available water, which if used sensibly, could provide enough water for all. The new look invariably points out at recycle and reuse of wastewater that is being increasingly generated due to rapid growth of population and related developmental activities, including agriculture and industrial productions. Hence, wastewater reuse is perceived as a measure towards fulfilling following three fundamental objectives within a perspective of integrated water resources management.

- Environmental sustainability – reduction of pollutants load and their discharge into receiving water bodies, and the improvement of the quantitative and qualitative status of those water bodies (surface water, groundwater and coastal waters) and the soils.
- Economic efficiency – alleviating scarcity by promoting water efficiency, improving conservation, reducing wastage and balancing long term water demand and water supply.
- For some countries, contribution to food security – growing more food and reducing the need for chemical fertilizers through treated wastewater reuse.

The term wastewater reuse is often used synonymously used with the terms wastewater recycling and wastewater reclamation. But they are three different terms in practical sense as defined here:

Wastewater reclamation:	Involves the treatment or processing of wastewater to make it reusable (Asano, 1998).
Wastewater reuse:	Water reuse is the beneficial use of treated wastewater (Asano, 1998).
Wastewater recycling:	Water recycling is the use of wastewater that is captured and redirect back into the same water use scheme (Metcalf and Eddy, 2003).

Reuse of wastewater for domestic and agricultural purposes has been occurring since historical times. However, planned reuse has gained importance only two or three decades ago, as the demands for water dramatically increased due to technological advancement, population growth, and urbanization, which put great stress on the natural water cycle. Reuse of wastewater for water-demanding activities, which, so far consumed limited freshwater resources is, in effect, imitating the natural water cycle through engineered processes. Even though most of the river basins worldwide depend on treated wastewater mixed with surface water drainage to maintain water resources for safe abstraction, it appears that in several countries including India, the reuse of treated wastewater is still shrouded in a mist of apprehensions, possibly as a result of misconceptions, lack of knowledge and incorrect stakeholder and public perception. Policies are unclear, when present, and institutional capabilities to manage wastewater reuse are often lacking. Therefore, the prime objectives of this report are to:

- **(i)** Present and compare the existing water quality guidelines and standards worldwide for wastewater reuse,
- **(ii)** Present and review some selected case studies of operating wastewater reuse installations worldwide in order to introduce new ideas and exchange experience,
- **(iii)** To review and discuss the environmental and public health aspects along with the economics of wastewater reuse,
- **(iv)** To review and discuss the community and public perception and participation towards wastewater reuse, and
- **(v)** To come up with general recommendations based on international case studies towards the promotion of wastewater reuse in the Ganga River Basin in respect to the Preparation of Ganga River Basin Management Plan (GRBMP).

2. Existing Water Quality Guidelines and Standards for Wastewater Reuse

In respect to wastewater reuse, there exists no common regulation in the world due to difference in geographical location, climatic, geological and geographical conditions, water resources, type of crops and soils, economic and social aspects, and country/state policies towards reusing wastewater for irrigation purposes. Some noted organizations and countries have already established reuse standards such as USEPA, State of California Water Recycling Criteria (Title 22), WHO, Israel, France, Italy, etc. The regulation requirements are based primarily on defining the extent of treatment required for wastewater reuse together with numerical limits on bacteriological quality, turbidity and suspended solids. A comparison of international guidelines and standards might help to develop guidelines for any specific area or country for wastewater reuse. Table 1 summarizes some of the existing guidelines and standards worldwide for wastewater reuse in agriculture.

Table 1: Comparison of Selected Water Quality Guidelines/Standards of Wastewater Reuse for Irrigation

Parameter	California Ca/T-22 (1978)	USEPA (1992)	WHO (1989)	Israel (1978)	Tunisia (1975)	Cyprus (1997)	Chile (1984)	France (1991)	Italy (1977)	Germany
								EU Guidelines		
Type	Law	Guidelines	Guidelines	Law	Law	Provisional Standards	Guidelines	Guidelines	Law	Guidelines
Minimum Treatment Required	Advanced	Advanced	Stabilization Ponds	Secondary	Stabilization Ponds	Tertiary		Stabilization Ponds	Secondary	Only Heavy Metals are considered in the guidelines
Total BOD (mg/L)		10		15	30	10				
Suspended Solids (SS) (mg/L)		5		15	30	10				
Total Coliform (MPN/100 ml)	2.2	0		2.2					2	
Fecal Coliform (MPN/100 ml)		14 (which means not detectable)	1000			50	1000	1000		
Helminths (eggs/100 cm^3)			1		<1	0		1		
Sodium Absorption Ratio (SAR)									<10	
Main Treatment Process	Oxidation, clarification, filtration & disinfection	Filtration & disinfection	Stabilization ponds or equivalent	Long storage & disinfection	Stabilization ponds or equivalent	Filtration or disinfection		Stabilization ponds or equivalent		

3. Selected Case Studies

Several pioneering studies have provided the technological confidence for the safe reuse of reclaimed wastewater for beneficial uses. While initial emphasis was mainly on reuse for agricultural and non-potable reuses, the recent trends prove that there are direct reuse opportunities to applications closer to the point of generation. There are also many projects that have proved to be successful for indirect or direct potable reuse. Followings are the selected case studies of wastewater reuse as a viable alternative source of water:

3.1 Vitoria-Gasteiz, Spain

Title of Case Study: Vitoria-Gasteiz Integral Recycling Plan

Type of Case Study: Recycling Plan with measures already in place and which aims to incorporate regenerated wastewater in the water cycle.

Objective of Case Study: To demonstrate water recycling scheme which provides farm irrigation and improves river water quality.

Background of Case Study: Vitoria, a medium-sized city (227,568 inhabitants in 2006) situated in the north of Spain, is the administrative capital of the Basque Country. Vitoria is characterized as a service-based city with a well developed industrial sector. The city stands on the banks of the river Zadorra, a tributary of the river Ebro, and has been in constant growth since the 1950's. With regard to wastewater treatment, Vitoria has Crispijana wastewater treatment plant (WWTP) situated close to Vitoria-Gasteiz (Spain) urban area (0.5 million population equivalent) and is designed to treat a flow of industrial and municipal wastewater of 0.12 million m^3 per day. WWTP includes a secondary treatment by activated sludge process.

Salient Features: The Recycling Plan is a result of the extension of activities related with recycling for irrigation and to improve the quality of the river Zadorra for sustenance of fish life. In the initial phase (1994-1999) the recycling of 3 million m^3 per year of urban wastewater was implemented to cover the deficit of irrigation water for nearby irrigated farming. For this purpose a tertiary treatment plant was constructed in order to adapt water quality to the intended use. The regeneration process consists of physical-chemical treatment including flocculation, sand filtering and chlorination.

The quality indices obtained after the application of this treatment are as follows:

- Turbidity: < 0.5 NTU
- Electrical conductivity: < 600 µs/cm
- BOD_5: < 5 mg/l
- NH_4^+-N: < 2 mg/l
- NO_3^--N: < 17 mg/l
- Phosphorus: < 1 mg/l
- Metals: < 0.1 mg/l
- Pathogens: Absent.

The Integral Recycling Plan helps the river Zadorra to become apt for fish life. The Recycling Plan helps to cover the deficit of irrigation water in the zone and to adapt the river quality for fish life. Expectations from recycling in the mid-term are estimated at 24 million m^3 per year, of which 8 million m^3 per year would be for farming use, 7 million m^3 per year for urban use and 9 million m^3 per year for the maintenance of the flow and the quality of the river Zadorra. As a final goal, the Integral Recycling Plan foresees the recycling of 100% of all generated wastewater.

Reference:

MED WWR WG, 2007. Mediterranean Wastewater Reuse Report, Mediterranean Wastewater Reuse Working Group (MED WWR WG), November 2007.

3.2 Sekem Farm, Egypt

Title of Case Study: Sekem Farm Zer0-M Project (sustainable concepts towards a zero outflow municipality)

Type of Case Study: Desert sandy area was reclaimed, irrigated with treated sewage water, community participation and community capacity building in combination creation of new communities, farmers and fertile soil, with zero out flow, efficient wastewater treatment facility.

Objective of Case Study: To implement an integrated model of wastewater management for peri-urban and deprived/remote regions for the purpose of saving and recycling the wastewater and to make the effluent suitable, safe and appropriate for its intended reuse while protecting the environment.

Background of Case Study: Due to the special type of agriculture at SEKEM, organic vegetables and medicine plants grown under anthroposophy rules, wastewater is not allowed to be used on the main farm crops. The irrigated land nearby the project site was originally desert sandy soil, was deprived from any kind of nutrient elements, and lacked any organic matters. The Farm was using the very poorly treated wastewater for irrigating this forest trees. The purpose of the Zer0-M Project was to treat and reuse of wastewater, save the wastewater, protect the environment as well as the public health, to share the European experience with the Mediterranean countries. The work was designed to implement the European experience with the local practice to construct integrated models of wastewater treatment and reuse. The project aimed on concepts and technologies to achieve optimized close-loop usage of all water flows in small municipalities or settlements (e.g. tourism facilities) non-connected to a central wastewater treatment.

Salient Features: The Zer0-M Project aimed to demonstrate the efficient wastewater treatment and reuse relatively small-scale sewage treatment systems that can be an example of conventional decentralized technology. The SEKEM farm wastewater and reuse work was designed to implement a constructed application of a simple, low cost, low energy and sustainable technology for the treatment and reuse of municipal wastewater through the MEDA Water European Program Support Action. The daily flow was calculated once from the water demand and secondly according to the number of people connected: 500 students at 20 l/day, plus 100 persons at the offices at 20 l/day, laundry plus residential houses leading to a total 15 m^3/day. The technology used is a combination of physical and biological treatment employing three compartments degreaser/ sedimentation/septic tank followed by constructed wetland. The treated wastewater is used for irrigating forest trees. The sludge is to be dried over sludge drying beds of another constructed wetland. Presently the project is fully operated. Treated wastewater is used for irrigating the forest trees. Quality of the treated wastewater is within the permissible limits of the Egyptian standards. No problems with odor or insects exist. The SEKEM administration is going to extend the scheme to all the schools in the municipality which would lead to a flow of approximately 20 m^3/day.

Reference:

MED WWR WG, 2007. Mediterranean Wastewater Reuse Report, Mediterranean Wastewater Reuse Working Group (MED WWR WG), November 2007.

3.3 Durban, South Africa

Title of Case Study: Durban Water Recycling (DWR) Project

Type of Case Study: Municipal wastewater reuse for industrial purposes.

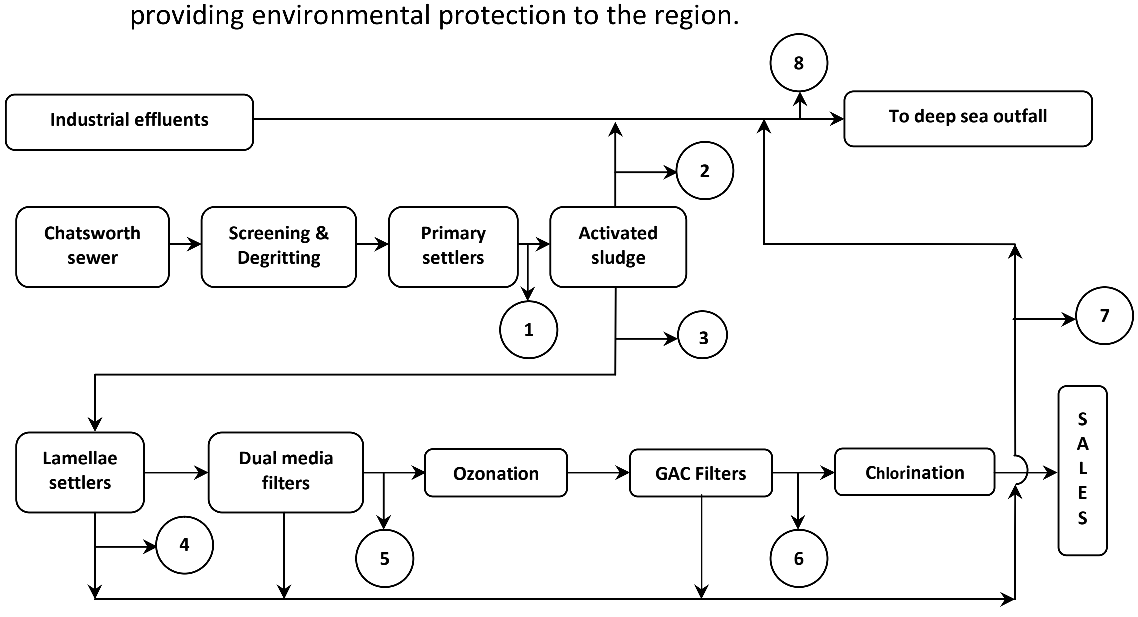
Objective of Case Study: To study a successful case of multi-sector partnership for water management and reuse projects.

Background of Case Study: The municipal authority, called "Durban Metro", experienced a dramatic population increase following the abolition of Apartheid. The population increased from 1 million to nearly 3 million due to the incorporation of 30 local authorities and surrounding townships into the metropolitan area. As a result, Durban Metro was under considerable pressure to provide basic services to its growing domestic customers, among whom 26% live in the townships and rely on standpipes for clean drinking water. Moreover, several industries are located in this area. In particular, Mondi Paper Mill and SAPREF refinery need a continuous supply of high quality water for process and cooling purposes. Unfortunately, natural water resources are not sufficient in the region to meet the increasing demand for water of drinking and ultrapure quality: the average rainfall is 200 mm/year, and the region suffers from periodic droughts. In order to develop a workable solution to the water and sanitation problems of developing countries, the KwaZulu Natal pilot project was launched. It was part of the Worldwide "Business Partners for Development" (BPD) programme created by the World Bank in 1998. This project allowed Durban Metro to install and operate a new affordable distribution network for the townships through innovations in service delivery and tariff structures – first 200 l/day of water was free for domestic customers. This was the result of a successful tri-sector partnership (public-private-NGOs). Based on the success of this first initiative, the Durban Metro authority decided to go further by implementing a public-private partnership water reuse project: the Durban Water Recycling (DWR) Project.

Salient Features: The Durban Water Recycling (DWR), run by Vivendi Water in association with the Durban Metro, was commissioned adjacent to the Southern Wastewater Treatment Works in May 2001. The DWR Project receives effluent from the Southern Wastewater Treatment Works and treats it to an acceptable standard for industrial use. The project included treating primary sewage and re-purifying the 47,500 m^3/day reclaimed water. As a result, about 7% of Durban's total wastewater generated (i.e. equivalent to the demand for 220,000 households in the area) was reclaimed as high quality water conforming to the South African water standard (SABS 241:1999) and supplied to the Mondi Paper Mill and SAPREF Refinery at a cost 25% lower than potable water instead of being discharged to the sea. The purification of the wastewater was handled by the newly refurbished Southern Wastewater Treatment Works based on activated sludge process (ASP) and integrating the water recycling plant consisting of tertiary treatment including dual media filtration, ozonation, granular activated carbon (GAC) filters and chlorination. The flow diagram of the Southern Wastewater Treatment Works integrated with the Durban Water Recycling (DWR) Plant is shown in Figure 1.

The Durban Metro was able to overcome the challenge of supplying drinking water to a number of people drastically increased by the abolition of the Apartheid due to the commissioning of the DWR project. The success of this project led to the following beneficial outcomes:

- The reclaimed water produced a low cost, high quality water supply for its industrial customers;
- Reclaimed water is more than 25% cheaper than the potable supply;
- Seven percent of Durban's total wastewater generated is recycled, which means that 7% more potable water is available for the community, which is equivalent to the demand for 220,000 households; and
- The flow to the overloaded sea outfall was reduced, thus extending its life and providing environmental protection to the region.



1. Influent to the ASP; **2.** Waste activated sludge (WAS); **3.** Effluent from the ASP; **4.** Sludge underflow from the lamellae settlers; **5.** Effluent from the dual media filters; **6.** Effluent from the GAC filters; **7.** Tertiary sludges underflow; **8.** Sea outfall

Figure 1: Flow diagram of the Southern Wastewater Treatment Works integrated with the Durban Water Recycling (DWR) Plant

Reference

Friedrich, E., Pillay, S., Buckley, C., 2004. The environmental impacts of potable and recycled water: a case study on effluent toxicity. In: Proceedings of the 2004 Water Institute of Southern Africa (WISA) Biennial Conference, 2-6 May, 2004, Cape Town, South Africa, pp. 253–262.

MED WWR WG, 2007. Mediterranean Wastewater Reuse Report, Mediterranean Wastewater Reuse Working Group (MED WWR WG), November 2007.

3.4 Gerringong Gerroa, Nsw, Australia

Title of Case Study: Gerringong Gerroa Sewerage Scheme (GGSS), New South Wales, Australia

Type of Case Study: Reuse of municipal wastewater for irrigation purposes.

Objective of Case Study: To demonstrate an effluent reuse system with significant health and ecological benefits.

Background of Case Study: Gerringong and Gerroa are coastal towns with 3,500 permanent local residents. They are located 120 km from Sydney on the South East Cost of Australia. The region is a popular holiday destination and very well known for its diversified flora and fauna, as well as its beaches. This is why there was a public demand to minimize the effluents' negative impacts when released to the environment, especially considering that before the project started in June 2001, the area did not have a reticulated system and total wastewater generated passed to septic tanks. The existing sewerage facilities in the two towns consisted of on-site systems. Improper maintenance of these on-site systems resulted in rapid deterioration of effluent quality. This delicate situation held potential health risks, and contributed to the decline of the water quality in the local waterways and the bathing water quality. In this context, the Gerringong Gerroa sewerage scheme (GGSS) was implemented in 2001 and consisted of the construction of a state of the art wastewater treatment plant (WWTP) in the Gerringong Gerroa region which became operational in 2002.

Salient Features: The sewerage scheme was designed to meet the local community needs up to the year 2022 for an estimated population of 11,000 inhabitants. Sewage is treated using a high level of tertiary treatment, including: inlet works comprising screening, de-gritting and flow measuring; secondary and tertiary treatment using biological treatment, clarification and sand filtration; advanced tertiary treatment involving ozonation, biological activated carbon (BAC), microfiltration and disinfection. The flow diagram of the Gerringong Gerroa Wastewater Treatment Plant for wastewater Reuse under the GGSS is presented in Figure 2. The effluent reuse system is designed to reuse up to 80% of the treated effluents produced. Final effluent is stored in a 50,000 m^3 storage reservoir before being pumped to a local dairy farm to be reused for pasture irrigation. When irrigation is not possible and the storage reservoir is full, high quality effluent is discharged to the local receiving waters via an on-site dunal system. The plant also produces Grade A biosolids that are recycled and used for land application.

The effluent reuse plant under the GGSS has provided improved wastewater services to more than 2,000 households. The reuse plant facilitates in reusing at least 80% effluent and 100% biosolids for agricultural purposes. Development and tourism in the area has increased and pollution to local streams (Crooked River and Blue Angle Creek), lagoons (Werri Lagoon) and beaches decreased substantially resulting in a positive impact to the area. Furthermore, the advanced wastewater treatment scheme enables water reuse on neighboring agriculture properties. This scheme is regarded as one of the most innovative ecologically sustainable sewerage schemes in Australia utilizing global best practice in water treatment processes.

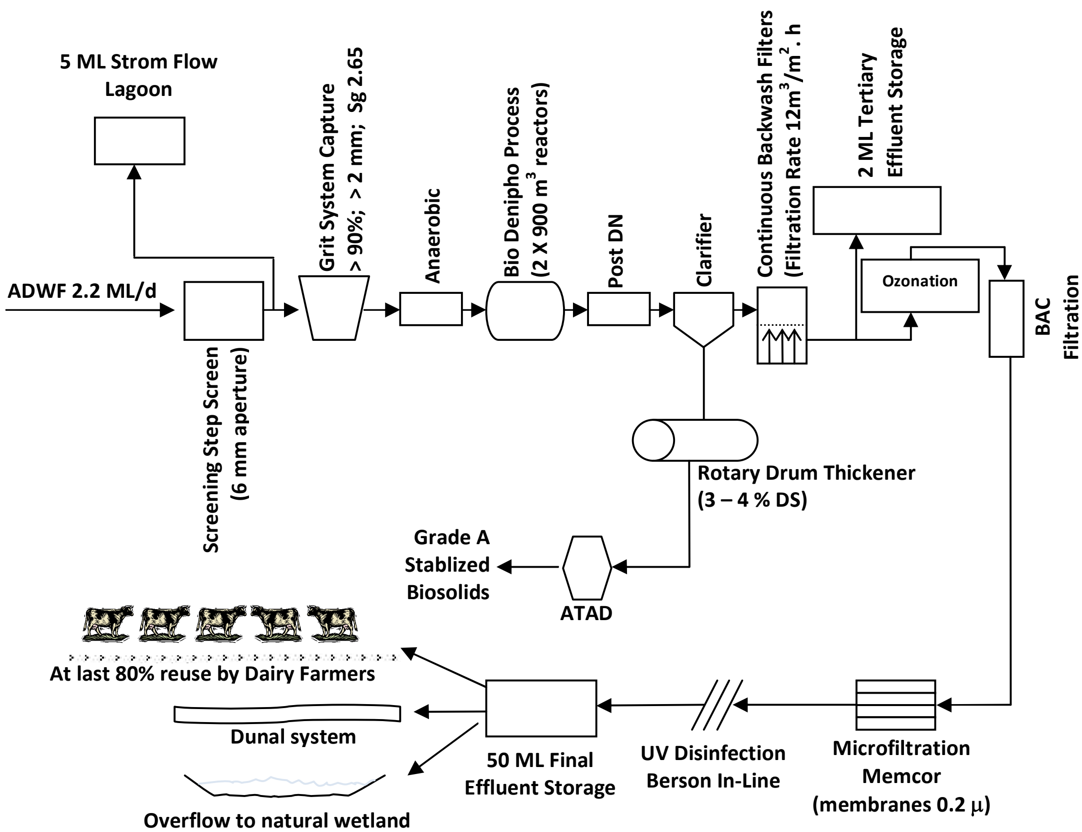


Figure 2: **Flow diagram of the Gerringong Gerroa Wastewater Treatment Plant for Wastewater Reuse**

Reference:

Boake, M.J., 2006. Recycled water – case study: Gerringong Gerroa. Desalination 188, 89–96.

MED WWR WG, 2007. Mediterranean Wastewater Reuse Report, Mediterranean Wastewater Reuse Working Group (MED WWR WG), November 2007.

3.5 Ochiai Water Reclamation Center for Meguro River Restoration, Tokyo, Japan

Title of Case Study: Ochiai Water Reclamation Center for Meguro River Restoration, Tokyo, Japan by Tokyo Metropolitan Government
Type of Case Study: Beneficial treated wastewater reuse for river restoration.

Objective of Case Study: To demonstrate wastewater reuse system for river water quality and biodiversity restoration.

Background of Case Study: The Meguro River, which flows through a residential area in Tokyo, had been abandoned by residents due to the decreasing flow of water and increasing pollution with an unpleasant color and odor due to ever increasing urbanization since the Meiji Period. In order to restore river water quality and biodiversity, the Tokyo Metropolitan Government used highly treated effluent from the Ochiai Water Reclamation Center to discharge into the river.

Salient Features: Located very close to the sub-center of the Shinjuku area, the Ochiai Water Reclamation Center is environment-friendly and thoroughly controlled as a water reclamation center surrounded by residential districts. The treatment area includes most of Nakano-ward and a part of Shinjuku-ward, Setagaya-ward, Shibuya-ward, Suginami-ward, Toshima-ward and Nerima-ward, totaling 3,506 ha in area. The treatment units of the reclamation center include grit chamber and primary sedimentation tank as preliminary and primary treatment, activated sludge process (ASP) as secondary treatment and A_2O process for nutrient removal, sand and membrane filtration and UV radiation as tertiary treatment. The schematic of the sequence of various treatment units of the Ochiai Water Reclamation Center is presented in Figure 3. The highly treated water (Table 2) is discharged for restoration of streams in Meguro River and other two rivers which nearly dried up in the southern downtown area of Tokyo and some part of the treated water is used effectively for flushing water in toilet in buildings of Nishi-shinjuku and Nakano-sakaue districts. The generated sludge is pumped through pressure pipelines to Tobu sludge plant for treatment. With the drastic improvement in water volume and quality, various living species have returned to the Meguro River. The condition of the Meguro River before and after restoration is shown in Figure 4. Many insects and small animal populations have been re-established, and fish such as Japanese trout, striped mullets and gobies also returned to the river after the introduction of highly treated water. Biodiversity and environmental amenities have thus been restored effectively with wastewater reuse.

Table 2: Average Influent and Effluent Water Quality for the Ochiai Water Reclamation Facility

Parameters	Intake water		Discharge Water	Regional water quality standards
	Low stage	High stage	High stage	
BOD_5 (mg/L)	220	190	1	25 or bellow
COD (mg/L)	92	92	7	—
Total nitrogen (mg/L)	31.7	27.9	11.5	30 or bellow
Total phosphorus (mg/L)	3.7	3.0	1.5	3.0 or bellow

Reference:

MED WWR WG, 2007. Mediterranean Wastewater Reuse Report, Mediterranean Wastewater Reuse Working Group (MED WWR WG), November 2007.

UNEP, 2005. Water and Wastewater Reuse: An Environmentally Sound Approach for Sustainable Urban Water Management, United Nations Environment Programme, Osaka, Japan.

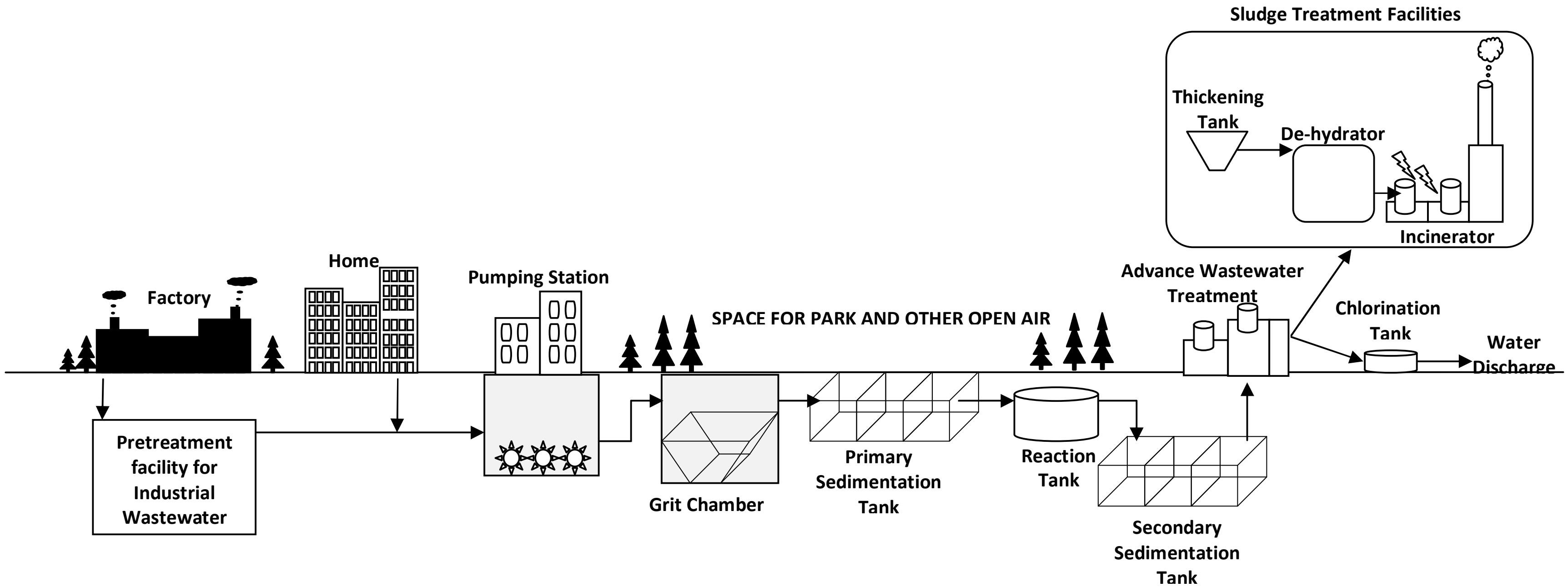


Figure 3: The Sequence of Treatment Units in Ochiai Water Reclamation Facility for Wastewater Reclamation

(a) **(b)**

Figure 4: The Condition of Meguro River (a) Before and (b) After the Restoration using Reclaimed Wastewater

3.6 Pomona Water Reclamation Plant With Integrated Aqua-Culture Wetland Ecosystem, Los Angeles County, California, USA

Title of Case Study: Pomona Water Reclamation Plant with Integrated Aquaculture-Wetland Ecosystem (AWE), Los Angeles County, California, USA

Type of Case Study: Reuse of municipal wastewater for irrigation purposes.

Objective of Case Study: To demonstrate an effluent reuse system with significant health and ecological benefits.

Background of Case Study: Los Angeles (LA) County, California is a severely water-stressed region, depending on imported water from the neighboring river basins (Colorado River for example). However, the imported supplies are dependent on climate variability, environmental, political and energy consumption issues. Over 90% of LA's wastewater was discharged into the San Gabriel River then to ocean, or directly into the ocean at San Pedro Bay. In this context, there has been an increasing effort to upgrade all of LA's treatment plants to tertiary wastewater facilities and to expand water markets for wastewater reuse inland as an alternative to ocean disposal in order to maintain integrated water resources management.

Salient Features: The Pomona Water Reclamation Plant (WRP) is located at 295 Humane Way in the City of Pomona. The plant occupies 14 acres northeast of the intersection of the Pomona and Orange Freeways. The original plant was known as the Tri-City Plant and was owned by the cities of Pomona, Claremont, and La Verne. It was placed into operation in July 1926 with effluent reuse beginning in 1927. The Sanitation Districts took over operations in 1966 and increased the plant capacity to 4 MGD/day (15.16 MLD). In 1970, the plant capacity was expanded to 10 MGD/day (37.9 MLD) with the construction of additional primary, aeration, and final sedimentation tanks. In 1977, the plant capacity increased to 15 MGD/day (56.85 MLD) with the implementation of tertiary level wastewater treatment, including activated-carbon gravity filters, chlorine contact tanks, and a dechlorination system. In the early 1990s, the plant underwent a third expansion with the construction and retrofit of the activated-carbon gravity filters to deep bed anthracite filters and the addition of a third chlorine contact tank for additional disinfection capacity.

Currently, the Pomona WRP provides primary, secondary and tertiary treatment of wastewater at 13 MGD/day (49.27 MLD) (see Figure 5). The plant serves a population of approximately 130,000 people. Approximately 8 MGD/day (30.32 MLD) of the purified water is reused at over 90 different reuse sites. Reuse includes landscape irrigation of parks, schools, golf courses, greenbelts, etc.; irrigation and dust control at the Spadra Landfill; and industrial use by local manufacturers. The remainder of the purified water is put back into the San Jose Creek channel where it makes its way to the unlined portion of the San Gabriel River. Therefore, nearly 100% of the water is reused since most of the river water recharges into the ground water.

Although it is a common perception that tertiary sewage treatment plants (TSTPs) are the preferred method of waste utilization and are 'environmentally friendly', many TSTPs do not remove inorganic nitrogen and phosphorus to levels below which these nutrients stimulate marine aquatic production. Therefore, the existing WRP is further upgraded using an aquaculture–wetland ecosystem (AWE) to simultaneously accomplish aquatic food production and inorganic nitrogen removal from the tertiary-treated wastewater received from the Pomona, TSTP. The AWE consists of a 28-m^3 wastewater supply tank, three 200–240 m^2 (1-m deep) aquaculture ponds, and a 0.05 ha artificial wetland (Figure 6).

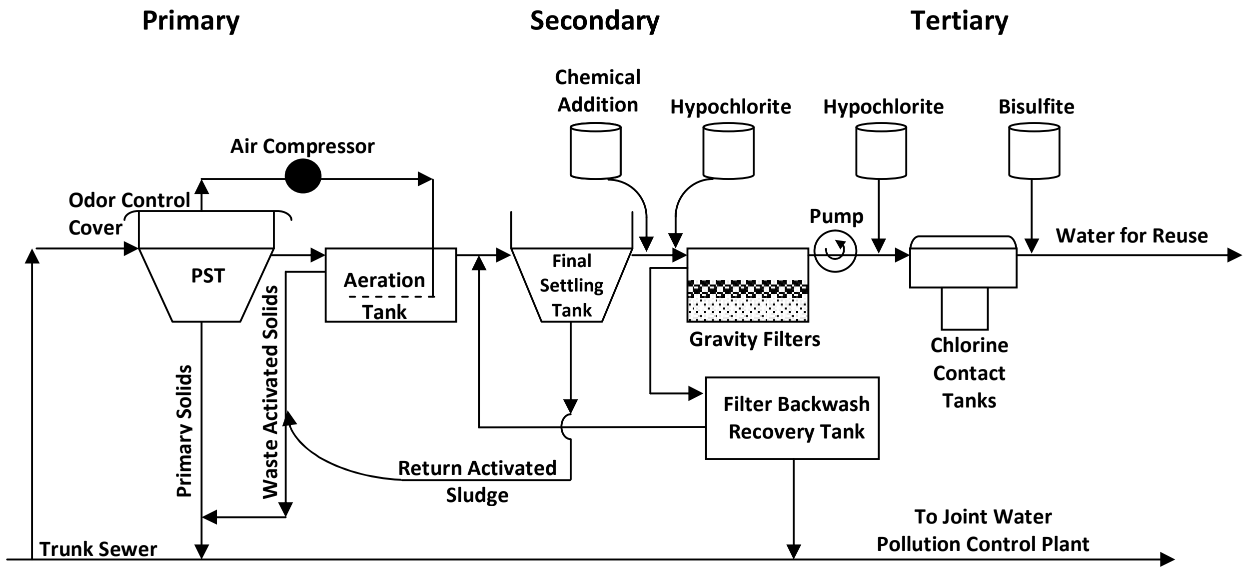


Figure 5: Flow diagram of the Pomona Water Reclamation Plant (WRP), Los Angeles County, California, USA

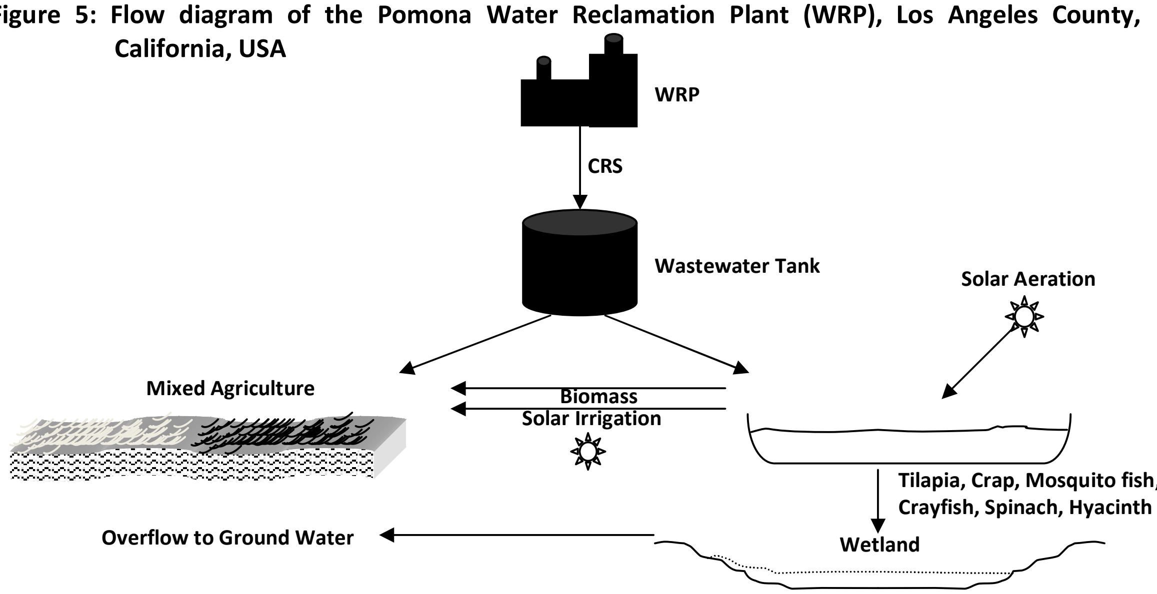


Figure 6: Flow Diagram of the Integrated Aquaculture-Wetland Ecosystem (AWE)

The wetland is a simple bowl-shaped depression where waters are impounded by a rock dam. The wetland develops a *Typha*–water hyacinth–duckweed (*Lemna* sp.) aquatic plant community on its own, with the emergent plants and duckweed comprising about 50% of the surface area of the wetland, and the water hyacinths occupying the remainder. Reclaimed wastewater is pumped from the Pomona TSTP to the storage tank located on a hill. Ponds are filled initially by gravity with a mixture of 50% potable water: 50% reclaimed water to allow water hyacinths to get established, thereafter they are flushed 20% per week with reclaimed water. A polyculture species stocking is used which defined 'target' and 'janitor' species. The target species are hybrid, all male, sex-reversed tilapia (*Oreochromis mossambicus_O. hornorum*). Janitor fish species stocked are common carp (*Cyprinus carpio*) and mosquitofish (*Gambusia affinis*). Water hyacinths (*Eichhornia crassipes*) are added to all ponds at 10–20% of the pond area and maintained at about 50% of the pond surface area by use of floating booms and manual harvesting every 2 weeks. The AWE accomplishes aquatic food production and almost complete removal of inorganic nitrogen from wastewater, functioning as a 'quaternary' wastewater treatment/food production ecosystem. The case study demonstrates that the concept of using tertiary-treated wastewater for aquatic food production may be attractive in the peri-urban areas of many mega-cities like Los Angeles, both for fish markets and to stem the growing discharges of wastewaters that are causing coastal pollution.

Reference:

Costa-Pierce, B.A., 1998. Preliminary investigation of an integrated aquaculture - wetland ecosystem using tertiary-treated municipal wastewater in Los Angeles County, California. Ecol. Eng. 10, 341–354.

LACSD, 2010. Ponoma Water Reclamation Plant, Sanitation Districts of Los Angeles County (LACSD). In Website:http://www.lacsd.org/about/wastewater_facilities/joint_outfall_system_water_reclamation_plants/pomona.asp (Accessed on January 02, 2010).

3.7 Florida Water Reuse Program, Florida, USA

Title of Case Study: Florida Water Reuse Program, Florida, USA

Type of Case Study: Reuse of domestic wastewater for the purposes of land application and residential irrigation, groundwater recharge and indirect potable reuse and industrial use of reclaimed water.

Objective of Case Study: To encourage and promote water reuse in Florida in compliance with the state objective for conserving freshwater supplies and preserving rivers, streams, lakes, and aquifers.

Background of Case Study: Florida is the fourth most populous state in the USA and population is projected to grow from about 16 million in 2000 to about 21 million in 2020. While Florida receives a large amount of rainfall every year compared to other states, the distribution is not even throughout the year and across the state. As the state continues to grow, demand for fresh water also will increase. In 1995, Florida used about 7.2 billion gallons of water each day (27,288 MLD). By 2020, water use is forecast to grow to 9.1 billion gallons per day (34,489 MLD). Florida is the largest user of irrigation water east of the Mississippi River. In 2020, agriculture is expected to account for about 46 percent of Florida's total demand for fresh water. Public water supply will account for about 34 percent of the total. The remaining 20 percent of water use will be associated with industrial/commercial/electric generation, recreational irrigation, and domestic self supply. In 2001, Florida's domestic wastewater treatment plants had a total capacity of about 2,220 MGD (8414 MLD) and actually treated about 1,486 MGD (5,632 MLD). In 2020, it is estimated that wastewater flows to be treated will reach 1,950 MGD (7,390 MLD). This represents 1,950 MGD (7,390 MLD) of a water resource that can and should be reclaimed and reused for beneficial purposes. Periodic droughts combined with increased demand for fresh, clean surface and groundwater for public consumption have resulted in periodic and prolonged water shortages. Conservation measures such as irrigation and groundwater recharge with reclaimed water are viewed as the plausible ways to reduce the use of existing potable water supplies and tackle the water shortages.

Salient Features: The Florida Department of Environment Protection (DEP) began looking at ways to promote reuse of reclaimed water in 1987. Reuse systems serving Tallahassee and St. Petersburg significantly influenced reuse in Florida and paved the way for today's multitude of excellent, innovative reuse projects. Table 3 shows the different types of reuse systems in Florida and a brief description of the treatment and disinfection requirements for each. As per the Florida Water Reuse 2009 inventory, a total of 484 domestic wastewater treatment facilities (WWTF) with permitted capacities of 0.1 MGD (0.379 MLD) or above that make reclaimed water available for reuse are there in the Florida state. These facilities have WWTF capacity totaling 2,287 MGD (8,668 MLD) and treated 1,421 MGD (5,386 MLD) of domestic wastewater in 2009. These treatment facilities serve 433 reuse systems. Approximately 673 MGD (2,551 MLD) of reclaimed water from these facilities is reused for beneficial purposes. The total reuse capacity associated with these systems is 1,559 MGD (5,909 MLD). Figure 7 shows the percentage of reclaimed water utilization by flow for each reuse type as per the Florida Water Reuse 2009 inventory. Irrigation of areas accessible to the public like residential areas, golf courses, athletic fields, parks, etc. represented about 56 percent of the 673 MGD (2,551 MLD) of reclaimed water reused. Reclaimed water from these systems was used to irrigate 276,471 residences, 533 golf courses, 873 parks, and 306 schools. Following public access areas, the next largest uses are industrial uses (14%) such as cooling water in power plants and groundwater recharge (13%). Most of the reclaimed water used for agricultural irrigation is used to grow feed, fiber, or other crops that are not for direct human consumption. Over 12,750 acres of edible crops on 75 farms are reported to be irrigated with reclaimed water. A demonstrative video on the Florida Water Reuse Program is available and can be viewed at: http://www.dep.state.fl.us/water/reuse/

In addition to the Florida Water Reuse Program, the Hazen and Sawyer in partnership with another national firm the Miami-Dade Water and Sewer Department are currently designing 21 MGD (79.6 MLD) South District Water Reclamation Plant (SDWRP), the largest advanced wastewater reclamation plant of its kind in the State of Florida, for replenishment of the Biscayne Aquifer via rapid infiltration, in which the domestic wastewater that has been treated to meet drinking water standards percolates through the soil down to the groundwater level. The SDWRP is planned to upgrade the South District Wastewater Treatment Plant (SDWWTP) and will treat secondary effluent from the SDWWTP which adds High Level Disinfection (HLD) to the existing pure oxygen secondary treatment plant. The first step in the treatment process will be strainers followed by microfiltration (MF) or ultrafiltration (UF) to minimize suspended solids from the secondary effluent. The RO treatment process at the SDWRP will remove organic carbon (TOC), total organic halides (TOX), and significantly reduce nitrogen and phosphorus to satisfy potable reuse and environmental application requirements. Microconstituents and emerging pollutants of concern (EPOC) will also be reduced in the final step of the process which includes advanced oxidation processes (AOP) like ultraviolet light (UV) application and hydrogen peroxide (H_2O_2) addition to form hydroxyl radicals (OH^-) which oxidize most organic compounds.

Table 3: Different Type of Reuse Systems under Florida Water Reuse Program

Reuse System Type	Reuse Activities	Treatment and Disinfection Requirements
Slow-rate land application systems; restricted public access	• Irrigation of pastures, trees, feed, fodder, fiber, or seed crops	Secondary treatment and basic disinfection
Slow-rate land application systems; public access areas, residential irrigation, and edible crops	• Residential, golf course, and other landscape irrigation • Toilet flushing • Fire protection • Dust control • Aesthetic features (ponds and fountains) • Irrigation of edible crops (direct contact only with crops that will be peeled, skinned, cooked, or thermally processed)	Secondary treatment, filtration, and high-level disinfection
Rapid-rate land application systems	• Rapid Infiltration Basins (RIBs) • Absorption Fields	Secondary treatment, basic disinfection, < 12 mg/L NO_3-N
Groundwater recharge and indirect potable reuse	• Salinity barriers • Augmentation of surface waters	Principal treatment and disinfection or full treatment and disinfection (depending on use)
Industrial uses of reclaimed water	• Cooling water • Wash water • Process water (not to include food processing for human consumption)	Secondary treatment and basic disinfection (additional treatment may be needed to meet needs of a particular application)

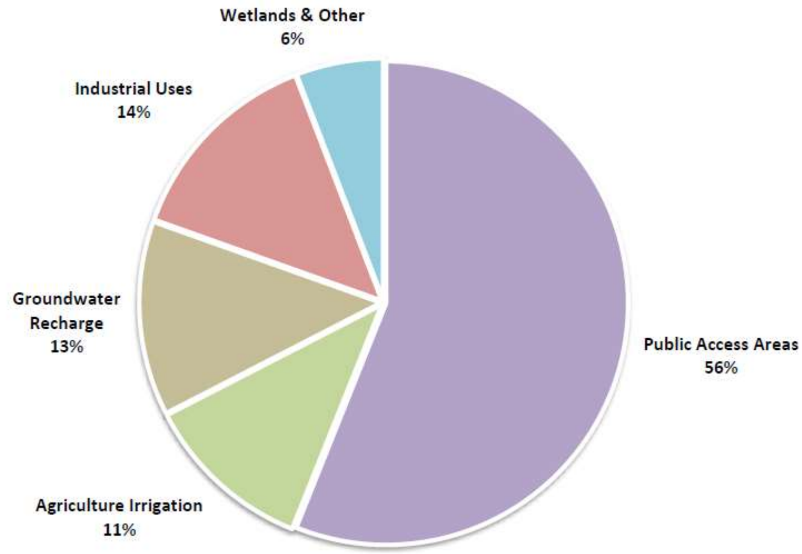


Figure 7: Reclaimed Water Utilization by Flow in Florida as per Water Reuse 2009 Inventory

Reference:

FDEP, 2007. Reuse of Reclaimed Water and Land Application: Rule 62-610 Florida Administrative Code (FAC), Florida Department of Environmental Protection (FDEP), 2007. In Website: http://www.dep.state.fl.us/legal/rules/wastewater/62-610.pdf (Accessed on January 05, 2011).

FDEP, 2010. 2009 Reuse Inventory, Florida Water Reuse Program, Florida Department of Environmental Protection (FDEP), September 2010. In Website: http://www.dep.state.fl.us/water/reuse/inventory.htm (Accessed on January 05, 2011).

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Hazen and Sawyer, 2011. Wastewater Reuse Project Will Boost Florida's Water Sustainability, Hazen and Sawyer, P.C., New York, USA, 2011. In Website: http://www.hazenandsawyer.com/news/wastewater-reuse-project-will-boost-floridas-water-sustainability/ (Accessed on January 05, 2011).

3.8 Singapore Water Reclamation Study (Newater Study), Singapore

Title of Case Study: Singapore Water Reclamation Study (NEWater Study), Singapore

Type of Case Study: A joint initiative between the Public Utilities Board (PUB) and the Ministry of the Environment (ENV) of Singapore to demonstrate the suitability of using NEWater (advanced treated wastewater) as a source of raw water to supplement Singapore's water supply.

Objective of Case Study: (i) To design, construct, commission and operate an advanced water reclamation plant for production of drinking water from wastewater for planned indirect potable reuse (IPR), (ii) to conduct a Sampling and Monitoring Programme (SAMP) for comprehensive physical, chemical and microbiological sampling and analysis of reclaimed water to assess its suitability as a source of raw water for planned IPR, and (iii) to run a Health Effects Testing Programme (HETP) to complement the comprehensive SAMP to determine the safety of reclaimed water.

Background of Case Study: Singapore has a population of 4.4 million people on an island with a land area of 700 km^2. Low land area in combination with high population density lead to consider Singapore to be a water-scarce country. Increased water demand due to population and economic growth, environmental needs, change in rainfall, flood contamination of good quality water and over abstraction of groundwater are all factors that continue to create water shortage problems. Singapore had a long-term agreement with the Malaysian Government to import water to meet its ever increasing water demand of 350 MGD (1,3266 MLD) at a price of less than one Singapore cent per 3,785 L. Due to the conflict related to the price for importing water from Malaysia, Singapore decided to embark on a water reclamation programme in order to ensure self-sufficiency in water.

Salient Features: Singapore has a unique political driver to ensure that its water consumption becomes self-sufficient by promoting wastewater reuse and will not have to rely on sources from Malaysia. In order to become self-sufficient in water and to promote wastewater reuse as an alternative source of raw water, The Public Utilities Board (PUB), a Government-owned utility for managing the country's entire water cycle in association with the Ministry of the Environment (ENV) of Singapore initiated a Water Reclamation Study (NEWater Study) in 1998. The NEWater Plant is a 10,000 m^3/d advanced water reclamation plant employing state-of-the-art dual-membrane (microfiltration and reverse osmosis) and UV disinfection treatment process train. The NEWater Plant treatment process train is shown in Figure 8.

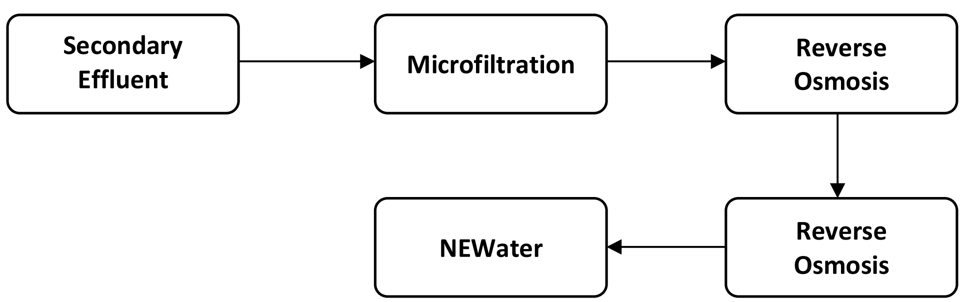

Figure 8: Treatment Process Flow Diagram of the NEWater Reclamation Plant, Singapore

This NEWater plant was built on a compact site downstream of the Bedok Water Reclamation Plant (WRP) (formerly known as Bedok Sewage Treatment Works) as the Bedok WRP receives more than 95% of its wastewater from domestic sources and commenced its operation in May 2000. The NEWater plant receives clarified secondary effluent as feed water from an activated sludge process with typical characteristics: 10 mg/L BOD_5, 10 mg/L TSS, 6 mg/L NH_4^+-N and 400 to 1,600 mg/L total dissolved solids (TDS) including 12 mg/L of total organic carbon (TOC). The secondary effluent is first subjected to micro-screening (0.3 mm) followed by microfiltration (MF) (pore size: 0.2 μm) for removal of fine solids and particles, and then demineralization in two parallel 5,000 m^3/d (5 MLD) reverse osmosis (RO) trains fitted with thin-film aromatic polyamide composite membranes configured for 80 to 85% recovery in a three-stage array. The RO permeate is disinfected by ultraviolet irradiation using three UV units in series equipped with broad-spectrum medium pressure UV lamps delivering a minimum design total UV dosage of 60 mJ/cm^2 as the final step. In order to control the rate of biofouling in the membrane systems, chlorine is added at two points before and after MF. The end product of the reclamation plant is called NEWater. Table 4 presents and compares the original plant design criteria against actual plant performance (monthly averages) since operation in May 2000. NEWater is considered to be safe for potable use as it is evaluated by the comprehensive SAMP and meets the stringent requirements of the USEPA's National Primary and Secondary Drinking Water Standards and the WHO's Drinking Water Quality Guidelines. Also, the findings from the HETP confirms that exposure to or consumption of NEWater does not have carcinogenic (cancer causing) effect on the mice and fish, or estrogenic (reproductive or developmental interference) effect on the fish. The average unit power consumption at NEWater Plant varies in the range of 0.7 to 0.9 kWh/m^3. The successful operation of the NEWater Reclamation Plant is a good example of the unique political will and the government initiative to drive and promote wastewater as an alternative source of water in order to address the country's water scarcity challenge.

Table 4: Design Specifications against the Actual Performance of NEWater Reclamation Plant

Parameter	Design Specification	Actual Performance
pH	None	5.9
TOC Removal (%)	> 97	> 99
NH_4^+-N Removal (%)	> 90	> 94
TDS Removal (%)	> 97	> 97
MF Filtrate Turbidity (NTU)	≤ 0.1	≤ 0.1

The outcome of the NEWater Reclamation Plant led the PUB to embark on new initiatives to supply NEWater to industries for non-potable use. Towards the new initiatives for wastewater reclamation, the PUB in association with the Vivendi Water Systems Asia set up a 40,000 m^3/d dual-membrane high grade water reclamation plant (HGWRP) at Kranji, Singapore and the plant started operation at the end of December 2002. The plant is designed to allow future expansion of capacity up to 72,000 m^3/d. The plant combines Memcor's CMF-S (Microfiltration) with Reverse Osmosis (RO) and UV to produce high purity water from secondary effluent. The CMF-S Submerged Continuous Microfiltration process combines Memcor's proven pressurized CMF product know-how with a submerged configuration to achieve increased product scale and improved operating economies. The multiple barrier approach in the plant ensures pathogen removal in wastewater. The main unit processes in the plant include:

- Secondary effluent pumping combined with chlorine dosing and equalization tank;
- Microfiltration: 6 units of 480S10T CMF-S cells;
- Filtered water storage combined with chlorine dosing;
- 5 units of two-stage (49 vessels 1st stage, 24 vessels 2nd stage, 7 elements/vessel) RO trains;
- 3 units of UV irradiation for disinfection; and
- Product water storage and pumping combined with pH and chlorine control.

Reference:

Durham, B., Koh, W.K., Thompson, G., Biltoft, B., 2002, Membrane Filtration - An Effective Pretreatment to RO in Water Reclamation Experience in the Municipal & Industrial Sectors, In: *Proceedings of the Water / Wastewater Management Conference*, November 20-21, 2002, Shangri-la Hotel, Singapore.

Singapore Public Utilities Board (PUB), 2002, Singapore Water Reclamation Study: Expert Panel Review and Findings Report, Singapore Public Utilities Board (PUB), June 2002. In Website: http://www.pub.gov.sg/water/newater/NEWaterOverview/Documents/review.pdf (Accessed on April 12, 2011).

Thompson, M., Powell, D, 2003, Case Study – Kranji High Grade Water Reclamation Plant, Singapore, In: *Proceedings of the IMSTEC '03*, September 2003, Sydney, Australia.

3.9 Wastewater Treatment Recycling Plants, Bangalore Water Supply and Sewerage Board (BWSSB), India

Title of Case Study: Wastewater Treatment Recycling Plants (60 MLD Vrishabhavathy Valley TTP; 10 MLD Yelahanka TTP), Bangalore Water Supply and Sewerage Board (BWSSB), India

Type of Case Study: Reuse of municipal and industrial wastewaters for non-potable and industrial uses.

Objective of Case Study: Recycling and reuse of wastewater in order to meet the water demands of ever growing population of Bangalore city in view of limited water resource and to reduce the high energy cost for pumping of water from Cauvery River.

Background of Case Study: Bangalore city has limited raw water resources to meet its water demands for ever growing population. City is almost completely depending on the Cauvery River, located more than 100 km away from the city for its requirements. The pumping of water from the river for water supply involves an exorbitantly high energy costs. In view of extremely finite source of raw water and high energy cost for pumping of water, the recycling and reuse of wastewater becomes absolutely imperative in Bangalore city and prompted the Bangalore Water Supply and Sewerage Board (BWSSB) to undertake a major initiative towards the recycling of wastewater. The BWSSB planned and established the two tertiary treatment plants (TTPs) in Bangalore at Yelahanka (capacity: 10 MLD) and another at Vrishabhavathy Valley (capacity: 60 MLD) for water recycling and reuse.

Salient Features: The 10 MLD TTP with recycling facilities at Yelahanka with funding support from KUIDFC/HUDCO under Megacity scheme and through Indo-French protocol has been commissioned in May 2003 for the BWSSB. The Yelahanka TTP has three treatment stages, viz., primary treatment, secondary treatment and tertiary treatment. The collected wastewater from Yelahanka is initially subjected to primary stage treatment (screening, grits and grease removal), followed by the secondary stage using primary settling and activated sludge process. Tertiary filtration (using sand and gravel) along with coagulation with aluminium sulphate are provided to the effluent from the secondary stage for removal of suspended solids. The chlorinated recycle water from the TTP is supplied to the ITC Ltd., Wheel and Axel Plant and the new International Devanahalli Airport to meet the non-potable water requirements. The characteristics of raw influent wastewater and tertiary treated effluent at the Yelahanka plant are shown in Table 5. Representative photographs of 10 MLD TTP at Yelahanka, Bangalore are presented in Figure 9.

Table 5: Characteristics of Raw Wastewater and Tertiary Treated Effluent at Yelahanka TTP

Parameter	Raw Wastewater	Treated wastewater
pH	6.8 – 7.5	7.0 – 8.0
Suspended solids (mg/L)	480	<5
Turbidity (NTU)	N.A.	<2
BOD_5 (mg/L)	380	<5
Fecal coliform (MPN/100 ml)	N.A.	<25

Figure 9: Photographs of 10 MLD Tertiary Treatment Plant (TTP) at Yelahanka, Bangalore

The BWSSB commissioned another 60 MLD capacity tertiary treatment plant (TTP) with recycling facilities at Vrishabhavathy Valley with funding support from KUIDFC/HUDCO under Megacity scheme and through Indo-French protocol in May 2003. The V. Valley TTP provides a combination of biological and physiochemical treatment to the secondary effluent from the existing 183 MLD STP based on conventional bio-filter near Kenchenahally. The treatment chain in the V. Valley TTP consists of trickling filter, DENSADEG high rate clarifier (combination flash mixer, lamella separators and counter current flow thickener), FLOPAC aerobic biological filtration unit and chlorine based disinfection. The chlorinated recycle water from the V. Valley TTP is supplied to M/s Karnataka Power Corporation Ltd. at Bidadi and M/s Pulikeshi

Power Corporation Ltd. at Kumbalgod for their power generation plants. Figure 10 shows the photograph of 60 MLD TTP at Vrishabhavathy Valley, Bangalore.

Figure 10: Photographs of 60 MLD Tertiary Treatment Plant (TTP) at Vrishabhavathy Valley, Bangalore

Reference:

BWSSB, 2005a. Recycling Treatment Plants, Vrishabhavathy Valley Tertiary Treatment Plant, The Bangalore Water Supply and Sewerage Board (BWSSB), 2005. In Website: http://www.bwssb.org/ current_project_recycle_treatment_vvalley.html (Accessed on January 11, 2011).

BWSSB, 2005b. Recycling Treatment Plants, Yelahanka Tertiary Treatment Plant, The Bangalore Water Supply and Sewerage Board (BWSSB), 2005. In Website: http://www.bwssb.org/ current_project_recycle_treatment_yehlenka.html (Accessed on January 11, 2011).

3.10 Sewage Reclamation Plant, The Rashtriya Chemicals and Fertilizers (RCF) Plant, Chembur, Mumbai, India

Title of Case Study: Sewage Reclamation Plant, The Rashtriya Chemicals and Fertilizers (RCF) Plant, Chembur, Mumbai, India

Type of Case Study: Reuse of complex wastewater (municipal sewage polluted with various industrial wastes) for industrial uses.

Objective of Case Study: Recycling and reuse of complex wastewater (municipal sewage polluted with various industrial wastes) for non-potable uses in the industry.

Background of Case Study: Municipal sewage generated in the vicinity of the Rashtriya Chemicals and Fertilizers (RCF) Plant, Chembur, Mumbai is heavily contaminated with various streams of industrial wastes and results into complex wastewater. In order to become water self-sufficient and to meet increasing process water requirements, the RCF plant realizes the importance of recycling and reuse of wastewater for non-potable industrial use and commissioned a sewage reclamation plant for the industry.

Salient Features: The RCF Plant commissioned a 23 MLD capacity sewage reclamation plant involving reverse osmosis in the year 2,000 and treats a complex wastewater comprising of the municipal sewage heavily contaminated with various industries wastes. The sewage reclamation plant at the RCF consists of following treatment units:
Screening → Grit Removal → Activated Sludge System → Clarifier → Sand Filter → Pressure Filter → Cartridge Filters → Reverse Osmosis → Degasser to remove CO_2 → Reuse in Industry.
The detailed flow sheet of the sewage reclamation plant for the RCF plant at Chembur is presented in Figure 11.

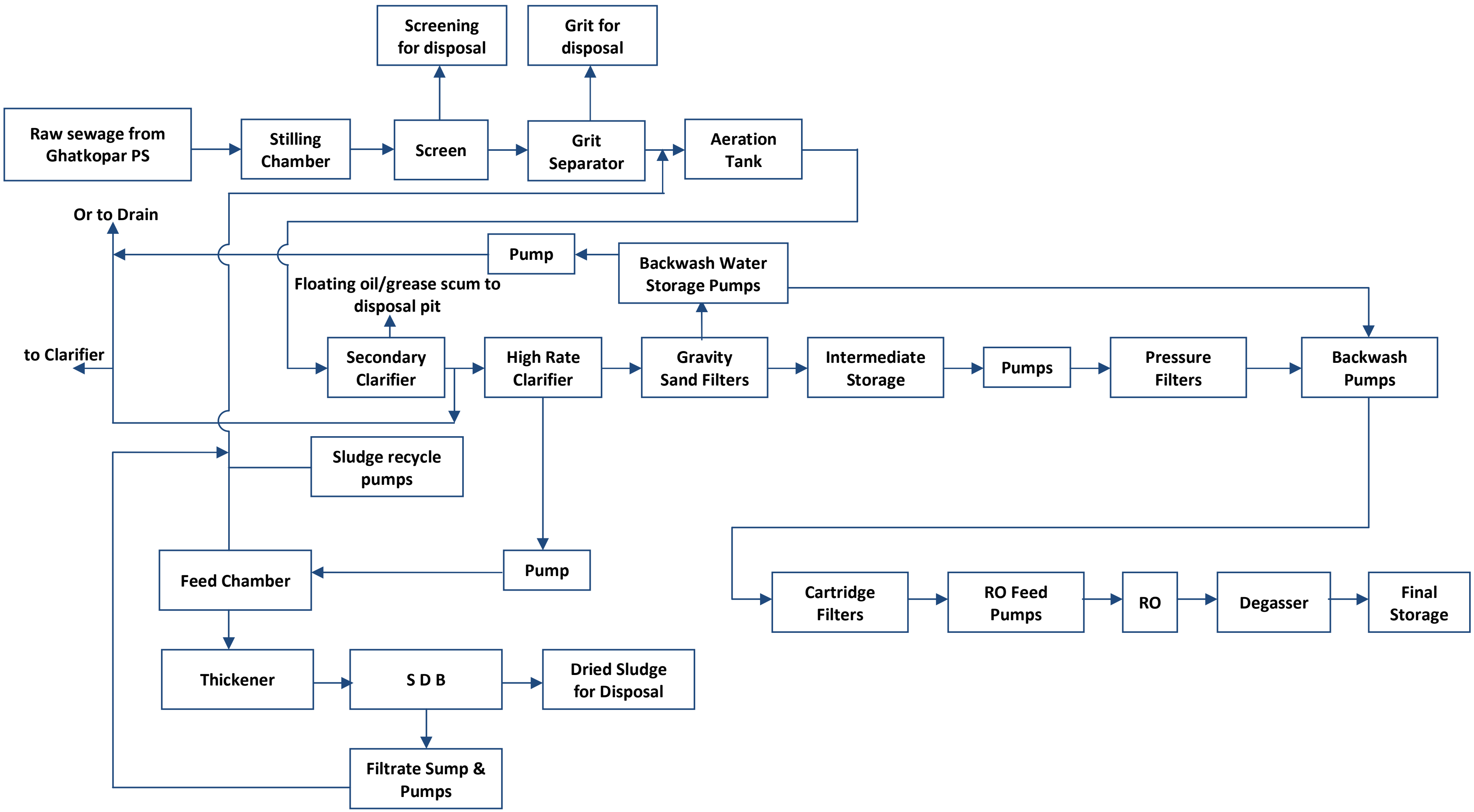

Figure 11: The Detailed Flow Sheet of the 23 MLD Sewage Reclamation Plant for the Rashtriya Chemicals and Fertilizers (RCF) Ltd., Chembur, Mumbai

The plant cost nearly Rs. 40 crores to build in 1998 and the operating cost as reported in 2005 came to Rs. 39/- per m^3. With the passage of time and the success of reuse schemes, the municipal charge levied also became higher at Rs 6/- per m^3 of raw sewage. Some additional treatment steps like use of Ultrafiltration became necessary in order to improve the quality of the water reaching the RO system (keeping the silt density index, SDI < 3.0) owing to the more polluted nature of the influent wastewater.

Reference:

Arceivala, S.J., Asolekar, S.R., 2007. Water Conservation and Reuse in Industry and Agriculture. In: Wastewater Treatment for Pollution Control and Reuse, 2007, Tata McGraw-Hill Publishing Company Limited, New Delhi, pp. 396–425.

3.11 Tertiary Treated Municipal Sewage Reuse, The Madras Refineries Ltd. and The Madras Fertilizers Ltd., Chennai, India

Title of Case Study: Tertiary Treated Municipal Sewage Reuse, The Madras Refineries Ltd. and The Madras Fertilizer Ltd., Chennai, India

Type of Case Study: Reuse of municipal sewage for industrial uses.

Objective of Case Study: Recycling and reuse of municipal sewage for non-potable uses in the refinery and fertilizer plant.

Background of Case Study: Chennai city has perennially finite water resources. Two industries i.e. the Madras Refineries Ltd. (MRL) and the Madras Fertilizer Ltd. (MFL) are the biggest users of water for their process requirements. Both industries commissioned tertiary treatment plant (TTP) for municipal sewage reuse in order to become water self-sufficient and to meet increasing process water requirements.

Salient Features: Since 1991, both the industry i.e. the Madras Refineries Ltd. started reusing municipal sewage producing 12 MLD of reusable water and the Madras Fertilizer Ltd. producing 16 MLD of reusable water. Based on these TTPs, the Chennai Metro Water and Sewerage Board supplies secondary treated sewage (with BOD 120 mg/L even after secondary treatment) and the industries provide the required further treatment depending on their end uses. The TTPs which receive secondary treated wastewater from the Chennai city at the Madras Refineries Ltd. and the Madras Fertilizer Ltd. consist of following treatment units:

Additional Secondary Biological treatment → Chemically-aided Settling + Pressure Filtration + Ammonia Stripping, Carbonation, Clarification, Pressure Filtration → Chlorination → Sodium Bisulfate Dosing → Multimedia Filtration → Cartridge Filtration → Reverse Osmosis → Permeate for Reuse.

Figure 12 presents the detailed flow sheet of the 12 MLD TTP at the Madras Refineries Ltd.

The rejects containing high TDS are disposed to the sea through a submerged outfall. As per the 1991 estimate, the capital cost for building the MRL plant was around Rs. 24 crores. The treatment costs for the MRL plant are reported to be about Rs. 35/- per 1,000 liters of water, which is much less in comparison to the charge of Rs. 60 per liters for fresh water supplied to industries. The Chennai Metro Water and Sewerage Board also charges a much higher tariff rate of Rs. 5.2/- per 1,000 liter of water to cover its treatment costs up to secondary stage.

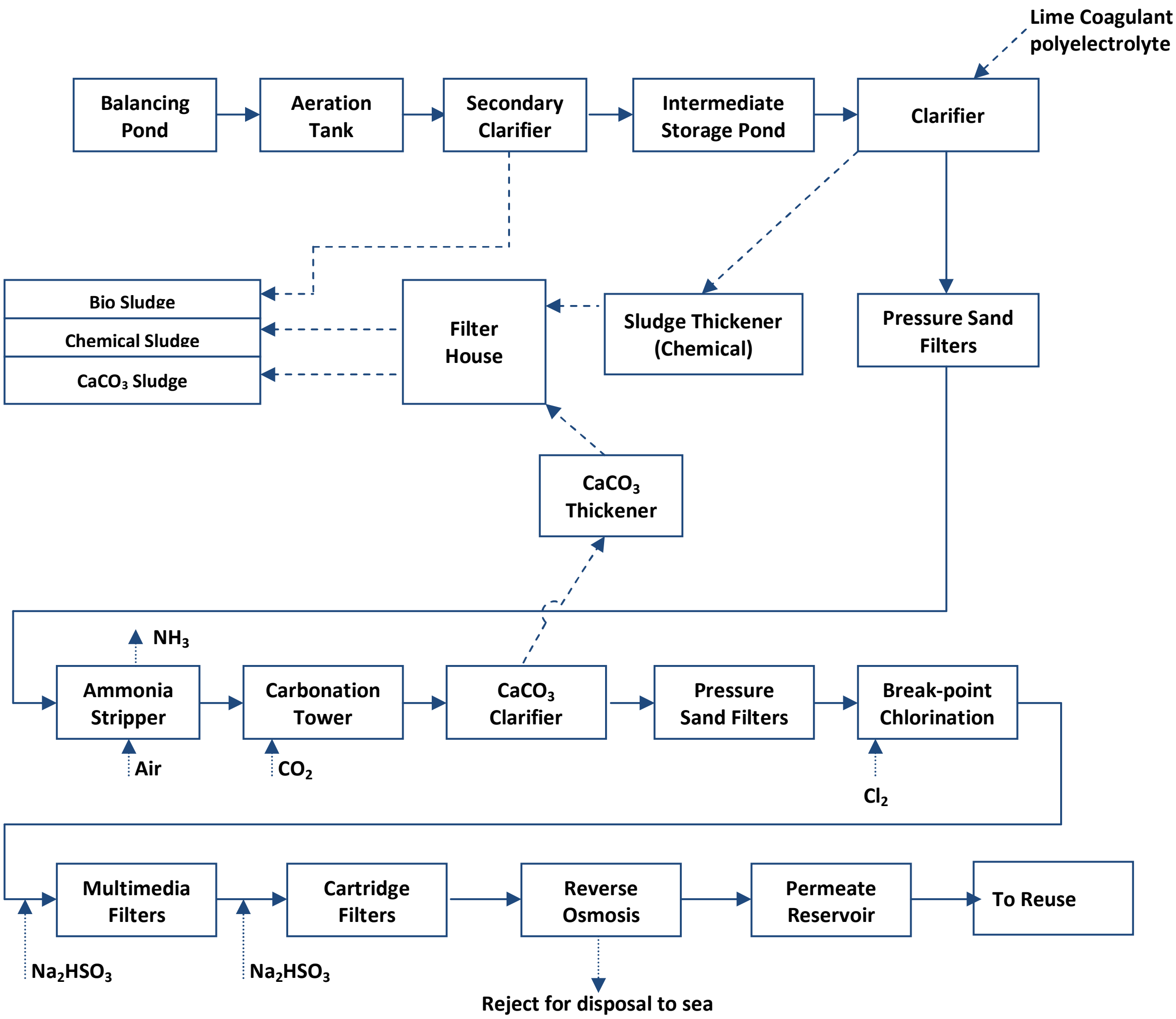

Figure 11: The Detailed Flow Sheet of the 12 MLD Tertiary Treatment Plant (TTP) for the Madras Refineries Ltd., Chennai

Reference:

Arceivala, S.J., Asolekar, S.R., 2007. Water Conservation and Reuse in Industry and Agriculture. In: Wastewater Treatment for Pollution Control and Reuse, 2007, Tata McGraw-Hill Publishing Company Limited, New Delhi, pp. 396–425.

3.12 Reverse Osmosis Plant for Wastewater Reuse, Vadodara, Gujarat, India

Title of Case Study: Reverse Osmosis Plant for Wastewater Reuse, Vadodara, Gujarat, India

Type of Case Study: Reuse of highly polluted wastewater for industrial uses.

Objective of Case Study: Recycling and reuse of highly polluted industrial wastewater for non-potable industry uses.

Background of Case Study: The reverse osmosis-based wastewater reuse plant was established in order to demonstrate the plausibility of reuse of highly polluted complex wastewater consisting of various industrial effluent streams for non-potable uses in the industry.

Salient Features: The reverse osmosis-based wastewater reuse plant uses highly polluted wastewater from an effluent disposal channel into which several industries viz. refineries, fertilizers, petrochemicals discharge their raw wastes. The successful operation of the plant demonstrated that at least 75% of the wastewater could be made available for reuse at treatment cost of Rs. 36/- per 1,000 liters as per the 1999 estimates. The remaining 25% constituted of the rejects and sludge from the reverse osmosis plant and needs to be disposed of separately. The treatment chain for the 3 MLD capacity reverse osmosis plant for wastewater reuse at Vadodara comprises of following units:

Wastewater from Effluent Channel → Chemical Feeding (Lime, Polyelectrolyte, Soda Ash) → Clarification → HCl Addition → Press Filtration → Sodium Bisulfate → Cartridge Filtration → Reverse Osmosis → Degasser to remove CO_2 → For Reuse.

The detailed flow diagram of the 3 MLD reverse osmosis plant for wastewater reuse at Vadodara is shown in Figure 13.

Reference:

Arceivala, S.J., Asolekar, S.R., 2007. Water Conservation and Reuse in Industry and Agriculture. In: Wastewater Treatment for Pollution Control and Reuse, 2007, Tata McGraw-Hill Publishing Company Limited, New Delhi, pp. 396–425.

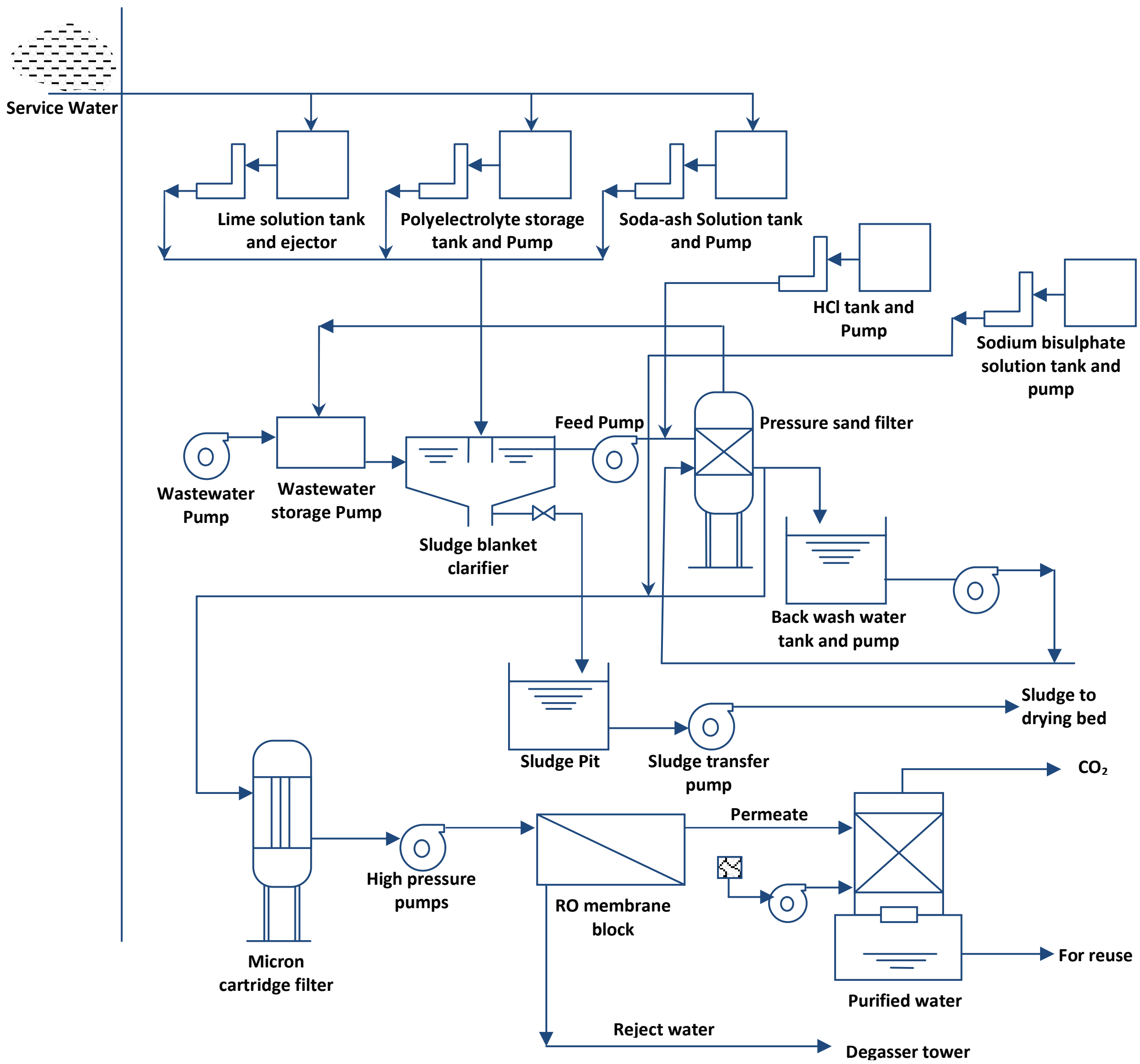

Figure 13: The Detailed Flow Diagram of the 3 MLD Reverse Osmosis Plant for Wastewater Reuse at Vadodara, Gujarat

3.13 Greywater Reuse System in Residential School, Ganganagar, Dhar District, Madhya Pradesh, India

Title of Case Study: Grey-water Reuse System in Residential School, Ganganagar, Dhar District, Madhya Pradesh, India

Type of Case Study: Reuse of treated grey-water for toilet flushing and irrigating the food crops.

Objective of Case Study: Treatment and reuse of grey-water from residential school for toilet flushing and irrigating the food crops.

Background of Case Study: The Central Indian state of Madhya Pradesh has a population of 28,928,245 spanning 308,245 km^2. The infrastructure for ensuring proper wastewater and its reuse is currently inadequate in the state with a third of the rural, and a quarter of urban, households with no wastewater drainage system. Therefore, there is a necessity to implement wastewater reuse system in the state. Towards the implementation of wastewater reuse, a grey-water reuse system has been initiated in one Girls boarding school in Ganganagar, District Dhar of Madhya Pradesh. The school has following characteristics:

No. of girl inmates: 300
School period: July 1 to April 30
Water requirement: 10,000 L
Grey-water generation: 4000 – 6000 L.

Salient Features: The National Environmental Engineering Research Institute (NEERI), Nagpur, Public Health Engineering Department (PHED), NGO partners and UNICEF, Madhya Pradesh have developed and implemented a grey-water reuse system in the residential school to provide sufficient water for flushing of toilets, cleaning of school floors and small-scale irrigation. The grey-water is treated using following primary, secondary and tertiary treatment technologies:

- ***Primary treatment:*** absorption of soap suds using a synthetic sponge, *sedimentation* baffled/graded settlement tank,
- ***Secondary treatment*:** involves filtration of the reuse water using gravel (10–60 mm size) and sand roughing filtration, and
- ***Tertiary treatment*:** the effluent is treated using aeration and chlorination before being pumped to an overhead tank for toilet flushing.

The techno-economical feasibility of the grey-water reuse system reveals that the system is performing exceedingly well and the internal and external benefits of the system are substantially higher than the internal and external costs. The reuse of grey-water has resulted in no occurrence of diarrhoea annually. The public perception study of the reuse system concluded that the grey-water reuse system is acceptable to the community and school children. Considering the successful operation of the grey-water reuse system in the residential school, Government of Madhya Pradesh has allocated funds for construction of 412 grey-water reuse systems in April 2006 and about 200 systems are already built in schools in Madhya Pradesh, India.

Reference:

Godfrey, S., Labhasetwar, P., Wate, S., 2009. Greywater reuse in residential schools in Madhya Pradesh, India – A case study of cost-benefit analysis. Resour. Conserv. Recycling. 53, 287–293.

3.14 Water Reuse Facility, Indian Institute Technology, Madras, Tamil Nadu, India

Title of Case Study: Water Reuse Facility, Indian Institute Technology, Madras, Tamil Nadu, India

Type of Case Study: Reuse of campus wastewater for toilet flushing and gardening.

Objective of Case Study: Treatment, storage and reuse of wastewater from hostels, residential apartments and the institution for toilet flushing in the hostels and gardening.

Background of Case Study: The Indian Institute of Technology Madras (IITM) campus has thirteen hostels, two guest houses and many residential apartments and bungalows with a total population of nearly 10,000 people. The total water consumption in the IITM campus is around 1.5 MLD and the total quantity of wastewater generated including the institute section varies from 1.0 to 1.2 MLD. Till 2004, the wastewater generated in the campus was treated in two oxidation ponds of capacity 136 m x 136 m x 2.5 m and the characteristics of the treated effluent from the pond was: 200-250 mg/L of BOD_5 (total) and 35-40 mg/L of BOD_5 (soluble), which is highly unsuitable for discharge into existing water bodies as per the Tamil Nadu Pollution Control Board (TNPCB) norms. In order to reuse the water, to prevent the formation of marshy area and to discharge the treated effluent to existing water bodies (Buckingham canal) there was a need to improve the existing treatment system. Moreover, the marshy area existing in and around the wastewater treatment system used to overflow during rainy season and contaminate the lake water as well as the swimming pool water in the campus. On the backdrop of these problems and in order to conserve water in water-starved place like Chennai and to reduce the procurement of water from outside, water reuse is viewed as essential in the campus.

Salient Features: A preliminary investigation to come up with a feasible treatment option for the campus suggested that a water reuse facility consisting of aerated lagoon followed by tertiary treatment is the best option for the existing condition with a possibility of around 0.2-0.4 MLD of wastewater reuse for toilet flushing and gardening in the hostel zone. The water reuse facility designed and installed to treat 1.4 MLD of wastewater and comprises of aerated lagoon, clariflocculator, chlorination, pressure filter, storage unit and sludge drying bed. There are two units of aerated lagoon with volume of 2600 m^3 each and take care of organic matter in the wastewater. The detention time provided in the aerated lagoon is relatively high compared to conventional ASP and thereby ensuring negligible sludge production. The effluent from the aerated lagoon is subjected to clariflocculation in order to remove colloidal and suspended solids. Alum and poly-electrolytes are being used as coagulant and coagulant aid respectively. The clariflocculator is also designed for a capacity of 1.4 MLD. After the clariflocculator, about two-third of the water (1 MLD) is send to the storage tank which was an oxidation pond earlier. The remaining one-third water (0.4 MLD) is chlorinated and filtered through a pressure filter. The pressure filter improves the quality of the water considerably by further removing the colloidal and suspended solids. Chlorination helps to reduce the pathogenic organisms substantially and keeps the filter relatively free from the microbial growth. The last unit in the reuse facility is the storage tank of water for further distribution.

The performance characteristics of various treatment units of the reuse facility are presented in Table 6. The highly treated effluent is reused for toilet flushing and gardening in the hostel zone alone. The sludge generated in the whole system is disposed off on the sludge drying bed. The schematic of the water reuse facility system is shown in Figure 14. This case study is a good example of sustainable water management and a notable initiative towards the reuse of wastewater from residential as well as from the institution sectors in India.

Table 6: Performance Characteristics of Various Treatment Units of the Water Reuse Facility

Treatment Unit		Parameter			
		Quantity, m^3/d	**BOD, mg/L**	**SS, mg/L**	**MPN/ml**
Aerated Lagoon	Influent	1400	200	100	N.A.
	Effluent	1428	20	49	N.A.
Clariflocculator	Influent	1428	20	49	N.A.
	Effluent	1358	10	29.45	100
Pressure Filter	Influent	400	10	29.45	100
	Effluent	400	4.0	5.0	50

Reference:

Philip, L., 2011. Water reuse facility at Indian Institute of Technology, Madras, Personal Communication.

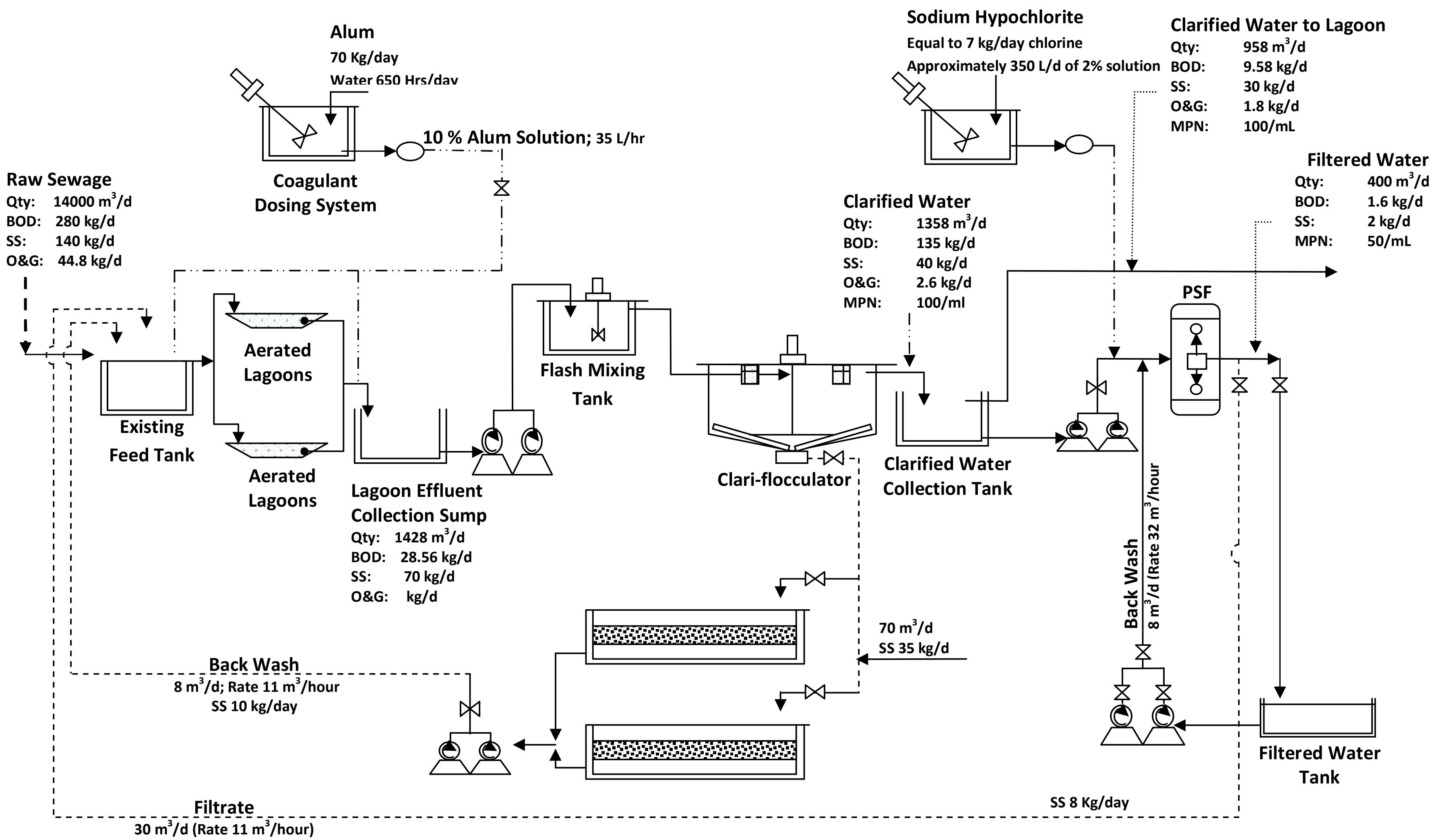

Figure 14: The Detailed Flow Schematic of the Water Reuse Facility at Indian Institute of Technology, Madras, Tamil Nadu

4. Environmental Impacts of Wastewater Reuse

The wastewater reuse is the most promising alternative to augment water supply and means of alleviating the anthropogenic impacts on the environment: it reduces the volume of wastewater discharged to receiving waters, and its substitution for freshwater leaves more water for the environment. Wastewater can be reused for a variety of purposes, including agricultural irrigation, heavy industry, urban and landscape irrigation, groundwater recharge, and wetland creation (Hartling and Nellor, 1998; Radcliffe, 2004). The wastewater reuse schemes have the potential to extend existing water supplies, lessen the demand on sensitive water bodies, lower the cost of developing new water supplies, reduce disposal costs, lessen the discharge of pollutants to the environment, and provide water to serve a variety of beneficial uses (Atwater, 1998). Wastewater, treated, partially-treated or untreated, is most widely reused for irrigation in an agricultural setting in developing countries as well as the water-scarce regions of the developed countries. There are many ill effects of reusing untreated or partially treated wastewater for irrigation like groundwater pollution, soil contamination, and the adverse effect on farmers and consumers of wastewater products. The environmental impacts of reuse of highly reclaimed wastewater using advanced or tertiary treatments have only been considered in this section. The potential environmental benefits of reuse of highly reclaimed wastewater are as follows.

Prevention of Over-extraction and Conservation of Freshwater Resources: Over-extraction of freshwater resources, mainly for municipal and agricultural activities, has led to significant degradation of rivers, lakes, aquifers, and dependent systems, such as wetlands. Wastewater reuse provides a renewable and alternative source of water supplies for municipal and agriculture purposes and it decreases the pressure on freshwater resources. Liberation of freshwater for the environment through substitution with wastewater reuse has been widely promoted as a means of prevention of over-extraction of freshwater resources and reduction of anthropogenic impacts (Anderson, 2003; Hamilton et al., 2005).

Pollution Reduction of Receiving Water Bodies and Associated Habitats: The other major environmental benefit to be garnered from reusing wastewater is diminution in pollution of waters receiving discharge of sewage and the restoration of ecosystem health. The wastewater reuse eliminates discharge of effluent into surface water and thereby decreases the associated pollution loads in terms of organics, nutrients and coliforms. Major environmental pollution in surface water bodies such as dissolved oxygen depletion, eutrophication and algal blooms, foaming, fish kills and destruction of floral and faunal biodiversity can be avoided. The wastewater reuse for the water recycling projects in the Costa Brava area demonstrated reduction in nutrient discharges to the environment, which accounted for 25 tons of nitrogen and 6 tons of phosphorus recycled every year (Nieto et al., 2001), and the marked improvement in the microbiological quality of the bathing waters of the beach at the mouth of the Muga river in Castelló d'Empúries. Planned reuse of wastewater for irrigation prevents pollutions and reduces the resulting damage that if quantified, can partly offset the costs of the reuse scheme.

Stabilizing Groundwater Table and Restoration of Surface Water Bodies: Wastewater reuse has played a major role in matching demands and available raw water supplies. It has been highly emphasized in various developed countries that the high quality reclaimed wastewater should be returned to stream of origin unless applied to beneficial reuse. As a result, recycled water is used in substantial proportion to maintain the base flow or ecological flow in many rivers and replenishing and stabilizing the groundwater through seasonal storage in surface reservoirs. For example, reclaimed wastewater is reused to supplement about 50% of the inflow into Hartbeespoort Dam which supplies water to Pretoria and Johannesburg in South Africa (Odendaal et al., 1998). It has also been demonstrated that wastewater reuse for irrigation has resulted in an increase in groundwater recharge in the Mezquital Valley in Mexico City including the creation of a new shallow aquifer and an increase in the base flow of local streams (Jimenez et al., 1998). Recovery and restoration of rivers and streams with the reclaimed wastewater in arid and semi-arid countries like Israel have also been demonstrated (Friedler and Juanico, 1995; 1996; 1997; Juanico and Friedler, 1999). There are also various other instances like Whittier Narrows in Los Angeles, Orange County in California, and Upper Occaquan reservoir in North Virginia where high quality reclaimed wastewater has been reused for direct groundwater recharge (Anderson, 2003).

Creation and Enhancement of Wetlands and Riparian (Stream) Habitats: Wetlands are the natural systems which help to provide wildlife habitat, improve water quality, result in flood diminishment, and support fisheries breeding grounds. For wetlands that have been impaired or dried due to water diversion, water flow can be augmented with wastewater reuse to sustain and improve the aquatic and wildlife habitat. Examples of wetland environmental restoration projects where water flow has been augmented using reclaimed water are Empuriabrava, Girona (7 hectare), Granollers, Barcelona (1 hectare) and Prat de Llobregat, Barcelona (18 hectare) in the region of Catalonia, Spain (Sala *et al*., 2004).

Increased Crop Yield and Agricultural Products: The reuse of wastewater for agricultural irrigation reduces the amount of water that needs to be extracted from natural water sources (USEPA, 1992; Gregory, 2000). It has been demonstrated in many instances that the wastewater reuse for irrigation can significantly increase crop growth and yield, and associated agricultural products. The reuse of reclaimed wastewater for irrigation has greatly increased crop yields in the Mezquital Valley in Mexico City (Anderson, 2003). The paddy rice irrigation with reclaimed wastewater from waste stabilization pond followed by a constructed wetlands in a decentralized rural area with conventional fertilization resulted in about 50% greater average rice yield than that of control, indicating that the reclaimed water can increase the crop yield substantially (Ham *et al*., 2007). Cultivating rice with reclaimed wastewater has shown no adverse effects on crop growth or yield; instead, the average yield for the rice plots irrigated with the reclaimed wastewater (6,680 kg/ha) resulted in about 19%

greater yields than the control plots irrigated with natural groundwater and it also showed more than the national average yield (4,500 kg/ha) in Korea (Jang *et al*., 2010). The wastewater reuse facilitates in effective use of nutrients contained in reclaimed wastewater for irrigation leading to reduction in uses of chemical fertilizer (Lazarova and Asano, 2005). Soil microorganisms have been observed to have increase metabolic activity when reclaimed wastewater is reused for irrigation (Meli *et al*., 2002; Ramirez-Fuentes *et al*., 2002).

Energy Savings: Wastewater reuses on-site or nearby reduces the energy needed to transport and distribute water longer distances or pump water from deep within an aquifer. The energy needed to treat wastewater also reduces by tailoring water quality to a specific water reuse. For example, the water quality required for flushing a toilet is less stringent than that for drinking water purposes and requires less energy to achieve. Reuse of reclaimed wastewater with lower quality for specific purposes that don't require high quality water saves energy and money by reducing treatment requirements.

In summary, the environmental benefits of reuse of highly reclaimed wastewater include: (a) Freshwater resources and quality benefits such as - (i) displace the need for over-extraction of freshwater resources, (ii) reliable, secure, and drought-proof water source, (iii) freshwater conservation by closing the water cycle, (iv) reduction in freshwater diversions and more river flow for downstream users, (v) reduced impacts of developing new water retaining structures like dams, reservoirs, (vi) reduction in pollution loads and better downstream water quality, (vii) reduced environmental impact and improved river aesthetics, (viii) reduced impacts on fisheries and aquatic life, (ix) improved public health for downstream users, (x) improved recreational values of waterways; (b) Agricultural benefits such as - (i) reduced diversion costs, (ii) value of a secure drought-proof supply of reclaimed water, (iii) increased crop growth and yield, farm production, (iv) increased food production, and (iv) savings in fertiliser applications by virtue of value of reclaimed water nutrients.

There have been a number of adverse environmental effects identified for reusing wastewater for non-potable purposes. Some effects are short term and vary in severity depending on the potential for environmental contact, while others have longer term impacts which increase with continued use of recycled water. The potential adverse environmental effects of high quality reclaimed wastewater reuse are as follows:

Adverse Environmental Effects of Heavy Metals and Emerging Contaminants: High quality reclaimed wastewater may contain various emerging contaminants like pharmaceutically-active compounds (PhAC), endocrine disrupting compounds (EDC) and hormones apart from heavy metals. These PhACs and EDCs originate either from industrial or domestic sources. Very little is mentioned regarding the potential presence of these trace contaminants apart from heavy metals and some brief mention on PhACs (USEPA, 1992). There is concern about the potential environmental impact by the emerging contaminants if they survive treatment processes, and are able to accumulate in the environment and enter the food chain. Heavy metals are easily and efficiently removed during common treatment processes and the majority of heavy metal concentrations in raw sewage end up in the biosolids fraction of the treatment process with very low heavy metal concentrations present in the treated effluents (Sheikh *et al*., 1987). Thus, heavy metals are of little concern for irrigation of crops using reclaimed wastewater. Ofosu-Asiedu *et al*. (1999) examined the uptake of heavy metals by crops irrigated with reuse of sewage and found that the levels in the crops irrigated with reuse of sewage was similar to background environmental levels and thus posed no environmental risks. Angelova *et al*. (2004) observed that fibre crops such as flax and cotton did take up heavy metals when grown in heavily contaminated soils, however the concentrations detected in the leaves and seeds were only a small percentage of the concentration present in the soil. Apart from heavy metals, most of the environmental concerns regarding the wastewater reuse revolve around the trace emerging contaminants. The endocrine disrupting compounds (EDCs) are compounds outside of an organism which can impact on the structure and function of an organism's endocrine system causing effects on the organism or its progeny (Lim *et al*., 2000). Known EDCs that can be found in wastewaters include the estradiol compounds commonly found in the contraceptive pill, phytoestrogens, pesticides, industrial chemicals such as bisphenol A and nonyl phenol, and heavy metals (Lintelmann *et al*., 2003). It has been demonstrated that wildlife (e.g., alligators in Florida and riverine fish in the UK) that are in constant or near constant contact with reclaimed water containing EDCs can have potential adverse effects like problems relating to the size and development of male gonads in Juvenile male alligators and increase in intersexuality of riverine fish (Guillette *et al*., 1994; Jobling *et al*., 1998). Sewage effluent usually contains a variety of hormones which increase the endogenous production of hormones (phyto-hormones) in legumes like alfalfa when the effluent is reused for irrigation. These phyto-hormones can then cause fertility problems in sheep and cattle that eat the forage (Colborn *et al*., 1993; Shore *et al*., 1995; Guan and Roddick, 1998). The pharmaceutically-active compounds (PhACs) are drugs used for a variety of therapeutic uses for both humans and animals. The PhACs detected in reclaimed water include analgesics such as Ibuprofen, caffeine, antiepiletics, cholesterol reducing drugs such as atorvastatin (common brand name Lipitor), antibiotics and antidepressants. One of the major concerns relating to PhACs is the development of antibiotic resistance in soil and water microorganisms due to the reuse of wastewater for irrigation (Guardabassi *et al*., 1998).

Adverse Effects of Salinity of Recycled Water on Soil Properties and Crop Growth: The physical characteristics of recycled water can have an impact on the environment in which it is used. The most important physical characteristics of recycled water to be used for irrigation purposes is the salinity, particularly in forms of sodium and chloride and can have a deleterious effect on soil properties and certain sensitive plants, thereby impairing the usefulness of recycled water. The most reliable index of the sodium hazard of irrigation water is the sodium adsorption ratio (SAR). The threshold value of SAR of less than 3 indicates no restriction on the use of recycled water for irrigation, while severe damage could be observed when SAR is over 9, in particular for surface irrigation (Lazarova *et al*., 2005). At a given SAR, the infiltration rate increases as salinity increases and vice versa. Recycled water is often high in sodium, and the resulting high SAR is a major concern in planning water reuse projects. The adverse effects of salinity are usually associated with an increase in soil salinity and the osmotic pressure in the soil solutions, and thereby with adverse effects on both crop and soil. Sodium and other forms of salinity are the most persistent in recycled water and difficult to remove from water as it requires the use of expensive cation exchange resins or reverse osmosis membranes. For some sensitive crops and landscape ornamentals, the presence of boron and trace element toxicity in the recycled water for irrigation could be of major concern. Salinity in the form of sodium can directly affect soil properties like soil permeability through the phenomena of swelling and dispersion due the interaction of positively charged sodium with the negatively charged layers (known as platelets) of clay particles (Halliwell *et al.*, 2001). The salinization of soil through the reuse of wastewater with high salinity for irrigation purposes affects clay particles in the soil and thereby reduces the hydraulic conductivity. The interaction of dissolved organic matter present in the reclaimed water with the soil profile also reduces the hydraulic conductivity of soil (Tarchitzky *et al.*, 1999). High salinity in the reclaimed water can lead to a decrease in productivity for certain crops, destabilizing the soil structure. Salinity also affects crop transpiration and growth (fewer and smaller leaves) (Bouwer, 2005). Higher salinity in the root-zone of plant leads to decrease in the osmotic potential of the soil-water solution and retards the water uptake rate of the plant. The plant expends considerable energy trying to extract water by osmotically adjusting and accumulating ions at the expense of plant growth and yield (Maas and Grattan, 1999).

The reuse of high quality reclaimed wastewater for various purposes has a numbers of genuine environmental benefits. Using recycled water as an alternative source of water reduces the pressures on the environment by reducing the use of freshwater resources. However, proper care and precautions must be taken in the haste to reap these benefits, as wastewater reuse itself also has the potential to be environmentally detrimental. There are certain issues that need to be properly resolved including the adverse environmental effects of presence of emerging contaminants as well as salinity on soil properties and crop growth in order to convince stakeholders for wide acceptability of wastewater reuse.

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5. Public Health Impacts of Wastewater Reuse

Recycling of highly reclaimed wastewater for various beneficial purposes has been perceived as a possible solution and an alternative source of water for an anticipated ever-growing water shortage problem in many parts of the world. Currently, there is considerable interest and apprehension for the potential health effects associated with the wastewater reuse. The possible risk to public health due to wastewater reuse is essentially depends on the degree of treatment provided to the wastewater. Depending on the extent of treatment received before reuse, the public health concerns related to the wastewater reuse can be classified in two categories: (i) Biological risks due to presence of microbial pathogens and indicators like enteric bacteria, virus and protozoa and helminths, and (ii) Chemical risks due to presence of various emerging contaminants like pharmaceutically-active compounds (PhAC), endocrine disrupting compounds (EDC) and hormones. Biological risks related to wastewater reuse have been recognized since the very beginning of this reuse practice. On the other hand, the considerations related to chemical risks have been developed recently following improvements in analytical capabilities. Additionally, biological risks have a relatively immediate outcome (illnesses develop in a short period of time), while chemical risks are translated into time-delayed illnesses (carcinogens, long-term toxicity, etc.). The public health concerns related to the reuse of untreated and partially-treated wastewater have been reviewed and summarized (Frerichs, 1984; Cooper, 1991). This section reviews the potential public health concerns due to the reuse of highly reclaimed wastewater only.

Biological Risks due to Presence of Microbial Pathogens and Indicators: The most common human microbial pathogens found in recycled water are enteric in origin. Enteric pathogens enter the environment in the faeces of infected hosts and can enter water either directly through defecation into water, contamination with sewage effluent or from run-off from soil and other land surfaces (Feachem *et al*., 1983). Enteric viruses are the smallest of the pathogens found in reclaimed water and most enteric viruses have a narrow host range meaning that most viruses of interest in recycled water only infect humans (Haas *et al*., 1999). This means that only human faecal contamination of water needs to be considered as a concern for viral infection of humans. Bacteria are the most common of the microbial pathogens found in recycled waters (Toze, 1999). Like other enteric pathogens, a common mode of transmission is via contaminated water and food and by direct person to person contact (Haas *et al*., 1999). A number of these bacterial pathogens can also infect, or be carried by wild and domestic animals. Enteric protozoan pathogens are unicellular eukaryotes, which are obligate parasites. There are several protozoan pathogens sometimes found in recycled water like *Entamoeba histolytica*, *Giardia intestinalis* (formerly known as *Giardia lamblia*), and *Cryptosporidium parvum* (Gennaccaro *et al*., 2003). Infection from all three of these protozoan pathogens can occur after consumption of food or water contaminated with the oocysts or through person to person contact (Carey *et al*., 2004). Helminths (nematodes and tape worms) are common intestinal parasites which are transmitted the faecal-oral route and require an intermediate host for development prior to becoming infectious for humans (Toze, 1999). Helminth parasites that are of significant health risk due to the presence in reused waters include the round worm (*Ascaris lumbricoides*), the hook worm (*Ancylostoma duodenale* or *Necator americanus*), and the whip worm (*Trichuris trichiura*).

The presence of microbial pathogens like enteric bacteria, virus and protozoa and helminthes in recycled water, particularly when sourced from sewage effluent is arguably the major concern for health regulators, farmers and the general public. Tertiary treated recycled water is a common treatment level where close contact with the water is considered a possibility. It has been shown that pathogens can still be detected in tertiary treated recycled water (Rose *et al*., 1996; Gennaccaro *et al*., 2003) and that some pathogens are resistant to disinfection processes. Examples of notable disinfectant-resistant pathogens are: *Cryptosporidium* is resistant to chlorination (Finch and Belosevic, 2002) and adenovirus is resistant to UV radiation (Meng and Gerba, 1996). It has been observed that infection rates, particularly for adults, decreased with treatment of the sewage effluent with infection rates decreasing at a rate that could be linked to the level of treatment (Lazarova *et al*., 2005). Epidemiological studies conducted to date have not established definitive adverse health impacts attributable to the use of appropriately treated recycled water for irrigation (Lazarova *et al*., 2005). There have been indications that the greatest health risk is associated with spray irrigation of recycled water when concentrations of nematode eggs are over 1 egg/L, particularly for children who eat vegetables irrigated with such water (Lazarova *et al.*, 2005). No strong evidence has been found to suggest that population groups residing near wastewater recycling plants or recycled water irrigation sites are subject to increased risk from pathogens resulting from aeration processes or sprinkler irrigation (Blumenthal *et al*., 2000). A 5-year field pilot study in the Monterey Wastewater Reclamation Study for Agriculture (MWRSA) in Monterey, California indicated that there was an absence of microorganisms of concern for food safety in the water and on the edible and residual plant tissues of raw-eaten food crops, including lettuce, broccoli, and celery irrigated with recycled water having received tertiary treatment followed by disinfection (Sheikh *et al*., 1999). Some experts have concluded that the annual risk of enteric virus and bacterial ingestion from eating lettuce irrigated with recycled water meeting WHO guideline levels ranges from 10^{-5} to 10^{-9} (Blumenthal *et al*., 2000). The findings from the Health Effects Testing Programme (HETP) of NEWater Study in Singapore confirms that the reclaimed water is safe for potable use and exposure to or consumption of reclaimed water does not have carcinogenic (cancer causing) effect on the mice and fish, or estrogenic (reproductive or developmental interference) effect on the fish (SPUB, 2002). A more specific study (Vigneswaran and Sundaravadivel, 2004) of the city of St. Petersburg, Florida to estimate the potential risk to the exposed population concluded that: (i) there is no evidence of increased enteric diseases in urban regions housing areas irrigated with treated reclaimed wastewater, and (ii) there is no evidence of significant risks of viral or microbial diseases as a result of exposure to effluent aerosols from spray irrigation with reclaimed water. Another study on a grey-water reuse system in one Girls boarding school in Ganganagar, District Dhar of Madhya Pradesh showed that the occurrence of water-borne and water-washed diseases like diarrhoea have reduced substantially with implementation of the water reuse system (Godfrey et al., 2009). However, the potential presence of microbial pathogens in recycled water, even at very low numbers, must be considered a real biological risk and public health concern and the wastewater must be reused with due regard to this risk.

Chemical Risks due to Presence of Emerging Contaminants: Owing to the impressive improvement in analytical capacity, it has been made possible to discover various emerging contaminants like pharmaceutically-active compounds (PhAC), endocrine disrupting compounds (EDC) and hormones in natural water, raw and recycled wastewater capable of exerting negative public health impacts. Public health-related concerns pertaining to these emerging contaminants in recycled water are receiving increased attention. These chemicals tend to be present at very low concentrations in treated recycled water (usually in the range of ng/L) as well as require the ingestion of large doses over long time periods to produce any clinical effect (Durodié, 2003). Even if very long exposure occurs, it has been concluded that the actual concentration of compounds consumed would have minimal, if any, impact on a person or their offspring (Durodié, 2003). Due to the paucity of information on environmental persistence and potential health impacts due to the presence of emerging contaminants in recycled water, however, it is an area that currently remains a concern for health regulators and the public and potential fertile field for research. The current large number of known EDCs and PhACs present in reclaimed wastewater, as well as the possible existence of other potential and as yet unknown chemicals-of-concern, pose as barrier towards the promotion of wastewater reuse. Therefore, proper care and precautions must be taken in selecting advanced treatment techniques in water reclamation schemes for the removal of these emerging contaminants which are usually present in very low concentrations in the reclaimed water. It has been demonstrated that the tertiary treatment of wastewater like sand filtration, advanced oxidation processes (AOP) like ultraviolet light (UV) disinfection, ozonation and hydrogen peroxide (H_2O_2) addition can reduce these emerging contaminants in reclaimed water to below detection limits (Moore and Chapman, 2003).

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6. Economics of Wastewater Reuse

Financial and economic analyses are generally concerned with the identification, valuation, and comparison of costs and benefits with a view to judging whether a proposed activity is worthwhile or not. Costs play an important part in determining the practicability of wastewater reuse schemes. However, the costs incurred for any wastewater reuse scheme alone do not necessarily determine the economic desirability of any such scheme. It is important to have a clear view on the purpose of the valuation of the costs of a wastewater recycling and reuse installation whether the purpose is to determine overall financial feasibility, to determine charges to water users, to determine the need for borrowing to finance the project, or whether the purpose is to assess the wider economic performance of the investment, including the value of any environmental impact. Costs must be compared to the overall benefits of the scheme in evaluating the economics of wastewater reuse. The economic analyses of wastewater reuse must consider whether a particular wastewater reclamation installation is absolutely worthwhile in itself, that is, whether the overall benefits are greater than the costs incurred. Generally, the type and scale of benefits and costs of wastewater recycling and reuse are very location-specific, such that generalizations are difficult and can be misleading. A wide variation in recycled water unit pricing exists depending on the type of reuse, flow rates, and local conditions, ranging from USD 0 to 0.52/m^3 (INR 0 to 23.1 per m^3; USD1.0 = INR44.4) (Morris *et al*., 2005). Almost 50% of 34 wastewater reuse projects assessed by the Water Environment Research Foundation (WERF) ranged from USD 0.15 to 0.52/m^3 (INR 6.7 to 23.1 per m^3; USD1.0 = INR44.4) (Mantovani *et al*., 2001). Among existing wastewater reuse projects, the prices of recycled water appear consistently lower than those of potable water. The Durban Water Recycling (DWR) Scheme, run by Vivendi Water in association with the Durban Metro, supplies high quality reclaimed water to the Mondi Paper Mill and SAPREF Refinery at a cost 25% lower than potable water (MED WWR WG, 2007). Radcliffe (2003) argues that the costs and pricing mechanisms for wastewater reuse schemes are not transparent, as the true cost of irrigation, potable and recycled water is not reflected in the current prices. The disparities in pricing water from recycling schemes ranged from AUD7 to 83 cents per kL (INR3.4 to 40.25 per kL), compared to the true cost of reclaimed water that ranged from AUD1.45 to 3.00 per kL (INR 70.3 to 145.5 per kL; AUD1 = INR48.5) and can be attributed to unaccounted costs and the fact that environmental externalities are not considered and internalized. According to Muir (2006) price signals from the use of recycled water should be set at the long run marginal costs of supply. If this is done then appropriate decisions on existing stand alone schemes or the comparison of different proposals can be made. The existing managed potable water supply with heavy subsidy by municipal or regional authorities can lead to inefficient use of already scare water resources and market inefficiencies for wastewater reuse initiatives. Subsidized prices not only tend to discourage proper use of water among those who often could afford to pay more, but may also reduce the incentive for investment in wastewater treatment and reuse. When recycled water is provided for non-potable uses, especially irrigation, it is often offered at a lower price than potable water to encourage its use. The subsidized price combined with undervaluing of potable water has led the recycling projects fail to recover full cost and thereby fail to attain financial sustainability. The subsidized and real costs of recycled water for some recycled water schemes in Australia have been compared and presented in Table 7. Also, a survey of 79 wastewater recycling projects found that only 5 in the United States and 7 elsewhere recovered full costs (Mantovani *et al*, 2001). For the other U.S. projects, operating revenues covered between 0 and 80% of the full cost, implying a high level of subsidy. However, the failure to recover costs due to subsidized cost of recycled water does not imply that wastewater reuse schemes are uneconomic: the costs of wastewater reuse schemes may be justified in terms of broad economic, social, and environmental objectives where the overall target is wise use of available water supplies in support of local, regional, or national development objectives. Wastewater recycling improves the economic conditions of any region by creating employment and increasing the property values. For example, the social advantages in employment and populations were identified in the Lockyer Valley Water Recycling Scheme in South East Queensland by using reclaimed water and the financial gains for individual property owners through increase in property value (Mekala *et al*., 2008). The cost-benefit analyses of a grey-water reuse system in one Girls boarding school in Ganganagar, District Dhar of Madhya Pradesh showed that the internal and external benefits of grey-water reuse are substantially higher than the internal and external costs (Godfrey *et al*., 2009). The construction cost (material and labour costs) and the O&M cost of the system are INR 50,300 and INR 5725 per year, respectively. Internal benefits of the system are estimated to be INR 30,000 per year due to the reduction in fresh water supply. The external benefits in terms of the environmental and health benefits of the system are estimated as INR 44,000 and INR 793,380 respectively.

Table 7: Comparison of Subsidized and Real Costs of Recycled Water for Some Recycled Water Schemes in Australia (Source: Mekala *et al*., 2008)

Location	Use of Recycled Water	Subsidized Cost of Recycled Water/kL	Real Cost of Recycled Water/kL	Drinking Water Price/kL
Springfield, Queensland	Residential: toilet flushing, gardening	AUD43 cent	AUD1.45	90 cent per quarter for 100-150 kL
Rouse Hill, New South Wales	Residential: toilet flushing, gardening	AUD28 cent	AUD3.00-AUD4.00	98 cent
Olympic Park, New South Wales	Residential: toilet flushing, gardening, laundry	AUD83 cent	AUD1.60 (operating costs only)	98 cent
Mawson Lake, South Australia	Residential: toilet flushing, gardening	AUD77 cent	Not Available	AUD1.03 for >125 kL

AUD1.0 = INR48.50

Most of the existing wastewater reuse schemes worldwide use effluent from the secondary processes for further purification in advanced or tertiary treatment units and the additional costs involves in installing and operating the advanced or tertiary processes. Therefore, it is utmost necessary to review and discuss the costs involved in providing additional tertiary or advanced treatment in the context of the economics of the wastewater reuse. The distribution of capital and O&M costs of additional tertiary treatment for wastewater reuse varies from one project to another and depends on the type of the treatment processes used. Other major factors and local constraints like price of the building site, distance between the production site and the consumers, and necessity to install a dual distribution system or retrofitting also highly influence the capital and O&M costs of additional treatment. The latter two constraints are of major importance since the major capital investment concerns the distribution system in many wastewater reuse schemes and can reach 70–200% of the overall costs depending on site-specific conditions (Lazarova, 2005). Storage, mainly seasonal storage in form of surface reservoirs, represents significant part of investment. The cost of retrofitting of existing networks is comparatively higher than the installing new systems. Among the tertiary treatments, polishing pond treatment is the most simple and unsophisticated but has proven to be a competitive, efficient solution for small communities. This technology is the cheapest solution for flows under 3000 m^3/d (15,000 population equivalent) with average total annualized cost of about USD 5–7 cents/kL (INR2.22–3.11/kL; USD1.0 = INR44.4) (Lazarova, 2005). As the project size increases, polishing pond treatment becomes less and less competitive compared to other solutions, not taking its storage function into account. The construction of filtration as tertiary treatment unit results in a two- to three-fold increase in the capital and operating costs as compared to the disinfection processes. For project sizes more than 7500 m^3/d (50,000 population equivalent), the cost for UV treatment or chlorination becomes comparable to maturation ponds within the error margin of the cost estimation. For small and medium-size wastewater reuse schemes (<50,000 population equivalent), chlorination and UV irradiation are more competitive than ozonation, with average total annualized cost of about USD 2.2–8.0 cents/kL (INR0.98–3.55/kL; USD1.0 = INR44.4) (Lazarova, 2005). The cost difference between UV irradiation and ozonation decreases with plant size. The competitiveness of ozonation appears clear for large recycling plants (>100,000 population equivalent), where total costs are in the typical range of USD 0.8–2.5 cents/kL (INR0.35–1.11/kL; USD1.0 = INR44.4), and in some cases could be less than UV irradiation (Lazarova, 2005). Ozonation is generally considered and recommended as a viable option for large plants since ozonation improves the visual aspect of the recycled water and sometimes lessens its odor. The costs of membrane filtration (micro- and ultra-filtration) are significantly higher compared to the other disinfection processes and typically reach USD 0.40–0.70/kL (INR17.8–31.1/kL; USD1.0 = INR44.4) for plant capacity in the range of 20,000–500,000 population equivalent (Lazarova, 2005). The cost difference decreases when compared with combined sand filtration and UV or ozone disinfection. The widespread application of membrane bioreactors (MBRs) despite all the process advantages is constrained by the high cost of membranes apart from high O&M cost for fouling tendency. Compared to the conventional ASP, the overall costs for MBR remain up to 20% and 50% higher than the conventional ASP depending on plant size. Reported MBR costs typically vary from USD 0.095 to 0.20/kL (INR4.22–8.88/kL; USD1.0 = INR44.4) for treatment plant size up to 50,000 population equivalent (Lazarova, 2005). The operating costs are about 45–50% of the total annual costs for UV irradiation and increase up to 50–70% for chlorination and ozonation, respectively for small to large wastewater reuse schemes (Lazarova, 2005). Operation and maintenance costs incurred by chlorination and ozonation are primarily those associated with chemical costs. Higher reagent costs up to 60% of the operating costs are characteristic for chlorination. Operating costs for UV systems consist mostly of lamp replacement and cleaning.

Treatment of wastewater to a high level, using secondary to tertiary processes, for reuse and recycling can be very energy intensive and the economics of the wastewater reuse schemes is directly related to the energy consumption. Energy costs are about 2–5% of the operating costs for chlorination. Energy costs for UV irradiation and ozonation are between 15 and 35% of the operating costs respectively, depending on plant size. Water reclamation from wastewater with less total dissolved solids than seawater has lower energy costs for reverse osmosis. The comparative energy consumption for various technologies for per kL of potable water production is presented in Table 8.

Table 8: Comparative Energy Consumption for Various Technologies for Potable Water Production

Technology	Energy Consumption, kWh/kL	Reference
Reverse Osmosis of Seawater	3.2 – 3.5	Sanz and Stover (2007)
Brackish Reverse Osmosis	0.7 – 1.2	Swinton (2005)
Conventional Water Treatment	0.4 – 0.6	Swinton (2005)
Wastewater Reclamation	0.7 – 0.9	Singapore Public Utilities Board (2002)
	0.8 – 1.0	Swinton (2005)

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7. Community and Public Perception and Participation towards Wastewater Reuse

The wastewater reuse in any context can quite understandably be a source of concern for general public and communities at large who have no previous direct experience of similar schemes. Irrespective of what conclusions scientific enquiry leads to, the impressions and attitudes that the public holds can speedily and effectively bring a halt to any reuse scheme. The central dilemma for anybody attempting to understand how individuals respond to change is that people interpret their surroundings in a highly personal manner. Not only is interpretation individualistic, it is also dynamic (i.e., changes over time) and as such is extremely difficult to monitor. The psychological factor is essential for initiating, implementing and sustaining a long-term wastewater reuse program. The general community has openly acknowledged that there is a “yuck” factor or a psychological barrier to using recycled water on many occasions (Melbourne Water, 1998). In psychological terminology, the “yuck” factor or disgust is defined as the emotional discomfort generated from close contact with certain unpleasant stimuli. Any neutral object through brief contact with another object may acquire disgusting properties as per the law of contagion (Rozin and Fallon, 1987). People may still perceive the wastewater reuse to be disgusting because the water has been in contact with human wastes which results in disgusting stimuli irrespective of the highest degree of treatment provided to the wastewater. Therefore, the development of sustainable water recycling schemes needs to include an understanding of the social and cultural aspects of wastewater reuse. A wastewater reuse project may fail in absence of social support. The public attitude plays an important role even for non-potable reuse purposes including the perception of water quality, willingness to pay or to accept any wastewater reuse project (Lazarova et al., 2000). It has to be kept in mind while studying on the public as well as on the community acceptance that wastewater reuse has different driving forces: (i) It is a supplemental water supply in water scarce regions, and (ii) It can be a viable alternative to the disposal of treated effluents in rivers and other surface water bodies and there with a driving force also for regions with humid climate. Hence, the particular issue of public and community perception and participation require complex and complicated understanding since it is related to the beliefs, attitudes, and trust.

Studies of public and community attitudes to wastewater reuse have been carried out since the late 1950s (originally in the United States, but more recently in Europe, Central America, and Africa). A summary of such studies reported that individuals who consider their potable supplies to be under threat (in terms of either quality or quantity) or perceive an economic benefit are generally more positive towards the idea of recycling water (Bruvold and Crook, 1989). Other study has demonstrated that acceptance of water recycling schemes in general is influenced by the degree of human contact associated with the reuse application (Bruvold, 1985). Uses such as garden irrigation and toilet flushing are consistently preferred over uses such as food preparation and cooking. Faby *et al*. (1999) criticize the very stringent restrictions which are even much higher than the WHO (1994) guidelines concerning reuse in agriculture in some parts of the world. This is detrimental to the public acceptance of wastewater reuse schemes. A study about the industrial sector in Thailand and its willingness to adopt wastewater reuse practices indicates that only 10.5% of the industries included in survey reuse their treated effluent (Visvanathan and Cippe, 2000). Furthermore, the tendency of the industries is directed into non-adoption of industrial wastewater reuse. Another study has considered other determinants of attitudes to reuse schemes, including the scale of the scheme (e.g., single house/multiple house) and the context of the scheme (e.g., domestic, commercial, or public premises) (Jeffrey, 2002). The sources of recycled water as well as the environment in which it is to be used are likely to influence attitudes towards the system as a whole. However, the communities and societies at large also differ just like individuals vary in their attitudes towards water reuse. The dangers inherent in ignoring cultural (ethnic/historical/religious) norms have been recently demonstrated (Mancy *et al*., 2000), and the benefits provided by public education have been pointed out (Sbeih, 1996; Crites, 2002). Po *et al*. (2004) suggested that people may perceive reusing wastewater too risky because (i) the source of this water is not natural, (ii) it may have potential to harm people, (iii) there might be unknown future consequences of reusing wastewater, (iv) their decision to recycle water may be irreversible, and (v) the quality and safety of the water is not within their control. The major findings from various surveys conducted in France, Italy, and the United Kingdom in order to identify the major barriers to water reuse across a range of reuse project types and cultural contexts are as follows (Jeffrey, 2005):

- Communities are sensitive to water reuse issues, although this is more evident in the northern part of the continent than in the south.
- Many corporate stakeholders are nervous about supporting reuse projects in the absence of clear and legally binding water quality guidelines.
- Use of a water recycling system where the source and application are located within their own household is acceptable to the vast majority of the population as long as they have trust in the organization that sets standards for water reuse. Using recycled water from second party or public sources is less acceptable, although half the population show no concern, irrespective of the water source.

- Water recycling is generally more acceptable in non-urban areas than in urban areas. (This disparity is most pronounced for systems where the source and use are not within the respondent's own residence).
- Willingness to use recycled water, particularly from community sources, is higher among metered households than among non-metered households, and higher among those households that take water conservation measures than among those who do not.
- The use of recycled waters for irrigation is widely accepted by farmers who believe them to be safer than river waters.
- There are strong concerns over the sale of products that have been irrigated with reclaimed wastewater, especially vegetables. Farmers can overcome resistance through positive evidence from the consumers and the retailers that there will be a market for the products cultivated with the reclaimed water.
- The establishment of standards for the reuse and management of monitoring programmes promote confidence in reuse schemes.

Studies conducted by Bruvold (1988) and ARCWIS (2002) showed that closer the recycled water is to human contact or ingestion, the more people are opposed to reuse the wastewater. Therefore, introducing recycled water for non-potable non-human contact uses and gradually moving along the contact continuum and wastewater reuse awareness programmes through public education are expected to increase the acceptability of recycled water.

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8. Concluding Remarks and Recommendations

The implementation of treated wastewater reuse is underdeveloped in India. This is based on the total degree of water scarcity (which has forced the other parts of the world including the US and Australia to take a more comprehensive approach to water resources management), but also because urban treated wastewater reuse is not well understood compared with the high priority water management activities of potable water production to protect public health and wastewater treatment to protect the environment. Reuse can be more difficult to implement due to the large number of end users, the vicinity to the public, relatively high cost due to complex distribution and treatment systems as well as potential risks of accidental public exposure in the case of cross-connections in dual supply systems and irrigation of public spaces. Factors such as the increased demand for water, coupled with increased water stress, water scarcity and the compliance measures towards environmental legislation, are likely to increase the drive towards the use of treated wastewater.

The benefits of treated wastewater reuse are very evident even though some risks have to be taken into account. Treated wastewater reuse is vital in the widely promoted concept of "integrated urban water management". Treated wastewater reuse alternatives should be included as part of the demand driven river basin management plans like the Ganga River Basin Management to maximize water management efficiency. In this context, the total closure of the river basin water cycle needs to be adopted in India as common practice following the reported case studies where treated wastewater is used to recharge the ground water in order to maintain integrated water resources management. Moreover, the concept of zero discharge municipality/city by integrating the reuse of highly treated wastewater adopting tertiary-level advanced treatment techniques needs to be promoted in the Ganga Basin. Therefore, following general recommendations can be made based on the review presented in this report towards the promotion of wastewater reuse in the Ganga River Basin:

- Highly reclaimed wastewater reuse schemes should be included and promoted as an alternative source of water for non-potable non-human contact uses (except food industry) as part of the demand driven river basin management plans like the Ganga River Basin Management to conserve freshwater resources and to maximize water management efficiency.
- Groundwater recharge should be encouraged in the entire Ganga Basin for replenishing and stabilizing the groundwater using highly reclaimed water through seasonal storage in surface reservoirs in order to maintain the base flow or ecological flow in the rivers.
- Zero discharge municipality/city concept (i.e. completely prohibit the disposal of treated or untreated wastewater into surface water bodies) needs to be promoted in the Ganga Basin by reusing entire wastewater generated within the municipality/city adopting tertiary level advanced treatment techniques. Emphasis should be given on natural treatment systems like wetlands and pond systems. Separate distinct treatment chain should be adopted based on the water quality requirements for each of the intended purpose of wastewater reuse.
- A proper water quality standard or guidelines pertaining to wastewater reuse for each of the various beneficial purposes should be developed and strictly enforced as law/regulation in India through peer or public monitoring protocols.
- Irrigation with highly reclaimed water should be promoted in the entire Ganga Basin in order to prevent excessive extraction of surface water and groundwater. For this purpose, separate storage and distribution systems need to be installed completely detached from the distribution systems of other types of water, especially from potable water in order to prevent any contamination.
- Research is warranted on the potential public health impacts due to the presence of microbial pathogens and emerging contaminants, if any, in highly reclaimed wastewater before reuse. Risk assessment studies should also be conducted for the possible public health impacts due to the presence of microbial pathogens and emerging contaminants. Proper surveillance and monitoring of water quality for wastewater reuse should be performed frequently.
- Awareness campaign, workshops, conferences on the potential benefits of wastewater reuse should be conducted in order to promote wastewater reuse and educate people for changing the wrong notion/perception and remove any psychological barrier about wastewater reuse and ensuring the public and community participation towards wastewater reuse. School and college curricula should be appropriately modified to educate next generation on conservation and reuse/recycle of water.

Assessment of Some Aspects of Provisioning Sewerage Systems

in Urban Agglomeration of Ganga Basin

GRBMP: Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay	IIT Delhi	IIT Guwahati	IIT Kanpur	IIT Kharagpur	IIT Madras	IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRBMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. Lists of persons who have contributed directly and those who have taken lead in preparing this report is given on the reverse side.

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Contents

1. Introduction

Consortium of 7 "Indian Institute of Technology"s has been engaged by the Government of India to prepare Ganga River Basin Management Plan (GRBMP). One of the most important challenges of the Consortium is to prepare an action plan for "Un-polluted Flow" or "Nirmal Dhara" in all rivers of the Ganga Basin. The main approach to achieve the ultimate objective of "Nirmal Dhara" has been to identify the type of polluting wastes, their sources of generation (point and non-point sources), and the techno-economic feasibility of collecting and treating them for their safe environmental discharge and/or possible recycle or reuse. Figure 1.01 illustrates the main identification results and the tasks.

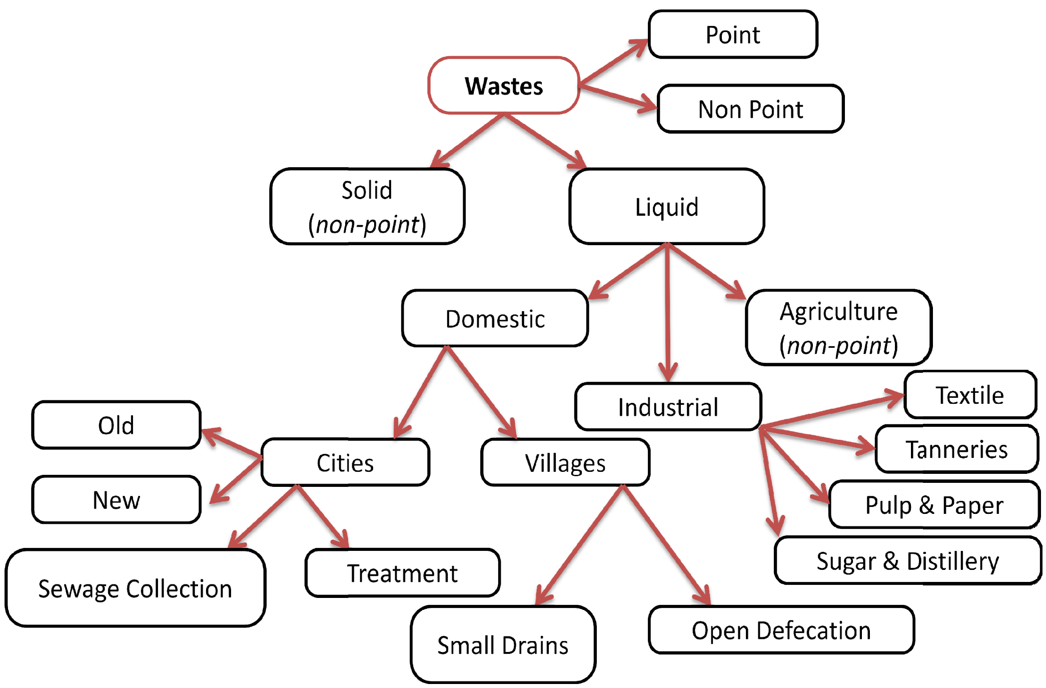

Figure 1.01: Types and Sources of Wastes and Main Identification Tasks
(IIT GRBMP Report, 2013)

Among point sources, urban and industrial wastewaters are the major sources of pollution, needing immediate remediation. In consideration of the magnitudes of domestic wastewater generation from different urban locales, urban settlements are divided into Class I Towns (having population over 100,000) and Class II Towns (having population between 50,000 to 100,000). The following main steps concerning sewerage infrastructure for medium to long term (over the next 25 years) are considered essential.

1. Complete stoppage of the discharge of sewage, either treated or un-treated, from Class I and Class II towns into any river.

2. All sewage generated in Class I and Class II towns of GRB needs to be collected and treated up to tertiary level with treated effluent standards of: Bio-chemical Oxygen Demand (BOD) < 10 mg/L; Suspended Solids (SS) < 5 mg/L; fully nitrified effluent; Phosphorous < 0.5 mg/L; Fecal Coliform (FC) < 230/100 mL.

3. The tertiary treated water should be reused for various non-potable purposes, such as industrial, irrigation, horticultural, and non-contact/non-potable domestic use. Unused treated water may be utilized for groundwater recharge but only via surface storages and subsequent infiltration and percolation through soil.

The above measures are essential to overcome the declining state of urban wastewater management in GRB. Although much money and effort have been spent in Ganga Action Plan over the past few decades, the overall achievement has been limited. And, yet, the same approach has persisted over the years, leading to general disillusionment and cynicism. This attitudinal blockade is illustrated in Figure 1.02.

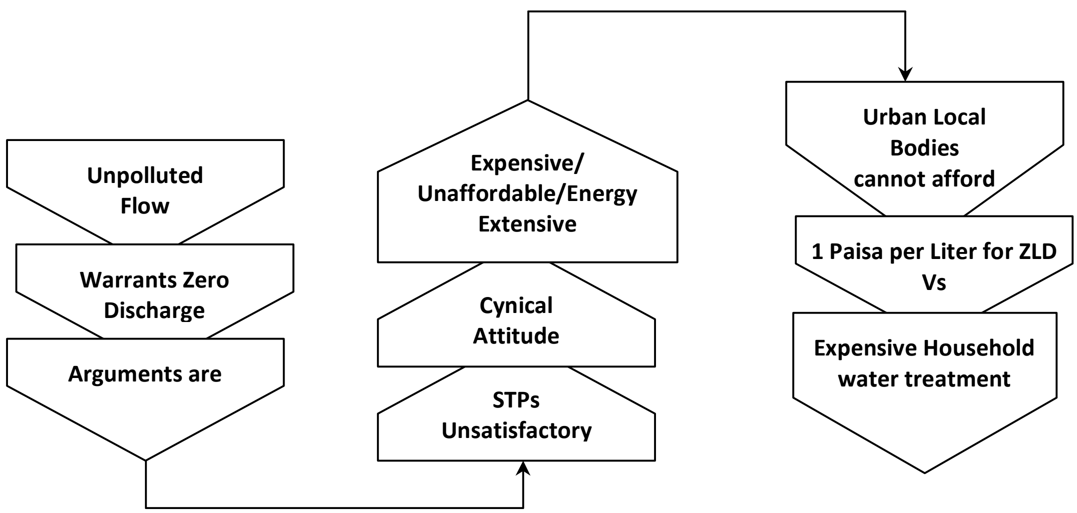

Figure 1.02: Schematic Representation of Attitudinal Blockade in Managing Urban Sewerage Infrastructure

But such despondency and cynicism can be easily overcome if water is considered as a "resource" rather than as "dirt". By adequately treating wastewater and re-using it instead of dumping the untreated or partially treated wastewater to sully the environment, urban wastewater treatment can achieve "Zero Liquid Discharge" (or ZLD) and recover the value of water as a "resource". However, costs and benefits of such strategies need to be delineated in quantitative terms to convince the policy makers. It is to satisfy this end that the present study was initiated.

2. Background and Review of Literature

2.1. General

The genesis of this study has been the recommendations of the Environmental Quality and Pollution (EQP) Group of the Consortium of 7 IITs preparing the Ganga River Basin Management Plan to have full coverage of sewerage systems in all urban agglomerations in the basin. It is important to have appropriate ballpark estimates of expenditure on provisioning sewerage systems, and the tangible and intangible benefits that would accrue. A complete sewerage system includes sewerage network, sewage pumping/lifting and sewage treatment. A study about the urban centers in India based on population estimates of 2008 from 2001 census by the Central Pollution Control Board (CPCB), New Delhi reports that capacity to partially treat only 11,787 MLD sewage (out of 38,524 MLD generated) exists in the country (CPCB, 2009). Most of these sewage treatment plants (STPs) do not perform satisfactorily for various reasons including grossly inadequate sewerage network and sewage pumping, and a very small fraction of sewage gets treated to the regulatory standards while most of the sewage finds its way directly or indirectly into the water bodies. Thus it would not be an exaggerated statement to say that most water supplies in the country are through highly polluted water bodies including rivers. As such it is necessary to have an estimate of expenditure on sewerage infrastructure for full coverage of urban agglomerations in the country, in general, and Ganga River Basin (GRB) in particular.

2.2. Cost Estimates of Sewerage Systems: Conventional Approach

The Central Public Health and Environmental Engineering Organisation (CPHEEO), Ministry of Urban Development (CPHEEO Manual, 2013) provides following for cost estimates of sewerage systems.

a) Capital costs shall include all the cost such as civil construction, equipment supply and erection costs, land purchase costs, engineering design and supervision charges, interest charge on loan, and

b) Operation and Maintenance cost after the project is started shall consider, amortization and interest charges on capital borrowing, expenditure made on staff, chemicals, energy, transport, repair work, all the equipment/tools, insurance and overheads.

According to the manual, the planning should start with the preparation of City Master Plan (CMP) and City Sanitation Plan (CSP) which should form the base of the sewerage system project. Presently very few towns have prepared CMPs and CSPs. And most CSPs are based on inadequate data and information. Use of GIS based information systems is rare.

2.2.1. Collection of Information

To calculate the cost of the sewerage systems, all the basic information is required to be collected. Some of the essential information/data includes

a) Topography of the area to be covered for design of sewers and location of sewage treatment works, outfall and disposal works

b) Subsoil conditions, such as the strata likely to be found, ground water table level.

c) Structures like storm drain and appurtenances, house connections for water supply and sewerage, electricity supply lines and telephone cables, gas pipelines, etc.

d) Sewerage master plan, long-term comprehensive development plans for cities and towns, urban planning, city planning area, urbanization zone, and urbanization control area, land use plan, road plan, urban development as rezoning, residential estates, and industrial complexes, etc.

e) Population data and quantification of sewer generation, water supply data, etc.

After collection of aforementioned information several reports like feasibility reports, pre-feasibility reports, and identification reports are to be made. This kind of work generally ends with the executive summary report which covers the project's essential features, basic strategy, approach adopted in developing the project, and the salient features of financial and administrative aspects.

2.2.2. Methodology

CPHEEO Manual (2013) recommends that cost estimation of each component of the project is prepared and annual requirement of funds for each year is worked out, due allowance should be made for physical contingencies and annual inflation. This exercise results in arriving at total funds required annually for the execution of the project. Further it is required to prepare recurring annual costs of the project for the next few years (say 10years) covering operation and maintenance expenditure for the entire system (staff, chemicals, energy, spare parts and other materials for system operation, transportation, etc.). The cost estimates are prepared considering the following points.

a) Outlining the basic assumptions made for unit prices, physical contingencies, price contingencies and escalation.

b) Summarising the estimated cost of each component for each year till its completion and working out total annual costs to know annual cash flow requirements.

c) Estimation of foreign exchange cost if required to be incurred.

d) Working out per capita cost of the project on the basis of design population, cost per unit of sewage treated and disposed, and comparing these with the government norms, if any.

Once the estimation of cost of sewerage systems is completed, the need for an Institutional and Financial Plan rises which needs the identification of responsible and capable organization which can be trusted for the completion of the project and also the identification of all sources of funds for implementation of the project, indicating year-by-year requirements from these sources, to meet expenditure as planned for completing the project as per schedule, stating how the interest during construction period will be paid, or whether it will be capitalized and will be paid in loan, explaining the procedures involved in obtaining funds from the various sources.

2.3. Cost Estimates of Sewerage Systems: Other Approaches

The conventional approach followed is to prepare bill of quantities (BOQ) for various items and use unit costs to get the total expenditure. However, this approach requires availability of detailed design and specifications. In most cases at the planning stage it is not possible to prepare BOQs. Mostly thumb rules and past experiences are used. Most of these thumb rules are not available in any published literature but are available with organisations involved in planning and execution of sewerage systems.

2.3.1. Sewerage Network

Sewerage network includes sewers and manholes. In order to have cost estimate, the first step is to compile information on lengths of various sizes of sewers, number and sizes of manholes, and unit costs. Generally the unit costs can be easily worked out for different settings. However, the other information is generally not available. Thus other approaches are necessary. For example, in estimation of sewerage network costs it is assumed that cost of pipes is about 15 % of the total network cost. But the use of this approach requires that total length of various diameter pipes be known. Again, as a thumb rule, it is assumed that 70 to 80 percent of total sewer length is of 150 and 200 mm diameter sewers. It is not possible to estimate the total length unless the detailed plan of the town is available. Essentially no published information could be found on this. Thus it is necessary to develop methods for estimating lengths of various sizes of sewers contributing to sewerage network. Similarlyoperation and maintenance costs are estimated based on thumb rules and taken as 1.5 % of the capital expenditure as per the survey conducted by Water and Sanitation Program (WSP Flagship Report, 2011)

2.3.2. Sewage Pumping

The major components of sewage pumping stations include pumps, civil works and miscellaneous material supplies such as inlet and outlet pipes, fittings such as valves, connectors, pipes, etc. In order to estimate pump sizes it is necessary to get the information on quantity of sewage to be pumped and the pumping head. No published literature could be found to arrive at the pump sizes without detailed design of sewer networks. For other items thumb rules are used by the practicing engineers and professionals. For example it is assumed that civil construction cost of pumping stations is about 10 % of the cost of the pumps. Similarly, for the cost of miscellaneous material supplies is assumed as 1-2 % of the cost of pumps.

The operation and maintenance costs of pumping stations are essentially those of energy consumptions. Other costs are minor costs and are assumed to be 1 % of the energy bill.

2.3.3. Sewage Treatment

Estimation of sewage treatment costs requires information on treatment technology, unit costs and quantity of sewage to be treated. This can generally be done without detailed design as unit costs of various treatment technologies with their performance are available (Tare and Bose, 2009; IIT_GRB Report: 003_GBP_IIT_EQP_S&R_02_Ver 1_2010). Also estimation of quantity of sewage can be done based on population and water supply rates (CPHEEO Manual, 2013). Similarly operation and maintenance costs for various types of treatment technologies are also available (IIT_GRB Report: 003_GBP_IIT_EQP_S&R_02_Ver 1_2010).

2.4. Concluding Remarks

The conventional approach for estimation of expenditure on provisioning sewerage systems calls for detailed specifications of sewerage network, sewage pumping stations and sewage treatment plants. Requisite information to arrive at such information is often not available at the planning stage. This warrants exploring other approaches for ballpark estimates of sewerage systems at the planning stage which do not depend on detailed specifications. Essentially no published literature is available on such approaches although practicing engineers, professionals and consulting organisations engaged in planning and developing proposals adopt thumb rules based on past experiences and the data available from various detailed project reports. Such data are generally not accessible to all. It is plausible to develop approaches based on huge amount of information available on sewerage systems in India with urban local bodies, consulting firms and practicing engineers and professionals for ballpark estimates of sewerage systems with some reasonable assumptions.

3. Objective and Scope

State of sewerage infrastructure in India in general, and in Ganga River Basin in particular is very poor. This is believed to be due to lack of adequate resources required to develop such infrastructure. In the past few decades Government of India launched several large programmes such as Ganga Action Plan (GAP), Yamuna Action Plan (YAP), Jawaharlal Nehru National Urban Renewal Mission (JNNURM), etc. to pump in huge funds. However, this has been done without systemic assessment of the actual resources required, and to a large extent on an ad hoc planning. Also, very little planning has been done to fill the huge gap, and for operation and maintenance of the assets created. As a result not much benefit has been seen on ground and no sustainable model is in the sight. It is very important that an appropriate techno-commercial frame work is developed for sustainable sewerage system for the urban centers.

The first and foremost requirement is to have an assessment of provisioning sewerage systems in economic sense. This need has been the genesis of the present study. Provisioning of sewerage systems yields certain benefits depending upon the choice of technologies and components, their designs, and efforts and investments made. Based on past experience of implementing aforementioned programmes and their wide spread criticism due to insignificant improvement in the pollution status of most water bodies, Consortium of 7 IITs preparing the Ganga River Basin Management Plan (GRBMP) is considering full coverage of sewage collection and treatment of sewage up to tertiary level so that treated sewage could be recycled and/or reused instead of disposal in water bodies or application on land in all urban agglomerations in the basin.

The present study is a part of this larger framework and aims at estimating the financial layout for provisioning sewerage infrastructure in all Class I and Class II towns of the Ganga River Basin (GRB) with the objective of recycling and reuse of sewage alongwith assessment of fresh water savings that could facilitate in management of Environmental Flows (E-Flows) in the rivers. Following specific objectives are set for this study to achieve this goal.

1. Develop suitable methodology for obtaining ballpark estimates for full coverage of sewerage network in Class I and Class II towns of GRB.
2. Develop suitable framework for obtaining ballpark estimates for sewage pumping and sewage treatment up to tertiary level.
3. Obtain ballpark estimates of capital investments for provisioning sewerage infrastructure and annualized expenditure towards capital (capex) and sustainable operation and maintenance (opex) of such infrastructure in all Class I and Class II towns of GRB.
4. Assess financial implications of provisioning sustainable sewerage infrastructure on individuals residing in the urban agglomerations of GRB.
5. Assessment of fresh water savings that can assist in managing Environmental Flows (E-Flows) in the rivers.

The scope of the study is restricted to availability of secondary data on (i) design and cost estimation of sewerage network for various urban centers in India from urban local bodies, consultants and practitioners, (ii) empirical practices used in design and cost of estimation of sewage pumping stations, (iii) sewage treatment plant design and cost estimation available with Consortium of 7 IITs, and (iv) population from 2011 census and areas of Class I and Class II towns of GRB as collected from various urban local bodies.

4. Methodology

4.1. General

Sewerage infrastructure includes (i) sewer network, (ii) sewage pumping and (iii) sewage treatment plants. Estimation of capital (Capex) and operation and maintenance (Opex) costs for these three components has been worked out separately for all Class I and Class II towns in Ganga River Basin (GRB). Following sections briefly describe the methodology adopted.

4.2. Estimation of Capex and Opex of Sewerage Network

This involves estimation of length of sewer pipes of different diameter and cost of laying unit length including the supply of materials, barricading the area, timbering in trenches, excavation of earth, laying, jointing of sewer lines, surface relaying, costs of manholes, labors, dewatering, etc.

An empirical approach is followed to arrive at these costs. Data from approximately 45 different urban locations where sewer networks have been laid or designed is gathered from various local bodies and consulting firms. This data included population, area covered, lengths of various diameter pipes, bill of quantities (BOQs), cost estimates and total cost of the project. The BOQs and cost estimates had all the details which are required for the estimation of sewerage network costs.

Several approaches, outlined as follows by which unit costs could be worked out, were attempted.

Approach I: The unit cost (average per meter length of sewer laid including all items in BOQs) is taken as the total cost of the sewerage network project divided by the total sewer length (all diameter sewers). This cost comes around INR 4,000 to 5,500 per meter of the sewer length. This is the cost of laying the fresh sewer lines with minimal hindrances as it includes only, the supply of materials, barricading the area, timbering in trenches, excavation of earth, laying, jointing of sewer lines, surface relaying, costs of manholes, labors, dewatering etc. In general this unit cost could be considered for green field projects i.e. for newly developed areas or colonies where there are no obstructions (rail lines, roads, buildings, other infrastructure networks such as water supply lines, cable networks, etc., encroachments and/or monuments of historical or religious importance, etc.). This unit cost increases to INR 6,500 -10,000 when some miscellaneous items like crossing of railway lines, crossing through drains etc., some extra sewer lines due to uncertainties in estimation of total sewer lengths, adoption of trenchless technology for some area, dismantling of roads, relaying of roads, etc. The unit costs considered in this study are as follows.

- INR 5,000 for green field sites.
- INR 8,000 for sties involving few hindrances and moderate degree of congestion.
- INR 10,000 for sties involving many hindrances and high degree of congestion.

Approach II: Unit cost of the sewer pipes can be estimated with high degree of confidence and does not vary much from one site to the others. Thus for various projects cost estimates were made based on BOQs of various items and percentage of the cost incurred in supply of sewer pipes was computed. The cost of supply of sewer pipes ranged between 12 to 15 percent of the total amount of the sewer line laying, jointing, labors, excavation of soil, manholes, etc. Based on this the total cost of sewerage network can be taken as x/0.15, where x is the cost of supply of sewer pipes. In this study this is only used for cross validation of the costs estimated using Approach I described earlier.

Approach III: In this approach unit cost of various sizes of pipes is calculated based on BOQs and keeping provision for some exigencies based on tips received from practicing engineers. The average unit cost is worked out through weighted average based on percentage lengths of various size pipes in the total sewer network length. This approach is also used for cross validation of the costs estimated using Approach I described earlier.

Operation and maintenance (Opex) costs are estimated based on thumb rules and taken as 1.5% of Capex as per the survey conducted by Water and Sanitation Program, (WSP Flagship Report, 2011)

4.3. Estimation of Capex and Opex of Sewerage Pumping

Sewage pumping involves pumps, pumping stations and some miscellaneous material supplies such as valves, inlet and outlet pipes, pipe fittings, etc. Pump capacity is estimated based on (i) total daily sewage flow, (ii) average 12 hour pumping in a day, (iii) pumping head assuming 1 in 80 slope of the trunk sewer and length of the trunk sewer as diagonal of area served by sewerage network assuming shape of town to be a square. Cost of the pumps is estimated based on market survey and information provided by practicing engineers as INR 25,000/KW. Cost of miscellaneous material supplies such as valves, inlet and outlet pipes, pipe fittings, etc. generally varies in the range 1-2% of the pump cost. To have conservative estimates, a value of 2% is assumed in this study. Estimated cost of pumping stations is assumed as 10% of the cost of pumps based on thumb rule generally used by practicing engineers and consulting firms.

Opex cost of sewage pumping is computed based on energy consumption for running the pumps considering prevailing average electricity tariff (INR 6 per KW-h or a unit of electricity consumed). In addition, 1 % of energy bill for running the pumps is considered as other miscellaneous opex for sewage pumping based on thumb rule generally used by practicing engineers and consulting firms.

4.4. Estimation of Capex and Opex of Sewage Treatment Plant

Estimation of cost of sewage treatment has been done considering that the sewage treatment plants will use sewage as source of water and produce water that would be suitable for reuse for many purposes including that for non-human contact domestic activities such as toilet flushing, car/floor washing, air conditioning, other bulk commercial uses, horticulture and gardening, and maintaining surface water bodies for recreation and ground water recharging. Typically the treatment would be done in three stages, namely primary, secondary and tertiary. For cost estimations, most widely used and time tested conventional activated sludge process (ASP) is considered at the secondary level with sludge dewatering adopting filter press or centrifuge instead of sludge drying beds. At the tertiary level, coagulation-flocculation followed by filtration is considered for cost estimation purposes.

Much of the information used for cost estimation is adopted from the report prepared by Consortium of 7 IITs preparing GRBMP (IIT_GRB Report, 2010). However, cost estimates have been revised for the current year i.e. 2013. Relevant information is presented in Table 4.1.

Table 4.01: Details of Information Used in Cost Estimation of Sewage Treatment

Item Number	Item	Value	Range
1.0	**Expected Outlet Parameters after Secondary Treatment**		
1.1	Effluent BOD, mg/L	<20	
1.2	Effluent SS, *mg/L*	<30	
1.3	Faecal coliform removal, *log unit*	2 - 3	
1.4	T-N Removal Efficiency, *%*	10-20	
1.5	Nitrification	> 95 %	
2.0	**Expected Outlet Parameters after Tertiary Treatment**		
2.1	Effluent BOD, *mg/L*	< 10	
2.2	Effluent SS, *mg/L*	< 5	
2.3	Effluent NH_3-N, *mg/L*	< 1	
2.4	Effluent TP, *mg/L*	< 0.5	
2.5	Effluent Total Coliforms, *MPN/100 mL*	10	
3.0	**Capital Cost, Millions of INR/MLD**		
3.1	Total Capital Cost (Secondary + Tertiary)	11	10 - 12.5
3.2	Civil Works, *% of total capital costs*	60	
3.3	E & M Works, *% of total capital costs*	40	

… … … … Table 4.01 Continued to next page

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Item Number	Item	Value	Range
4.0	**Land Requirement, ha/MLD**		
4.1	Average Area, *ha/MLD* *Secondary Treatment + Secondary Sludge Handling*	0.09	
4.2	Average Area, *ha/MLD* *Tertiary Treatment + Tertiary Sludge Handling*	0.01	
4.3	Total Area, *ha/MLD* *Secondary + Tertiary Treatment*	0.10	0.08-0.1
5.0	**Operation and Maintenance Cost, Millions of INR/MLD/Year**		
5.1	**Cost of Energy**		
5.1.1	Avg. Technology Power Requirement, *kWh/d/MLDSecondary Treatment + Secondary Sludge Handling*	200	180 - 220
5.1.2	Avg. Technology Power Requirement, *kWh/d/MLD* *Tertiary Treatment + Tertiary Sludge Handling*	1	
5.1.3	Avg. Non-Technology Power Req., *kWh/d/MLD* *Secondary Treatment*	7	5 - 7.5
5.1.4	Avg. Non-Technology Power Req., *kWh/d /MLD* *Tertiary Treatment*	0.2	
5.1.5	Total Daily Power Requirement (avg.), *kWh/d /MLD*	208.2	
5.1.6	Daily Power Cost (@*Rs.*6.0 per KWh), *INR /MLD/h* *(Including Standby power cost)*	52.05	
5.1.7	Yearly Power Cost, Millions of INR/MLD/Year	4.56	
5.2	**Cost of Repairs**		
5.2.1	Civil Works per Annum, *as % of Civil Works Cost*	3	
5.2.2	E&M Works, *as % of E&M Works Cost*	1	
5.2.3	Civil Works Maintenance, Millions of INR/MLD/Year	0.2	
5.2.4	E & M Works Maintenance, Millions of INR/MLD/Year	0.04	
5.2.5	Annual repairs costs, Millions of INR/MLD/Year	0.24	
5.3	**Cost of Chemicals**		
5.3.1	Total Chemical Cost, Millions of INR/MLD/Year	0.61	
5.4	**Manpower Cost**		
5.4.1	Manager, *Millions of INR. pa* (1 No.)	0.42	
5.4.2	Chemist/Engineer, *Millions of INR pa (1 No.)*	0.42	
5.4.3	Operators, *Millions of INR pa (6@ INR 15000 pm)*	1.08	
5.4.4	Skilled technicians, *Millions of INR pa (6@ INR 12000 pm)*	0.864	
5.4.5	Unskilled personnel, *Millions of INR pa (6@ INR 10000 pm)*	0.72	
5.4.6	Total Salary Costs, Millions of INR/MLD/Year	3.5	
5.4.7	Benefits (50% of total salary), Millions of INR/MLD/Year	1.76	
5.4.8	Salary + Benefits, Millions of INR/MLD/Year	5.26	
5.4.9	Total annual O&M costs, Millions of INR/MLD/Year	1.40	
6.0	**NPV (2013) of Capital + O&M Cost for 30 years, Millions of INR/MLD/Year**	**22.34**	
Total Treatment Cost, INR/KL		**7.90**	

5. Results and Discussion

5.1. General

An appropriate techno-commercial frame work is a prerequisite for sustainable sanitation solutions in urban centers. The first step towards developing such a framework is to have an assessment of provisioning sanitation systems in economic sense. Provisioning of sanitation systems yields certain benefits depending upon the choice of technologies and components, their designs, and efforts and investments made. For example onsite sanitation systems like septic tanks, soak pits, etc. may appear to be low cost, less energy consuming, and simple, but may also pose serious concerns such as pollution of surface and ground waters. On the other hand sewerage system with provision of treating sewage up to tertiary level and using treated sewage for various beneficial uses may be considered very complex and unaffordable. Making a right decision is greatly facilitated if costs and benefits can be assessed.

The present study aims at estimating the per capita expenditure on sewerage system with provision of reuse and recycle of water which can subsequently be compared with other options. It is also important to note that energy consumption and footprint are also important alongwith expenditure incurred and hence are also estimated separately. The study also aims at estimating the financial layout for provisioning sewerage infrastructure in all Class I and Class II towns of the Ganga River Basin (GRB) with the objective of recycling and reuse of sewage alongwith assessment of fresh water savings that could facilitate in management of Environmental Flows (E-Flows) in the rivers.

Sewerage infrastructure includes (i) sewer network, (ii) sewage pumping and (iii) sewage treatment plants. An attempt has been made to arrive at ballpark estimations of capital (Capex) and operation and maintenance (Opex) costs for these three components separately for all Class I and Class II towns in Ganga River Basin (GRB). Following sections describe and discuss the outcome of such an attempt based on the approach and methods described in the previous chapter.

5.2. Sewerage Network

Estimation of costs of sewerage network calls for complete layout including lengths of sewers of various diameters, number and sizes of manholes, ground conditions (type of soil/rock, water table, present usage, etc.), depth of sewers, etc. Gathering such type of information is a humungous task and is generally not available prior to preparation of detailed project report (DPR). Hence, an empirical approach is followed to arrive at ballpark estimates.

5.2.1. Estimation of Sewer Lengths

Data from 45 different Indian urban locations where sewer networks have been laid or designed is gathered from various local bodies, consulting firms and practicing engineers. Based on these data empirical correlations are examined to first estimate the lengths of various diameter sewers as a function of area covered and population served. The outcome of such correlations is presented in Table 5.01 and Figures 5.01 to 5.03.

Table 5.01: Outcome of Empirical Correlations to Estimate Lengths of Various Diameters of Sewers as a Function of Area Covered and Population Served

S No	Diameter of Sewer in mm	Length of Sewer in Km as a Function of Area Covered in km^2 and Population Served in Thousands	Number of Data Points	Coefficient of Correlation, (R)	Value of R for Statistically Significant Correlation at 95 % Confidence Level
01	150	$5.045 * (A^{0.284}) * (P^{0.632})$	45	0.828	0.294
02	200	$4.420 * (A^{0.523}) * (P^{0.485})$	45	0.916	0.294
03	250	$0.116 * (A^{0.533}) * (P^{0.209})$	45	0.743	0.294
04	300	$0.182 * (A^{0.481}) * (P^{0.358})$	45	0.807	0.294
05	350	$0.817 * (A^{0.185}) * (P^{0.336})$	39	0.260	0.316
06	400	$0.167 * (A^{0.426}) * (P^{0.228})$	41	0.554	0.308
07	450	$0.480 * (A^{0.299}) * (P^{0.326})$	44	0.571	0.297
08	500	$0.005 * (A^{0.850}) * (P^{-0.263})$	33	0.755	0.344
09	600	$0.041 * (A^{0.650}) * (P^{0.021})$	42	0.628	0.304
10	700	$0.007 * (A^{0.803}) * (P^{-0.087})$	25	0.742	0.396
11	750	$0.407 * (A^{0.305}) * (P^{0.170})$	33	0.600	0.344
12	800	$0.190 * (A^{0.404}) * (P^{0.141})$	31	0.438	0.355
13	900	$0.012 * (A^{0.809}) * (P^{0.134})$	35	0.666	0.334
14	1000	$0.142 * (A^{0.526}) * (P^{0.530})$	29	0.841	0.367
15	1100	$1.487 * (A^{0.319}) * (P^{0.797})$	33	0.811	0.355
16	1200	$0.636 * (A^{0.201}) * (P^{-0.552})$	11	0.394	0.602
17	1400	$0.456 * (A^{0.386}) * (P^{0.309})$	11	0.721	0.602
18	1600	$0.611 * (A^{0.414}) * (P^{0.416})$	12	0.726	0.576

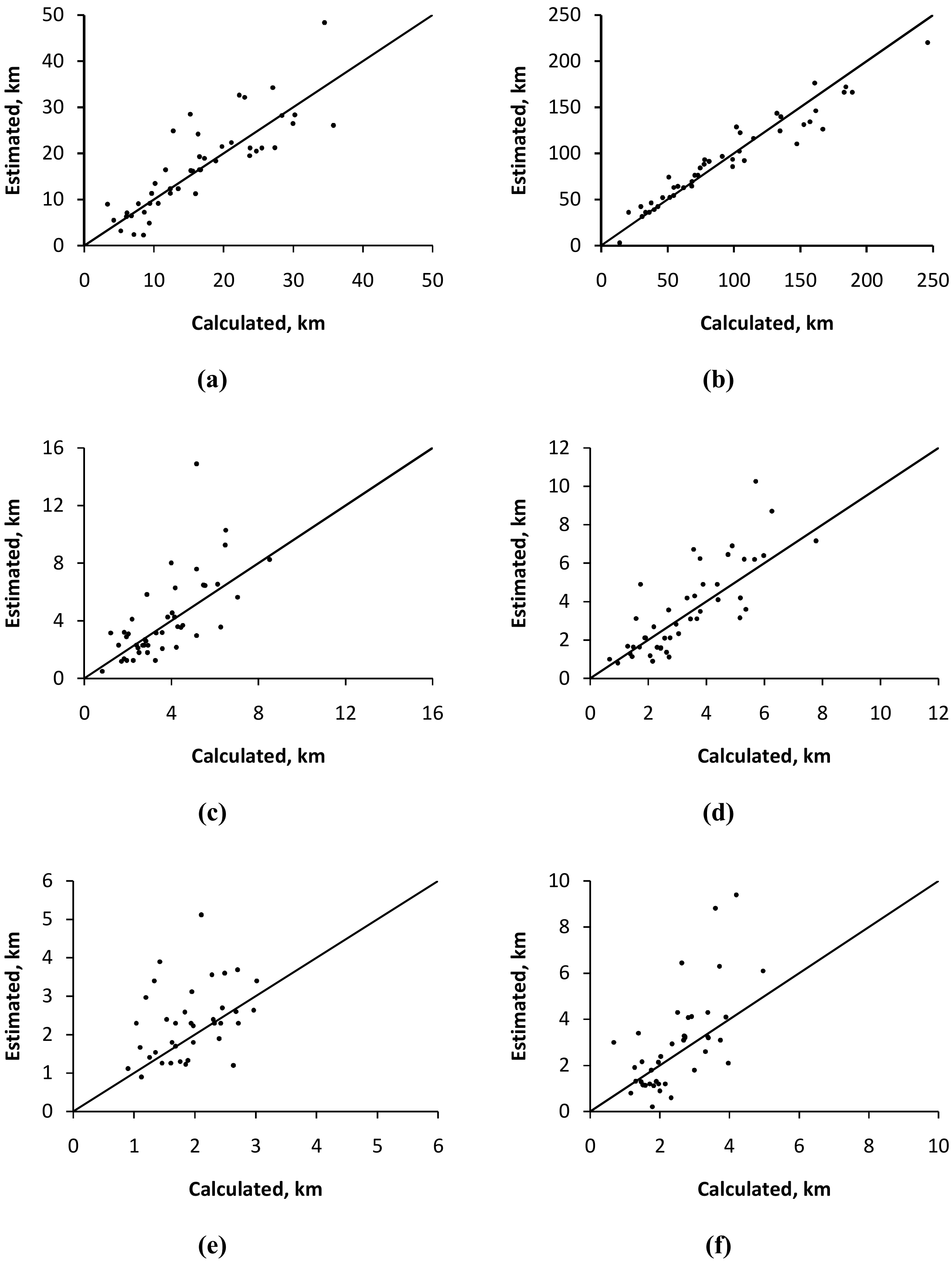

Figure 5.01: Representation of Estimated Versus Calculated Lengths of (a) 150, (b) 200, (c) 250, (d) 300, (e) 350, and (f) 400 mm Diameter Sewers

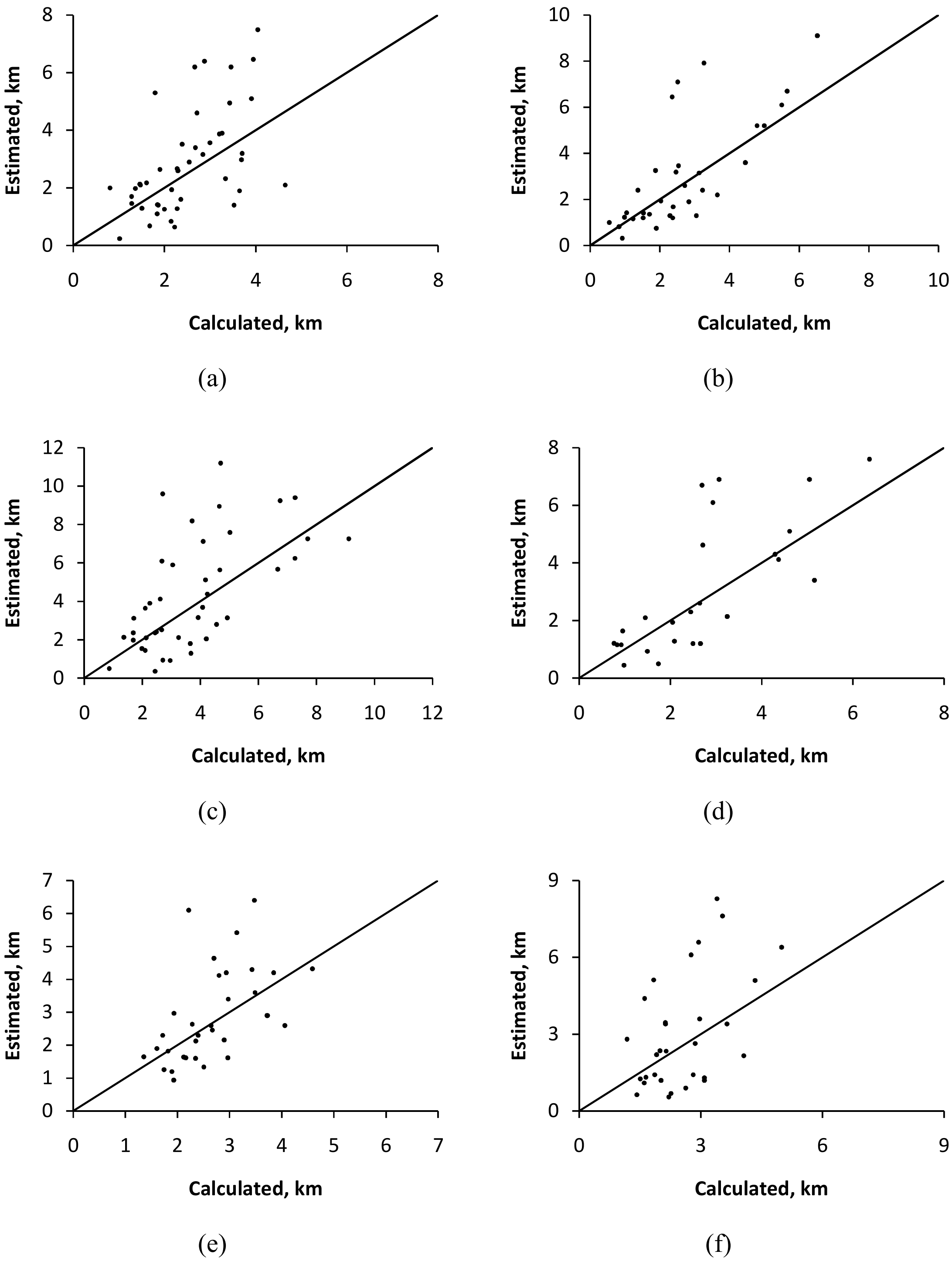

Figure 5.02: Representation of Estimated Versus Calculated Lengths of (a) 450, (b) 500, (c) 650, (d) 700, (e) 750, and (f) 800 mm Diameter Sewers

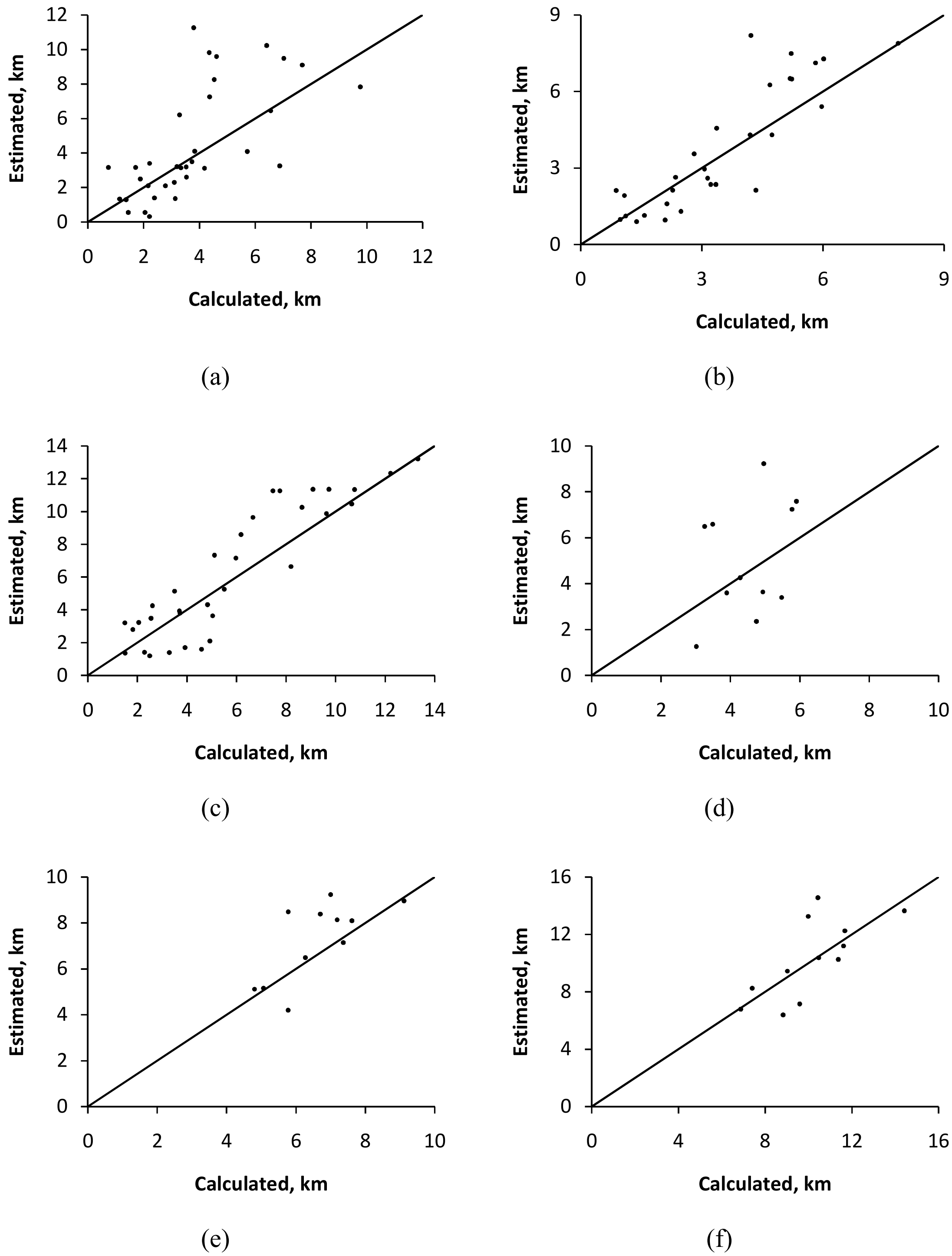

Figure 5.03: Representation of Estimated Versus Calculated Lengths of (a) 900, (b) 1000, (c) 1100, (d) 1200, (e) 1400, and (f) 1600 mm Diameter Sewers

Except for 300 and 1200 mm diameter pipes, the relationships developed are statistically significant at 95 % confidence level. The correlations developed are considered acceptable for arriving at ballpark estimations of lengths of laterals and branch sewers not more than

750 mm diameter. For main or trunk sewers length could be approximately taken as diagonal of the town assuming town area to be square shape. The trunk sewer is designed for (i) total sewage generated from a town, (ii) maximum depth of flow as 3/4th of diameter of sewer, (iii) slope of 1 in 1000, (iv) Manning's Coefficient as 0.01 for HDPE pipe, (v) infiltration at 10 % and (vi) peak factor 2.25 as per CPHEEO Manual (CPHEEO, 2013). Branch sewers are considered to be of maximum 750 mm diameter or one available size lower than the size of the trunk sewer, whichever is lower. Population of Cass I and Class II towns has been taken from Census 2011 data. Water supply rate is taken as 135 lpd (CPHEEO, 2013) and sewage generation is assumed to be 80 % of water supply. Information on area of towns is obtained from local bodies and/or information available on internet such as Google earth. With the information given here and empirical equations reported in Table 5.01, lengths of various diameter pipes were calculated for Class I and Class II towns of GRB to arrive at ballpark estimates of total length of sewerage network. Information on population, area, estimated total length of sewers, percentage distribution of various size of primary, lateral, branch sewers, and trunk sewers is presented state wise for Class I and Class II towns of GRB in Appendix I (Tables A1.01 to A1.22).

A comparison of the estimated percentage distribution of lengths of various diameter sewers for a typical Class I town whose actual data was available is presented in Figure 5.04. Results suggest that the estimated and actual distribution match reasonably well for the purpose of arriving at ballpark estimates.

The correlations could be substantially improved if actual data on road lengths is also made available so that lengths of sewers are considered as function of road length and population density. It is to be noted that this approach is not to be used for obtaining actual lengths of sewers in a town.

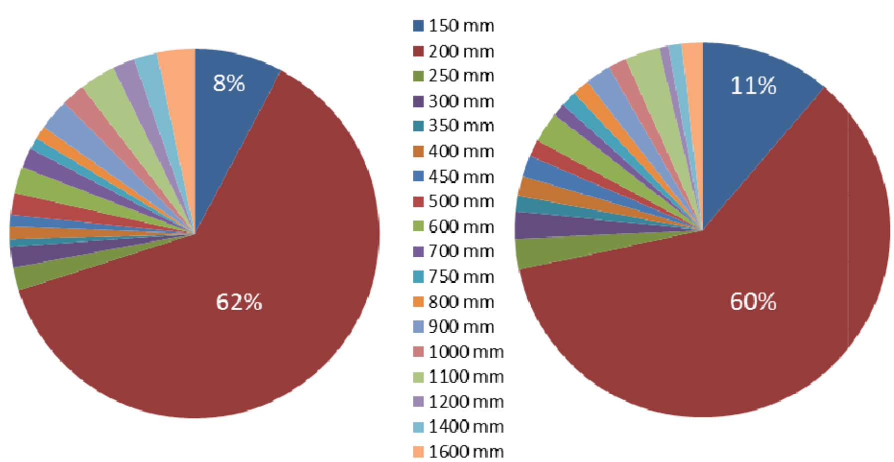

Figure 5.04: Comparison of the Estimated and Actual Percentage Distribution of Lengths of Various Diameter Sewers for a Typical Class I Town

5.2.2. Estimation of Costs

Sewerage network costs have been estimated by multiplying the weighted average (based on percentage distribution of various diameter sewers shown in Figure 5.04) unit cost per meter length of sewer laid (including all items in BOQs) multiplied by the total length of sewer network estimated as given in previous section. The details of typical estimated unit costs for various diameter sewers as per BOQ are presented in Table 5.02 and Figures 5.05.

The estimated weighted average unit cost varies from INR 4,000 to 5,000 per meter of the sewer length for various towns. This is the cost of laying the fresh sewer lines with minimal hindrances as it includes only, the supply of materials, barricading the area, timbering in trenches, excavation of earth, laying, jointing of sewer lines, surface relaying, costs of manholes, labors, dewatering etc. Typical breakup of average unit costs as per BOQ amongst major components is presented in Figure 5.06. However, considering low to moderate and moderate levels of hindrances in Class I and Class II towns average unit costs are considered to be INR 7000 and INR 6000 per m length of sewers respectively for estimating the expenditure on sewerage network in GRB based on discussions with practicing engineers and representatives of several consulting firms involved in turnkey projects on sewerage systems such as Tata Consulting Engineers, AECOM, etc.

Table 5.02: Typical Estimated Percentage Contributions of Various Items in Unit Cost of Laying Sewers of Different Diameters

Item	Sewer Diameter, mm												
	150	200	250	300	350	400	450	500	600	700	750	>750	Weighted Average
MS	5.3	4.9	4.5	4.0	3.2	2.9	2.5	2.1	1.6	1.3	1.1	0.6	3.2
Excavation	2.2	4.0	6.5	9.0	10.9	15.5	19.3	23.9	29.2	34.0	36.7	47.7	19.1
Timbering	23.5	24.3	25.2	24.4	21.8	21.5	19.4	18.0	15.3	13.1	12.3	9.0	19.0
Pipe Cost	7.1	8.2	8.5	11.0	19.5	19.3	18.6	16.8	18.5	17.6	17.3	20.4	13.2
Laying	3.6	4.9	4.5	6.6	7.5	6.8	7.4	7.0	5.8	5.5	5.3	6.1	5.4
Sand filling	0.6	0.5	0.5	0.4	0.3	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0.3
Dewatering	2.3	2.1	1.9	1.7	1.4	1.3	1.0	0.9	0.7	0.5	0.5	0.3	1.4
CW	2.1	2.6	3.0	3.2	3.0	3.1	2.9	2.8	2.5	2.4	2.3	1.6	2.4
Manholes	53.3	48.6	45.3	39.7	32.3	29.3	28.6	28.2	26.3	25.4	24.5	14.3	36.0

MS: Material Supply; CW: Concrete Work

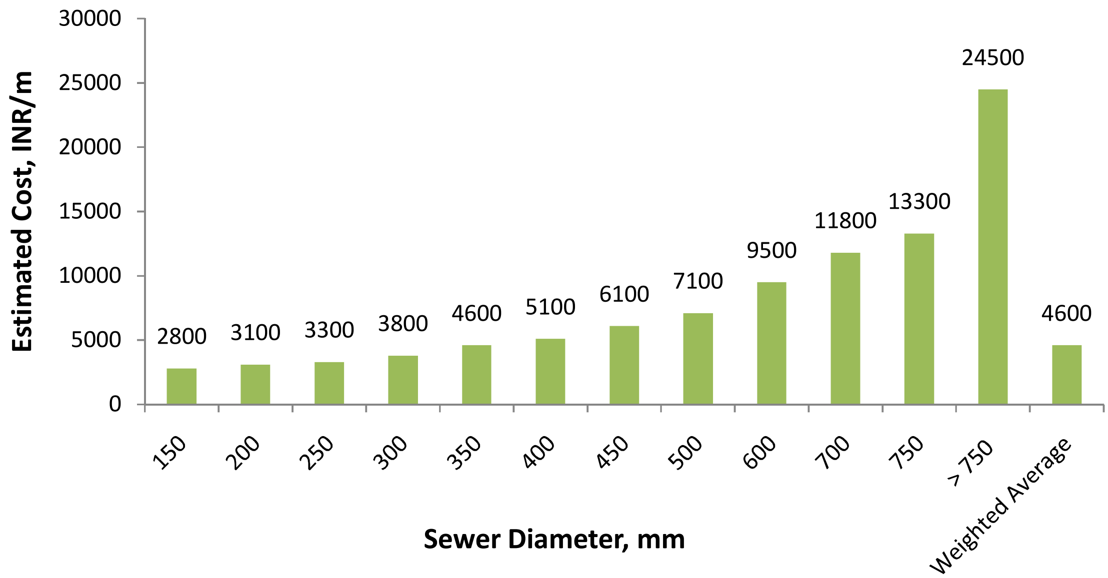

Figure 5.05: Typical Variation in Unit Cost of Laying Sewer of Various Diameters

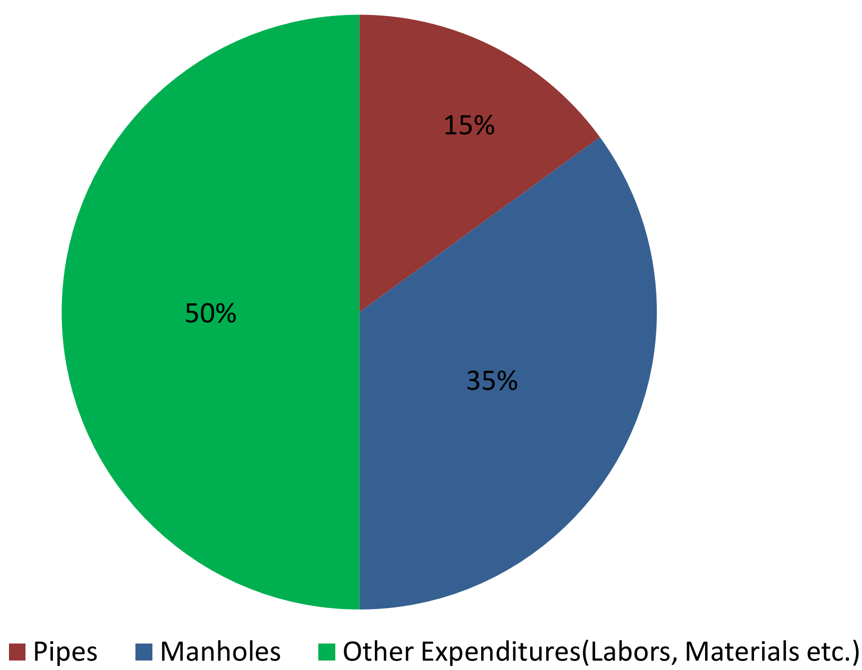

Figure 5.06: Typical Break up of Capital Expenditure (Capex) on Sewerage Network

5.3. Sewage Pumping

A typical pattern of distribution of estimated expenditure on sewage pumping adopting the methodology described in Section 4.3 is presented in Figures 5.07 to 5.09.

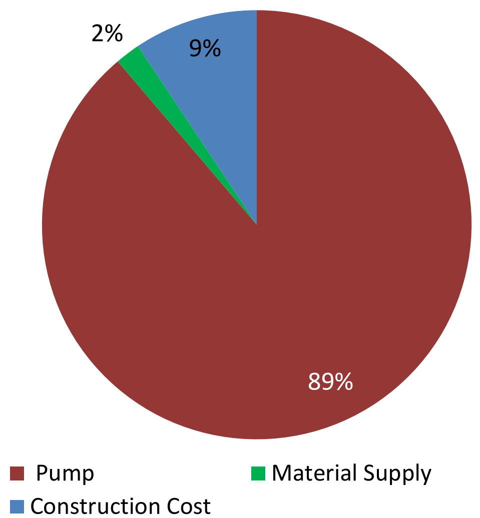

Figure 5.07: Typical Breakup of Estimated Capital Expenditure on Sewage Pumping Stations

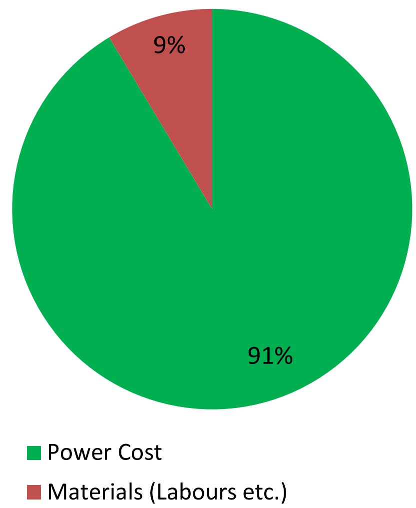

Figure 5.08: Typical Breakup of Operation and Maintenance Expenditure on Sewage Pumping Stations

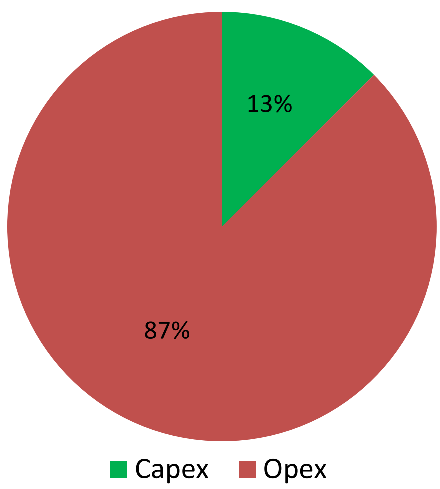

Figure 5.09: Typical Distribution of Estimated Annualized Capital (Capex) and Operation and Maintenance (Opex) Expenditure on Sewage Pumping

It may be noted that in sewage pumping the major expenditure is on Operation and Maintenance (almost 85 – 90 %) in which 90 % is on energy consumption. In the capital expenditure, the major expenditure (almost 85 – 90 %) is on procurement of pumps.

5.4. Sewage Treatment

The cost of treating sewage is estimated with the consideration that sewage would be converted into water that could be recommended for use for all domestic, commercial, industrial, horticultural and agricultural purposes except for direct human contact such as drinking, bathing, etc. This is based on the extensive studies conducted by Consortium of 7 IITs for preparing Ganga River Basin Management Plan (GRBMP). For ballpark estimates of such kind of treatment a standard chain of treatment processes involving activated sludge process at the secondary level and coagulation-flocculation followed by rapid sand filtration and disinfection using chlorination at the tertiary level is considered. It is to be noted that this does not imply that other equivalent treatment processes are not acceptable. It is to arrive at most reasonable and conservative estimates for planning processes that such a treatment chain is considered in this study.

The capital investment (Capex) and annual operation and maintenance expenditure (Opex) for such treatment has been worked out as INR 11 and 1.4 million per MLD respectively (refer Section 4.4). Considering 30 year of operation and maintenance (Opex) cost and discounting at 12% per year, a typical net present value (NPV) of expenditure on sewage treatment is estimated at INR 22.34 million/MLD. A typical breakup of capex and opex on sewage treatment is presented in Figure 5.10.

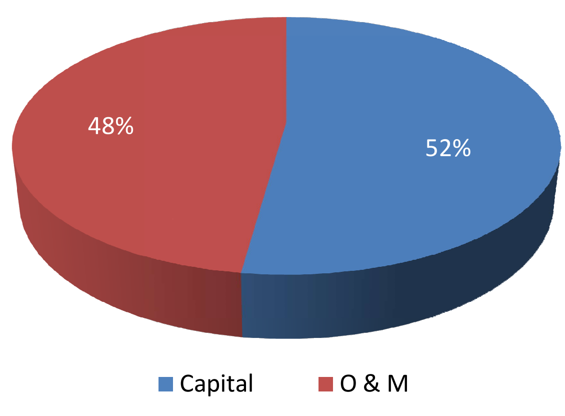

Figure 5.10: Typical Breakup of Capital (Capex) and Operation and Maintenance (Opex) Expenditure on Sewage Treatment

5.5. Sewerage System

The entire sewerage system costs can be arrived at by adding the cost of its three components, namely sewerage network, sewage pumping and sewage treatment. The results are presented in Figures 5.11 and 5.12.

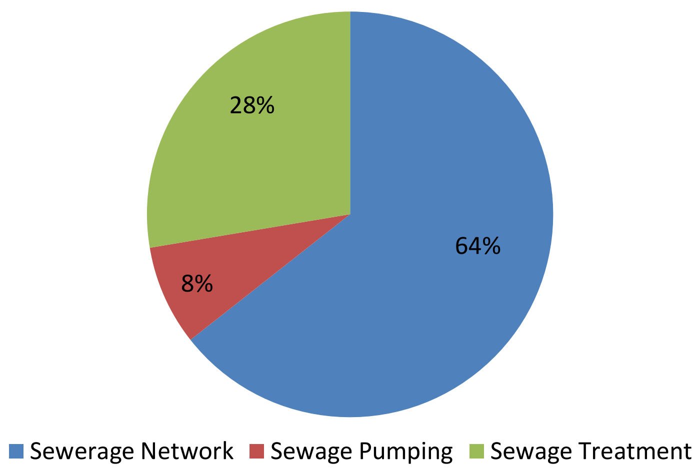

Figure 5.11: Typical Breakup of Estimated Total Annual Expenditure Amongst Three Components of Sewerage Systems

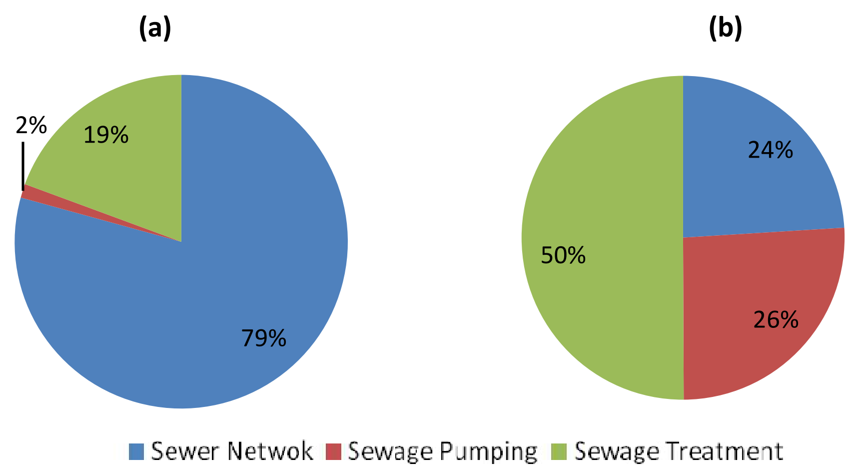

Figure 5.12: Typical Breakup of Estimated (a) Capex and (b) Opex Expenditure Amongst Three Components of Sewerage Systems

It is important to note that major share (64%) of the total annual expenditure is incurred on sewerage network, which is unavoidable if water flush toilets are used and onsite treatment of sewage is not possible. This is generally the case in most urban agglomerations. These costs could be substantially reduced if several small sewerage networks are planned as this would effectively reduce the total area covered while serving the same population as sewerage network cost increases at a much higher rate with increase in coverage area than the increase in population. This can be inferred from the empirical relations developed for estimating lengths of different diameter sewers (refer Table 5.01). For higher diameter sewers, exponent of area is much higher than that for population, and hence contribution of higher diameter sewers to the sewerage network costs increases. This supports the case of decentralized sewerage systems.

Analysis of opex expenditure on sewerage systems (Figure 5.12 b) reveals that 26 % of the expenditure is incurred on pumping sewage, which again can be substantially reduced if the area covered is reduced. It is important to note that out of the 26 % opex expenditure on sewage pumping approximately 91 % is on energy which increases the carbon footprint. It is also important to note that out of total annual energy consumption on sewerage system, major portion (56 %) is on sewage pumping (Figure 5.13). While energy consumption on sewage pumping can be reduced by adopting decentralized sewerage network, energy consumption on sewage treatment is unlikely to change.

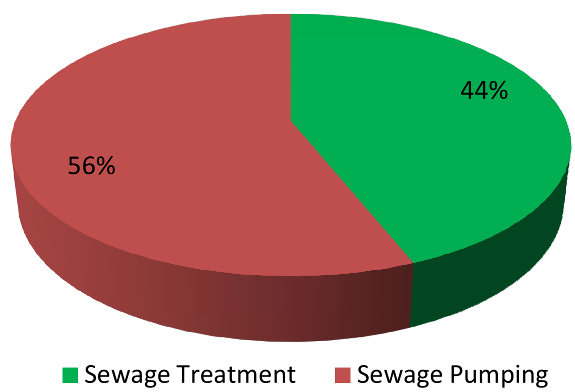

Figure 5.13: Typical Distribution of Energy Consumption between Sewage Treatment and Sewage Pumping in Centralized Sewerage Systems

5.6. Estimated Cost of Provisioning Sewerage Systems in Major Urban Agglomerations in Ganga River Basin

Based on (i) the methodology developed and results reported in the preceding sections of this chapter, and (ii) the information collated for urban agglomerations in Ganga River Basin (GRB) an attempt has been made to arrive at ballpark estimates of expenditure on provisioning sewerage infrastructure. Significant urban agglomerations are considered as Class I and Class II towns defined on the basis of population (Class I Towns: Population ≥ 100,000; Class II Towns: Population exceeding 50,000 and less than 100,000). Tables A2.01 to A2.22 in Appendix II present (i) population as per Indian Census 2011, (ii) estimated sewage generation as per CPHEEO guidelines (CPHEEO Manual, 2013), (iii) approximate town area, (iv) estimated total length of sewerage network, (v) capital expenditure on all three components of sewerage system, and (vi) the total estimated capital expenditure on provisioning complete sewerage infrastructure for all Class I and Class II towns of GRB spread over 11 different Indian states. A summary of the total ballpark estimates of capital expenditures on provisioning sewerage infrastructure for Class I and Class II towns of each of the GRB states is presented in Tables 5.03 to 5.05 based on information given in aforementioned tables of Appendix II. Provisioning of toilets and connection to the sewerage network are excluded from these estimates as these are considered as part of housing infrastructure.

For each Class I and Class II towns of GRB, annual expenditure on the capital investment (Capex) for all three components of sewerage systems has been worked out by multiplying capital expenditure with capital recovery factor (CRF). The CRF has been calculated as 0.147 using 12 % interest over 15 years period. Operation and Maintenance (Opex) has also been estimated for each of these towns for all three components separately using methodology presented in Chapter 4 and results described in previous section of this chapter. Results are presented in Tables A3.01 to A3.22 of Appendix III. These tables also include (i) ballpark estimates of total annual expenditure to recover capital investment on entire sewerage system within 15 years, (ii) footprint for sewage treatment, (iii) energy consumption, (iv)per capita energy consumption, and (v) estimates of expenditure per person per day for availing centralized sanitation facility. A summary of these results for each of the GRB states is presented in Tables 5.06to 5.08 for Class I and Class II towns.

Estimates given in the aforementioned tables can serve as significant inputs in preparing Ganga River Basin Management Plan (GRBMP) and formulating strategy for water supply and sanitation in Class I and Class II towns of GRB. The figures of annual investments on provisioning sewerage systems reported in Tables 5.03 to 5.08 may appear to be very high, and the general perception is that such systems require huge land, consume large amount of energy and are very expansive and unaffordable for people in the developing countries like India. Based on this perception other sanitation systems such as septic tanks, soak pits, decentralized wastewater systems using Anaerobic Baffled Reactors followed by root zone treatment, bioremediation techniques, etc. are being advocated. These are perceived to be low energy consuming and low cost technologies. In order to get more clarity and facilitate in making rational decision than taking decisions based on perceptions, estimates on (i) footprint for sewage treatment, (ii) energy consumption, and (iii) per capita daily expenditure on availing the benefits of sewerage infrastructure have been worked out. Footprint for sewerage networks has been excluded as they are underground and do not require separate space. Footprint for sewage pumping is much smaller and negligible compared to the footprint for sewage treatment.

Table 5.03: Estimated Capital Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Millions) of NRGB

S No	State	Population in Millions	Estimated Sewage Generation, MLD	Estimated Capital Expenditure, Millions of INR			Estimated Total Capital Expenditure, Millions of INR
				Sewerage Network	Sewage Pumping	Sewage Treatment	
01	Uttarakhand	2.121	229.1	9038.3	92.2	2519.9	**11650.4**
02	Uttar Pradesh	29.613	3198.3	146248.7	2494.2	35181.1	**183924.0**
03	Himachal Pradesh	**No Class I town**					
04	Haryana	5.317	574.2	33802.0	384.3	6316.7	**40503.0**
05	Delhi	13.482	1456.1	42641.2	2052.9	16016.7	**60710.8**
06	Rajasthan	7.689	830.4	60368.8	1010.2	9134.6	**70513.6**
07	Madhya Pradesh	11.934	1288.8	72775.7	1051.0	14177.5	**88004.2**
08	Bihar	6.929	748.3	35890.0	364.0	8231.2	**44485.2**
09	Chhattisgarh	3.138	338.9	24319.2	265.2	3727.9	**28312.3**
10	Jharkhand	4.801	518.5	28133.4	321.2	5703.8	**34158.4**
11	West Bengal	17.124	1849.4	83049.3	1046.8	20342.9	**104439.0**
Total		**102.148**	**11032.0**	**536266.6**	**9082.0**	**121352.3**	**666700.9**

Table 5.04: Estimated Capital Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of NRGB

S No	State	Population in Millions	Estimated Sewage Generation, MLD	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
				Sewerage Network	Sewage Pumping	Sewage Treatment	
01	Uttarakhand	0.212	22.9	1354.1	4.9	252.4	**1611.4**
02	Uttar Pradesh	3.109	335.8	17549.0	79.0	3693.2	**21321.2**
03	Himachal Pradesh	**No Class II towns**					
04	Haryana	0.164	17.7	963.5	3.7	194.3	**1161.5**
05	Delhi	0.862	93.1	2850.2	11.7	1023.7	**3885.6**
06	Rajasthan	0.287	31.0	2640.3	11.9	340.8	**2993.0**
07	Madhya Pradesh	0.654	70.6	4481.4	19.2	777.0	**5277.6**
08	Bihar	1.462	157.9	9834.4	41.0	1736.6	**11612.0**
09	Chhattisgarh	0.448	48.4	6150.8	28.0	532.0	**6710.8**
10	Jharkhand	1.236	133.5	9482.3	42.8	1468.1	**10993.2**
11	West Bengal	1.000	108.0	7523.6	31.7	1188.1	**8743.4**
Total		**9.433**	**1018.9**	**62829.6**	**273.9**	**11206.2**	**74309.7**

Table 5.05: Estimated Capital Expenditure on Sewerage Infrastructure in Class I (Population > 0.1 Millions) and Class II (Population between 0.05 and 0.1 Million) Towns of NRGB

S No	State	Population in Millions	Estimated Sewage Generation, MLD	Estimated Capital Expenditure, Millions of INR			Estimated Total Capital Expenditure, Millions of INR
				Sewerage Network	Sewage Pumping	Sewage Treatment	
01	Uttarakhand	2.333	252.0	10392.4	97.1	2772.3	**13261.8**
02	Uttar Pradesh	32.722	3534.1	163797.7	2573.2	38874.3	**205245.2**
03	Himachal Pradesh	**No Class I or II towns**					
04	Haryana	5.481	591.9	34765.5	388.0	6511.0	**41664.5**
05	Delhi	14.344	1549.2	45491.4	2064.6	17040.4	**64596.4**
06	Rajasthan	7.976	861.4	63009.1	1022.1	9475.4	**73506.6**
07	Madhya Pradesh	12.588	1359.4	77257.1	1070.2	14954.5	**93281.8**
08	Bihar	8.391	906.2	45724.4	405.0	9967.8	**56097.2**
09	Chhattisgarh	3.586	387.3	30470.0	293.2	4259.9	**35023.1**
10	Jharkhand	6.037	652.0	37615.7	364.0	7171.9	**45151.6**
11	West Bengal	18.124	1957.4	90572.9	1078.5	21531.0	**113182.4**
Total		**111.582**	**12050.9**	**599096.2**	**9355.9**	**132558.5**	**741010.6**

Table 5.06: Estimated Annual Capital (Capex) and Operation and Maintenance (Opex) Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Millions) of NRGB

S No	State	Population in Millions	Estimated Sewage Generation, MLD	Estimated Annual Expenditure, Millions of INR						Estimated Total Annual Expenditure, Millions of INR
				Sewerage Network		Sewage Pumping		Sewage Treatment		
				Capex	Opex	Capex	Opex	Capex	Opex	
01	Uttarakhand	2.121	229.1	1328.6	135.6	13.6	86.5	370.4	322.5	**2257.2**
02	Uttar Pradesh	29.613	3198.3	21498.6	2193.7	366.7	2341.2	5171.6	4503.1	**36074.9**
03	Himachal Pradesh	**No Class I town**								
04	Haryana	5.317	574.2	4968.9	507.0	56.5	360.8	928.5	808.5	**7630.2**
05	Delhi	13.482	1456.1	6268.3	639.6	301.8	1926.8	2354.4	2050.1	**13541**
06	Rajasthan	7.689	830.4	8874.2	905.5	148.5	948.0	1342.8	1169.2	**13388.2**
07	Madhya Pradesh	11.934	1288.8	10698.0	1091.6	154.5	986.6	2084.1	1814.7	**16829.5**
08	Bihar	6.929	748.3	5275.8	538.3	53.5	341.7	1210.0	1053.6	**8472.9**
09	Chhattisgarh	3.138	338.9	3574.9	364.8	39.0	248.9	548.0	477.2	**5252.8**
10	Jharkhand	4.801	518.5	4135.6	422.0	47.2	301.4	838.5	730.1	**6474.8**
11	West Bengal	17.124	1849.4	12208.2	1245.7	153.9	982.4	2990.4	2603.9	**20184.5**
Total		**102.148**	**11032.0**	**78831.3**	**8044.0**	**1335.2**	**8524.3**	**17838.7**	**15532.9**	**130106.0**

Table 5.07: Estimated Annual Capital (Capex) and Operation and Maintenance (Opex) Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of NRGB

S No	State	Population in Millions	Estimated Sewage Generation, MLD	Estimated Annual Expenditure, Millions of INR						Estimated Total Annual Expenditure, Millions of INR
				Sewerage Network		Sewage Pumping		Sewage Treatment		
				Capex	Opex	Capex	Opex	Capex	Opex	
01	Uttarakhand	0.212	22.9	199.1	20.3	0.7	4.7	37.1	32.3	**294.2**
02	Uttar Pradesh	3.109	335.8	2579.7	263.2	11.7	74.4	542.9	472.7	**3944.6**
03	Himachal Pradesh	**No Class II town**								
04	Haryana	0.164	17.7	141.6	14.5	0.5	3.5	28.6	24.9	**213.6**
05	Delhi	0.862	93.1	419.0	42.8	1.7	10.9	150.5	131.0	**755.9**
06	Rajasthan	0.287	31.0	388.1	39.6	1.7	11.1	50.1	43.6	**534.2**
07	Madhya Pradesh	0.654	70.6	658.8	67.2	2.8	18.1	114.2	99.4	**960.5**
08	Bihar	1.462	157.9	1445.7	147.5	6.1	38.6	255.3	222.3	**2115.5**
09	Chhattisgarh	0.448	48.4	904.2	92.3	4.1	26.3	78.2	68.1	**1173.2**
10	Jharkhand	1.236	133.5	1393.9	142.2	6.3	40.2	215.8	187.9	**1986.3**
11	West Bengal	1.000	108.0	1106.0	112.9	4.7	29.9	174.6	152.1	**1580.2**
Total		**9.433**	**1018.9**	**9236.1**	**942.5**	**40.3**	**257.7**	**1647.3**	**1434.3**	**13558.2**

Table 5.08: Estimated Annual Expenditure on Sewerage Infrastructure in Class I (Population > 0.1 Millions) and Class II (Population between 0.05 and 0.1 Million) Towns of NRGB

S No	State	Population in Millions	Estimated Sewage Generation, MLD	Estimated Annual Expenditure, Millions of INR							
				Sewerage Network		Sewage Pumping		Sewage Treatment		Total	
				Capex	Opex	Capex	Opex	Capex	Opex	Capex	Opex
01	Uttarakhand	1223.2	136.5	1527.7	155.9	14.3	91.2	407.5	354.8	1949.5	601.9
02	Uttar Pradesh	19206.5	2143.5	24078.3	2456.9	378.4	2415.6	5714.5	4975.8	30171.2	9848.3
03	Himachal Pradesh	**No Class I or II town**									
04	Haryana	5.481	570.0	5110.5	521.5	57	364.3	957.1	833.4	**6124.6**	**1719.2**
05	Delhi	14.344	1491.7	6687.3	682.4	303.5	1937.7	2504.9	2181.1	**9495.7**	**4801.2**
06	Rajasthan	7.976	829.5	9262.3	945.1	150.2	959.1	1392.9	1212.8	**10805.4**	**3117**
07	Madhya Pradesh	12.588	1309.1	11356.8	1158.8	157.3	1004.7	2198.3	1914.1	**13712.4**	**4077.6**
08	Bihar	8.391	872.6	6721.5	685.8	59.6	380.3	1465.3	1275.9	**8246.4**	**2342**
09	Chhattisgarh	3.586	372.9	4479.1	457.1	43.1	275.2	626.2	545.3	**5148.4**	**1277.6**
10	Jharkhand	6.037	627.8	5529.5	564.2	53.5	341.6	1054.3	918	**6637.3**	**1823.8**
11	West Bengal	18.124	1884.9	13314.2	1358.6	158.6	1012.3	3165	2756	**16637.8**	**5126.9**
Total		**111.582**	**11604.3**	**88067.2**	**8986.3**	**1375.5**	**8782**	**19486**	**16967.2**	**108928.7**	**34735.5**

However, energy consumption for both sewage pumping and sewage treatment has been considered. Estimated per capita footprint, daily energy consumption and daily expenditure on availing the sewerage infrastructure for each of the Class I and Class II towns in GRB are included in the tables given in Appendix III. Tables 5.09 and 5.10 present summary of such results for all Class I and Class II towns belonging to eleven different Indian states, and are part of the GRB.

It is interesting to note that footprint for sewage treatment is approximately 0.1 m^2 per person which is one tenth of the size of the toilet. The energy consumption in sewage pumping and treatment ranges from 0.03 to 0.1 KW-h which is equivalent to lighting 30 to 100 watt bulb for 1 h. The total per capita expenditure in availing sewerage infrastructure is estimated to be in the range INR 1.8 to 10.8 with an average of INR 3.93 and standard deviation 1.4. The higher values correspond to towns with very low population density and the lower values correspond to very high population densities. The sewerage network and sewage pumping cost increase with decrease in population density. In cases where habitations are separated by major roads, streams, water bodies, parks, playgrounds, open fields, large commercial establishments, etc., it may be much meaningful to plan for decentralized sewerage treatment systems by dividing the town into number of zones with separate sewerage system for each zone. This may reduce both energy consumption and total per capita expenditure. It is interesting to note from some of the recent studies (Luthra, 2013) that expenditure on some of the perceived to be low cost alternative sanitation systems are also in the same range with much lower quality and substantial adverse impacts on environment.

5.7. Benefits of Provisioning Sewerage Systems

Provisioning of sewerage systems has many tangible and intangible benefits. The intangible benefits include aesthetically improved towns, much less exposure to infectious diseases thereby substantial savings in expenditure on health, less suffering and higher quality time available for meaningful activities, etc. Some of the tangible benefits include unpolluted water bodies, more water of better quality available for many functions including ecological. Here, an attempt has been made to quantify availability of good quality water through treatment of sewage up to tertiary level and compare it with present day dry weather flows (November through May) at some select locations on some select rivers in the Ganga Basin. Select locations are some of the flow monitoring sites of the Central Water Commission (CWC), Ministry of Water Resources (MoWR), GoI. The sites are shown on the map of Indian part of GRB (Figure 5.13).

Table 5.09: Estimated Footprint, Energy Consumption and Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Millions) of NRGB

S No	State	Number of Class I Towns	Population in Millions	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
						Energy Consumption in GWH	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWH (Unit of Electricity)	Expenditure in INR
01	Uttarakhand	8	2.121	0.1	51.0	0.087	2257.3	0.03-0.05	2.2-4.4
02	Uttar Pradesh	62	29.613	0.1	755.0	1.735	36074.9	0.03-0.09	2.3-5.5
03	Himachal Pradesh	**No Class I town**							
04	Haryana	16	5.317	0.1	133.3	0.284	7630.2	0.03-0.08	2.5-5.8
05	Delhi	15	13.482	0.1	376.5	1.183	13541.0	0.03-0.10	1.8-6.2
06	Rajasthan	19	7.689	0.1	209.0	0.606	13388.3	0.04-0.11	3.2-8.0
07	Madhya Pradesh	27	11.934	0.1	305.9	0.719	16829.5	0.03-0.09	1.8-10.8
08	Bihar	28	6.929	0.1	168.8	0.312	8473.0	0.03-0.06	2.5-5.5
09	Chhattisgarh	9	3.138	0.1	80.0	0.184	5252.7	0.03-0.08	3.3-7.3
10	Jharkhand	15	4.801	0.1	119.4	0.246	6474.8	0.03-0.07	2.0-6.5
11	West Bengal	62	17.124	0.1	422.4	0.834	20184.6	0.03-0.07	1.3-7.2
Total/Range		**261**	**102.148**		**2621.3**	**6.190**	**130106.3**	**0.03-0.11**	**1.3-10.8**

Table 5.10: Estimated Footprint, Energy Consumption and Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of NRGB

S No	State	Number of Class II Towns	Population in Millions	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
						Energy Consumption in GWH	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWH (Unit of Electricity)	Expenditure in INR
01	Uttarakhand	4	0.212	0.1	5.0	0.007	294.2	0.03-0.04	2.2-6.6
02	Uttar Pradesh	43	3.109	0.1	72.7	0.104	3944.7	0.03-0.05	1.8-8.6
03	Himachal Pradesh	**No Class II town**							
04	Haryana	3	0.164	0.1	3.8	0.005	213.6	0.03-0.03	3.3-3.9
05	Delhi	14	0.862	0.1	19.8	0.024	755.9	0.03-0.04	1.8-4.5
06	Rajasthan	4	0.287	0.1	6.9	0.011	534.3	0.04-0.04	4.2-5.9
07	Madhya Pradesh	10	0.654	0.1	15.4	0.023	960.6	0.03-0.04	2.9-5.2
08	Bihar	23	1.462	0.1	34.3	0.051	2115.5	0.03-0.04	2.6-6.6
09	Chhattisgarh	6	0.448	0.1	11.1	0.022	1173.1	0.04-0.07	4.8-10.7
10	Jharkhand	17	1.236	0.1	29.3	0.046	1986.3	0.03-0.05	2.8-7.0
11	West Bengal	15	1.000	0.1	23.6	0.036	1580.2	0.03-0.04	2.7-6.4
	Total/Range	**139**	**9.433**		**221.9**	**0.329**	**13558.4**	**0.03-0.07**	**1.8-10.7**

The map also shows some Class I and Class II towns immediate upstream of the monitoring sites whose treated or untreated sewage, directly or indirectly, likely to contribute to the river flows. Comparison of the ninety percent dependable dry weather flows with the treated water available from sewage of the Class I and Class II towns located immediately upstream of the selected CWC monitoring sites is presented in Table 5.11.

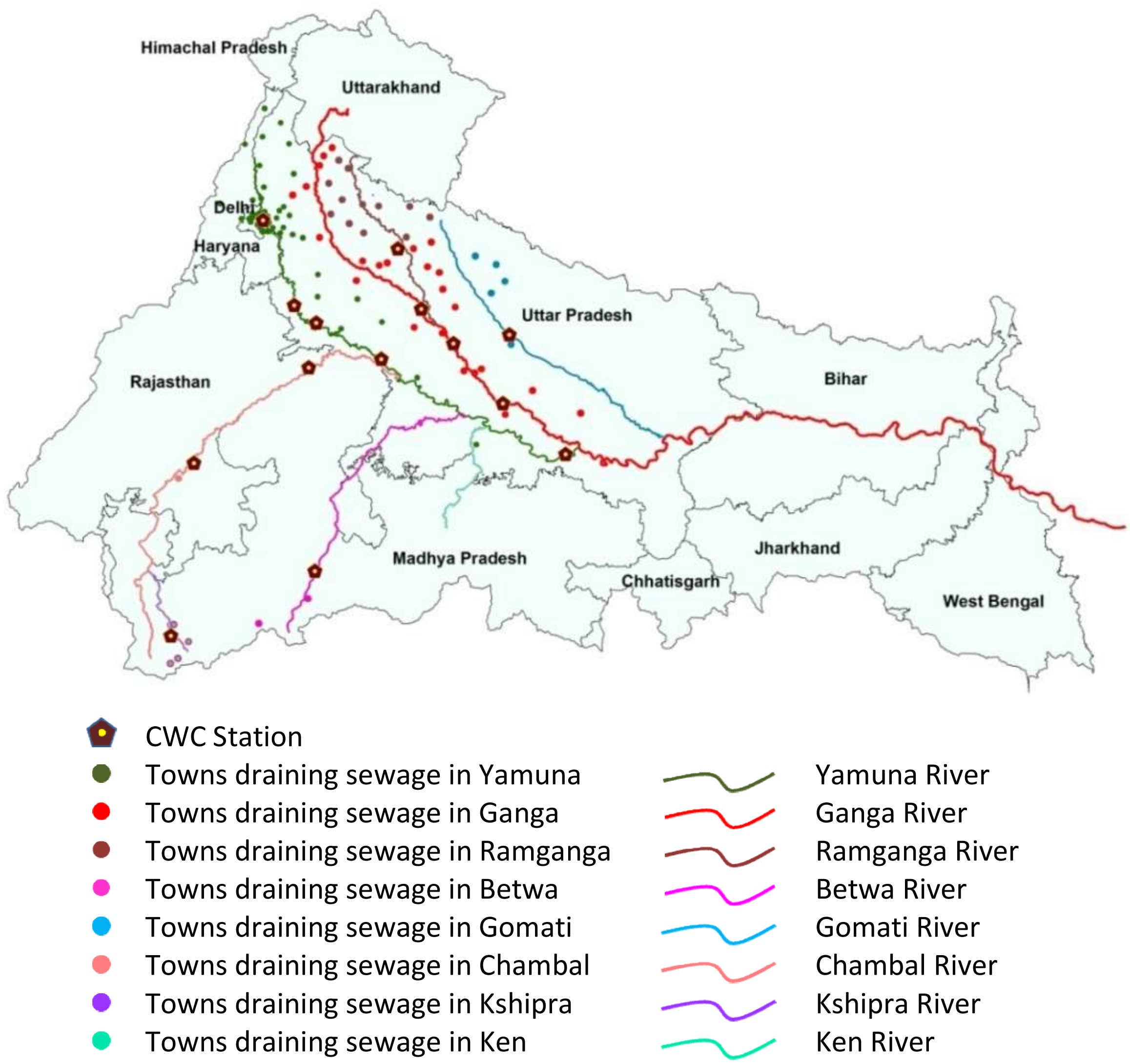

Figure 5.13: Schematic Representation of GRB showing a Few Rivers of the Basin, and Class I and Class II Towns in the Immediate Upstream of Selected Flow Measuring Sites of CWC

Table 5.11: Comparison of Dry Weather Flow with Estimated Available Water from Treated Sewage at Select Locations in Ganga River Basin

River	CWC Monitoring Station			Nearby Town	Dry Weather (November 1 – May 31) 90 % Dependable Flow, m^3/s	Estimated Available Water from Treated Sewage, m^3/s	Percent of Dry Weather Flow, %	Group of Class I and Class II Towns Immediate Upstream of the Monitoring Station
	Name	Latitude, N	Longitude, E					
Yamuna	Delhi Railway Bridge	28°39'43.95"	77°14'44.88"	Delhi	16.24	1.24	7.64	1
Yamuna	Mathura	27°30'04.88"	77°41'45.73"	Delhi	14.24	12.61	88.55	2
Yamuna	Mathura	27°30'04.88"	77°41'45.73"	Mathura	14.24	7.26	50.98	3
Yamuna	Agra Poiyghat	27°15'26.47"	78° 1'24.52"	Agra	11.27	6.86	60.87	4
Yamuna	Etawah	26°44'41.96"	78°59'19.46"	Etawah	12.20	2.17	17.79	5
Yamuna	Pratappur	25°21'27.78"	81°40'52.82"	Allahabad	147.95	0.33	0.22	6
Kshipra	Ujjain	23°10'10.57"	75°46'15.61"	Ujjain	0.00	2.72	-	7
Betwa	Basoda	23°54'04.99"	77°55'19.80"	Basoda	0.00	2.74	-	8
Chambal	Mandwara	25°23'04.59"	76°09'07.64"	Kota	0.72	0.88	122.22	9
Chambal	Dholpur	26°39'16.79"	77°53'45.33"	Dholpur	8.75	0.11	1.26	10
Gomti	Lucknow	26°52'05.89"	80°55'31.30"	Lucknow	9.55	2.95	30.89	11
Ramganga	Bareily	28°16'32.00"	79°22'40.00"	Bareily	17.18	2.87	16.71	12
Ganga	Fatehgarh	27°24'00.00"	79°37'00.00"	Farrukhabad	15.15	2.74	18.09	13
Ganga	Ankinghat	26°55'00.00"	80°05'00.00"	Kanpur	69.94	0.64	0.92	14
Ganga	Bhitaura	26°02'13.65"	80°49'57.50"	Allahabad	96.97	1.98	2.04	15

Group 1: Bahadurgarh, Jagadhari, Jind, Karnal, Rohtak, Sonipat; **Group 2:** Delhi; **Group 3:** Aligarh, Baghpat, Baraut, Deoband, Bulandshehar, Dadri, Etah, Gangoh, Ghaziabad, Greater Noida, Hathras, Kairana, Khatauli, Loni, Modinagar, Muradnagar, Noida, Pilkhuwa, Saharanpur, Sikandrabad; **Group 4:** Mathura, Vrindavan; **Group 5:** Agra, Firozabad, Mainpuri; **Group 6:** Auraiya, Banda, Chitrakoot, Etawah; **Group 7:** Ujjain, Dewas, Indore, Pithampur; **Group 8:** Vidisha, Sehore; **Group 9:** Kota; **Group 10:** Dholpur; **Group 11:** Sitapur, Gola, Lakhimpur, Laharpur, Lucknow; **Group 12:** Bareilly, Baheri, Chandausi, Nagina, Pilibhit, Shambhal, Rampur, Moradabad, Hasanpur, Amroha, Chandpur, Sherkot; **Group13:** Bisalpur, Bijnor, Budaun, Faridpur, Kasganj, Najibabad, Jahangirabad, Kiratpur, Meerut, Mawana, Sahaswann, Shahbad, Shahjanpur, Tilhar, Ujhani; **Group 14:** Gangaghat, Chhibramau, Hardoi, Farrukhabad, Kannauj; **Group 15:** Pratapgarh, Fatehpur, Raebareily, Unnao, Kanpur.

The data presented in Table 5.11 reveals that contribution of treated sewage in comparison to dry weather flows are very high at many places. The quantities of treated sewage are estimated as 70 % of the sewage generated. In other words approximately 56% of water supply can be supplemented and saved by recycling treated sewage. It may be noted that in many locations/stretches of the rivers the entire dry weather flow could be due to sewage. It is also important to note that at very few locations or stretches of the river the dry weather flows exceed ten times the estimated treated sewage flows, which is generally assumed while setting the effluent discharge standards. In reality the situation at most locations/stretches is inferior to what is presented here due to cumulative effect. Thus looking at the comparison of the estimated sewage generation and dry weather flows it can be inferred that treatment of sewage up to tertiary level or equivalent is essential if river water quality standards befitting the ecological needs are to be maintained. It is thus necessary to consider sewage as significant source of water for both human and ecological needs, and bring in the concept of much higher level (at least tertiary level) of treatment for Class I and Class II towns in the GRB. The cost of provisioning sewerage systems does not appear to be unaffordable on per capita per day basis considering the benefits and savings in water supply and health related expenditures.

6. Conclusions and Recommendations

6.1. Conclusions

Following conclusions may be drawn based on the synthesis of the information available in the literature and the results presented in this thesis.

- Length of the sewers of various sizes up to 750 mm diameter appears to be strongly correlated to the population served and area covered by the sewer network.
- Empirical relations developed from the data gathered from various sources on sewerage networks for various urban agglomerations in India can be very useful in estimating the lengths of sewers of various primary, lateral and branch sewers up to 750 mm diameter.
- Approximately 70 % of the total length of sewers is comprised of 150 and 200 mm diameter sewers in typical Indian urban agglomerations.
- Approximately 15, 35 and 50 % of total capital expenditure on sewerage network is incurred on sewer pipes, manholes and laying (including excavation, timbering, dewatering, bedding, etc.) respectively.
- About 85-90 % of annual expenditure on sewage pumping is towards energy consumption, and about 90 % of the capital expenditure on sewage pumping stations is required for procurement of pumps.
- Typical breakup of total annual expenditure on sewage treatment between capex and opex is 52 and 48 % respectively.
- About 79, 2 and 19 % of the total capital expenditure on sewerage system is towards sewer network, sewage pumping and sewage treatment respectively while about 24, 26 and 50 % of the total opex expenditure is incurred in sewer network, sewage pumping and sewage treatment.
- Approximately 68, 8 and 28 % of the total annual expenditure on sewerage system is incurred on sewerage network, sewage pumping and sewage treatment respectively in a typical Indian town.
- Approximately 56 % of the energy bill is towards sewage pumping while only 44% of energy expenditure is incurred on sewage treatment.
- Total annual capex and opex for provisioning sewerage systems in all Class I and Class II towns of GRB is expected to be INR 1,08,930 and 34,740 million

respectively. This amounts to average per capita per day expenditure of INR 3.93.

- The average per capita per day energy consumption in availing sewerage systems is approximately equivalent to lighting a 40 watt bulb for 1 h.
- The expenditure on sewerage expenditure may be justified in GRB based on tangible and intangible benefits.

6.2. Recommendations

Following recommendations are made for logical continuation of the work described in this thesis based on the experience gained in conducting the present study.

- The relation developed to estimate lengths of various diameter sewers can be further improved if total road length of the area covered is included as an independent parameter.
- Data from many towns on sewerage network to improve the confidence level in estimating lengths of various diameter sewers.
- A detailed study on comparison of contribution of sewage from various Class I and Class II towns to the dry weather flows at many locations on many streams/rivers of the GRB.
- Information on energy consumption and cost of water supplies from various towns through distribution network and long distance conveyance of water to compute per liter cost of water supplies.

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Appendix I

Estimated Length of Various Diameter Pipes in Sewerage Network in Class I and Class II Towns of GRB

Table A1.01: Estimated Length of Various Diameter Pipes in Sewerage Network in Class I Towns (Population > 0.1 Million) of Uttarakhand in NRGB

S No	Town	Population in Thousands	Area in km^2	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
01	Dehradun	870.519	52.29	495	10.6	73.6	2.2	2.1	0.8	1.3	1.2	1.4	2.2	1.5	1.1	2.1
02	Haldwani	169.147	10.62	111	10.6	64.3	3.0	2.5	1.5	2.0	2.0	2.5	3.3	2.1	2.3	4.1
03	Hardwar	487.923	13.00	193	12.7	69.0	2.4	2.3	1.3	1.6	1.7	1.3	2.2	1.3	1.7	2.6
04	Kashipur	121.610	5.46	70	11.4	61.4	3.1	2.5	1.8	2.2	2.3	2.4	3.4	2.0	2.8	4.7
05	Nainital	110.726	11.06	94	9.8	63.5	3.3	2.6	1.5	2.1	2.0	3.4	4.0	2.7	0.0	5.0
06	Rishikesh	102.138	10.00	86	9.8	63.0	3.3	2.6	1.6	2.2	2.1	3.4	4.1	2.7	0.0	5.2
07	Roorkee	118.188	20.20	131	8.7	64.3	3.3	2.5	1.2	2.0	1.8	4.0	4.2	3.1	0.0	4.9
08	Rudrapur	140.884	12.43	112	9.9	63.5	3.1	2.5	1.4	2.0	1.9	2.9	3.6	2.4	2.3	4.5

Table A1.02: Estimated Length of Various Diameter Pipes in Sewerage Network in Class II Towns (Population between 0.05 and 0.1 Million) of Uttarakhand in NRGB

S No	Town	Population in Thousands	Area in km^2	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
01	BHEL Ranipur	51.910	26.94	108	6.8	60.9	3.9	2.6	1.2	2.3	1.8	7.6	6.1	0.0	0.0	6.8
02	Manglaur	51.101	1.32	23	13.1	57.4	3.6	2.8	3.2	2.9	3.4	2.7	3.9	0.0	0.0	6.9
03	Pithoragarh	53.957	9.00	62	8.9	60.8	3.8	2.7	1.7	2.5	2.3	5.2	5.2	0.0	0.0	6.8
04	Ramnagar	55.446	2.42	32	11.9	59.1	3.7	2.8	2.6	2.8	3.0	3.2	4.2	0.0	0.0	6.8

Table A1.03: Estimated Length of Various Diameter Pipes in Sewerage Network in Class I Towns (Population > 0.1 Million) of Uttar Pradesh in NRGB

S No	Town	Population in Thousands	Area in km²	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
01	Agra	1746.467	141.00	1111	9.7	77.3	1.9	2.0	0.5	1.0	0.9	1.2	1.9	1.4	0.7	1.5
02	Aligarh	909.559	36.70	423	11.5	73.1	2.1	2.2	0.9	1.3	1.3	1.2	2.0	1.3	1.2	2.0
03	Allahabad	1216.719	63.07	631	10.8	74.9	2.0	2.1	0.7	1.2	1.1	1.2	1.9	1.3	1.0	1.8
04	Amroha	197.135	12.00	126	10.7	65.2	2.9	2.4	1.4	1.9	1.9	2.3	3.2	2.0	2.1	3.9
05	Azamgarh	116.165	12.60	102	9.6	63.9	3.3	2.6	1.5	2.1	2.0	3.4	4.0	2.7	0.0	4.9
06	Badaun	159.221	4.39	70	12.6	62.2	2.9	2.5	1.9	2.1	2.3	1.9	2.9	1.7	2.7	4.2
07	Ballia	111.287	16.00	113	9.0	63.8	3.3	2.5	1.3	2.1	1.9	3.8	4.2	3.0	0.0	5.0
08	Banda	154.388	11.05	109	10.3	63.9	3.0	2.5	1.5	2.0	2.0	2.6	3.4	2.2	2.3	4.3
09	Barabanki	154.692	3.87	65	12.9	61.8	2.9	2.5	2.0	2.1	2.4	1.8	2.9	1.6	2.8	4.3
10	Baraut	101.241	25.00	138	7.9	63.3	3.4	2.5	1.2	2.0	1.7	4.7	4.6	3.5	0.0	5.1
11	Bareilly	979.933	106.43	745	9.3	75.1	2.2	2.1	0.6	1.2	1.0	1.6	2.3	1.7	0.9	2.0
12	Basti	114.651	19.43	127	8.7	64.1	3.3	2.5	1.3	2.0	1.8	4.0	4.3	3.1	0.0	4.9
13	Bijnour	115.381	3.65	55	12.6	62.2	3.2	2.6	2.2	2.3	2.6	2.2	3.3	1.9	0.0	4.9
14	Bulandsahar	222.826	32.50	218	8.9	67.2	2.9	2.4	1.0	1.7	1.5	3.0	3.5	2.6	1.7	3.7
15	Chandausi	114.254	8.80	84	10.4	63.5	3.3	2.6	1.6	2.2	2.1	3.1	3.8	2.5	0.0	5.0
16	Deoria	129.570	16.19	124	9.1	63.3	3.2	2.5	1.3	2.0	1.8	3.4	3.9	2.7	2.2	4.6
17	Etah	131.023	13.49	113	9.5	63.2	3.1	2.5	1.4	2.0	1.9	3.2	3.8	2.6	2.3	4.6
18	Etawah	256.790	48.00	282	8.4	68.3	2.8	2.3	0.9	1.6	1.4	3.1	3.5	2.7	1.5	3.5
19	Faizabad	259.160	16.60	166	10.6	67.1	2.8	2.4	1.2	1.7	1.7	2.1	3.0	2.0	1.9	3.5
20	Farrukhabad	318.540	16.80	182	11.1	68.0	2.6	2.4	1.2	1.7	1.7	1.9	2.8	1.8	1.8	3.2
21	Fatehpur	193.801	56.98	276	7.5	66.6	3.0	2.3	0.8	1.7	1.4	4.0	4.0	3.2	1.6	3.9
22	Firozabad	603.797	21.35	270	12.0	70.8	2.3	2.2	1.1	1.4	1.5	1.3	2.2	1.4	1.4	2.4
23	Gazipur	121.136	13.45	110	9.4	62.7	3.2	2.5	1.4	2.0	1.9	3.3	3.9	2.7	2.3	4.7
24	Ghaziabad	2358.525	215.00	1573	9.3	78.7	1.8	1.9	0.4	0.9	0.8	1.1	1.7	1.3	0.6	1.3
25	Gonda	138.929	24.62	157	8.4	64.1	3.1	2.4	1.1	1.9	1.7	3.7	4.0	3.0	2.0	4.5

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S No	Town	Population in Thousands	Area in km²	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
26	Gorakhpur	692.519	147.00	756	8.0	74.1	2.4	2.1	0.6	1.2	1.0	2.3	2.8	2.3	0.9	2.3
27	Greater Noida	642.381	27.93	317	11.4	71.5	2.3	2.2	1.0	1.4	1.4	1.4	2.2	1.4	1.3	2.4
28	Hapur	262.801	42.00	266	8.7	68.3	2.8	2.3	0.9	1.6	1.4	2.9	3.4	2.6	1.6	3.4
29	Hardoi	197.046	11.05	121	10.9	65.1	2.9	2.4	1.4	1.9	1.9	2.2	3.1	2.0	2.2	3.9
30	Hathras	161.289	8.40	97	11.1	63.6	3.0	2.5	1.6	2.0	2.1	2.3	3.2	2.0	2.4	4.2
31	Jaunpur	168.128	20.00	153	9.3	65.1	3.0	2.4	1.2	1.9	1.7	3.1	3.6	2.6	2.0	4.1
32	Jhansi	549.391	169.50	738	7.4	73.1	2.5	2.2	0.5	1.3	1.0	2.9	3.1	2.7	1.0	2.5
33	Kanpur	2920.067	261.50	1914	9.3	79.5	1.7	1.9	0.4	0.9	0.8	1.0	1.6	1.3	0.6	1.2
34	Kasganj	101.241	7.10	72	10.6	62.6	3.3	2.6	1.8	2.3	2.3	3.1	3.9	2.5	0.0	5.2
35	Lakhimpur	164.925	10.20	108	10.7	64.1	3.0	2.5	1.5	2.0	2.0	2.5	3.3	2.1	2.3	4.2
36	Lalitpur	133.041	18.00	132	9.0	63.6	3.1	2.5	1.3	2.0	1.8	3.4	3.9	2.8	2.2	4.5
37	Loni	512.296	34.48	319	10.5	71.1	2.4	2.3	0.9	1.4	1.4	1.7	2.5	1.7	1.4	2.6
38	Lucknow	2901.474	330.00	2147	8.8	79.8	1.7	1.8	0.4	0.8	0.7	1.1	1.7	1.3	0.5	1.2
39	Mainpuri	133.078	7.50	85	10.9	62.5	3.1	2.5	1.7	2.1	2.1	2.5	3.4	2.1	2.6	4.6
40	Mathura	454.937	32.80	295	10.3	70.6	2.5	2.3	0.9	1.5	1.4	1.9	2.6	1.8	1.4	2.7
41	Mau	279.060	39.00	263	9.0	68.5	2.8	2.3	0.9	1.6	1.4	2.7	3.3	2.4	1.6	3.4
42	Meerut	1424.908	41.94	554	12.1	74.5	1.9	2.1	0.8	1.1	1.2	0.9	1.7	1.1	1.0	1.7
43	Mirzapur	233.691	40.00	248	8.5	67.6	2.9	2.4	0.9	1.7	1.5	3.1	3.5	2.7	1.6	3.6
44	Modinagar	182.811	14.00	132	10.2	65.1	2.9	2.4	1.3	1.9	1.8	2.6	3.3	2.2	2.1	4.0
45	Moradabad	889.810	80.00	618	9.7	74.4	2.2	2.1	0.7	1.2	1.1	1.6	2.3	1.7	1.0	2.0
46	Mugalsarai	154.692	14.43	125	9.8	64.2	3.0	2.5	1.3	1.9	1.9	2.9	3.6	2.4	2.2	4.3
47	Muradanagar	100.080	12.00	94	9.4	63.0	3.4	2.6	1.5	2.2	2.0	3.7	4.2	2.9	0.0	5.2
48	Muzaffar Nagar	316.729	12.04	154	11.9	67.3	2.6	2.4	1.3	1.7	1.8	1.7	2.6	1.6	1.9	3.2
49	Noida	642.381	203.16	865	7.3	74.0	2.4	2.1	0.5	1.2	0.9	2.7	3.0	2.6	0.9	2.3
50	Orai	190.625	16.00	143	10.0	65.5	2.9	2.4	1.3	1.9	1.8	2.6	3.4	2.3	2.0	3.9
51	Pililbhit	160.146	9.50	103	10.8	63.8	3.0	2.5	1.5	2.0	2.0	2.4	3.3	2.1	2.3	4.2

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S No	Town	Population in Thousands	Area in km²	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
52	Raibareliy	191.625	34.00	211	8.5	66.3	3.0	2.4	1.0	1.7	1.5	3.4	3.7	2.8	1.7	3.9
53	Rampur	359.062	20.20	210	10.9	68.8	2.6	2.3	1.1	1.6	1.6	1.8	2.7	1.8	1.7	3.0
54	Saharanpur	703.345	73.72	535	9.4	73.4	2.3	2.2	0.7	1.3	1.2	1.8	2.5	1.8	1.1	2.3
55	Sahaswann	178.000	7.50	96	11.6	63.9	2.9	2.5	1.6	2.0	2.1	2.1	3.1	1.8	2.4	4.0
56	Sahjahanpur	356.103	11.37	157	12.3	67.6	2.5	2.4	1.3	1.7	1.8	1.5	2.5	1.5	1.9	3.0
57	Shambhal	221.334	15.65	151	10.4	66.2	2.8	2.4	1.3	1.8	1.8	2.3	3.2	2.1	2.0	3.7
58	Sitapur	188.230	35.00	212	8.4	66.2	3.0	2.4	1.0	1.7	1.5	3.4	3.8	2.9	1.7	3.9
59	Sultanpur	116.211	16.00	115	9.1	64.1	3.3	2.5	1.3	2.1	1.9	3.7	4.1	2.9	0.0	4.9
60	Ujhani	191.000	6.50	92	12.1	63.9	2.8	2.5	1.7	2.0	2.1	1.9	2.9	1.7	2.4	3.9
61	Unnao	178.681	21.50	162	9.2	65.5	3.0	2.4	1.2	1.8	1.7	3.0	3.6	2.5	1.9	4.0
62	Varansi	1435.113	79.79	764	10.6	75.8	2.0	2.0	0.6	1.1	1.0	1.1	1.9	1.3	0.9	1.7

Table A1.04: Estimated Length of Various Diameter Pipes in Sewerage Network in Class II Towns (Population between 0.05 and 0.1 Million) of Uttar Pradesh in NRGB

S No	Town	Population in Thousands	Area in km²	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
01	Auraiya	70.515	4.00	46	11.3	61.3	3.6	2.7	2.2	2.6	2.7	3.3	4.2	0.0	0.0	6.2
02	Baghpat	50.380	2.83	36	11.2	58.9	3.7	2.8	2.5	2.8	2.9	3.6	4.5	0.0	0.0	7.0
03	Baheri	74.869	15.00	91	8.6	63.4	3.7	2.7	1.4	2.3	2.0	5.0	5.0	0.0	0.0	6.0
04	Balrampur	90.000	36.28	161	7.0	62.3	3.5	2.5	1.0	2.0	1.6	5.7	5.0	4.1	0.0	5.3
05	Bhadohi	94.563	8.00	75	10.1	62.3	3.4	2.6	1.7	2.3	2.2	3.3	4.0	2.6	0.0	5.4
06	Bisalpur	83.347	4.58	54	11.1	60.9	3.4	2.7	2.0	2.4	2.5	3.0	3.9	2.4	0.0	5.6
07	Chandpur	83.456	23.40	124	7.7	61.9	3.5	2.5	1.2	2.1	1.8	5.2	4.9	3.8	0.0	5.5

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S No	Town	Population in Thousands	Area in km^2	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
08	Chibramau	55.296	11.10	70	8.5	61.1	3.8	2.7	1.6	2.5	2.2	5.5	5.3	0.0	0.0	6.8
09	Chitrakoot	57.452	7.77	59	9.3	61.1	3.8	2.7	1.8	2.5	2.4	4.7	5.0	0.0	0.0	6.7
10	Dadri	91.345	6.50	66	10.5	61.9	3.4	2.6	1.8	2.3	2.3	3.2	4.0	2.5	0.0	5.4
11	Deoband	97.068	7.90	75	10.2	62.5	3.3	2.6	1.7	2.3	2.2	3.3	4.0	2.6	0.0	5.3
12	Faredpur	76.422	9.43	73	9.6	63.0	3.6	2.7	1.7	2.4	2.2	4.2	4.6	0.0	0.0	6.0
13	Gangaghat	84.301	4.91	56	11.0	61.1	3.4	2.6	2.0	2.4	2.5	3.0	3.9	2.4	0.0	5.6
14	Gangoh	59.463	6.00	52	9.9	61.0	3.7	2.7	2.0	2.6	2.5	4.2	4.7	0.0	0.0	6.6
15	Gola	53.842	10.08	66	8.6	60.9	3.8	2.7	1.7	2.5	2.2	5.4	5.3	0.0	0.0	6.8
16	Hasanpur	64.536	5.72	53	10.2	61.4	3.7	2.7	2.0	2.5	2.5	3.9	4.6	0.0	0.0	6.4
17	Jahangerabad	59.873	14.30	82	8.2	61.8	3.8	2.7	1.5	2.4	2.1	5.6	5.3	0.0	0.0	6.5
18	Jalaun	56.871	5.00	47	10.2	60.5	3.7	2.8	2.1	2.6	2.6	4.1	4.7	0.0	0.0	6.7
19	Kaimur	51.469	7.12	54	9.2	60.3	3.8	2.7	1.9	2.6	2.4	4.9	5.1	0.0	0.0	7.0
20	Kairana	95.092	7.11	70	10.4	62.2	3.3	2.6	1.8	2.3	2.3	3.2	4.0	2.5	0.0	5.4
21	Kannauj	71.727	70.70	202	5.9	63.1	3.7	2.5	0.9	2.0	1.4	8.5	6.1	0.0	0.0	5.9
22	Khatauli	72.478	3.76	45	11.5	61.4	3.5	2.7	2.3	2.6	2.7	3.1	4.1	0.0	0.0	6.1
23	Kiratpur	61.801	4.45	46	10.7	60.8	3.7	2.8	2.2	2.6	2.6	3.7	4.5	0.0	0.0	6.5
24	Konch	53.426	2.95	35	11.3	59.3	3.7	2.8	2.5	2.7	2.9	3.5	4.4	0.0	0.0	6.9
25	Laharpur	61.280	8.00	61	9.4	61.5	3.7	2.7	1.8	2.5	2.3	4.6	4.9	0.0	0.0	6.5
26	Mahoba	95.454	12.15	93	9.3	62.7	3.4	2.6	1.5	2.2	2.0	3.8	4.3	3.0	0.0	5.3
27	Mau Ranipur	58.456	5.53	50	10.1	60.8	3.7	2.7	2.0	2.6	2.5	4.1	4.7	0.0	0.0	6.7
28	Mawana	81.126	7.50	68	9.9	61.3	3.4	2.6	1.8	2.3	2.3	3.6	4.2	2.8	0.0	5.7
29	Mubarakpur	71.365	9.00	69	9.5	62.6	3.6	2.7	1.7	2.4	2.3	4.3	4.7	0.0	0.0	6.2
30	Nagina	71.350	10.30	74	9.2	62.7	3.7	2.7	1.6	2.4	2.2	4.5	4.8	0.0	0.0	6.1
31	Nazibabad	88.638	5.06	58	11.1	61.4	3.4	2.6	2.0	2.4	2.4	3.0	3.9	2.4	0.0	5.5
32	Obra	56.116	4.50	44	10.4	60.3	3.7	2.8	2.2	2.6	2.6	4.0	4.6	0.0	0.0	6.8
33	Pilkhuwa	81.651	5.80	60	10.5	61.1	3.4	2.6	1.9	2.4	2.4	3.3	4.1	2.6	0.0	5.7

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S No	Town	Population in Thousands	Area in km^2	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
34	Pratapgarh	76.750	12.00	82	9.1	63.3	3.6	2.7	1.6	2.3	2.1	4.5	4.8	0.0	0.0	6.0
35	Ramnagar	54.800	3.60	39	10.9	59.8	3.7	2.8	2.3	2.7	2.8	3.7	4.5	0.0	0.0	6.8
36	Rath	65.092	6.10	55	10.1	61.6	3.7	2.7	1.9	2.5	2.5	4.0	4.6	0.0	0.0	6.4
37	S R Nagar	94.563	8.00	75	10.1	62.3	3.4	2.6	1.7	2.3	2.2	3.3	4.0	2.6	0.0	5.4
38	Shahbad	80.305	9.70	77	9.3	61.5	3.5	2.6	1.6	2.3	2.1	4.0	4.4	3.0	0.0	5.7
39	Sherkot	62.148	6.00	53	10.0	61.3	3.7	2.7	2.0	2.5	2.5	4.1	4.7	0.0	0.0	6.5
40	Sikandrabad	80.309	1.14	27	14.7	58.1	3.2	2.7	3.1	2.7	3.3	1.9	3.2	1.6	0.0	5.7
41	Tanda	96.138	10.45	86	9.6	62.7	3.4	2.6	1.6	2.2	2.1	3.6	4.2	2.8	0.0	5.3
42	Tilhar	60.803	3.48	40	11.2	60.3	3.6	2.8	2.3	2.7	2.8	3.4	4.3	0.0	0.0	6.5
43	Vrindavann	62.926	13.49	81	8.4	62.1	3.8	2.7	1.5	2.4	2.1	5.4	5.2	0.0	0.0	6.4

37. S R Nagar – Sant Ravidas Nagar

Table A1.05: Estimated Length of Various Diameter Pipes in Sewerage Network in Class I Towns (Population > 0.1 Million) of Himanchal Pradesh in NRGB

S No	Town	Population in Thousands	Area in km^2	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
No Class I town																

Table A1.06: Estimated Length of Various Diameter Pipes in Sewerage Network in Class II Towns (Population between 0.05 and 0.1 Million) of Himanchal Pradesh in NRGB

S No	Town	Population in Thousands	Area in km^2	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
No Class II town																

Table A1.07: Estimated Length of Various Diameter Pipes in Sewerage Network in Class I Towns (Population > 0.1 Million) of Haryana in NRGB

S No	Town	Population in Thousands	Area in km²	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
01	Bahadur Garh	170.426	50.00	245	7.5	65.8	3.1	2.4	0.9	1.7	1.4	4.1	4.1	3.3	1.7	4.1
02	Bhiwani	197.662	47.78	254	7.9	66.7	3.0	2.4	0.9	1.7	1.4	3.7	3.9	3.0	1.6	3.8
03	Faridabad	1404.653	207.80	1226	8.6	77.2	2.0	2.0	0.5	1.0	0.9	1.6	2.2	1.7	0.7	1.7
04	Gurgoan	901.968	37.10	424	11.5	73.1	2.1	2.2	0.8	1.3	1.3	1.2	2.0	1.3	1.2	2.0
05	Hisar	301.249	48.03	301	8.7	69.1	2.8	2.3	0.9	1.6	1.4	2.8	3.3	2.5	1.5	3.3
06	Jagadhari	124.915	24.80	152	8.2	63.4	3.2	2.4	1.1	1.9	1.7	4.0	4.2	3.1	2.0	4.6
07	Jind	166.225	42.00	222	7.8	65.5	3.1	2.4	0.9	1.8	1.5	4.0	4.0	3.2	1.7	4.1
08	Kaithal	144.633	45.75	220	7.4	64.6	3.1	2.4	0.9	1.8	1.5	4.5	4.3	3.5	1.7	4.3
09	Karnal	286.974	12.00	147	11.6	66.9	2.7	2.4	1.4	1.8	1.8	1.8	2.7	1.7	1.9	3.3
10	Kurukshetra	154.962	34.50	195	8.0	65.0	3.1	2.4	1.0	1.8	1.5	3.9	4.0	3.1	1.8	4.3
11	Narnaul	134.067	41.10	202	7.4	64.1	3.2	2.4	1.0	1.8	1.5	4.5	4.4	3.5	1.8	4.5
12	Palwal	127.931	8.78	90	10.4	62.5	3.1	2.5	1.6	2.1	2.1	2.8	3.6	2.3	2.5	4.6
13	Panipat	294.15	41.40	277	8.9	68.9	2.8	2.3	0.9	1.6	1.4	2.7	3.3	2.4	1.5	3.3
14	Rohtak	373.133	47.50	327	9.1	70.2	2.6	2.3	0.9	1.5	1.3	2.4	3.0	2.2	1.4	3.0
15	Sonipat	292.339	52.80	312	8.4	69.1	2.8	2.3	0.8	1.6	1.3	3.0	3.4	2.6	1.4	3.3
16	Yamuna Nagar	241.723	34.50	233	8.9	67.7	2.9	2.4	1.0	1.7	1.5	2.9	3.4	2.5	1.6	3.6

Table A1.08: Estimated Length of Various Diameter Pipes in Sewerage Network in Class II Towns (Population between 0.05 and 0.1 Million) of Haryana in NRGB

S No	Town	Population in Thousands	Area in km²	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
01	Hodal	50.003	5.39	46	9.7	59.8	3.8	2.8	2.1	2.7	2.6	4.5	5.0	0.0	0.0	7.1
02	Narvana	61.800	10.00	69	9.0	61.8	3.8	2.7	1.7	2.4	2.2	4.9	5.0	0.0	0.0	6.5
03	Sahadab	51.786	5.00	45	10.0	59.9	3.8	2.8	2.1	2.7	2.6	4.3	4.8	0.0	0.0	7.0

Table A1.09: Estimated Length of Various Diameter Pipes in Sewerage Network in Class I Towns (Population > 0.1 Million) of Delhi in NRGB

S No	Town	Population in Thousands	Area in km^2	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
01	B J	197.150	6.70	94	12.1	64.1	2.8	2.5	1.7	2.0	2.1	1.9	2.9	1.7	2.4	3.9
02	Burari	145.584	11.19	108	10.2	63.6	3.1	2.5	1.5	2.0	2.0	2.8	3.5	2.3	2.3	4.4
03	Dallo Pura	154.955	2.29	51	14.3	60.5	2.8	2.5	2.3	2.2	2.6	1.5	2.7	1.4	3.1	4.2
04	Delhi Cantt.	116.352	42.97	193	7.2	64.2	3.3	2.4	1.0	1.9	1.5	5.1	4.7	3.9	0.0	4.8
05	DMC	11007.835	431.09	4572	10.4	82.2	1.2	1.6	0.3	0.6	0.6	0.5	1.0	0.7	0.3	0.6
06	Deoli	169.410	10.12	109	10.8	64.2	3.0	2.5	1.5	2.0	2.0	2.4	3.3	2.1	2.3	4.1
07	Gokalpur	121.938	2.32	46	13.5	59.5	3.0	2.5	2.4	2.3	2.7	1.8	2.9	1.5	3.2	4.7
08	Hastal	177.033	6.75	91	11.8	63.7	2.9	2.5	1.7	2.0	2.1	2.0	3.0	1.8	2.4	4.1
09	Karawal Nagar	224.666	4.75	84	13.4	63.8	2.7	2.4	1.8	1.9	2.2	1.5	2.6	1.4	2.5	3.7
10	K S N	282.598	4.74	93	14.0	64.6	2.6	2.4	1.8	1.9	2.2	1.3	2.4	1.3	2.3	3.3
11	Mandoli	120.345	41.77	196	7.2	63.3	3.2	2.4	1.0	1.8	1.5	4.9	4.5	3.7	1.8	4.7
12	Mustafabad	127.012	1.29	36	15.3	58.0	2.8	2.5	2.8	2.3	3.0	1.4	2.6	1.2	3.5	4.5
13	Nangloi Jat	205.497	6.67	96	12.3	64.3	2.8	2.5	1.7	1.9	2.1	1.8	2.8	1.7	2.4	3.8
14	NDMC	249.998	42.74	263	8.6	68.0	2.8	2.3	0.9	1.6	1.4	3.1	3.5	2.6	1.6	3.5
15	Sultanpur Majra	181.624	2.86	60	14.1	61.7	2.8	2.5	2.2	2.1	2.5	1.5	2.6	1.3	2.8	4.0

01. B J- Bhalswa Jahangirpur
05. DMC – Delhi Municipal Corporation
10. K S N – Kirari Suleman Nagar
14. NDMC – New Delhi Municipal Corporation

Table A1.10: Estimated Length of Various Diameter Pipes in Sewerage Network in Class II Towns (Population between 0.05 and 0.1 Million) of Delhi in NRGB

S No	Town	Population in Thousands	Area in km^2	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
01	Babarpur	52.918	0.79	19	14.6	56.2	3.5	2.8	3.7	3.0	3.7	2.2	3.6	0.0	0.0	6.8
02	C S B	81.374	2.58	40	12.5	59.9	3.3	2.7	2.5	2.5	2.8	2.5	3.6	2.0	0.0	5.7
03	Gharoli	84.722	3.56	48	11.8	60.7	3.3	2.7	2.2	2.4	2.6	2.7	3.7	2.2	0.0	5.6
04	Jaffrabad	70.089	0.90	22	15.2	57.8	3.3	2.8	3.5	2.8	3.5	1.9	3.3	0.0	0.0	6.0
05	Khajoori Khas	55.006	0.94	21	14.3	56.9	3.5	2.8	3.5	2.9	3.6	2.3	3.6	0.0	0.0	6.7
06	Mithe Pur	49.583	1.81	27	12.3	58.0	3.7	2.8	2.9	2.9	3.2	3.1	4.2	0.0	0.0	7.1
07	Molar Band	49.439	4.12	40	10.3	59.4	3.8	2.8	2.2	2.7	2.7	4.2	4.8	0.0	0.0	7.1
08	Mundka	53.525	11.89	71	8.3	61.0	3.9	2.7	1.6	2.5	2.2	5.7	5.4	0.0	0.0	6.8
09	Pooth Kalan	61.727	6.97	57	9.7	61.4	3.7	2.7	1.9	2.5	2.4	4.3	4.8	0.0	0.0	6.5
10	Pulpehlad	64.484	2.16	33	12.6	59.6	3.5	2.8	2.7	2.7	3.0	2.8	3.9	0.0	0.0	6.4
11	S P G	52.730	1.05	21	13.9	57.0	3.5	2.8	3.4	2.9	3.5	2.4	3.8	0.0	0.0	6.8
12	Taj Pul	72.764	1.22	26	14.4	58.8	3.3	2.8	3.2	2.7	3.3	2.1	3.4	0.0	0.0	6.0
13	Tigri	54.774	1.05	22	14.0	57.2	3.5	2.8	3.4	2.9	3.5	2.4	3.7	0.0	0.0	6.7
14	Ziauddin Pur	58.661	1.80	29	12.8	58.8	3.6	2.8	2.9	2.8	3.1	2.8	3.9	0.0	0.0	6.6

02. C S B – Chilla Saroda Bangar
11. S P G – Sadat Pur Gurjan

Table A1.11: Estimated Capital Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Million) of Rajasthan in NRGB

S No	Town	Population in Thousands	Area in km^2	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
01	Ajmer	542.580	87.00	521	8.6	72.6	2.5	2.2	0.7	1.3	1.1	2.3	2.8	2.2	1.1	2.5
02	Alwar	315.310	49.00	310	8.7	69.4	2.7	2.3	0.9	1.5	1.4	2.7	3.2	2.4	1.4	3.2
03	Bahilwara	360.009	69.00	390	8.3	70.4	2.7	2.3	0.8	1.5	1.2	2.8	3.2	2.5	1.3	3.0
04	Baran	118.157	72.36	260	6.2	63.0	3.3	2.3	0.8	1.7	1.3	5.9	4.9	4.3	1.6	4.6
05	Bharatpur	252.109	29.00	217	9.4	67.7	2.8	2.4	1.0	1.7	1.5	2.7	3.3	2.3	1.7	3.5
06	Bundi	102.823	22.76	132	8.1	63.4	3.4	2.5	1.2	2.0	1.8	4.5	4.5	3.4	0.0	5.1
07	Chittaugarh	116.409	30.50	161	7.8	64.3	3.3	2.5	1.1	1.9	1.6	4.6	4.5	3.5	0.0	4.8
08	Dhaulpur	126.142	32.00	174	7.7	63.6	3.2	2.4	1.0	1.9	1.6	4.3	4.3	3.4	1.9	4.6
09	Gangapurcity	224.773	17.22	159	10.2	66.4	2.8	2.4	1.2	1.8	1.7	2.4	3.2	2.1	1.9	3.7
10	Hindauncity	105.690	48.00	198	6.8	63.4	3.4	2.4	0.9	1.9	1.5	5.6	4.9	4.2	0.0	5.0
11	Jaipur	3073.350	485.00	2679	8.2	80.4	1.7	1.8	0.3	0.8	0.7	1.2	1.8	1.5	0.5	1.2
12	Jhunjhunun	118.966	50.00	215	6.9	63.2	3.3	2.4	0.9	1.8	1.4	5.2	4.7	3.9	1.8	4.7
13	Kishangarh	155.019	100.00	341	6.2	64.9	3.1	2.3	0.7	1.6	1.2	5.5	4.6	4.2	1.4	4.1
14	Kota	1001.365	527.03	1710	6.4	76.4	2.2	2.0	0.4	1.0	0.7	2.8	2.8	2.7	0.7	1.9
15	Nagaur	100.618	37.81	171	7.2	63.2	3.4	2.5	1.0	1.9	1.6	5.4	4.9	4.0	0.0	5.1
16	Sikar	237.579	39.90	249	8.6	67.7	2.9	2.4	0.9	1.7	1.5	3.1	3.5	2.6	1.6	3.6
17	Swaimadhavpur	120.998	49.00	214	6.9	63.3	3.2	2.4	0.9	1.8	1.4	5.1	4.6	3.9	1.8	4.6
18	Tonk	165.363	16.00	135	9.7	64.7	3.0	2.5	1.3	1.9	1.8	2.9	3.5	2.4	2.1	4.2
19	Udaipur	451.735	56.91	389	9.1	71.3	2.5	2.3	0.8	1.4	1.3	2.3	2.9	2.1	1.3	2.7

Table A1.12: Estimated Length of Various Diameter Pipes in Sewerage Network in Class II Towns (Population between 0.05 and 0.1 Million) of Rajasthan in NRGB

S No	Town	Population in Thousands	Area in km^2	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
01	Jhalawara	66.500	12.95	81	8.6	62.5	3.7	2.7	1.5	2.4	2.1	5.1	5.1	0.0	0.0	6.3
02	Makrana	94.447	36.00	163	7.1	62.7	3.4	2.5	1.0	2.0	1.6	5.5	4.9	4.0	0.0	5.2
03	Nawalgarh	64.903	27.91	119	7.2	62.6	3.8	2.6	1.2	2.2	1.8	6.7	5.7	0.0	0.0	6.3
04	Nimbahera	61.000	12.74	77	8.5	61.9	3.8	2.7	1.5	2.4	2.1	5.4	5.2	0.0	0.0	6.5

Table A1.13: Estimated Length of Various Diameter Pipes in Sewerage Network in Class I Towns (Population > 0.1 Million) of Madhya Pradesh in NRGB

S No	Town	Population in Thousands	Area in km^2	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
01	Bhind	197.332	17.79	153	9.9	65.8	2.9	2.4	1.2	1.8	1.7	2.6	3.4	2.3	2.0	3.9
02	Bopal	1883.381	285.00	1640	8.4	78.4	1.9	1.9	0.4	0.9	0.8	1.4	2.0	1.6	0.6	1.5
03	Chatarpur	147.688	54.00	242	7.1	64.8	3.1	2.4	0.9	1.7	1.4	4.6	4.4	3.6	1.7	4.3
04	Damoh	147.515	16.00	129	9.4	64.1	3.1	2.5	1.3	1.9	1.8	3.1	3.7	2.5	2.2	4.4
05	Datia	100.466	6.85	71	10.7	62.5	3.3	2.6	1.8	2.3	2.3	3.0	3.9	2.4	0.0	5.2
06	Dewas	289.438	102.00	437	7.2	69.3	2.8	2.3	0.7	1.5	1.2	3.7	3.7	3.1	1.3	3.3
07	Guna	180.978	45.75	240	7.8	66.1	3.0	2.4	0.9	1.7	1.4	3.9	4.0	3.1	1.7	4.0
08	Gwalior	1101.981	173.88	1006	8.5	76.1	2.1	2.0	0.5	1.1	0.9	1.8	2.3	1.9	0.8	1.9
09	Indore	2167.447	131.17	1181	10.2	77.7	1.8	1.9	0.5	1.0	0.9	1.0	1.7	1.2	0.7	1.4
10	Jabalpur	1267.564	135.00	941	9.2	76.3	2.1	2.0	0.5	1.1	1.0	1.5	2.1	1.6	0.8	1.7
11	Katni	221.875	68.60	320	7.5	67.6	2.9	2.3	0.8	1.6	1.3	3.9	3.9	3.2	1.5	3.7
12	Mandsour	141.468	36.00	193	7.8	64.4	3.2	2.4	1.0	1.8	1.5	4.2	4.2	3.3	1.8	4.4
13	Morena	200.506	12.00	127	10.8	65.3	2.9	2.4	1.4	1.9	1.9	2.3	3.2	2.0	2.1	3.9
14	Neemuch	128.575	22.00	144	8.5	63.5	3.2	2.5	1.2	1.9	1.7	3.8	4.1	3.0	2.1	4.6

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S No	Town	Population in Thousands	Area in km^2	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
15	Pithampur	126.099	89.90	299	6.0	63.3	3.2	2.3	0.7	1.7	1.3	6.0	4.9	4.5	1.5	4.5
16	Ratlam	273.892	39.19	261	8.9	68.5	2.8	2.3	0.9	1.6	1.4	2.8	3.3	2.5	1.6	3.4
17	Rewa	235.422	102.00	403	6.9	68.0	2.9	2.3	0.7	1.5	1.2	4.2	4.0	3.5	1.3	3.5
18	Sagar	370.296	33.75	275	9.8	69.7	2.6	2.3	1.0	1.5	1.4	2.2	2.9	2.0	1.5	3.0
19	Satna	283.004	12.00	146	11.6	66.9	2.7	2.4	1.4	1.8	1.8	1.8	2.8	1.7	2.0	3.3
20	Sehore	1090.025	13.10	278	14.7	70.9	2.0	2.1	1.1	1.3	1.5	0.7	1.6	0.9	1.3	1.8
21	Shahdol	100.565	28.24	147	7.7	63.3	3.4	2.5	1.1	2.0	1.7	4.9	4.7	3.7	0.0	5.1
22	Shepour	105.026	5.00	61	11.5	62.3	3.2	2.6	2.0	2.3	2.4	2.7	3.6	2.2	0.0	5.1
23	Shivpuri	179.972	86.55	334	6.7	66.1	3.1	2.3	0.7	1.6	1.2	4.8	4.3	3.8	1.4	3.9
24	Singrauli	220.295	280.66	674	5.3	66.8	2.9	2.2	0.5	1.4	0.9	6.1	4.6	4.7	1.1	3.5
25	Tikamgarh	101.786	6.22	68	10.9	62.4	3.3	2.6	1.8	2.3	2.3	2.9	3.8	2.4	0.0	5.2
26	Ujjain	515.215	92.68	527	8.4	72.4	2.5	2.2	0.7	1.3	1.1	2.4	2.9	2.3	1.1	2.6
27	Vidisha	155.959	8.83	98	10.9	63.6	3.0	2.5	1.6	2.0	2.0	2.4	3.3	2.1	2.4	4.3

Table A1.14: Estimated Length of Various Diameter Pipes in Sewerage Network in Class II Towns (Population between 0.05 and 0.1 Million) of Madhya Pradesh in NRGB

S No	Town	Population in Thousands	Area in km^2	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
01	Basoda	78.265	5.90	58	10.7	62.5	3.5	2.7	1.9	2.5	2.5	3.5	4.3	0.0	0.0	5.9
02	Bina	64.579	12.00	77	8.7	62.2	3.7	2.7	1.6	2.4	2.1	5.1	5.1	0.0	0.0	6.4
03	Dabra	61.260	12.00	75	8.6	61.9	3.8	2.7	1.6	2.4	2.2	5.2	5.2	0.0	0.0	6.5
04	Dhar	95.000	30.00	148	7.5	62.8	3.4	2.5	1.1	2.0	1.7	5.2	4.8	3.8	0.0	5.2
05	Jaora	65.111	5.54	52	10.3	61.4	3.7	2.7	2.0	2.5	2.5	3.9	4.5	0.0	0.0	6.4
06	Mandla	55.145	8.87	62	8.9	60.9	3.8	2.7	1.7	2.5	2.3	5.1	5.2	0.0	0.0	6.8

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S No	Town	Population in Thousands	Area in km^2	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
07	Narshimpur	59.858	14.71	83	8.1	61.9	3.8	2.7	1.5	2.4	2.1	5.7	5.4	0.0	0.0	6.5
08	Panna	50.432	4.50	43	10.2	59.6	3.8	2.8	2.2	2.7	2.7	4.2	4.8	0.0	0.0	7.0
09	Shajapur	70.000	11.16	76	9.0	62.7	3.7	2.7	1.6	2.4	2.2	4.7	4.9	0.0	0.0	6.2
10	Sidhi	54.317	12.31	73	8.3	61.1	3.9	2.7	1.6	2.5	2.2	5.7	5.4	0.0	0.0	6.8

Table A1.15: Estimated Length of Various Diameter Pipes in Sewerage Network in Class I Towns (Population > 0.1 Million) of Bihar in NRGB

S No	Town	Population in Thousands	Area in km^2	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
01	Arrah	261.099	30.97	227	9.3	68.0	2.8	2.4	1.0	1.7	1.5	2.7	3.3	2.3	1.7	3.5
02	Aurangabad	101.520	8.00	77	10.3	62.7	3.3	2.6	1.7	2.2	2.2	3.2	3.9	2.5	0.0	5.2
03	Bagaha	113.012	11.00	94	9.9	63.7	3.3	2.6	1.5	2.1	2.0	3.3	4.0	2.7	0.0	5.0
04	Begusarai	251.136	8.98	121	12.0	65.8	2.7	2.4	1.5	1.8	2.0	1.8	2.8	1.6	2.1	3.5
05	Bettiah	132.896	11.55	105	9.9	63.1	3.1	2.5	1.4	2.0	2.0	3.0	3.7	2.4	2.4	4.6
06	B M C	398.138	30.17	268	10.2	69.9	2.6	2.3	1.0	1.5	1.5	2.0	2.8	1.9	1.5	2.9
07	B M C	296.889	22.46	204	10.3	68.2	2.7	2.4	1.1	1.7	1.6	2.2	3.0	2.0	1.7	3.3
08	Buxar	102.591	8.00	77	10.3	62.8	3.3	2.6	1.7	2.2	2.2	3.2	3.9	2.5	0.0	5.2
09	Chapra (NP)	201.597	16.96	151	10.0	65.9	2.9	2.4	1.2	1.8	1.8	2.6	3.3	2.2	2.0	3.9
10	Darbhanga	294.116	19.18	188	10.6	67.9	2.7	2.4	1.2	1.7	1.7	2.1	2.9	1.9	1.8	3.3
11	Dehri	137.068	21.32	145	8.7	63.9	3.1	2.4	1.2	1.9	1.7	3.6	4.0	2.9	2.1	4.5
12	D N	182.241	11.63	120	10.6	64.8	2.9	2.5	1.4	1.9	1.9	2.4	3.3	2.1	2.2	4.0
13	Gaya	463.454	50.17	369	9.4	71.3	2.5	2.3	0.8	1.4	1.3	2.1	2.8	2.0	1.3	2.7
14	Hajipur	147.126	19.64	143	9.0	64.3	3.1	2.4	1.2	1.9	1.7	3.3	3.8	2.7	2.1	4.4
15	Jamalpur	105.221	10.65	90	9.8	63.2	3.3	2.6	1.5	2.2	2.1	3.4	4.1	2.7	0.0	5.1

TableA1.15 continued to next page … … … …

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S No	Town	Population in Thousands	Area in Km^2	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
16	Jehanabad	102.456	20.23	124	8.4	63.4	3.4	2.5	1.3	2.1	1.8	4.3	4.5	3.3	0.0	5.1
17	Katihar	225.982	24.54	191	9.5	66.9	2.9	2.4	1.1	1.7	1.6	2.7	3.3	2.4	1.8	3.7
18	Kishanganj	107.076	30.12	155	7.7	63.7	3.4	2.5	1.1	2.0	1.6	4.8	4.6	3.6	0.0	5.0
19	M T	105.000	8.50	80	10.3	63.0	3.3	2.6	1.7	2.2	2.2	3.2	3.9	2.5	0.0	5.1
20	Motihari	125.183	13.52	111	9.4	62.9	3.2	2.5	1.4	2.0	1.9	3.3	3.8	2.6	2.3	4.7
21	Munger	213.101	17.50	157	10.1	66.2	2.9	2.4	1.2	1.8	1.7	2.5	3.3	2.2	1.9	3.8
22	Muzaffarpur	351.838	26.43	238	10.3	69.2	2.6	2.3	1.0	1.6	1.5	2.1	2.8	1.9	1.6	3.1
23	Nawada	109.141	5.68	66	11.3	62.7	3.2	2.6	1.9	2.3	2.4	2.7	3.6	2.2	0.0	5.1
24	Patna	1683.200	108.34	957	10.2	76.7	1.9	2.0	0.6	1.0	1.0	1.1	1.8	1.3	0.8	1.5
25	Purnia	280.547	44.52	282	8.7	68.7	2.8	2.3	0.9	1.6	1.4	2.9	3.4	2.5	1.5	3.4
26	Saharsa	155.175	21.13	152	9.0	64.7	3.1	2.4	1.2	1.9	1.7	3.3	3.8	2.7	2.0	4.3
27	Sasaram	147.396	12.00	112	10.1	63.7	3.1	2.5	1.4	2.0	1.9	2.8	3.5	2.3	2.3	4.4
28	Siwan	134.458	15.68	123	9.3	63.5	3.1	2.5	1.3	2.0	1.8	3.3	3.8	2.6	2.2	4.5

06. B M C – Bhagalpur Municipal Corporation
07. B M C – Biharsharif Municipal Corporation
12. DN – Dinapur Nizamat
19. MT – Madhubani Town

Table A1.16: Estimated Length of Various Diameter Pipes in Sewerage Network in Class II Towns (Population between 0.05 and0.1 Million) of Bihar in NRGB

S No	Town	Population in Thousands	Area in km²	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
01	Araria	80.000	4.50	52	11.1	60.7	3.4	2.7	2.1	2.4	2.5	3.1	4.0	2.4	0.0	5.7
02	Barahiya	50.230	26.54	106	6.7	60.6	3.9	2.6	1.2	2.3	1.8	7.7	6.1	0.0	0.0	6.9
03	Barh	61.037	4.50	46	10.6	60.7	3.7	2.8	2.2	2.6	2.6	3.8	4.5	0.0	0.0	6.5
04	Bhabua	52.611	7.12	54	9.3	60.4	3.8	2.7	1.9	2.6	2.4	4.8	5.1	0.0	0.0	6.9
05	D M	67.995	11.30	76	8.9	62.5	3.7	2.7	1.6	2.4	2.2	4.8	4.9	0.0	0.0	6.3
06	Dumraon	57.716	15.33	83	8.0	61.6	3.8	2.7	1.5	2.4	2.0	5.9	5.5	0.0	0.0	6.6
07	Forbesganj	52.289	4.98	45	10.0	60.0	3.8	2.8	2.1	2.7	2.6	4.3	4.8	0.0	0.0	7.0
08	Gopalganj	66.624	11.11	75	8.9	62.4	3.7	2.7	1.6	2.4	2.2	4.8	5.0	0.0	0.0	6.3
09	Kaimur	51.469	7.12	54	9.2	60.3	3.8	2.7	1.9	2.6	2.4	4.9	5.1	0.0	0.0	7.0
10	Khagaria	56.978	2.97	36	11.4	59.7	3.7	2.8	2.5	2.7	2.9	3.4	4.3	0.0	0.0	6.7
11	Khagaul	60.866	5.32	50	10.3	61.0	3.7	2.7	2.0	2.6	2.5	4.0	4.6	0.0	0.0	6.6
12	Lakhisarai	98.123	24.79	136	7.9	63.1	3.4	2.5	1.2	2.0	1.7	4.8	4.7	3.6	0.0	5.2
13	Madhepura	56.739	25.84	109	7.0	61.6	3.9	2.6	1.2	2.3	1.8	7.1	5.9	0.0	0.0	6.6
14	Masaurhi	57.012	9.43	65	8.9	61.2	3.8	2.7	1.7	2.5	2.3	5.1	5.1	0.0	0.0	6.7
15	Mokameh	71.335	14.18	87	8.6	63.0	3.7	2.7	1.5	2.3	2.1	5.0	5.0	0.0	0.0	6.1
16	Narkatiaganj	51.446	10.96	67	8.4	60.6	3.9	2.7	1.6	2.5	2.2	5.7	5.4	0.0	0.0	7.0
17	Phulwari Sharif	67.348	6.48	57	10.1	61.8	3.7	2.7	1.9	2.5	2.4	4.0	4.6	0.0	0.0	6.3
18	Raxaul Bazar	52.429	5.82	49	9.7	60.2	3.8	2.8	2.0	2.6	2.5	4.5	4.9	0.0	0.0	6.9
19	Samastipur	70.042	3.45	42	11.6	61.0	3.5	2.7	2.3	2.6	2.7	3.1	4.1	0.0	0.0	6.2
20	Shekhpura	54.322	15.58	82	7.8	61.2	3.9	2.7	1.4	2.4	2.0	6.2	5.6	0.0	0.0	6.8
21	Sitamarhi	87.279	8.00	72	10.0	61.8	3.4	2.6	1.7	2.3	2.2	3.5	4.2	2.7	0.0	5.5
22	Sultanganj	52.867	12.29	72	8.2	60.9	3.9	2.7	1.6	2.5	2.2	5.8	5.5	0.0	0.0	6.9
23	Supaul	85.200	22.37	122	7.8	62.1	3.5	2.5	1.2	2.1	1.8	5.0	4.8	3.7	0.0	5.5

05. D M – Digha-Mainpura

Table A1.17: Estimated Length of Various Diameter Pipes in Sewerage Network in Class I Towns (Population > 0.1 Million) of Chhatisgarh in NRGB

S No	Town	Population in Thousands	Area in km^2	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
01	Ambikapur	114.575	9.39	87	10.2	63.6	3.3	2.6	1.6	2.2	2.1	3.1	3.9	2.5	0.0	5.0
02	Bhilai Nagar	625.697	141.30	709	8.0	73.6	2.4	2.1	0.6	1.2	1.0	2.5	2.9	2.4	1.0	2.4
03	Bilaspur	330.106	37.56	276	9.4	69.4	2.7	2.3	0.9	1.6	1.4	2.4	3.1	2.2	1.5	3.1
04	Durg	268.679	66.09	339	7.9	68.7	2.8	2.3	0.8	1.6	1.3	3.4	3.6	2.9	1.4	3.4
05	Jagdalpur	125.345	22.49	144	8.4	63.4	3.2	2.5	1.2	1.9	1.7	3.9	4.1	3.0	2.1	4.6
06	Korba	363.210	215.02	707	6.4	70.7	2.7	2.2	0.5	1.3	1.0	4.1	3.7	3.5	1.0	2.9
07	Raigarh	137.097	20.68	143	8.8	63.9	3.1	2.5	1.2	1.9	1.7	3.5	3.9	2.8	2.1	4.5
08	Raipur	1010.087	108.66	763	9.3	75.3	2.2	2.1	0.6	1.2	1.0	1.6	2.3	1.7	0.9	1.9
09	Rajnandgaon	163.122	78.09	305	6.7	65.4	3.1	2.3	0.8	1.7	1.3	4.9	4.4	3.8	1.5	4.1

Table A1.18: Estimated Length of Various Diameter Pipes in Sewerage Network in Class II Towns (Population between 0.05 and 0.1 Million) of Chhatisgarh in NRGB

S No	Town	Population in Thousands	Area in km^2	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
01	Bhatapara	54.846	30.42	117	6.7	61.3	3.9	2.6	1.2	2.2	1.8	7.6	6.1	0.0	0.0	6.7
02	Bhilai Charoda	95.848	141.30	343	5.0	61.2	3.4	2.3	0.6	1.7	1.1	8.3	5.7	5.7	0.0	4.9
03	Chirmiri	99.934	64.94	228	6.2	62.7	3.4	2.4	0.8	1.8	1.4	6.4	5.2	4.6	0.0	5.0
04	Dalli-Rajhara	55.684	37.25	131	6.4	61.3	3.9	2.6	1.1	2.2	1.7	8.1	6.2	0.0	0.0	6.6
05	Dhamtari	89.857	23.40	127	7.8	62.5	3.4	2.5	1.2	2.1	1.8	4.9	4.8	3.7	0.0	5.4
06	Mahasamund	51.543	14.68	78	7.8	60.8	3.9	2.7	1.5	2.4	2.1	6.3	5.7	0.0	0.0	6.9

Table A1.19: Estimated Length of Various Diameter Pipes in Sewerage Network in Class I Towns (Population > 0.1 Million) of Jharkhand in NRGB

S No	Town	Population in Thousands	Area in Km^2	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
01	Aditya	173.988	49.82	247	7.6	65.9	3.1	2.4	0.9	1.7	1.4	4.1	4.1	3.3	1.6	4.0
02	Bhuli	110.127	11.74	96	9.7	63.6	3.3	2.6	1.5	2.1	2.0	3.5	4.0	2.7	0.0	5.0
03	Bokaro	413.934	162.91	644	7.0	71.5	2.6	2.2	0.6	1.3	1.0	3.4	3.4	3.0	1.0	2.8
04	Chas	141.618	20.49	144	8.8	64.1	3.1	2.4	1.2	1.9	1.7	3.5	3.9	2.8	2.1	4.4
05	Deoghar	203.116	14.00	138	10.5	65.6	2.9	2.4	1.3	1.9	1.8	2.4	3.2	2.1	2.1	3.8
06	Dhanbad	1161.561	23.39	379	13.2	72.6	2.0	2.1	1.0	1.2	1.4	0.8	1.7	1.0	1.2	1.8
07	Giridih	114.447	9.75	89	10.2	63.6	3.3	2.6	1.6	2.2	2.1	3.2	3.9	2.5	0.0	5.0
08	Hazaribag	142.494	26.37	165	8.4	64.3	3.1	2.4	1.1	1.9	1.6	3.8	4.0	3.0	2.0	4.4
09	JNAC	629.659	59.80	459	9.7	72.7	2.4	2.2	0.8	1.3	1.2	1.8	2.5	1.8	1.2	2.4
10	Jharia	100.839	4.42	57	11.7	61.9	3.3	2.6	2.0	2.3	2.5	2.6	3.6	2.1	0.0	5.2
11	Jorapokhar	104.673	16.40	112	8.8	63.5	3.3	2.5	1.3	2.1	1.9	4.0	4.3	3.1	0.0	5.1
12	MNAC	224.002	19.45	169	9.9	66.6	2.9	2.4	1.2	1.8	1.7	2.5	3.2	2.2	1.9	3.7
13	Phusro	102.673	40.64	179	7.1	63.3	3.4	2.4	1.0	1.9	1.5	5.4	4.9	4.0	0.0	5.0
14	Ranchi	1073.440	177.19	1004	8.4	76.1	2.2	2.1	0.5	1.1	0.9	1.8	2.4	1.9	0.8	1.9
15	Saunda	104.642	24.26	137	8.1	63.5	3.4	2.5	1.2	2.0	1.7	4.5	4.5	3.5	0.0	5.1

09. JNAC – Jamshedpur Notified Area Committee
12. MNAC – Mango Notified Area Committee

Table A1.20: Estimated Length of Various Diameter Pipes in Sewerage Network in Class II Towns (Population between 0.05 and 0.1 Million) of Jharkhand in NRGB

S No	Town	Population in Thousands	Area in km^2	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
01	Bagbera	82.559	10.70	82	9.2	61.7	3.5	2.6	1.6	2.3	2.1	4.0	4.4	3.1	0.0	5.6
02	Bhowrah	54.483	15.73	83	7.8	61.2	3.9	2.7	1.4	2.4	2.0	6.2	5.6	0.0	0.0	6.8
03	Bhuli	99.990	8.60	79	10.1	62.7	3.3	2.6	1.7	2.2	2.2	3.3	4.0	2.6	0.0	5.2
04	Chaibasa	78.287	11.11	82	9.0	61.4	3.5	2.6	1.5	2.3	2.1	4.2	4.5	3.2	0.0	5.7
05	Chatra	51.685	3.45	38	10.8	59.4	3.8	2.8	2.4	2.7	2.8	3.8	4.6	0.0	0.0	7.0
06	Daltonganj	87.849	14.00	97	8.8	62.2	3.4	2.6	1.4	2.2	2.0	4.2	4.5	3.2	0.0	5.5
07	Dumka	55.336	6.12	51	9.7	60.6	3.8	2.7	2.0	2.6	2.5	4.5	4.9	0.0	0.0	6.8
08	Gumia	56.024	26.11	109	7.0	61.5	3.9	2.6	1.2	2.3	1.8	7.2	5.9	0.0	0.0	6.6
09	Jhumri Tilaiya	85.489	51.14	190	6.3	61.6	3.5	2.4	0.9	1.9	1.5	6.5	5.3	4.6	0.0	5.3
10	Jugsalai	56.720	3.69	40	10.9	60.0	3.7	2.8	2.3	2.7	2.8	3.7	4.5	0.0	0.0	6.7
11	Katras	63.017	5.00	49	10.5	61.1	3.7	2.7	2.1	2.6	2.6	3.8	4.5	0.0	0.0	6.5
12	Lohardaga	56.821	14.57	81	8.0	61.5	3.8	2.7	1.5	2.4	2.1	5.9	5.5	0.0	0.0	6.7
13	Madhupur	58.211	18.36	92	7.7	61.7	3.8	2.7	1.4	2.3	2.0	6.2	5.6	0.0	0.0	6.6
14	Ramgarh Cantt.	90.324	34.46	157	7.1	62.4	3.5	2.5	1.0	2.0	1.6	5.6	5.0	4.1	0.0	5.3
15	Sahibganj	98.589	8.98	80	10.0	62.7	3.3	2.6	1.6	2.2	2.2	3.4	4.1	2.7	0.0	5.3
16	Sindri	94.398	46.65	187	6.7	62.5	3.4	2.4	0.9	1.9	1.5	6.0	5.1	4.3	0.0	5.2
17	Tisra	65.894	14.02	84	8.4	62.5	3.7	2.7	1.5	2.4	2.1	5.3	5.2	0.0	0.0	6.3

Table A1.21: Estimated Length of Various Diameter Pipes in Sewerage Network in Class I Towns (Population > 0.1 Million) of West Bengal in NRGB

S No	Town	Population in Thousands	Area in km²	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
01	Alipurduar	127.342	9.80	95	10.1	62.6	3.1	2.5	1.5	2.1	2.0	2.9	3.6	2.4	2.5	4.6
02	Asansol	564.491	127.87	645	8.0	73.1	2.5	2.2	0.6	1.3	1.1	2.5	2.9	2.4	1.0	2.5
03	A-K	123.906	18.44	130	8.8	63.2	3.2	2.5	1.3	2.0	1.8	3.6	4.0	2.9	2.2	4.7
04	Baidyabati	121.081	7.89	84	10.5	62.0	3.1	2.5	1.6	2.1	2.1	2.8	3.6	2.3	2.6	4.7
05	Bally	115.715	11.68	98	9.8	63.9	3.3	2.6	1.5	2.1	2.0	3.3	4.0	2.7	0.0	4.9
06	Balurghat	151.183	10.46	106	10.4	63.7	3.0	2.5	1.5	2.0	2.0	2.6	3.4	2.2	2.3	4.3
07	Bangaon	110.668	24.70	142	8.1	63.9	3.3	2.5	1.2	2.0	1.7	4.4	4.5	3.4	0.0	5.0
08	Bankura	138.036	19.06	138	8.9	63.9	3.1	2.5	1.2	1.9	1.8	3.4	3.9	2.8	2.1	4.5
09	Bansberia	103.799	9.07	83	10.1	63.0	3.3	2.6	1.6	2.2	2.1	3.3	4.0	2.6	0.0	5.2
10	Bara Nagar	248.466	7.12	107	12.6	65.2	2.7	2.4	1.6	1.9	2.0	1.6	2.7	1.5	2.2	3.5
11	Barasat	283.443	34.50	248	9.2	68.5	2.8	2.3	1.0	1.6	1.5	2.6	3.2	2.3	1.6	3.3
12	Bardhaman	314.638	26.30	226	10.0	68.7	2.7	2.3	1.0	1.6	1.5	2.2	3.0	2.0	1.6	3.2
13	Barrackpore	154.475	11.65	112	10.2	63.9	3.0	2.5	1.4	2.0	1.9	2.7	3.5	2.3	2.3	4.3
14	Basirhat	127.135	22.50	145	8.4	63.5	3.2	2.4	1.2	1.9	1.7	3.8	4.1	3.0	2.1	4.6
15	Beharampore	195.363	31.43	204	8.7	66.4	3.0	2.4	1.0	1.7	1.5	3.2	3.7	2.7	1.8	3.9
16	Bhadreswar	101.334	8.28	78	10.2	62.8	3.3	2.6	1.7	2.2	2.2	3.2	4.0	2.6	0.0	5.2
17	Bhatpara	390.467	30.42	266	10.2	69.8	2.6	2.3	1.0	1.5	1.5	2.0	2.8	1.9	1.5	2.9
18	Bidhannagar	218.323	30.00	208	9.0	67.0	2.9	2.4	1.0	1.7	1.6	3.0	3.5	2.5	1.7	3.7
19	Chakdaha	132.855	15.54	122	9.3	63.4	3.1	2.5	1.3	2.0	1.8	3.3	3.8	2.7	2.2	4.6
20	Champadani	110.983	6.47	71	11.0	63.0	3.2	2.6	1.8	2.2	2.3	2.8	3.7	2.3	0.0	5.0
21	Chandernagore	166.949	22.03	160	9.0	65.2	3.0	2.4	1.2	1.9	1.7	3.2	3.7	2.6	2.0	4.2
22	Chinsurah	180.502	17.24	146	9.7	65.3	3.0	2.4	1.3	1.9	1.8	2.8	3.5	2.4	2.0	4.0
23	Darjiling	120.414	10.57	97	9.8	62.4	3.2	2.5	1.5	2.1	2.0	3.1	3.8	2.5	2.5	4.7
24	Dhulian	239.022	10.27	126	11.6	65.8	2.8	2.4	1.4	1.8	1.9	1.9	2.9	1.8	2.1	3.6
25	Durgapur	566.937	1.10	64	20.8	61.2	2.0	2.2	2.5	1.7	2.6	0.5	1.3	0.5	2.4	2.3

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S No	Town	Population in Thousands	Area in km²	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
26	Habra	149.675	21.80	152	8.8	64.5	3.1	2.4	1.2	1.9	1.7	3.4	3.8	2.8	2.0	4.3
27	Haldia	200.762	104.90	385	6.6	66.9	3.0	2.3	0.7	1.6	1.2	4.7	4.2	3.8	1.4	3.8
28	Halisahar	126.893	8.28	88	10.5	62.4	3.1	2.5	1.6	2.1	2.1	2.7	3.6	2.2	2.5	4.6
29	H-C	177.209	8.29	100	11.3	64.1	2.9	2.5	1.6	2.0	2.0	2.2	3.1	1.9	2.3	4.1
30	Jalpaiguri	107.351	12.50	98	9.5	63.5	3.3	2.6	1.5	2.1	2.0	3.6	4.1	2.8	0.0	5.1
31	Jamuria	144.791	73.23	282	6.6	64.6	3.2	2.3	0.8	1.7	1.3	5.2	4.6	4.0	1.6	4.3
32	Jangipore	122.875	7.86	84	10.6	62.1	3.1	2.5	1.6	2.1	2.1	2.7	3.6	2.2	2.6	4.7
33	Kalyani	100.62	21.91	128	8.2	63.3	3.4	2.5	1.2	2.0	1.8	4.5	4.5	3.4	0.0	5.2
34	Kamarhati	336.579	20.48	205	10.7	68.6	2.6	2.3	1.1	1.6	1.6	1.9	2.8	1.8	1.7	3.1
35	Kanchapara	122.181	29.21	164	7.9	63.3	3.2	2.4	1.1	1.9	1.6	4.3	4.3	3.3	2.0	4.7
36	Kharagpur	206.923	90.65	361	6.9	67.1	3.0	2.3	0.7	1.6	1.2	4.4	4.1	3.6	1.4	3.7
37	Khardaha	111.13	10.96	93	9.8	63.6	3.3	2.6	1.5	2.1	2.1	3.4	4.0	2.7	0.0	5.0
38	Kolkata	4486.689	185.00	1964	10.8	79.6	1.5	1.8	0.4	0.8	0.8	0.7	1.3	0.9	0.5	1.0
39	Konnagar	124.585	9.07	91	10.3	62.4	3.1	2.5	1.6	2.1	2.1	2.8	3.6	2.3	2.5	4.7
40	Krishnanagar	181.182	6.87	92	11.9	63.8	2.9	2.5	1.7	2.0	2.1	2.0	3.0	1.8	2.4	4.0
41	Madhyamgram	198.964	21.32	169	9.5	66.1	2.9	2.4	1.2	1.8	1.7	2.8	3.4	2.4	1.9	3.9
42	Mahestala	449.423	21.50	238	11.3	69.8	2.5	2.3	1.1	1.5	1.6	1.6	2.5	1.6	1.6	2.8
43	Medinipur	169.127	14.78	131	9.9	64.8	3.0	2.5	1.3	1.9	1.8	2.8	3.5	2.3	2.1	4.1
44	Nabadwip	125.528	11.66	104	9.7	62.8	3.1	2.5	1.4	2.0	2.0	3.1	3.8	2.5	2.4	4.7
45	Naihati	221.762	11.55	130	11.1	65.7	2.8	2.4	1.4	1.8	1.9	2.1	3.0	1.9	2.1	3.7
46	N B	134.825	17.17	129	9.1	63.6	3.1	2.5	1.3	2.0	1.8	3.4	3.9	2.7	2.2	4.5
47	NDD	253.625	26.45	207	9.6	67.6	2.8	2.4	1.1	1.7	1.6	2.6	3.2	2.3	1.7	3.5
48	Panihati	383.522	6.89	127	13.8	66.6	2.4	2.4	1.6	1.7	2.0	1.2	2.2	1.2	2.0	2.9
49	Puruliya	121.436	13.90	112	9.3	62.8	3.2	2.5	1.4	2.0	1.9	3.3	3.9	2.7	2.3	4.7
50	Raiganj	183.682	10.64	115	10.8	64.7	2.9	2.5	1.5	1.9	1.9	2.3	3.2	2.0	2.2	4.0
51	R G	404.991	28.00	260	10.4	69.8	2.6	2.3	1.0	1.5	1.5	1.9	2.7	1.8	1.5	2.9

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S No	Town	Population in Thousands	Area in Km^2	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
52	R S	423.806	49.25	352	9.3	70.8	2.6	2.3	0.8	1.5	1.3	2.2	2.9	2.1	1.3	2.8
53	Rana Ghat	235.583	7.72	109	12.2	65.2	2.7	2.4	1.6	1.9	2.0	1.7	2.8	1.6	2.2	3.6
54	Raniganj	128.624	23.44	149	8.4	63.6	3.2	2.4	1.2	1.9	1.7	3.9	4.1	3.0	2.1	4.6
55	Rishra	124.591	6.48	77	11.0	61.9	3.1	2.5	1.7	2.1	2.2	2.5	3.4	2.1	2.7	4.7
56	Santipur	151.774	24.60	163	8.6	64.7	3.1	2.4	1.1	1.9	1.7	3.5	3.9	2.9	2.0	4.3
57	Serampore	183.339	14.50	134	10.1	65.2	2.9	2.4	1.3	1.9	1.8	2.6	3.4	2.2	2.1	4.0
58	Siliguri	509.709	41.90	351	10.0	71.4	2.5	2.3	0.9	1.4	1.3	1.9	2.6	1.8	1.3	2.6
59	S D D	410.524	17.39	206	11.6	69.0	2.5	2.3	1.2	1.6	1.6	1.6	2.5	1.6	1.7	2.9
60	Titagarh	118.426	3.24	54	12.6	60.2	3.0	2.5	2.2	2.2	2.5	2.0	3.1	1.7	3.1	4.7
61	Uluberia	221.175	33.72	222	8.8	67.2	2.9	2.4	1.0	1.7	1.5	3.1	3.5	2.6	1.7	3.7
62	Uttarpara K	162.386	16.34	136	9.6	64.7	3.0	2.5	1.3	1.9	1.8	2.9	3.6	2.4	2.1	4.2

03. A K – Ashokenagar-Kalyangarh
29. H C – Hooghly- Chinsurah
46. N B – New Barrackpore
47. NDD – North Dum Dum
51. R G – Rajarhat Gopalpur
52. R S – Rahjpur Sonarpur
59. S D D – South Dum Dum
62. Uttapara K – Uttapara Kotrung

Table A1.22: Estimated Length of Various Diameter Pipes in Sewerage Network in Class II Towns (Population between 0.05 and 0.1 Million) of West Bengal in NRGB

S No	Town	Population in Thousands	Area in Km^2	Estimated Total Length of Sewer Network, km	Estimated Percentage Lengths of Various Diameter (mm) Pipes											
					150	200	250	300	350	400	450	500	600	700	750	> 750
01	Arambagh	67.000	34.75	135	6.8	62.8	3.8	2.6	1.1	2.2	1.7	7.1	5.8	0.0	0.0	6.2
02	Baduria	52.500	22.43	98	7.1	61.0	3.9	2.6	1.3	2.3	1.9	7.1	5.9	0.0	0.0	6.8
03	Bankra	55.229	3.59	39	10.9	59.8	3.7	2.8	2.3	2.7	2.8	3.7	4.5	0.0	0.0	6.8
04	Baruipur	53.500	9.50	63	8.7	60.8	3.8	2.7	1.7	2.5	2.3	5.3	5.3	0.0	0.0	6.9
05	Bishnupur	70.620	22.01	108	7.7	63.2	3.7	2.6	1.3	2.2	1.9	5.9	5.3	0.0	0.0	6.1
06	Bolpur	74.890	10.73	77	9.2	63.1	3.6	2.7	1.6	2.4	2.2	4.4	4.7	0.0	0.0	6.0
07	Budge Budge	76.858	9.06	71	9.7	63.0	3.6	2.7	1.7	2.4	2.3	4.1	4.6	0.0	0.0	6.0
08	Chittaranjan	52.391	19.65	92	7.3	61.0	3.9	2.6	1.3	2.4	1.9	6.8	5.8	0.0	0.0	6.8
09	Contai	88.365	14.25	98	8.7	62.3	3.4	2.6	1.4	2.2	2.0	4.2	4.5	3.2	0.0	5.5
10	Gangarampur	61.028	10.29	69	8.9	61.7	3.8	2.7	1.7	2.4	2.2	5.0	5.1	0.0	0.0	6.5
11	Garulia	91.116	5.38	60	11.0	61.7	3.3	2.6	1.9	2.3	2.4	3.0	3.9	2.4	0.0	5.4
12	Gayeshpur	65.398	30.00	124	7.0	62.7	3.8	2.6	1.2	2.2	1.8	6.8	5.7	0.0	0.0	6.3
13	Gobardanga	57.878	13.50	78	8.2	61.6	3.8	2.7	1.5	2.4	2.1	5.7	5.4	0.0	0.0	6.6
14	J-A Ganj	51.790	11.66	70	8.3	60.7	3.9	2.7	1.6	2.5	2.2	5.8	5.5	0.0	0.0	6.9
15	Katwa	81.510	7.93	70	9.8	61.4	3.4	2.6	1.7	2.3	2.2	3.7	4.3	2.8	0.0	5.7

14. J-A Ganj – Jiyaganj-Azimganj

Appendix II

Estimated Capital Expenditure on Sewerage Infrastructure in Class I and Class II Towns of GRB

Table A2.01: Estimated Capital Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Million) of Uttarakhand in NRGB

S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
01	Dehradun	870.519	94.0	52.29	495	3463.8	54.7	1034.2	4552.7
02	Haldwani	169.147	18.3	10.62	111	778.8	4.8	200.9	984.5
03	Hardwar	487.923	52.7	13.00	193	1348.4	15.3	579.7	1943.4
04	Kashipur	121.610	13.1	5.46	70	490.4	2.5	144.5	637.4
05	Nainital	110.726	12.0	11.06	94	655.2	3.2	131.5	789.9
06	Rishikesh	102.138	11.0	10.00	86	603.1	2.8	121.3	727.2
07	Roorkee	118.188	12.8	20.20	131	915.6	4.6	140.4	1060.6
08	Rudrapur	140.884	15.2	12.43	112	783.0	4.3	167.4	954.7
Total		**2121.135**	**229.1**	**135.06**	**1292**	**9038.3**	**92.2**	**2519.9**	**11650.4**

Table A2.02: Estimated Capital Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of Uttarakhand in NRGB

S No	Town	Population in Thousand	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
01	BHEL Ranipur	51.910	5.6	26.94	108	646.9	2.3	61.7	710.9
02	Manglaur	51.101	5.5	1.32	23	140.5	0.5	60.7	201.7
03	Pithoragarh	53.957	5.8	9.00	62	371.8	1.4	64.1	437.3
04	Ramnagar	55.446	6.0	2.42	32	194.9	0.7	65.9	261.5
Total		**212.414**	**22.9**	**39.68**	**225**	**1354.1**	**4.9**	**252.4**	**1611.4**

Table A2.03: Estimated Capital Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Million) of Uttar Pradesh in NRGB

S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
01	Agra	1746.467	188.6	141.00	1111	7773.7	180.2	2074.8	10028.7
02	Aligarh	909.559	98.2	36.70	423	2962.2	47.9	1080.6	4090.7
03	Allahabad	1216.719	131.4	63.07	631	4416.4	84.0	1445.5	5945.9
04	Amroha	197.135	21.3	12.00	126	881.0	5.9	234.2	1121.1
05	Azamgarh	116.165	12.5	12.60	102	713.6	3.6	138.0	855.2
06	Badaun	159.221	17.2	4.39	70	492.0	2.9	189.2	684.1
07	Ballia	111.287	12.0	16.00	113	793.2	3.9	132.2	929.3
08	Banda	154.388	16.7	11.05	109	765.6	4.5	183.4	953.5
09	Barabanki	154.692	16.7	3.87	65	457.3	2.6	183.8	643.7
10	Baraut	101.241	10.9	25.00	138	964.7	4.4	120.3	1089.4
11	Bareilly	979.933	105.8	106.43	745	5215.0	87.9	1164.2	6467.1
12	Basti	114.651	12.4	19.43	127	886.9	4.4	136.2	1027.5
13	Bijnour	115.381	12.5	3.65	55	382.3	1.9	137.1	521.3
14	Bulandsahar	222.826	24.1	32.50	218	1529.4	11.0	264.7	1805.1
15	Chandausi	114.254	12.3	8.80	84	590.7	2.9	135.7	729.3
16	Deoria	129.570	14.0	16.19	124	865.9	4.5	153.9	1024.3
17	Etah	131.023	14.2	13.49	113	793.0	4.2	155.7	952.9
18	Etawah	256.790	27.7	48.00	282	1976.4	15.5	305.1	2297.0
19	Faizabad	259.160	28.0	16.60	166	1159.7	9.2	307.9	1476.8
20	Farrukhabad	318.540	34.4	16.80	182	1272.3	11.3	378.4	1662.0
21	Fatehpur	193.801	20.9	56.98	276	1932.4	12.7	230.2	2175.3
22	Firozabad	603.797	65.2	21.35	270	1889.5	24.2	717.3	2631.0
23	Gazipur	121.136	13.1	13.45	110	767.9	3.9	143.9	915.7
24	Ghaziabad	2358.525	254.7	215.00	1573	11014.1	300.5	2801.9	14116.5
25	Gonda	138.929	15.0	24.62	157	1101.8	6.0	165.0	1272.8

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S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
26	Gorakhpur	692.519	74.8	147.00	756	5290.2	73.0	822.7	6185.9
27	Greater Noida	642.381	69.4	27.93	317	2217.3	29.5	763.1	3009.9
28	Hapur	262.801	28.4	42.00	266	1863.2	14.8	312.2	2190.2
29	Hardoi	197.046	21.3	11.05	121	845.5	5.7	234.1	1085.3
30	Hathras	161.289	17.4	8.40	97	679.9	4.1	191.6	875.6
31	Jaunpur	168.128	18.2	20.00	153	1067.8	6.5	199.7	1274.0
32	Jhansi	549.391	59.3	169.50	738	5165.6	62.2	652.7	5880.5
33	Kanpur	2920.067	315.4	261.50	1914	13399.5	410.4	3469.0	17278.9
34	Kasganj	101.241	10.9	7.10	72	505.2	2.3	120.3	627.8
35	Lakhimpur	164.925	17.8	10.20	108	755.5	4.6	195.9	956.0
36	Lalitpur	133.041	14.4	18.00	132	923.3	4.9	158.1	1086.3
37	Loni	512.296	55.3	34.48	319	2230.9	26.1	608.6	2865.6
38	Lucknow	2901.474	313.4	330.00	2147	15025.7	458.0	3447.0	18930.7
39	Mainpuri	133.078	14.4	7.50	85	594.8	3.2	158.1	756.1
40	Mathura	454.937	49.1	32.80	295	2067.5	22.6	540.5	2630.6
41	Mau	279.060	30.1	39.00	263	1838.5	15.1	331.5	2185.1
42	Meerut	1424.908	153.9	41.94	554	3876.3	80.2	1692.8	5649.3
43	Mirzapur	233.691	25.2	40.00	248	1733.3	12.8	277.6	2023.7
44	Modinagar	182.811	19.7	14.00	132	922.6	5.9	217.2	1145.7
45	Moradabad	889.810	96.1	80.00	618	4328.3	69.2	1057.1	5454.6
46	Mugalsarai	154.692	16.7	14.43	125	876.0	5.1	183.8	1064.9
47	Muradanagar	100.080	10.8	12.00	94	656.7	3.0	118.9	778.6
48	Muzaffar Nagar	316.729	34.2	12.04	154	1076.6	9.6	376.3	1462.5
49	Noida	642.381	69.4	203.16	865	6054.6	79.6	763.1	6897.3
50	Orai	190.625	20.6	16.00	143	1003.4	6.6	226.5	1236.5
51	Pililbhit	160.146	17.3	9.50	103	720.6	4.3	190.3	915.2
52	Raibareliy	191.625	20.7	34.00	211	1473.8	9.7	227.7	1711.2

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S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
53	Rampur	359.062	38.8	20.20	210	1467.2	14.0	426.6	1907.8
54	Saharanpur	703.345	76.0	73.72	535	3748.4	52.5	835.6	4636.5
55	Sahaswann	178.000	19.2	7.50	96	669.4	4.2	211.5	885.1
56	Sahjahanpur	356.103	38.5	11.37	157	1100.8	10.4	423.1	1534.3
57	Shambhal	221.334	23.9	15.65	151	1054.8	7.6	262.9	1325.3
58	Sitapur	188.230	20.3	35.00	212	1485.4	9.7	223.6	1718.7
59	Sultanpur	116.211	12.6	16.00	115	806.6	4.0	138.1	948.7
60	Ujhani	191.000	20.6	6.50	92	642.5	4.2	226.9	873.6
61	Unnao	178.681	19.3	21.50	162	1134.8	7.2	212.3	1354.3
62	Varansi	1435.113	155.0	79.79	764	5349.2	111.4	1704.9	7165.5
TOTAL		**29613.440**	**3198.3**	**2869.73**	**20894**	**146248.7**	**2494.2**	**35181.1**	**183924.0**

Table A2.04: Estimated Capital Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of Uttar Pradesh in NRGB

S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
01	Auraiya	70.515	7.6	4.00	46	274.7	1.2	83.8	359.7
02	Baghpat	50.380	5.4	2.83	34	202.5	0.7	59.9	263.1
03	Baheri	74.869	8.1	15.00	91	546.4	2.5	88.9	637.8
04	Balrampur	90.000	9.7	36.28	161	964.1	4.7	106.9	1075.7
05	Bhadohi	94.563	10.2	8.00	75	447.8	2.3	112.3	562.4
06	Bisalpur	83.347	9.0	4.58	54	321.7	1.6	99.0	422.3

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S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
07	Chandpur	83.456	9.0	23.40	124	743.8	3.5	99.1	846.4
08	Chibramau	55.296	6.0	11.10	70	417.6	1.6	65.7	484.9
09	Chitrakoot	57.452	6.2	7.77	59	353.3	1.4	68.3	423.0
10	Dadri	91.345	9.9	6.50	66	397.7	2.0	108.5	508.2
11	Deoband	97.068	10.5	7.90	75	449.5	2.4	115.3	567.2
12	Faredpur	76.422	8.3	9.43	73	435.1	2.0	90.8	527.9
13	Gangaghat	84.301	9.1	4.91	56	334.6	1.6	100.1	436.3
14	Gangoh	59.463	6.4	6.00	52	314.3	1.3	70.6	386.2
15	Gola	53.842	5.8	10.08	66	393.6	1.5	64.0	459.1
16	Hasanpur	64.536	7.0	5.72	53	316.8	1.3	76.7	394.8
17	Jahangerabad	59.873	6.5	14.30	82	490.0	2.0	71.1	563.1
18	Jalaun	56.871	6.1	5.00	47	281.9	1.1	67.6	350.6
19	Kaimur	51.469	5.6	7.12	54	324.2	1.2	61.1	386.5
20	Kairana	95.092	10.3	7.11	70	422.8	2.2	113.0	538.0
21	Kannauj	71.727	7.7	70.70	202	1209.5	5.2	85.2	1299.9
22	Khatauli	72.478	7.8	3.76	45	269.3	1.2	86.1	356.6
23	Kiratpur	61.801	6.7	4.45	46	274.8	1.1	73.4	349.3
24	Konch	53.426	5.8	2.95	35	211.7	0.8	63.5	276.0
25	Laharpur	61.280	6.6	8.00	61	367.5	1.5	72.8	441.8
26	Mahoba	95.454	10.3	12.15	93	556.3	2.9	113.4	672.6
27	Mau Ranipur	58.456	6.3	5.53	50	299.7	1.2	69.4	370.3
28	Mawana	81.126	8.8	7.50	68	408.4	1.9	96.4	506.7
29	Mubarakpur	71.365	7.7	9.00	69	413.7	1.9	84.8	500.4
30	Nagina	71.350	7.7	10.30	74	442.9	2.0	84.8	529.7
31	Nazibabad	88.638	9.6	5.06	58	346.5	1.7	105.3	453.5
32	Obra	56.116	6.1	4.50	44	266.1	1.0	66.7	333.8

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S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in Km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
33	Pilkhuwa	81.651	8.8	5.80	60	359.4	1.7	97.0	458.1
34	Pratapgarh	76.750	8.3	12.00	82	492.3	2.3	91.2	585.8
35	Ramnagar	54.800	5.9	3.60	39	236.0	0.9	65.1	302.0
36	Rath	65.092	7.0	6.10	55	328.2	1.4	77.3	406.9
37	S R Nagar	94.563	10.2	8.00	75	447.8	2.3	112.3	562.4
38	Shahbad	80.305	8.7	9.70	77	463.9	2.2	95.4	561.5
39	Sherkot	62.148	6.7	6.00	53	319.7	1.3	73.8	394.8
40	Sikandrabad	80.309	8.7	1.14	27	160.4	0.7	95.4	256.5
41	Tanda	96.138	10.4	10.45	86	516.4	2.7	114.2	633.3
42	Tilhar	60.803	6.6	3.48	40	241.7	1.0	72.2	314.9
43	Vrindavann	62.926	6.8	13.49	81	484.4	2.0	74.8	561.2
TOTAL		**3108.862**	**335.8**	**420.69**	**2928**	**17549.0**	**79.0**	**3693.2**	**21321.2**

37. S R Nagar – Sant Ravidas Nagar

Table A2.05: Estimated Capital Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Million) of Himanchal Pradesh in NRGB

S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in Km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
No Class I town									

Table A2.06: Estimated Capital Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of Himanchal Pradesh in NRGB

S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in Km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
No Class II town									

Table A2.07: Estimated Capital Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Million) of Haryana in NRGB

S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
01	Bhadur Garh	170.426	18.4	50.00	245	1718.4	10.5	202.5	1931.4
02	Bhiwani	197.662	21.3	47.78	254	1777.4	11.9	234.8	2024.1
03	Faridabad	1404.653	151.7	207.80	1226	8579.9	176.0	1668.7	10424.6
04	Gurgoan	901.968	97.4	37.10	424	2967.0	47.7	1071.5	4086.2
05	Hisar	301.249	32.5	48.03	301	2109.3	18.1	357.9	2485.3
06	Jagadhari	124.915	13.5	24.80	152	1061.9	5.4	148.4	1215.7
07	Jind	166.225	18.0	42.00	222	1554.7	9.4	197.5	1761.6
08	Kaithal	144.633	15.6	45.75	220	1541.6	8.5	171.8	1721.9
09	Karnal	286.974	31.0	12.00	147	1030.6	8.6	340.9	1380.1
10	Kurukhetra	154.962	16.7	34.50	195	1367.0	7.9	184.1	1559
11	Narnaul	134.067	14.5	41.10	202	1416.9	7.5	159.3	1583.7
12	Palwal	127.931	13.8	8.78	90	633.2	3.3	152.0	788.5
13	Panipat	294.150	31.8	41.40	277	1936.5	16.4	349.5	2302.4
14	Rohtak	373.133	40.3	47.50	327	2291.3	22.3	443.3	2756.9
15	Sonipat	292.339	31.6	52.80	312	2187.0	18.5	347.3	2552.8
16	Yamuna Nagar	241.723	26.1	34.50	233	1629.3	12.3	287.2	1928.8
Total		**5317.010**	**574.2**	**775.84**	**4827**	**33802.0**	**384.3**	**6316.7**	**40503.0**

Table A2.08: Estimated Capital Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of Haryana in NRGB

S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
01	Hodal	50.003	5.4	5.39	46	278.7	1.0	59.4	339.1
02	Narvana	61.800	6.7	10.00	69	412.9	1.7	73.4	488.0
03	Sahadab	51.786	5.6	5.00	45	271.9	1.0	61.5	334.4
Total		**163.589**	**17.7**	**20.39**	**160**	**963.5**	**3.7**	**194.3**	**1161.5**

Table A2.09: Estimated Capital Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Million) of Delhi in NRGB

S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
01	B J	197.150	21.3	6.70	94	660.8	4.4	234.2	899.4
02	Burari	145.584	15.7	11.19	108	752.6	4.2	173.0	929.8
03	Dallo Pura	154.955	16.7	2.29	51	355.6	2.0	184.1	541.7
04	Delhi Cantt.	116.352	12.6	42.97	193	1350.9	6.6	138.2	1495.7
05	DMC	11007.835	1188.8	431.09	4572	32002.2	1986.2	13077.3	47065.7
06	Deoli	169.410	18.3	10.12	109	760.8	4.7	201.3	966.8
07	Gokalpur	121.938	13.2	2.32	46	323.9	1.6	144.9	470.4
08	Hastal	177.033	19.1	6.75	91	634.2	4.0	210.3	848.5
09	Karawal Nagar	224.666	24.3	4.75	84	590.7	4.3	266.9	861.9
10	K S N	282.598	30.5	4.74	93	651.2	5.3	335.7	992.2
11	Mandoli	120.345	13.0	41.77	196	1372.8	6.8	143.0	1522.6
12	Mustafabad	127.012	13.7	1.29	36	249.3	1.3	150.9	401.5
13	Nangloi Jat	205.497	22.2	6.67	96	670.9	4.6	244.1	919.6
14	NDMC	249.998	27.0	42.74	263	1842.4	14.2	297.0	2153.6
15	Sultanpur Majra	181.624	19.6	2.86	60	422.9	2.7	215.8	641.4
Total		**13482.000**	**1456.1**	**618.25**	**6092**	**42641.2**	**2052.9**	**16016.7**	**60710.8**

01. B J – Bhalswa Jahangirpur
05. DMC – Delhi Municipal Corporation
10. K S N – Kirari Suleman Nagar
14. NDMC – New Delhi Municipal Corporation

Table A2.10: Estimated Capital Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of Delhi in NRGB

S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
01	Babarpur	52.918	5.7	0.79	19	111.5	0.4	62.9	174.8
02	C S B	81.374	8.8	2.58	40	239.6	1.1	96.7	337.4
03	Gharoli	84.722	9.1	3.56	48	285.6	1.4	100.6	387.6
04	Jaffrabad	70.089	7.6	0.90	22	133.2	0.6	83.3	217.1
05	Khajoori Khas	55.006	5.9	0.94	21	123.0	0.5	65.3	188.8
06	Mithe Pur	49.583	5.4	1.81	27	161.8	0.6	58.9	221.3
07	Molar Band	49.439	5.3	4.12	40	242.5	0.9	58.7	302.1
08	Mundka	53.525	5.8	11.89	71	427.4	1.6	63.6	492.6
09	Pooth Kalan	61.727	6.7	6.97	57	343.8	1.4	73.3	418.5
10	Pulpehlad	64.484	7.0	2.16	33	195.9	0.8	76.6	273.3
11	S P G	52.730	5.7	1.05	21	127.5	0.5	62.6	190.6
12	Taj Pul	72.764	7.9	1.22	26	156.3	0.7	86.4	243.4
13	Tigri	54.774	5.9	1.05	22	129.5	0.5	65.1	195.1
14	Ziauddin Pur	58.661	6.3	1.80	29	172.6	0.7	69.7	243.0
Total		**861.796**	**93.1**	**40.84**	**476**	**2850.2**	**11.7**	**1023.7**	**3885.6**

02. C S B – Chilla Saroda Bangar

11. S P G – Sadat Pur Gurjan

Table A2.11: Estimated Capital Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Million) of Rajasthan in NRGB

S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
01	Ajmer	542.580	58.6	87.00	521	3648.2	44.0	644.6	4336.8
02	Alwar	315.310	34.1	49.00	310	2171.1	19.2	374.6	2564.9
03	Bahilwara	360.009	38.9	69.00	390	2731.0	26.0	427.7	3184.7
04	Baran	118.157	12.8	72.36	260	1823.1	8.7	140.4	1972.2
05	Bharatpur	252.109	27.2	29.00	217	1517.5	11.8	299.5	1828.8
06	Bundi	102.823	11.1	22.76	132	923.9	4.3	122.2	1050.4
07	Chittaugarh	116.409	12.6	30.50	161	1128.1	5.6	138.3	1272.0
08	Dhaulpur	126.142	13.6	32.00	174	1215.9	6.2	149.9	1372.0
09	Gangapurcity	224.773	24.3	17.22	159	1113.5	8.1	267.0	1388.6
10	Hindauncity	105.690	11.4	48.00	198	1383.2	6.4	125.6	1515.2
11	Jaipur	3073.350	331.9	485.00	2679	18750.6	588.2	3651.1	22989.9
12	Jhunjhunun	118.966	12.8	50.00	215	1502.5	7.3	141.3	1651.1
13	Kishangarh	155.019	16.7	100.00	341	2388.4	13.5	184.2	2586.1
14	Kota	1001.365	108.1	527.03	1710	11967.9	199.8	1189.6	13357.3
15	Nagaur	100.618	10.9	37.81	171	1196.9	5.4	119.5	1321.8
16	Sikar	237.579	25.7	39.90	249	1742.6	13.0	282.2	2037.8
17	Swaimadhavpur	120.998	13.1	49.00	214	1495.8	7.4	143.7	1646.9
18	Tonk	165.363	17.9	16.00	135	947.6	5.7	196.5	1149.8
19	Udaipur	451.735	48.8	56.91	389	2721.0	29.6	536.7	3287.3
	Total	**7688.995**	**830.4**	**1818.49**	**8625**	**60368.8**	**1010.2**	**9134.6**	**70513.6**

Table A2.12: Estimated Capital Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of Rajasthan in NRGB

S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
01	Jhalawara	66.500	7.2	12.95	81	484.4	2.1	79.0	565.5
02	Makrana	94.447	10.2	36.00	163	976.9	4.9	112.2	1094.0
03	Nawalgarh	64.903	7.0	27.91	119	714.0	3.0	77.1	794.1
04	Nimbahera	61.000	6.6	12.74	77	465.0	1.9	72.5	539.4
Total		**286.85**	**31.0**	**89.6**	**440**	**2640.3**	**11.9**	**340.8**	**2993.0**

Table A2.13: Estimated Capital Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Million) of Madhya Pradesh in NRGB

S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
01	Bhind	197.332	21.3	17.79	153	1073.3	7.2	234.4	1314.9
02	Bopal	1883.381	203.4	285.00	1640	11477.8	276.3	2237.5	13991.6
03	Chatarpur	147.688	16.0	54.00	242	1694.4	9.4	175.5	1879.3
04	Damoh	147.515	15.9	16.00	129	905.6	5.1	175.2	1085.9
05	Datia	100.466	10.9	6.85	71	494.6	2.3	119.4	616.3
06	Dewas	289.438	31.3	102.00	437	3060.6	25.4	343.9	3429.9
07	Guna	180.978	19.5	45.75	240	1679.3	10.6	215.0	1904.9
08	Gwalior	1101.981	119.0	173.88	1006	7042.7	126.3	1309.2	8478.2
09	Indore	2167.447	234.1	131.17	1181	8269.7	215.7	2574.9	11060.3
10	Jabalpur	1267.564	136.9	135.00	941	6588.6	128.0	1505.9	8222.5
11	Katni	221.875	24.0	68.60	320	2242.8	16.0	263.6	2522.4
12	Mandsour	141.468	15.3	36.00	193	1349.7	7.4	168.1	1525.2
13	Morena	200.506	21.7	12.00	127	887.2	6.0	238.2	1131.4

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S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
14	Neemuch	128.575	13.9	22.00	144	1009.6	5.2	152.7	1167.5
15	Pithampur	126.099	13.6	89.90	299	2095.1	10.4	149.8	2255.3
16	Ratlam	273.892	29.6	39.19	261	1829.0	14.9	325.4	2169.3
17	Rewa	235.422	25.4	102.00	403	2823.2	20.7	279.7	3123.6
18	Sagar	370.296	40.0	33.75	275	1921.7	18.7	439.9	2380.3
19	Satna	283.004	30.6	12.00	146	1024.5	8.5	336.2	1369.2
20	Sehore	1090.025	117.7	13.10	278	1944.2	34.3	1294.9	3273.4
21	Shahdol	100.565	10.9	28.24	147	1025.8	4.6	119.5	1149.9
22	Shepour	105.026	11.3	5.00	61	430.0	2.0	124.8	556.8
23	Shivpuri	179.972	19.4	86.55	334	2338.0	14.6	213.8	2566.4
24	Singrauli	220.295	23.8	280.66	674	4720.5	32.1	261.7	5014.3
25	Tikamgarh	101.786	11.0	6.22	68	473.7	2.2	120.9	596.8
26	Ujjain	515.215	55.6	92.68	527	3686.6	43.1	612.1	4341.8
27	Vidisha	155.959	16.8	8.83	98	687.5	4.0	185.3	876.8
	TOTAL	**11933.77**	**1288.8**	**1904.16**	**10395**	**72775.7**	**1051.0**	**14177.5**	**88004.2**

Table A2.14: Estimated Capital Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of Madhya Pradesh in NRGB

S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
01	Basoda	78.265	8.5	5.90	58	347.2	1.7	93.0	441.9
02	Bina	64.579	7.0	12.00	77	460.8	1.9	76.7	539.4
03	Dabra	61.260	6.6	12.00	75	451.7	1.8	72.8	526.3
04	Dhar	95.000	10.3	30.00	148	888.9	4.5	112.9	1006.3

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S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
05	Jaora	65.111	7.0	5.54	52	312.8	1.3	77.4	391.5
06	Mandla	55.145	6.0	8.87	62	372.1	1.4	65.5	439.0
07	Narshimpur	59.858	6.5	14.71	83	497.1	2.0	71.1	570.2
08	Panna	50.432	5.4	4.50	43	255.4	0.9	59.9	316.2
09	Shajapur	70.000	7.6	11.16	76	457.9	2.0	83.2	543.1
10	Sidhi	54.317	5.9	12.31	73	437.5	1.7	64.5	503.7
Total		**653.967**	**70.6**	**116.99**	**747**	**4481.4**	**19.2**	**777.0**	**5277.6**

Table A2.15: Estimated Capital Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Million) of Bihar in NRGB

S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
01	Arrah	261.099	28.2	30.97	227	1591.5	12.6	310.2	1914.3
02	Aurangabad	101.520	11.0	8.00	77	537.2	2.5	120.6	660.3
03	Bagaha	113.012	12.2	11.00	94	658.7	3.3	134.3	796.3
04	Begusarai	251.136	27.1	8.98	121	844.5	6.5	298.3	1149.3
05	Bettiah	132.896	14.4	11.55	105	737.4	3.9	157.9	899.2
06	B M C	398.138	43.0	30.17	268	1873.0	19.0	473.0	2365.0
07	B M C	296.889	32.1	22.46	204	1427.6	12.2	352.7	1792.5
08	Buxar	102.591	11.1	8.00	77	539.4	2.5	121.9	663.8
09	Chapra (NP)	201.597	21.8	16.96	151	1057.0	7.2	239.5	1303.7
10	Darbhanga	294.116	31.8	19.18	188	1314.1	11.2	349.4	1674.7
11	Dehri	137.068	14.8	21.32	145	1018.3	5.5	162.8	1186.6
12	D N	182.241	19.7	11.63	120	840.0	5.4	216.5	1061.9

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S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
13	Gaya	463.454	50.1	50.17	369	2580.5	28.5	550.6	3159.6
14	Hajipur	147.126	15.9	19.64	143	1003.8	5.7	174.8	1184.3
15	Jamalpur	105.221	11.4	10.65	90	630.0	3.0	125.0	758.0
16	Jehanabad	102.456	11.1	20.23	124	867.7	4.0	121.7	993.4
17	Katihar	225.982	24.4	24.54	191	1333.7	9.7	268.5	1611.9
18	Kishanganj	107.076	11.6	30.12	155	1086.2	5.1	127.2	1218.5
19	M T	105.000	11.3	8.50	80	561.3	2.7	124.7	688.7
20	Motihari	125.183	13.5	13.52	111	779.8	4.0	148.7	932.5
21	Munger	213.101	23.0	17.50	157	1098.3	7.7	253.2	1359.2
22	Muzaffarpur	351.838	38.0	26.43	238	1663.4	15.7	418.0	2097.1
23	Nawada	109.141	11.8	5.68	66	465.4	2.3	129.7	597.4
24	Patna	1683.200	181.8	108.34	957	6698.7	152.3	1999.6	8850.6
25	Purnia	280.547	30.3	44.52	282	1971.1	16.3	333.3	2320.7
26	Saharsa	155.175	16.8	21.13	152	1063.8	6.2	184.3	1254.3
27	Sasaram	147.396	15.9	12.00	112	783.2	4.4	175.1	962.7
28	Siwan	134.458	14.5	15.68	123	864.4	4.6	159.7	1028.7
TOTAL		**6928.657**	**748.3**	**628.87**	**5127**	**35890.0**	**364.0**	**8231.2**	**44485.2**

06. B M C – Bhagalpur Municipal Corporation
07. B M C – Biharsharif Municipal Corporation
12. DN – Dinapur Nizamat
19. MT – Madhubani Town

Table A2.16: Estimated Capital Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of Bihar in NRGB

S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
01	Araria	80.000	8.6	4.50	52	313.8	1.5	95.0	410.3
02	Barahiya	50.230	5.4	26.54	106	634.5	2.2	59.7	696.4
03	Barh	61.037	6.6	4.50	46	275.0	1.1	72.5	348.6
04	Bhabua	52.611	5.7	7.12	54	326.9	1.2	62.5	390.6
05	D M	67.995	7.3	11.30	76	455.7	2.0	80.8	538.5
06	Dumraon	57.716	6.2	15.33	83	501.0	2.0	68.6	571.6
07	Forbesganj	52.289	5.6	4.98	45	272.4	1.0	62.1	335.5
08	Gopalganj	66.624	7.2	11.11	75	448.3	1.9	79.1	529.3
09	Kaimur	51.469	5.6	7.12	54	324.2	1.2	61.1	386.5
10	Khagaria	56.978	6.2	2.97	36	217.9	0.9	67.7	286.5
11	Khagaul	60.866	6.6	5.32	50	298.6	1.2	72.3	372.1
12	Lakhisarai	98.123	10.6	24.79	136	813.7	4.2	116.6	934.5
13	Madhepura	56.739	6.1	25.84	109	653.2	2.5	67.4	723.1
14	Masaurhi	57.012	6.2	9.43	65	388.7	1.5	67.7	457.9
15	Mokameh	71.335	7.7	14.18	87	521.2	2.3	84.7	608.2
16	Narkatiaganj	51.446	5.6	10.96	67	404.0	1.5	61.1	466.6
17	Phulwari Sharif	67.348	7.3	6.48	57	342.9	1.5	80.0	424.4
18	Raxaul Bazar	52.429	5.7	5.82	49	294.9	1.1	62.3	358.3
19	Samastipur	70.042	7.6	3.45	42	254.7	1.1	83.2	339.0
20	Shekhpura	54.322	5.9	15.58	82	494.0	1.9	64.5	560.4
21	Sitamarhi	87.279	9.4	8.00	72	434.1	2.1	103.7	539.9
22	Sultanganj	52.867	5.7	12.29	72	432.8	1.6	62.8	497.2
23	Supaul	85.200	9.2	22.37	122	731.9	3.5	101.2	836.6
TOTAL		**1461.957**	**157.9**	**259.98**	**1637**	**9834.4**	**41.0**	**1736.6**	**11612.0**

05. D M – Digha-Mainpura

Table A2.17: Estimated Capital Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Million) of Chhatisgarh in NRGB

S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
01	Ambikapur	114.575	12.4	9.39	87	611.1	3.1	136.1	750.3
02	Bhilai Nagar	625.697	67.6	141.30	709	4966.0	64.6	743.3	5773.9
03	Bilaspur	330.106	35.7	37.56	276	1933.0	17.6	392.2	2342.8
04	Durg	268.679	29.0	66.09	339	2372.6	19.0	319.2	2710.8
05	Jagdalpur	125.345	13.5	22.49	144	1011.2	5.2	148.9	1165.3
06	Korba	363.210	39.2	215.02	707	4947.4	46.3	431.5	5425.2
07	Raigarh	137.097	14.8	20.68	143	1002.6	5.4	162.9	1170.9
08	Raipur	1010.087	109.1	108.66	763	5340.6	91.5	1200.0	6632.1
09	Rajnandgaon	163.122	17.6	78.09	305	2134.7	12.5	193.8	2341.0
Total		**3137.918**	**338.9**	**699.28**	**3473**	**24319.2**	**265.2**	**3727.9**	**28312.3**

Table A2.18: Estimated Capital Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of Chhatisgarh in NRGB

S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
01	Bhatapara	54.846	5.9	30.42	117	703.2	2.6	65.2	771.0
02	Bhilai Charoda	95.848	10.4	141.30	343	2059.9	9.9	113.9	2183.7
03	Chirmiri	99.934	10.8	64.94	228	1366.6	7.0	118.7	1492.3
04	Dalli-Rajhara	55.684	6.0	37.25	131	786.9	3.0	66.2	856.1
05	Dhamtari	89.857	9.7	23.40	127	764.2	3.8	106.8	874.8
06	Mahasamund	51.543	5.6	14.68	78	470.0	1.7	61.2	532.9
Total		**447.712**	**48.4**	**311.99**	**1024**	**6150.8**	**28.0**	**532.0**	**6710.8**

Table A2.19: Estimated Capital Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Million) of Jharkhand in NRGB

S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
01	Aditya	173.988	18.8	49.82	247	1728.8	10.7	206.7	1946.2
02	Bhuli	110.127	11.9	11.74	96	674.0	3.3	130.8	808.1
03	Bokaro	413.934	44.7	162.91	644	4506.7	45.9	491.8	5044.4
04	Chas	141.618	15.3	20.49	144	1010.5	5.6	168.2	1184.3
05	Deoghar	203.116	21.9	14.00	138	963.1	6.6	241.3	1211.0
06	Dhanbad	1161.561	125.4	23.39	379	2651.7	48.8	1379.9	4080.4
07	Giridih	114.447	12.4	9.75	89	622.6	3.1	136.0	761.7
08	Hazaribag	142.494	15.4	26.37	165	1152.6	6.4	169.3	1328.3
09	JNAC	629.659	68.0	59.80	459	3215.1	42.3	748.0	4005.4
10	Jharia	100.839	10.9	4.42	57	397.8	1.8	119.8	519.4
11	Jorapokhar	104.673	11.3	16.40	112	784.6	3.7	124.4	912.7
12	MNAC	224.002	24.2	19.45	169	1182.0	8.6	266.1	1456.7
13	Phusro	102.673	11.1	40.64	179	1252.8	5.7	122.0	1380.5
14	Ranchi	1073.440	115.9	177.19	1004	7029.6	124.2	1275.2	8429.0
15	Saunda	104.642	11.3	24.26	137	961.5	4.5	124.3	1090.3
Total		**4801.213**	**518.5**	**660.63**	**4019**	**28133.4**	**321.2**	**5703.8**	**34158.4**

09. JNAC – Jamshedpur Notified Area Committee
12. MNAC – Mango Notified Area Committee

Table A2.20: Estimated Capital Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of Jharkhand in NRGB

S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
01	Bagbera	82.559	8.9	10.70	82	493.1	2.3	98.1	593.5
02	Bhowrah	54.483	5.9	15.73	83	497.0	1.9	64.7	563.6
03	Bhuli	99.999	10.8	8.60	79	474.8	2.5	118.8	596.1
04	Chaibasa	78.287	8.5	11.11	82	492.8	2.3	93.0	588.1
05	Chatra	51.685	5.6	3.45	38	225.8	0.8	61.4	288.0
06	Daltonganj	87.849	9.5	14.00	97	579.8	2.9	104.4	687.1
07	Dumka	55.336	6.0	6.12	51	308.8	1.2	65.7	375.7
08	Gumia	56.024	6.1	26.11	109	653.8	2.5	66.6	722.9
09	Jhumri Tilaiya	85.489	9.2	51.14	190	1137.8	5.3	101.6	1244.7
10	Jugsalai	56.720	6.1	3.69	40	242.1	0.9	67.4	310.4
11	Katras	63.017	6.8	5.00	49	293.4	1.2	74.9	369.5
12	Lohardaga	56.821	6.1	14.57	81	485.2	1.9	67.5	554.6
13	Madhupur	58.211	6.3	18.36	92	551.7	2.2	69.2	623.1
14	Ramgarh Cantt.	90.324	9.8	34.46	157	939.3	4.6	107.3	1051.2
15	Sahibganj	98.589	10.6	8.98	80	482.7	2.6	117.1	602.4
16	Sindri	94.398	10.2	46.65	187	1121.4	5.6	112.1	1239.1
17	Tisra	65.894	7.1	14.02	84	502.8	2.1	78.3	583.2
Total		**1235.685**	**133.5**	**292.69**	**1581**	**9482.3**	**42.8**	**1468.1**	**10993.2**

Table A2.21: Estimated Capital Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Million) of West Bengal in NRGB

S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in Km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
01	Alipurduar	127.342	13.8	9.80	95	667.8	3.5	151.3	822.6
02	Asansol	564.491	61.0	127.87	645	4517.7	55.5	670.6	5243.8
03	A-K	123.906	13.4	18.44	130	909.4	4.6	147.2	1061.2
04	Baidyabati	121.081	13.1	7.89	84	587.4	3.0	143.8	734.2
05	Bally	115.715	12.5	11.68	98	685.4	3.4	137.5	826.3
06	Balurghat	151.183	16.3	10.46	106	738.7	4.2	179.6	922.5
07	Bangaon	110.668	12.0	24.70	142	991.2	4.8	131.5	1127.5
08	Bankura	138.036	14.9	19.06	138	964.3	5.2	164.0	1133.5
09	Bansberia	103.799	11.2	9.07	83	577.5	2.7	123.3	703.5
10	Bara Nagar	248.466	26.8	7.12	107	750.4	5.8	295.2	1051.4
11	Barasat	283.443	30.6	34.50	248	1738.6	14.5	336.7	2089.8
12	Bardhaman	314.638	34.0	26.30	226	1583.2	14.0	373.8	1971.0
13	Barrackpore	154.475	16.7	11.65	112	786.3	4.6	183.5	974.4
14	Basirhat	127.135	13.7	22.50	145	1016.9	5.2	151.0	1173.1
15	Beharampore	195.363	21.1	31.43	204	1426.6	9.5	232.1	1668.2
16	Bhadreswar	101.334	10.9	8.28	78	546.2	2.5	120.4	669.1
17	Bhatpara	390.467	42.2	30.42	266	1865.3	18.7	463.9	2347.9
18	Bidhannagar	218.323	23.6	30.00	208	1456.3	10.4	259.4	1726.1
19	Chakdaha	132.855	14.3	15.54	122	856.4	4.6	157.8	1018.8
20	Champadani	110.983	12.0	6.47	71	500.1	2.5	131.8	634.4
21	Chandernagore	166.949	18.0	22.03	160	1118.4	6.8	198.3	1323.5
22	Chinsurah	180.502	19.5	17.24	146	1019.1	6.5	214.4	1240.0
23	Darjiling	120.414	13.0	10.57	97	678.5	3.4	143.1	825.0
24	Dhulian	239.022	25.8	10.27	126	883.5	6.7	284.0	1174.2
25	Durgapur	566.937	61.2	1.10	64	449.3	5.2	673.5	1128.0

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S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
26	Habra	149.675	16.2	21.80	152	1065.7	6.1	177.8	1249.6
27	Haldia	200.762	21.7	104.90	385	2696.3	17.9	238.5	2952.7
28	Halisahar	126.893	13.7	8.28	88	613.0	3.2	150.7	766.9
29	H-C	177.209	19.1	8.29	100	702.0	4.4	210.5	916.9
30	Jalpaiguri	107.351	11.6	12.50	98	689.1	3.3	127.5	819.9
31	Jamuria	144.791	15.6	73.23	282	1974.6	10.8	172.0	2157.4
32	Jangipore	122.875	13.3	7.86	84	589.7	3.0	146.0	738.7
33	Kalyani	100.62	10.9	21.91	128	898.4	4.1	119.5	1022.0
34	Kamarhati	336.579	36.4	20.48	205	1437.2	13.2	399.9	1850.3
35	Kanchapara	122.181	13.2	29.21	164	1146.0	5.7	145.2	1296.9
36	Kharagpur	206.923	22.3	90.65	361	2525.6	17.1	245.8	2788.5
37	Khardaha	111.13	12.0	10.96	93	653.1	3.2	132.0	788.3
38	Kolkata	4486.689	484.6	185.00	1964	13745.5	530.3	5330.2	19606.0
39	Konnagar	124.585	13.5	9.07	91	636.9	3.3	148.0	788.2
40	Krishnanagar	181.182	19.6	6.87	92	645.9	4.1	215.2	865.2
41	Madhyamgram	198.964	21.5	21.32	169	1179.8	8.0	236.4	1424.2
42	Mahestala	449.423	48.5	21.50	238	1666.4	18.1	533.9	2218.4
43	Medinipur	169.127	18.3	14.78	131	918.8	5.7	200.9	1125.4
44	Nabadwip	125.528	13.6	11.66	104	724.5	3.7	149.1	877.3
45	Naihati	221.762	24.0	11.55	130	907.5	6.5	263.5	1177.5
46	N B	134.825	14.6	17.17	129	906.1	4.9	160.2	1071.2
47	NDD	253.625	27.4	26.45	207	1452.0	11.3	301.3	1764.6
48	Panihati	383.522	41.4	6.89	127	891.0	8.7	455.6	1355.3
49	Puruliya	121.436	13.1	13.90	112	781.6	3.9	144.3	929.8
50	Raiganj	183.682	19.8	10.64	115	806.2	5.2	218.2	1029.6
51	R G	404.991	43.7	28.00	260	1817.5	18.6	481.1	2317.2

Table A2.21 continued to next page … … … …

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S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
52	R S	423.806	45.8	49.25	352	2461.6	25.8	503.5	2990.9
53	Rana Ghat	235.583	25.4	7.72	109	763.3	5.7	279.9	1048.9
54	Raniganj	128.624	13.9	23.44	149	1043.1	5.4	152.8	1201.3
55	Rishra	124.591	13.5	6.48	77	538.8	2.8	148.0	689.6
56	Santipur	151.774	16.4	24.60	163	1139.7	6.5	180.3	1326.5
57	Serampore	183.339	19.8	14.50	134	940.1	6.1	217.8	1164.0
58	Siliguri	509.709	55.0	41.90	351	2454.4	28.7	605.5	3088.6
59	S D D	410.524	44.3	17.39	206	1442.8	14.9	487.7	1945.4
60	Titagarh	118.426	12.8	3.24	54	376.0	1.9	140.7	518.6
61	Uluberia	221.175	23.9	33.72	222	1553.8	11.2	262.8	1827.8
62	Uttarpara K	162.386	17.5	16.34	136	950.8	5.7	192.9	1149.4
TOTAL		**17123.79**	**1849.4**	**1557.84**	**11863**	**83049.3**	**1046.8**	**20342.9**	**104439.0**

03. A K – Ashokenagar-Kalyangarh
29. H C – Hooghly- Chinsurah
46. N B – New Barrackpore
47. NDD – North Dum Dum
51. R G – Rajarhat Gopalpur
52. R S – Rahjpur Sonarpur
59. S D D – South Dum Dum
62. Uttapara K – Uttapara Kotrung

Table A2.22: Estimated Capital Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of West Bengal in NRGB

S No	Town	Population in Thousands	Estimated Sewage Generation, MLD	Town Area in km^2	Estimated Length of Sewer Network, km	Estimated Capital Expenditure, Millions of INR			Estimated Total Expenditure, Millions of INR
						Sewerage Network	Sewage Pumping	Sewage Treatment	
01	Arambagh	67.000	7.2	34.75	135	810.2	3.4	79.6	893.2
02	Baduria	52.500	5.7	22.43	98	589.9	2.2	62.4	654.5
03	Bankra	55.229	6.0	3.59	39	236.4	0.9	65.6	302.9
04	Baruipur	53.500	5.8	9.50	63	381.0	1.4	63.6	446.0
05	Bishnupur	70.620	7.6	22.01	108	651.0	2.9	83.9	737.8
06	Bolpur	74.890	8.1	10.73	77	460.8	2.1	89.0	551.9
07	Budge Budge	76.858	8.3	9.06	71	427.3	2.0	91.3	520.6
08	Chittaranjan	52.391	5.7	19.65	92	550.1	2.0	62.2	614.3
09	Contai	88.365	9.5	14.25	98	586.5	2.9	105.0	694.4
10	Gangarampur	61.028	6.6	10.29	69	417.0	1.7	72.5	491.2
11	Garulia	91.116	9.8	5.38	60	361.2	1.8	108.2	471.2
12	Gayeshpur	65.398	7.1	30.00	124	743.5	3.1	77.7	824.3
13	Gobardanga	57.878	6.3	13.50	78	469.7	1.8	68.8	540.3
14	J-A Ganj	51.790	5.6	11.66	70	418.1	1.5	61.5	481.1
15	Katwa	81.510	8.8	7.93	70	420.9	2.0	96.8	519.7
Total		**1000.073**	**108.0**	**224.73**	**1252**	**7523.6**	**31.7**	**1188.1**	**8743.4**

14. J-A Ganj – Jiyaganj-Azimganj

Appendix III

Estimated Footprint, Energy Consumption, and Expenditure on Sewerage Infrastructure in Class I and Class II Towns of GRB

Table A3.01: Estimated Footprint, Energy Consumption, and Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Million) of Uttarakhand in NRGB

S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in kWh (Unit of Electricity)	Expenditure in INR
01	Dehradun	870.519	52.29	495	9.4	0.1	21.5	43.0	904.9	0.05	2.8
02	Haldwani	169.147	10.62	111	1.8	0.1	4.0	5.9	186.6	0.03	3.0
03	Hardwar	487.923	13.00	193	5.3	0.1	11.5	17.5	394.4	0.04	2.2
04	Kashipur	121.610	5.46	70	1.3	0.1	2.8	3.8	121.9	0.03	2.7
05	Nainital	110.726	11.06	94	1.2	0.1	2.6	3.9	145.8	0.03	3.6
06	Rishikesh	102.138	10.00	86	1.1	0.1	2.4	3.5	134.1	0.03	3.6
07	Roorkee	118.188	20.20	131	1.3	0.1	2.8	4.6	191.9	0.04	4.4
08	Rudrapur	140.884	12.43	112	1.5	0.1	3.3	5.0	177.6	0.04	3.5
	Total/Range	**2121.135**	**167.15**	**1291**	**22.9**		**51.0**	**87.2**	**2257.3**	**0.03-0.05**	**2.2-4.4**

Table A3.02: Estimated Footprint, Energy Consumption and Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of Uttarakhand in NRGB

S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in kWh (Unit of Electricity)	Expenditure in INR
01	BHEL Ranipur	51.910	26.94	108	0.6	0.1	1.3	2.2	124.3	0.04	6.6
02	Manglaur	51.101	1.32	23	0.6	0.1	1.2	1.4	40.0	0.03	2.1
03	Pithoragarh	53.957	9.00	62	0.6	0.1	1.3	1.8	79.4	0.03	4.0
04	Ramnagar	55.446	2.42	32	0.6	0.1	1.3	1.6	50.5	0.03	2.5
	Total/Range	**212.414**	**39.68**	**226**	**2.3**		**5.0**	**6.9**	**294.2**	**0.03-0.04**	**2.2-6.6**

Table A3.03: Estimated Footprint, Energy Consumption and Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Million) of Uttar Pradesh in NRGB

S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in kWh (Unit of Electricity)	Expenditure in INR
01	Agra	1746.467	141.00	1111	18.9	0.1	45.7	116.5	2025.6	0.07	3.2
02	Aligarh	909.559	36.70	423	9.8	0.1	22.2	41.0	829.0	0.05	2.5
03	Allahabad	1216.719	63.07	631	13.1	0.1	30.4	63.3	1204.1	0.05	2.7
04	Amroha	197.135	12.00	126	2.1	0.1	4.6	7.0	213.6	0.04	3.0
05	Azamgarh	116.165	12.60	102	1.3	0.1	2.7	4.1	157.4	0.04	3.7
06	Badaun	159.221	4.39	70	1.7	0.1	3.7	4.8	134.9	0.03	2.3
07	Ballia	111.287	16.00	113	1.2	0.1	2.6	4.2	169.1	0.04	4.2
08	Banda	154.388	11.05	109	1.7	0.1	3.6	5.4	179.3	0.03	3.2
09	Barabanki	154.692	3.87	65	1.7	0.1	3.6	4.6	127.5	0.03	2.3
10	Baraut	101.241	25.00	138	1.1	0.1	2.4	4.2	194.1	0.04	5.3
11	Bareilly	979.933	106.43	745	10.6	0.1	25.2	59.7	1260.4	0.06	3.5
12	Basti	114.651	19.43	127	1.2	0.1	2.7	4.5	185.9	0.04	4.4
13	Bijnour	115.381	3.65	55	1.2	0.1	2.7	3.4	101.7	0.03	2.4
14	Bulandsahar	222.826	32.50	218	2.4	0.1	5.4	9.7	332.5	0.04	4.1
15	Chandausi	114.254	8.80	84	1.2	0.1	2.7	3.8	136.2	0.03	3.3
16	Deoria	129.570	16.19	124	1.4	0.1	3.1	4.9	187.5	0.04	4.0
17	Etah	131.023	13.49	113	1.4	0.1	3.1	4.7	175.8	0.04	3.7
18	Etawah	256.790	48.00	282	2.8	0.1	6.3	12.4	420.9	0.05	4.5
19	Faizabad	259.160	16.60	166	2.8	0.1	6.2	9.8	282.5	0.04	3.0

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S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in kWh (Unit of Electricity)	Expenditure in INR
20	Farrukhabad	318.540	16.80	182	3.4	0.1	7.6	12.0	322.5	0.04	2.8
21	Fatehpur	193.801	56.98	276	2.1	0.1	4.8	9.8	390.2	0.05	5.5
22	Firozabad	603.797	21.35	270	6.5	0.1	14.4	24.0	529.7	0.04	2.4
23	Gazipur	121.136	13.45	110	1.3	0.1	2.9	4.4	168.2	0.04	3.8
24	Ghaziabad	2358.525	215.00	1573	25.5	0.1	63.8	181.8	2881.1	0.08	3.3
25	Gonda	138.929	24.62	157	1.5	0.1	3.3	5.7	230.4	0.04	4.5
26	Gorakhpur	692.519	147.00	756	7.5	0.1	18.2	46.8	1162.5	0.07	4.6
27	Greater Noida	642.381	27.93	317	6.9	0.1	15.5	27.1	601.1	0.04	2.6
28	Hapur	262.801	42.00	266	2.8	0.1	6.4	12.3	403.8	0.05	4.2
29	Hardoi	197.046	11.05	121	2.1	0.1	4.6	6.9	207.5	0.03	2.9
30	Hathras	161.289	8.40	97	1.7	0.1	3.8	5.4	167.3	0.03	2.8
31	Jaunpur	168.128	20.00	153	1.8	0.1	4.0	6.6	235.0	0.04	3.8
32	Jhansi	549.391	169.50	738	5.9	0.1	14.6	39.0	1083.8	0.07	5.4
33	Kanpur	2920.067	261.50	1914	31.5	0.1	80.3	241.5	3570.2	0.08	3.3
34	Kasganj	101.241	7.10	72	1.1	0.1	2.4	3.3	117.5	0.03	3.2
35	Lakhimpur	164.925	10.20	108	1.8	0.1	3.9	5.7	181.2	0.03	3.0
36	Lalitpur	133.041	18.00	132	1.4	0.1	3.2	5.1	198.4	0.04	4.1
37	Loni	512.296	34.48	319	5.5	0.1	12.5	22.7	557.1	0.04	3.0
38	Lucknow	2901.474	330.00	2147	31.3	0.1	81.6	261.5	3879.3	0.09	3.7
39	Mainpuri	133.078	7.50	85	1.4	0.1	3.1	4.3	143.3	0.03	2.9

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S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
40	Mathura	454.937	32.80	295	4.9	0.1	11.0	19.9	508.1	0.04	3.1
41	Mau	279.060	39.00	263	3.0	0.1	6.8	12.8	405.4	0.05	4.0
42	Meerut	1424.908	41.94	554	15.4	0.1	34.9	66.4	1180.5	0.05	2.3
43	Mirzapur	233.691	40.00	248	2.5	0.1	5.7	10.8	371.1	0.05	4.4
44	Modinagar	182.811	14.00	132	2.0	0.1	4.3	6.7	215.6	0.04	3.2
45	Moradabad	889.810	80.00	618	9.6	0.1	22.5	49.6	1067.0	0.06	3.3
46	Mugalsarai	154.692	14.43	125	1.7	0.1	3.7	5.7	198.0	0.04	3.5
47	Muradanagar	100.080	12.00	94	1.1	0.1	2.4	3.5	142.4	0.04	3.9
48	Muzaffar Nagar	316.729	12.04	154	3.4	0.1	7.5	11.2	288.2	0.04	2.5
49	Noida	642.381	203.16	865	6.9	0.1	17.3	48.5	1277.1	0.08	5.4
50	Orai	190.625	16.00	143	2.1	0.1	4.5	7.1	232.0	0.04	3.3
51	Pililbhit	160.146	9.50	103	1.7	0.1	3.8	5.4	173.7	0.03	3.0
52	Raibareliy	191.625	34.00	211	2.1	0.1	4.7	8.5	311.9	0.04	4.5
53	Rampur	359.062	20.20	210	3.9	0.1	8.6	14.1	370.2	0.04	2.8
54	Saharanpur	703.345	73.72	535	7.6	0.1	17.7	38.3	894.0	0.05	3.5
55	Sahaswann	178.000	7.50	96	1.9	0.1	4.2	5.8	171.2	0.03	2.6
56	Sahjahanpur	356.103	11.37	157	3.8	0.1	8.4	12.5	306.0	0.04	2.4
57	Shambhal	221.334	15.65	151	2.4	0.1	5.2	8.2	251.4	0.04	3.1
58	Sitapur	188.230	35.00	212	2.0	0.1	4.6	8.4	312.6	0.04	4.6
59	Sultanpur	116.211	16.00	115	1.3	0.1	2.8	4.3	173.0	0.04	4.1

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S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
60	Ujhani	191.000	6.50	92	2.1	0.1	4.4	6.1	171.1	0.03	2.5
61	Unnao	178.681	21.50	162	1.9	0.1	4.3	7.1	250.0	0.04	3.8
62	Varansi	1435.113	79.79	764	15.5	0.1	36.2	80.0	1456.4	0.06	2.8
	Total/Range	**29613.440**	**2869.73**	**20893**	**319.8**		**755.0**	**1734.9**	**36074.9**	**0.03-0.09**	**2.3-5.5**

Table A3.04: Estimated Footprint, Energy Consumption and Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of Uttar Pradesh in NRGB

S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in kWh (Unit of Electricity)	Expenditure in INR
01	Auraiya	70.515	4.00	46	0.8	0.1	1.6	2.1	68.9	0.03	2.7
02	Baghpat	50.380	2.83	34	0.5	0.1	1.2	1.4	50.1	0.03	2.7
03	Baheri	74.869	15.00	91	0.8	0.1	1.8	2.8	115.7	0.04	4.2
04	Balrampur	90.000	36.28	161	1.0	0.1	2.2	4.0	190.7	0.04	5.8
05	Bhadohi	94.563	8.00	75	1.0	0.1	2.2	3.1	106.0	0.03	3.1
06	Bisalpur	83.347	4.58	54	0.9	0.1	1.9	2.5	81.0	0.03	2.7
07	Chandpur	83.456	23.40	124	0.9	0.1	2.0	3.4	151.6	0.04	5.0

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S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in kWh (Unit of Electricity)	Expenditure in INR
08	Chibramau	55.296	11.10	70	0.6	0.1	1.3	1.9	87.5	0.03	4.3
09	Chitrakoot	57.452	7.77	59	0.6	0.1	1.3	1.9	77.5	0.03	3.7
10	Dadri	91.345	6.50	66	1.0	0.1	2.1	2.9	96.5	0.03	2.9
11	Deoband	97.068	7.90	75	1.0	0.1	2.3	3.2	107.1	0.03	3.0
12	Faredpur	76.422	9.43	73	0.8	0.1	1.8	2.6	97.7	0.03	3.5
13	Gangaghat	84.301	4.91	56	0.9	0.1	2.0	2.6	83.5	0.03	2.7
14	Gangoh	59.463	6.00	52	0.6	0.1	1.4	1.9	71.7	0.03	3.3
15	Gola	53.842	10.08	66	0.6	0.1	1.3	1.8	83.0	0.03	4.2
16	Hasanpur	64.536	5.72	53	0.7	0.1	1.5	2.0	73.9	0.03	3.1
17	Jahangerabad	59.873	14.30	82	0.6	0.1	1.4	2.2	101.1	0.04	4.6
18	Jalaun	56.871	5.00	47	0.6	0.1	1.3	1.8	65.5	0.03	3.2
19	Kaimur	51.469	7.12	54	0.6	0.1	1.2	1.7	70.6	0.03	3.8
20	Kairana	95.092	7.11	70	1.0	0.1	2.2	3.1	101.9	0.03	2.9
21	Kannauj	71.727	70.70	202	0.8	0.1	1.8	3.9	225.1	0.05	8.6
22	Khatauli	72.478	3.76	45	0.8	0.1	1.7	2.2	68.6	0.03	2.6
23	Kiratpur	61.801	4.45	46	0.7	0.1	1.4	1.9	65.9	0.03	2.9
24	Konch	53.426	2.95	35	0.6	0.1	1.2	1.5	52.6	0.03	2.7
25	Laharpur	61.280	8.00	61	0.7	0.1	1.4	2.0	81.2	0.03	3.6
26	Mahoba	95.454	12.15	93	1.0	0.1	2.2	3.4	124.4	0.04	3.6
27	Mau Ranipur	58.456	5.53	50	0.6	0.1	1.4	1.8	68.9	0.03	3.2

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S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in kWh (Unit of Electricity)	Expenditure in INR
28	Mawana	81.126	7.50	68	0.9	0.1	1.9	2.7	94.8	0.03	3.2
29	Mubarakpur	71.365	9.00	69	0.8	0.1	1.7	2.4	92.4	0.03	3.5
30	Nagina	71.350	10.30	74	0.8	0.1	1.7	2.5	97.2	0.03	3.7
31	Nazibabad	88.638	5.06	58	1.0	0.1	2.1	2.7	87.0	0.03	2.7
32	Obra	56.116	4.50	44	0.6	0.1	1.3	1.7	62.6	0.03	3.1
33	Pilkhuwa	81.651	5.80	60	0.9	0.1	1.9	2.6	86.8	0.03	2.9
34	Pratapgarh	76.750	12.00	82	0.8	0.1	1.8	2.7	107.3	0.04	3.8
35	Ramnagar	54.800	3.60	39	0.6	0.1	1.3	1.6	57.1	0.03	2.9
36	Rath	65.092	6.10	55	0.7	0.1	1.5	2.1	76.0	0.03	3.2
37	Sant R D Nagar	94.563	8.00	75	1.0	0.1	2.2	3.1	106.0	0.03	3.1
38	Shahbad	80.305	9.70	77	0.9	0.1	1.9	2.7	103.8	0.03	3.5
39	Sherkot	62.148	6.00	53	0.7	0.1	1.4	2.0	73.5	0.03	3.2
40	Sikandrabad	80.309	1.14	27	0.9	0.1	1.8	2.1	53.0	0.03	1.8
41	Tanda	96.138	10.45	86	1.0	0.1	2.3	3.3	118.0	0.03	3.4
42	Tilhar	60.803	3.48	40	0.7	0.1	1.4	1.8	60.1	0.03	2.7
43	Vrindavann	62.926	13.49	81	0.7	0.1	1.5	2.3	101.2	0.04	4.4
Total/Range		**3108.862**	**420.69**	**2925**	**33.6**		**72.7**	**103.9**	**3944.7**	**0.03-0.05**	**1.8-8.6**

Table A3.05: Estimated Footprint, Energy Consumption and Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Million) of Himanchal Pradesh in NRGB

S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in kWh (Unit of Electricity)	Expenditure in INR
No Class I town											

Table A3.06: Estimated Footprint, Energy Consumption and Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of Himanchal Pradesh in NRGB

S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
No Class II town											

Table A3.07: Estimated Footprint, Energy Consumption and Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Million) of Haryana in NRGB

S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
01	Bahadur Garh	170.426	50.00	245	1.8	0.1	4.2	8.3	345.4	0.05	5.6
02	Bhiwani	197.662	47.78	254	2.1	0.1	4.9	9.5	365.4	0.05	5.1
03	Faridabad	1404.653	207.80	1226	15.2	0.1	37.9	107.0	2039.9	0.08	4.0
04	Gurgoan	901.968	37.10	424	9.7	0.1	22.0	40.7	827.2	0.05	2.5
05	Hisar	301.249	48.03	301	3.3	0.1	7.4	14.5	459.8	0.05	4.2
06	Jagadhari	124.915	24.80	152	1.3	0.1	3.0	5.1	218.7	0.04	4.8
07	Jind	166.225	42.00	222	1.8	0.1	4.1	7.7	316.3	0.05	5.2
08	Kaithal	144.633	45.75	220	1.6	0.1	3.6	6.9	306.2	0.05	5.8
09	Karnal	286.974	12.00	147	3.1	0.1	6.8	10.2	270.1	0.04	2.6
10	Kurukshetra	154.962	34.50	195	1.7	0.1	3.8	6.9	280.7	0.04	5.0
11	Narnaul	134.067	41.10	202	1.4	0.1	3.3	6.2	281.5	0.05	5.8
12	Palwal	127.931	8.78	90	1.4	0.1	3.0	4.3	148.0	0.03	3.2
13	Panipat	294.15	41.40	277	3.2	0.1	7.2	13.7	427.7	0.05	4.0
14	Rohtak	373.133	47.50	327	4.0	0.1	9.2	18.0	517.3	0.05	3.8
15	Sonipat	292.339	52.80	312	3.2	0.1	7.2	14.5	469.8	0.05	4.4
16	Yamuna Nagar	241.723	34.50	233	2.6	0.1	5.9	10.7	356.3	0.04	4.0
Total/Range		**5317.010**	**775.84**	**4829**	**57.4**		**133.3**	**284.3**	**7630.2**	**0.03-0.08**	**2.51-5.80**

Table A3.08: Estimated Footprint, Energy Consumption and Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of Haryana in NRGB

S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
01	Hodal	50.003	5.39	46	0.5	0.1	1.2	1.6	62.6	0.03	3.4
02	Narvana	61.800	10.00	69	0.7	0.1	1.5	2.1	88.9	0.03	3.9
03	Sahadab	51.786	5.00	45	0.6	0.1	1.2	1.6	62.1	0.03	3.3
	Total/Range	**163.589**	**20.39**	**161**	**1.8**		**3.8**	**5.3**	**213.6**	**0.03-0.03**	**3.3-3.9**

Table A3.09: Estimated Footprint, Energy Consumption and Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Million) of Delhi in NRGB

S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
01	B J	197.150	6.70	94	2.1	0.1	4.6	6.3	176.3	0.03	2.4
02	Burari	145.584	11.19	108	1.6	0.1	3.4	5.1	174.1	0.03	3.3
03	Dallo Pura	154.955	2.29	51	1.7	0.1	3.6	4.4	110.4	0.03	2.0
04	Delhi Cantt.	116.352	42.97	193	1.3	0.1	2.9	5.5	264.0	0.05	6.2
05	DMC	11007.835	431.09	4572	118.9	0.1	318.5	1098.7	10936.8	0.10	2.7
06	Deoli	169.410	10.12	109	1.8	0.1	4.0	5.8	183.7	0.03	3.0

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S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
07	Gokalpur	121.938	2.32	46	1.3	0.1	2.8	3.4	94.1	0.03	2.1
08	Hastal	177.033	6.75	91	1.9	0.1	4.1	5.7	164.9	0.03	2.6
09	Karawal Nagar	224.666	4.75	84	2.4	0.1	5.2	6.9	173.7	0.03	2.1
10	K S N	282.598	4.74	93	3.1	0.1	6.5	8.6	203.6	0.03	2.0
11	Mandoli	120.345	41.77	196	1.3	0.1	2.9	5.6	269.1	0.05	6.1
12	Mustafabad	127.012	1.29	36	1.4	0.1	2.9	3.4	83.2	0.03	1.8
13	Nangloi Jat	205.497	6.67	96	2.2	0.1	4.8	6.6	180.8	0.03	2.4
14	NDMC	249.998	42.74	263	2.7	0.1	6.1	11.7	395.6	0.05	4.3
15	Sultanpur Majra	181.624	2.86	60	2.0	0.1	4.2	5.2	130.7	0.03	2.0
Total/Range		**13482.000**	**618.25**	**6092**	**145.6**		**376.5**	**1183.0**	**13541.0**	**0.03-0.10**	**1.8-6.2**

01. B J- Bhalswa Jahangirpur
05. DMC (U) – Delhi Municipal Corporation
10. K S N – Kirari Suleman Nagar
14. NDMC – New Delhi Municipal Corporation

Table A3.10: Estimated Footprint, Energy Consumption and Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of Delhi in NRGB

S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
01	Babarpur	52.918	0.79	19	0.6	0.1	1.2	1.4	35.8	0.03	1.9
02	C S B	81.374	2.58	40	0.9	0.1	1.9	2.3	66.6	0.03	2.2
03	Gharoli	84.722	3.56	48	0.9	0.1	2.0	2.5	75.4	0.03	2.4
04	Jaffrabad	70.089	0.90	22	0.8	0.1	1.6	1.8	45.1	0.03	1.8
05	Khajoori Khas	55.006	0.94	21	0.6	0.1	1.3	1.4	38.4	0.03	1.9
06	Mithe Pur	49.583	1.81	27	0.5	0.1	1.1	1.4	43.0	0.03	2.4
07	Molar Band	49.439	4.12	40	0.5	0.1	1.1	1.5	56.4	0.03	3.1
08	Mundka	53.525	11.89	71	0.6	0.1	1.3	1.9	88.5	0.04	4.5
09	Pooth Kalan	61.727	6.97	57	0.7	0.1	1.4	2.0	77.4	0.03	3.4
10	Pulpehlad	64.484	2.16	33	0.7	0.1	1.5	1.8	53.7	0.03	2.3
11	S P G	52.730	1.05	21	0.6	0.1	1.2	1.4	38.4	0.03	2.0
12	Taj Pul	72.764	1.22	26	0.8	0.1	1.7	1.9	49.9	0.03	1.9
13	Tigri	54.774	1.05	22	0.6	0.1	1.2	1.4	39.4	0.03	2.0
14	Ziauddin Pur	58.661	1.80	29	0.6	0.1	1.3	1.6	47.9	0.03	2.2
	Total/Range	**861.796**	**40.84**	**475**	**9.3**		**19.8**	**24.4**	**755.9**	**0.03-0.04**	**1.8-4.5**

02. C S B – Chilla Saroda Bangar
11. S P G – Sadat Pur Gurjan

Table A3.11: Estimated Footprint, Energy Consumption and Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Million) of Rajasthan in NRGB

S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
01	Ajmer	542.580	87.00	521	5.9	0.1	13.8	31.0	816.0	0.06	4.1
02	Alwar	315.310	49.00	310	3.4	0.1	7.8	15.3	475.6	0.05	4.1
03	Bahilwara	360.009	69.00	390	3.9	0.1	9.0	19.2	588.3	0.05	4.5
04	Baran	118.157	72.36	260	1.3	0.1	3.0	6.4	343.4	0.05	8.0
05	Bharatpur	252.109	29.00	217	2.7	0.1	6.1	10.7	341.0	0.04	3.7
06	Bundi	102.823	22.76	132	1.1	0.1	2.5	4.1	187.9	0.04	5.0
07	Chittaugarh	116.409	30.50	161	1.3	0.1	2.8	5.0	226.8	0.04	5.3
08	Dhaulpur	126.142	32.00	174	1.4	0.1	3.1	5.5	244.9	0.04	5.3
09	Gangapurcity	224.773	17.22	159	2.4	0.1	5.3	8.5	262.6	0.04	3.2
10	Hindauncity	105.690	48.00	198	1.1	0.1	2.6	5.1	265.5	0.05	6.9
11	Jaipur	3073.350	485.00	2679	33.2	0.1	90.1	321.2	4680.2	0.10	4.2
12	Jhunjhunun	118.966	50.00	215	1.3	0.1	2.9	5.8	290.2	0.05	6.7
13	Kishangarh	155.019	100.00	341	1.7	0.1	4.0	9.3	452.2	0.06	8.0
14	Kota	1001.365	527.03	1710	10.8	0.1	29.7	108.1	2482.8	0.11	6.8
15	Nagaur	100.618	37.81	171	1.1	0.1	2.5	4.6	232.6	0.05	6.3
16	Sikar	237.579	39.90	249	2.6	0.1	5.8	10.9	374.1	0.05	4.3
17	Swaimadhavpur	120.998	49.00	214	1.3	0.1	3.0	5.9	289.8	0.05	6.6
18	Tonk	165.363	16.00	135	1.8	0.1	3.9	6.2	213.8	0.04	3.5
19	Udaipur	451.735	56.91	389	4.9	0.1	11.2	22.8	620.5	0.05	3.8
	Total/Range	**7688.995**	**1818.49**	**8624**	**83.0**		**209.0**	**605.8**	**13388.3**	**0.04-0.11**	**3.2-8.0**

Table A3.12: Estimated Footprint, Energy Consumption and Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of Rajasthan in NRGB

S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
01	Jhalawara	66.500	12.95	81	0.7	0.1	1.6	2.4	102.5	0.04	4.2
02	Makrana	94.447	36.00	163	1.0	0.1	2.3	4.2	194.5	0.04	5.6
03	Nawalgarh	64.903	27.91	119	0.7	0.1	1.6	2.7	140.1	0.04	5.9
04	Nimbahera	61.000	12.74	77	0.7	0.1	1.4	2.2	97.3	0.04	4.4
	Total/Range	**286.850**	**89.60**	**440**	**3.1**		**6.9**	**11.4**	**534.3**	**0.04-0.04**	**4.2-5.9**

Table A3.13: Estimated Footprint, Energy Consumption and Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Million) of Madhya Pradesh in NRGB

S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
01	Bhind	197.332	17.79	153	2.1	0.1	4.7	7.5	246.2	0.04	3.4
02	Bopal	1883.381	285.00	1640	20.3	0.1	52.2	160.8	2774.7	0.09	4.0
03	Chatarpur	147.688	54.00	242	1.6	0.1	3.7	7.4	333.0	0.05	6.2

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S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
04	Damoh	147.515	16.00	129	1.6	0.1	3.5	5.5	200.5	0.04	3.7
05	Datia	100.466	6.85	71	1.1	0.1	2.3	3.2	115.4	0.03	3.1
06	Dewas	289.438	102.00	437	3.1	0.1	7.4	17.4	618.0	0.06	5.8
07	Guna	180.978	45.75	240	2.0	0.1	4.4	8.6	342.7	0.05	5.2
08	Gwalior	1101.981	173.88	1006	11.9	0.1	29.3	78.9	1638.0	0.07	4.1
09	Indore	2167.447	131.17	1181	23.4	0.1	56.4	141.2	2282.0	0.07	2.9
10	Jabalpur	1267.564	135.00	941	13.7	0.1	33.1	83.4	1620.4	0.07	3.5
11	Katni	221.875	68.60	320	2.4	0.1	5.6	11.8	453.2	0.05	5.6
12	Mandsour	141.468	36.00	193	1.5	0.1	3.4	6.3	272.9	0.04	5.3
13	Morena	200.506	12.00	127	2.2	0.1	4.7	7.1	215.8	0.04	2.9
14	Neemuch	128.575	22.00	144	1.4	0.1	3.1	5.1	211.2	0.04	4.5
15	Pithampur	126.099	89.90	299	1.4	0.1	3.2	7.3	391.9	0.06	8.5
16	Ratlam	273.892	39.19	261	3.0	0.1	6.7	12.5	402.0	0.05	4.0
17	Rewa	235.422	102.00	403	2.5	0.1	6.0	14.1	556.7	0.06	6.5
18	Sagar	370.296	33.75	275	4.0	0.1	9.0	16.3	452.6	0.04	3.3
19	Satna	283.004	12.00	146	3.1	0.1	6.7	10.0	267.7	0.04	2.6
20	Sehore	1090.025	13.10	278	11.8	0.1	25.7	39.2	708.3	0.04	1.8
21	Shahdol	100.565	28.24	147	1.1	0.1	2.4	4.3	204.1	0.04	5.6
22	Shepour	105.026	5.00	61	1.1	0.1	2.4	3.2	106.2	0.03	2.8

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S No	Town	Population in Thousands	Town Area in km²	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m²	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
23	Shivpuri	179.972	86.55	334	1.9	0.1	4.6	10.3	453.4	0.06	6.9
24	Singrauli	220.295	280.66	674	2.4	0.1	6.1	18.7	871.5	0.08	10.8
25	Tikamgarh	101.786	6.22	68	1.1	0.1	2.4	3.2	112.4	0.03	3.0
26	Ujjain	515.215	92.68	527	5.6	0.1	13.1	30.1	812.3	0.06	4.3
27	Vidisha	155.959	8.83	98	1.7	0.1	3.7	5.2	166.7	0.03	2.9
Total/Range		**11933.770**	**1904.16**	**10397**	**128.9**		**305.9**	**718.8**	**16829.5**	**0.03-0.09**	**1.8-10.8**

Table A3.14: Estimated Footprint, Energy Consumption and Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of Madhya Pradesh in NRGB

S No	Town	Population in Thousands	Town Area in km²	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m²	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
01	Basoda	78.265	5.90	58	0.8	0.1	1.8	2.4	83.6	0.03	2.9
02	Bina	64.579	12.00	77	0.7	0.1	1.5	2.3	97.9	0.03	4.2
03	Dabra	61.260	12.00	75	0.7	0.1	1.4	2.1	95.2	0.03	4.3

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S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
04	Dhar	95.000	30.00	148	1.0	0.1	2.3	4.0	180.0	0.04	5.2
05	Jaora	65.111	5.54	52	0.7	0.1	1.5	2.0	73.4	0.03	3.1
06	Mandla	55.145	8.87	62	0.6	0.1	1.3	1.8	79.8	0.03	4.0
07	Narshimpur	59.858	14.71	83	0.6	0.1	1.4	2.2	102.3	0.04	4.7
08	Panna	50.432	4.50	43	0.5	0.1	1.2	1.5	58.9	0.03	3.2
09	Shajapur	70.000	11.16	76	0.8	0.1	1.6	2.4	99.3	0.03	3.9
10	Sidhi	54.317	12.31	73	0.6	0.1	1.3	1.9	90.4	0.04	4.6
Total/Range		**653.967**	**116.99**	**747**	**7.1**		**15.4**	**22.7**	**960.6**	**0.03-0.04**	**2.9-5.2**

Table A3.15: Estimated Footprint, Energy Consumption and Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Million) of Bihar in NRGB

S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
01	Arrah	261.099	30.97	227	2.8	0.1	6.3	11.3	356.8	0.04	3.7
02	Aurangabad	101.520	8.00	77	1.1	0.1	2.4	3.4	122.9	0.03	3.3
03	Bagaha	113.012	11.00	94	1.2	0.1	2.7	3.9	147.2	0.03	3.6
04	Begusarai	251.136	8.98	121	2.7	0.1	5.9	8.4	226.0	0.03	2.5
05	Bettiah	132.896	11.55	105	1.4	0.1	3.1	4.7	167.1	0.04	3.4
06	B M C	398.138	30.17	268	4.3	0.1	9.6	17.1	454.1	0.04	3.1
07	B M C	296.889	22.46	204	3.2	0.1	7.1	11.9	341.5	0.04	3.2
08	Buxar	102.591	8.00	77	1.1	0.1	2.4	3.4	123.6	0.03	3.3
09	Chapra (NP)	201.597	16.96	151	2.2	0.1	4.8	7.6	244.9	0.04	3.3
10	Darbhanga	294.116	19.18	188	3.2	0.1	7.0	11.4	321.1	0.04	3.0
11	Dehri	137.068	21.32	145	1.5	0.1	3.3	5.4	215.7	0.04	4.3
12	D N	182.241	11.63	120	2.0	0.1	4.3	6.4	201.5	0.04	3.0
13	Gaya	463.454	50.17	369	5.0	0.1	11.4	22.6	600.4	0.05	3.5
14	Hajipur	147.126	19.64	143	1.6	0.1	3.5	5.7	216.8	0.04	4.0
15	Jamalpur	105.221	10.65	90	1.1	0.1	2.5	3.6	139.7	0.03	3.6
16	Jehanabad	102.456	20.23	124	1.1	0.1	2.4	4.0	178.4	0.04	4.8
17	Katihar	225.982	24.54	191	2.4	0.1	5.4	9.3	300.5	0.04	3.6
18	Kishanganj	107.076	30.12	155	1.2	0.1	2.6	4.6	216.5	0.04	5.5
19	M T	105.000	8.50	80	1.1	0.1	2.5	3.5	128.1	0.03	3.3

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S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
20	Motihari	125.183	13.52	111	1.4	0.1	3.0	4.5	171.6	0.04	3.8
21	Munger	213.101	17.50	157	2.3	0.1	5.1	8.1	256.0	0.04	3.3
22	Muzaffarpur	351.838	26.43	238	3.8	0.1	8.5	14.6	401.5	0.04	3.1
23	Nawada	109.141	5.68	66	1.2	0.1	2.5	3.4	113.5	0.03	2.8
24	Patna	1683.200	108.34	957	18.2	0.1	43.3	103.1	1800.4	0.06	2.9
25	Purnia	280.547	44.52	282	3.0	0.1	6.9	13.3	428.6	0.05	4.2
26	Saharsa	155.175	21.13	152	1.7	0.1	3.7	6.1	229.8	0.04	4.1
27	Sasaram	147.396	12.00	112	1.6	0.1	3.5	5.2	179.9	0.04	3.3
28	Siwan	134.458	15.68	123	1.5	0.1	3.2	5.0	189.0	0.04	3.9
Total/Range		**6928.657**	**628.87**	**5127**	**74.8**		**168.8**	**311.8**	**8473.0**	**0.03-0.06**	**2.5-5.5**

06. B M C – Bhagalpur Municipal Corporation
07. B M C – Biharsharif Municipal Corporation
12. DN – Dinapur Nizamat
19. MT – Madhubani Town

Table A3.16: Estimated Footprint, Energy Consumption and Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of Bihar in NRGB

S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
01	Araria	80.000	4.50	52	0.9	0.1	1.9	2.4	78.6	0.03	2.7
02	Barahiya	50.230	26.54	106	0.5	0.1	1.2	2.1	121.6	0.04	6.6
03	Barh	61.037	4.50	46	0.7	0.1	1.4	1.9	65.7	0.03	2.9
04	Bhabua	52.611	7.12	54	0.6	0.1	1.2	1.7	71.5	0.03	3.7
05	D M	67.995	11.30	76	0.7	0.1	1.6	2.4	98.2	0.04	4.0
06	Dumraon	57.716	15.33	83	0.6	0.1	1.4	2.1	102.1	0.04	4.8
07	Forbesganj	52.289	4.98	45	0.6	0.1	1.2	1.6	62.3	0.03	3.3
08	Gopalganj	66.624	11.11	75	0.7	0.1	1.6	2.3	96.5	0.03	4.0
09	Kaimur	51.469	7.12	54	0.6	0.1	1.2	1.7	70.6	0.03	3.8
10	Khagaria	56.978	2.97	36	0.6	0.1	1.3	1.6	54.8	0.03	2.6
11	Khagaul	60.866	5.32	50	0.7	0.1	1.4	1.9	69.6	0.03	3.1
12	Lakhisarai	98.123	24.79	136	1.1	0.1	2.4	4.0	168.5	0.04	4.7
13	Madhepura	56.739	25.84	109	0.6	0.1	1.4	2.4	127.1	0.04	6.1
14	Masaurhi	57.012	9.43	65	0.6	0.1	1.3	1.9	83.2	0.03	4.0
15	Mokameh	71.335	14.18	87	0.8	0.1	1.7	2.6	110.3	0.04	4.2
16	Narkatiaganj	51.446	10.96	67	0.6	0.1	1.2	1.8	83.9	0.03	4.5
17	Phulwari Sharif	67.348	6.48	57	0.7	0.1	1.6	2.2	79.2	0.03	3.2
18	Raxaul Bazar	52.429	5.82	49	0.6	0.1	1.2	1.6	66.1	0.03	3.5

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S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
19	Samastipur	70.042	3.45	42	0.8	0.1	1.6	2.1	65.4	0.03	2.6
20	Shekhpura	54.322	15.58	82	0.6	0.1	1.3	2.0	99.8	0.04	5.0
21	Sitamarhi	87.279	8.00	72	0.9	0.1	2.0	2.9	101.2	0.03	3.2
22	Sultanganj	52.867	12.29	72	0.6	0.1	1.2	1.9	89.1	0.04	4.6
23	Supaul	85.200	22.37	122	0.9	0.1	2.0	3.4	150.2	0.04	4.8
Total/Range		**1461.957**	**259.98**	**1639**	**15.8**		**34.3**	**50.5**	**2115.5**	**0.03-0.04**	**2.6-6.6**

05. D M – Digha-Mainpura

Table A3.17: Estimated Footprint, Energy Consumption and Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Million) of Chhatisgarh in NRGB

S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
01	Ambikapur	114.575	9.39	87	1.2	0.1	2.7	3.9	139.7	0.03	3.3
02	Bhilai Nagar	625.697	141.30	709	6.8	0.1	16.4	41.8	1079.1	0.07	4.7
03	Bilaspur	330.106	37.56	276	3.6	0.1	8.1	15.0	440.1	0.05	3.7
04	Durg	268.679	66.09	339	2.9	0.1	6.7	14.2	492.7	0.05	5.0
05	Jagdalpur	125.345	22.49	144	1.4	0.1	3.0	5.0	210.4	0.04	4.6
06	Korba	363.210	215.02	707	3.9	0.1	9.8	28.0	970.4	0.08	7.3
07	Raigarh	137.097	20.68	143	1.5	0.1	3.3	5.4	213.1	0.04	4.3
08	Raipur	1010.087	108.66	763	10.9	0.1	26.0	61.9	1294.5	0.06	3.5
09	Rajnandgaon	163.122	78.09	305	1.8	0.1	4.1	9.0	412.7	0.06	6.9
	Total/Range	**3137.918**	**699.28**	**3474**	**33.9**		**80.0**	**184.20**	**5252.7**	**0.03-0.08**	**3.3-7.3**

Table A3.18 Estimated Footprint, Energy Consumption and Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of Chhatisgarh in NRGB

S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
01	Bhatapara	54.846	30.42	117	0.6	0.1	1.3	2.4	134.7	0.04	6.7
02	Bhilai Charoda	95.848	141.30	343	1.0	0.1	2.5	6.4	375.8	0.07	10.7
03	Chirmiri	99.934	64.94	228	1.1	0.1	2.5	5.2	261.6	0.05	7.2
04	Dalli-Rajhara	55.684	37.25	131	0.6	0.1	1.4	2.5	148.9	0.05	7.3
05	Dhamtari	89.857	23.40	127	1.0	0.1	2.2	3.6	157.3	0.04	4.8
06	Mahasamund	51.543	14.68	78	0.6	0.1	1.2	1.9	94.8	0.04	5.0
	Total/Range	**447.712**	**311.99**	**1025**	**4.8**		**11.1**	**22.1**	**1173.1**	**0.04-0.07**	**4.8-10.7**

Table A3.19: Estimated Footprint, Energy Consumption and Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Million) of Jharkhand in NRGB

S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
01	Aditya	173.988	49.82	247	1.9	0.1	4.3	8.5	348.5	0.05	5.5
02	Bhuli	110.127	11.74	96	1.2	0.1	2.6	3.9	148.7	0.04	3.7
03	Bokaro	413.934	162.91	644	4.5	0.1	10.9	29.0	915.2	0.07	6.1
04	Chas	141.618	20.49	144	1.5	0.1	3.4	5.6	216.0	0.04	4.2
05	Deoghar	203.116	14.00	138	2.2	0.1	4.8	7.4	229.6	0.04	3.1
06	Dhanbad	1161.561	23.39	379	12.5	0.1	27.9	47.0	862.1	0.04	2.0
07	Giridih	114.447	9.75	89	1.2	0.1	2.7	3.9	141.6	0.03	3.4
08	Hazaribag	142.494	26.37	165	1.5	0.1	3.4	5.9	240.2	0.04	4.6
09	JNAC	629.659	59.80	459	6.8	0.1	15.7	32.3	772.5	0.05	3.4
10	Jharia	100.839	4.42	57	1.1	0.1	2.3	3.1	99.4	0.03	2.7
11	Jorapokhar	104.673	16.40	112	1.1	0.1	2.5	3.9	165.3	0.04	4.3
12	MNAC	224.002	19.45	169	2.4	0.1	5.3	8.7	274.0	0.04	3.4
13	Phusro	102.673	40.64	179	1.1	0.1	2.5	4.7	242.7	0.05	6.5
14	Ranchi	1073.440	177.19	1004	11.6	0.1	28.6	77.4	1624.3	0.07	4.1
15	Saunda	104.642	24.26	137	1.1	0.1	2.5	4.3	194.8	0.04	5.1
Total/Range		**4801.213**	**660.63**	**4019**	**51.9**		**119.4**	**245.6**	**6474.8**	**0.03-0.07**	**2.0-6.5**

09. JNAC – Jamshedpur Notified Area Committee
12. MNAC – Mango Notified Area Committee

Table A3.20: Estimated Footprint, Energy Consumption and Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of Jharkhand in NRGB

S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
01	Bagbera	82.559	10.70	82	0.9	0.1	1.9	2.9	109.4	0.03	3.6
02	Bhowrah	54.483	15.73	83	0.6	0.1	1.3	2.0	100.4	0.04	5.0
03	Bhuli	99.990	8.60	79	1.1	0.1	2.3	3.3	112.4	0.03	3.1
04	Chaibasa	78.287	11.11	82	0.8	0.1	1.8	2.7	107.9	0.03	3.8
05	Chatra	51.685	3.45	38	0.6	0.1	1.2	1.5	54.4	0.03	2.9
06	Daltonganj	87.849	14.00	97	0.9	0.1	2.1	3.2	125.7	0.04	3.9
07	Dumka	55.336	6.12	51	0.6	0.1	1.3	1.8	69.4	0.03	3.4
08	Gumia	56.024	26.11	109	0.6	0.1	1.3	2.3	126.9	0.04	6.2
09	Jhumri Tilaiya	85.489	51.14	190	0.9	0.1	2.1	4.2	218.0	0.05	7.0
10	Jugsalai	56.720	3.69	40	0.6	0.1	1.3	1.7	58.8	0.03	2.8
11	Katras	63.017	5.00	49	0.7	0.1	1.5	1.9	69.5	0.03	3.0
12	Lohardaga	56.821	14.57	81	0.6	0.1	1.3	2.1	99.2	0.04	4.8
13	Madhupur	58.211	18.36	92	0.6	0.1	1.4	2.2	110.7	0.04	5.2
14	Ramgarh Cantt.	90.324	34.46	157	1.0	0.1	2.2	4.0	186.7	0.04	5.7
15	Sahibganj	98.589	8.98	80	1.1	0.1	2.3	3.3	113.2	0.03	3.1
16	Sindri	94.398	46.65	187	1.0	0.1	2.3	4.5	218.6	0.05	6.3
17	Tisra	65.894	14.02	84	0.7	0.1	1.6	2.4	105.3	0.04	4.4
	Total/Range	**1235.676**	**292.69**	**1580**	**13.3**		**29.3**	**46.2**	**1986.3**	**0.03-0.05**	**2.8-7.0**

Table A3.21: Estimated Footprint, Energy Consumption and Expenditure on Sewerage Infrastructure in Class I Towns (Population > 0.1 Million) of West Bengal in NRGB

S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
01	Alipurduar	127.342	9.80	95	1.4	0.1	3.0	4.3	153.5	0.03	3.3
02	Asansol	564.491	127.87	645	6.1	0.1	14.7	36.5	976.5	0.06	4.7
03	A-K	123.906	18.44	130	1.3	0.1	3.0	4.8	192.8	0.04	4.3
04	Baidyabati	121.081	7.89	84	1.3	0.1	2.8	4.0	137.9	0.03	3.1
05	Bally	115.715	11.68	98	1.2	0.1	2.7	4.1	152.6	0.04	3.6
06	Balurghat	151.183	10.46	106	1.6	0.1	3.6	5.2	173.7	0.03	3.1
07	Bangaon	110.668	24.70	142	1.2	0.1	2.7	4.5	201.9	0.04	5.0
08	Bankura	138.036	19.06	138	1.5	0.1	3.3	5.3	207.0	0.04	4.1
09	Bansberia	103.799	9.07	83	1.1	0.1	2.4	3.5	130.4	0.03	3.4
10	Bara Nagar	248.466	7.12	107	2.7	0.1	5.8	8.1	209.0	0.03	2.3
11	Barasat	283.443	34.50	248	3.1	0.1	6.9	12.6	390.0	0.04	3.8
12	Bardhaman	314.638	26.30	226	3.4	0.1	7.6	13.1	374.5	0.04	3.3
13	Barrackpore	154.475	11.65	112	1.7	0.1	3.6	5.4	182.8	0.04	3.2
14	Basirhat	127.135	22.50	145	1.4	0.1	3.0	5.1	212.0	0.04	4.6
15	Beharampore	195.363	31.43	204	2.1	0.1	4.7	8.5	305.3	0.04	4.3
16	Bhadreswar	101.334	8.28	78	1.1	0.1	2.4	3.4	124.3	0.03	3.4
17	Bhatpara	390.467	30.42	266	4.2	0.1	9.4	16.8	450.1	0.04	3.2

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S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
18	Bidhannagar	218.323	30.00	208	2.4	0.1	5.3	9.4	318.5	0.04	4.0
19	Chakdaha	132.855	15.54	122	1.4	0.1	3.1	4.9	187.1	0.04	3.9
20	Champadani	110.983	6.47	71	1.2	0.1	2.6	3.5	119.9	0.03	3.0
21	Chandernagore	166.949	22.03	160	1.8	0.1	4.0	6.7	243.1	0.04	4.0
22	Chinsurah	180.502	17.24	146	1.9	0.1	4.3	6.9	231.1	0.04	3.5
23	Darjiling	120.414	10.57	97	1.3	0.1	2.8	4.2	152.9	0.03	3.5
24	Dhulian	239.022	10.27	126	2.6	0.1	5.6	8.2	228.4	0.03	2.6
25	Durgapur	566.937	1.10	64	6.1	0.1	12.9	15.0	263.6	0.03	1.3
26	Habra	149.675	21.80	152	1.6	0.1	3.6	6.0	228.1	0.04	4.2
27	Haldia	200.762	104.90	385	2.2	0.1	5.2	12.2	521.8	0.06	7.1
28	Halisahar	126.893	8.28	88	1.4	0.1	3.0	4.2	144.2	0.03	3.1
29	H-C	177.209	8.29	100	1.9	0.1	4.1	5.9	176.4	0.03	2.7
30	Jalpaiguri	107.351	12.50	98	1.2	0.1	2.5	3.8	150.3	0.04	3.8
31	Jamuria	144.791	73.23	282	1.6	0.1	3.6	7.9	378.9	0.05	7.2
32	Jangipore	122.875	7.86	84	1.3	0.1	2.9	4.0	138.9	0.03	3.1
33	Kalyani	100.62	21.91	128	1.1	0.1	2.4	4.0	182.9	0.04	5.0
34	Kamarhati	336.579	20.48	205	3.6	0.1	8.0	13.2	357.2	0.04	2.9
35	Kanchapara	122.181	29.21	164	1.3	0.1	3.0	5.2	231.8	0.04	5.2
36	Kharagpur	206.923	90.65	361	2.2	0.1	5.3	12.0	495.3	0.06	6.6

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S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
37	Khardaha	111.13	10.96	93	1.2	0.1	2.6	3.9	145.6	0.03	3.6
38	Kolkata	4486.689	185.00	1964	48.5	0.1	119.8	328.2	4268.3	0.07	2.6
39	Konnagar	124.585	9.07	91	1.3	0.1	2.9	4.2	147.4	0.03	3.2
40	Krishnanagar	181.182	6.87	92	2.0	0.1	4.2	5.8	168.3	0.03	2.5
41	Madhyamgram	198.964	21.32	169	2.1	0.1	4.8	7.9	264.8	0.04	3.6
42	Mahestala	449.423	21.50	238	4.9	0.1	10.8	17.9	436.4	0.04	2.7
43	Medinipur	169.127	14.78	131	1.8	0.1	4.0	6.2	210.2	0.04	3.4
44	Nabadwip	125.528	11.66	104	1.4	0.1	3.0	4.4	162.4	0.04	3.5
45	Naihati	221.762	11.55	130	2.4	0.1	5.2	7.8	226.6	0.04	2.8
46	N B	134.825	17.17	129	1.5	0.1	3.2	5.1	196.1	0.04	4.0
47	NDD	253.625	26.45	207	2.7	0.1	6.1	10.6	330.4	0.04	3.6
48	Panihati	383.522	6.89	127	4.1	0.1	8.9	12.4	279.1	0.03	2.0
49	Puruliya	121.436	13.90	112	1.3	0.1	2.9	4.4	170.6	0.04	3.8
50	Raiganj	183.682	10.64	115	2.0	0.1	4.3	6.4	196.3	0.03	2.9
51	R G	404.991	28.00	260	4.4	0.1	9.8	17.1	447.0	0.04	3.0
52	R S	423.806	49.25	352	4.6	0.1	10.5	20.6	565.3	0.05	3.7
53	Rana Ghat	235.583	7.72	109	2.5	0.1	5.5	7.7	206.8	0.03	2.4
54	Raniganj	128.624	23.44	149	1.4	0.1	3.1	5.2	216.9	0.04	4.6
55	Rishra	124.591	6.48	77	1.3	0.1	2.9	4.0	131.0	0.03	2.9

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S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
56	Santipur	151.774	24.60	163	1.6	0.1	3.6	6.2	241.3	0.04	4.4
57	Serampore	183.339	14.50	134	2.0	0.1	4.3	6.7	218.8	0.04	3.3
58	Siliguri	509.709	41.90	351	5.5	0.1	12.5	23.7	595.3	0.05	3.2
59	S D D	410.524	17.39	206	4.4	0.1	9.8	15.6	384.0	0.04	2.6
60	Titagarh	118.426	3.24	54	1.3	0.1	2.7	3.5	101.6	0.03	2.4
61	Uluberia	221.175	33.72	222	2.4	0.1	5.4	9.8	336.1	0.04	4.2
62	Uttarpara K	162.386	16.34	136	1.8	0.1	3.9	6.1	213.3	0.04	3.6
Total/Range		**17123.790**	**1557.84**	**11864**	**184.9**		**422.4**	**833.6**	**20184.6**	**0.03-0.07**	**1.3-7.2**

03. A K – Ashokenagar-Kalyangarh;
29. H C – Hooghly- Chinsurah;
46. N B – New Barrackpore;
47. NDD – North Dum Dum;
51. R G – Rajarhat Gopalpur;
52. R S – Rahjpur Sonarpur;
59. S D D – South Dum Dum;
62. Uttapara K – Uttapara Kotrung

Table A3.22: Estimated Footprint, Energy Consumption and Expenditure on Sewerage Infrastructure in Class II Towns (Population between 0.05 and 0.1 Million) of West Bengal in NRGB

S No	Town	Population in Thousands	Town Area in km^2	Estimated Length of Sewer Network in km	Estimated STP Footprint in ha	Estimated STP Land Required Per Capita in m^2	Estimated Energy Demand in MW	Estimated Annual		Estimated Per Capita Per Day	
								Energy Consumption in MWh	Expenditure on Sewerage System in Millions of INR	Energy Consumption in KWh (Unit of Electricity)	Expenditure in INR
01	Arambagh	67.000	34.75	135	0.7	0.1	1.6	3.0	156.9	0.04	6.4
02	Baduria	52.500	22.43	98	0.6	0.1	1.3	2.1	115.1	0.04	6.0
03	Bankra	55.229	3.59	39	0.6	0.1	1.3	1.6	57.3	0.03	2.8
04	Baruipur	53.500	9.50	63	0.6	0.1	1.3	1.8	80.8	0.03	4.1
05	Bishnupur	70.620	22.01	108	0.8	0.1	1.7	2.8	131.7	0.04	5.1
06	Bolpur	74.890	10.73	77	0.8	0.1	1.8	2.6	101.4	0.03	3.7
07	Budge Budge	76.858	9.06	71	0.8	0.1	1.8	2.6	96.5	0.03	3.4
08	Chittaranjan	52.391	19.65	92	0.6	0.1	1.3	2.0	108.4	0.04	5.7
09	Contai	88.365	14.25	98	1.0	0.1	2.1	3.2	127.0	0.04	3.9
10	Gangarampur	61.028	10.29	69	0.7	0.1	1.4	2.1	89.3	0.03	4.0
11	Garulia	91.116	5.38	60	1.0	0.1	2.1	2.8	90.3	0.03	2.7
12	Gayeshpur	65.398	30.00	124	0.7	0.1	1.6	2.8	145.2	0.04	6.1
13	Gobardanga	57.878	13.50	78	0.6	0.1	1.4	2.1	97.0	0.04	4.6
14	J-A Ganj	51.790	11.66	70	0.6	0.1	1.2	1.8	86.3	0.04	4.6
15	Katwa	81.510	7.93	70	0.9	0.1	1.9	2.7	97.0	0.03	3.3
	Total/Range	**1000.073**	**224.73**	**1254**	**10.8**		**23.6**	**36.2**	**1580.2**	**0.03-0.04**	**2.7-6.4**

14. J-A Ganj – Jiyaganj-Azimganj

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- Dr Rajiv Sinha, Fluvial Geomorphology (FGM)
- Dr Vinod Tare, Environmental Flows (EFL)
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- Dr N C Narayanan and Dr Indrajit Dube, Policy Law and Governance (PLG)
- Dr Harish Karnick, Geospatial Database Management (GDM)
- Dr T V Prabhakar, Communication (COM)

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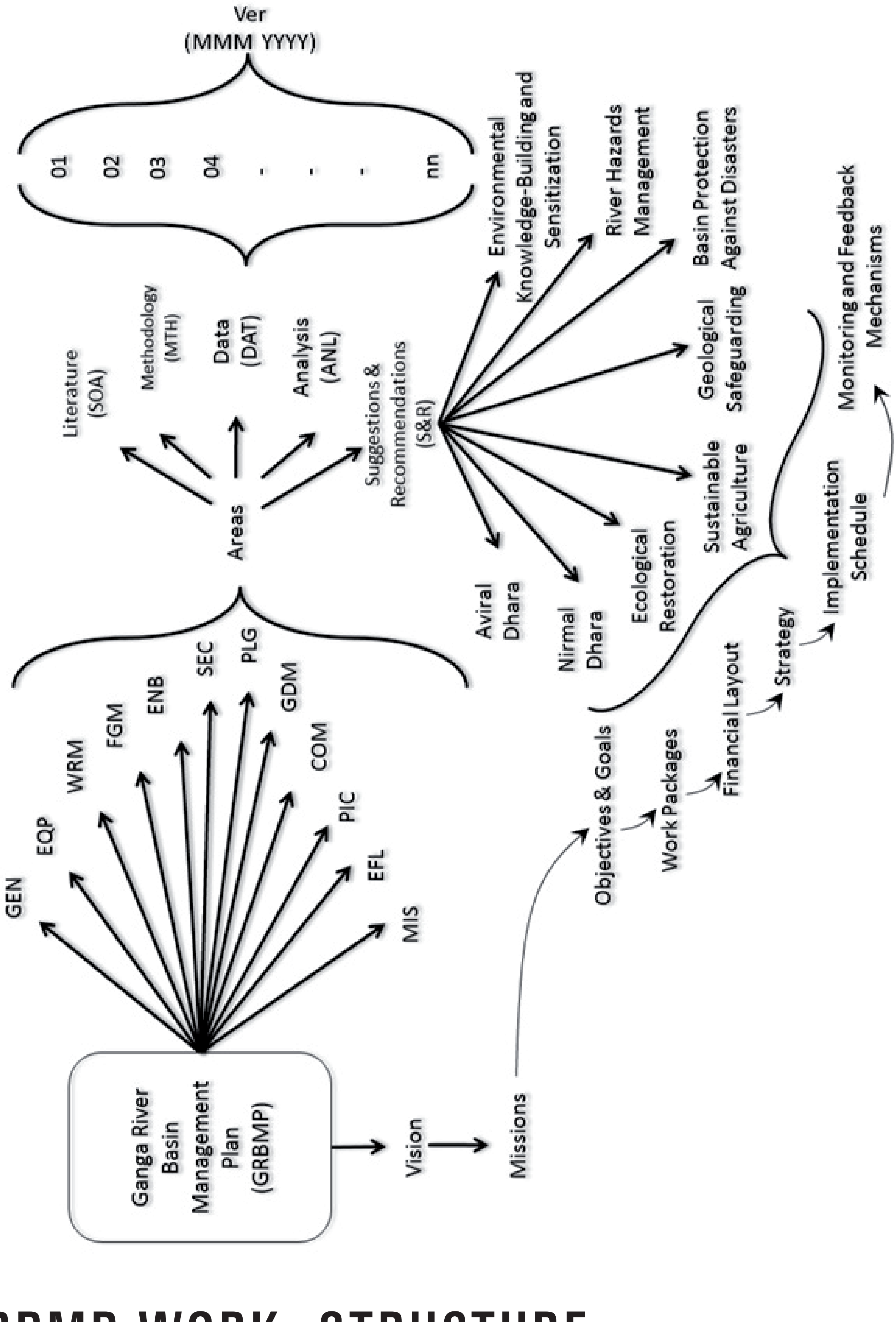
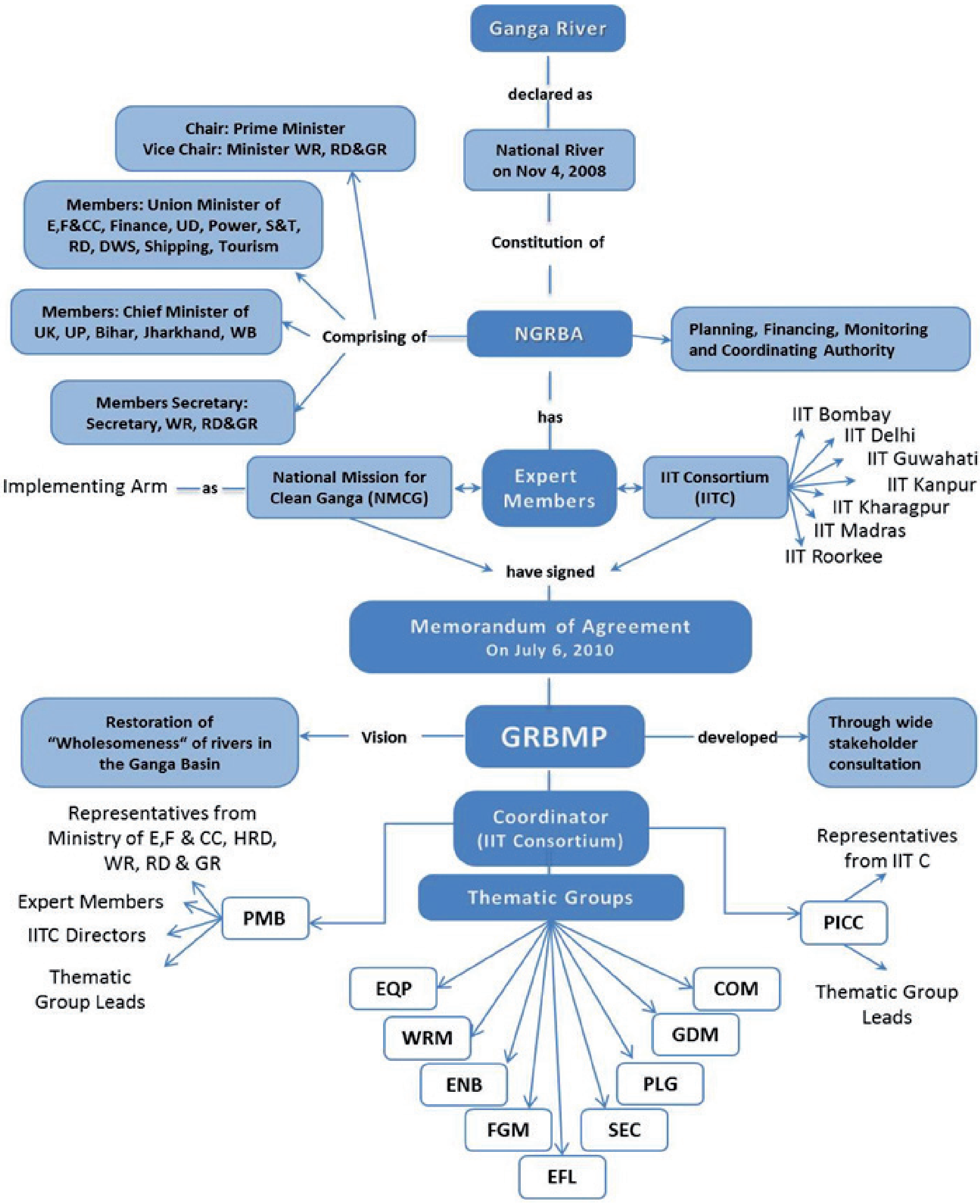


GRBMP WORK STRUCTURE

ORGANIZATIONAL STRUCTURE FOR PREPARING GRBMP



NGRBA: National Ganga River Basin Authority
NMCG: National Mission for Clean Ganga
MoEF: Ministry of Environment and Forests
MHRD: Ministry of Human Resource and Development
MoWR, RD&GR: Ministry of Water Resources, River Development and Ganga Rejuvenation
GRBMP: Ganga River Basin Management Plan
IITC: IIT Consortium
PMB: Project Management Board
PICC: Project Implementation and Coordination Committee

EQP: Environmental Quality and Pollution
WRM: Water Resources Management
ENB: Ecology and Biodiversity
FGM: Fluvial Geomorphology
EFL: Environmental Flows
SEC: Socio Economic and Cultural
PLG: Policy Law and Governance
GDM: Geospatial Database Management
COM: Communication

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