INTEGRATED WASTEWATER AND SEPTAGE MANAGEMENT DESIGN MODULE

PART C: WORKBOOK

National Institute of Urban Affairs

NFSSM Alliance

ECOSAN SERVICES FOUNDATION

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CONTENT
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INTEGRATED WASTEWATER & SEPTAGE MANAGEMENT DESIGN MODULE

PART C: WORKBOOK

Foreword

Acknowledgements

ABOUT NATIONAL FAECAL SLUDGE AND SEPTAGE MANAGEMENT ALLIANCE (NFSSMA)

The 'NFSSM Alliance' was formed with a vision to "Create an enabling environment which amplifies scaling of safe, sustainable and inclusive FSSM through knowledge, partnerships and innovative solutions by 2024."

Convened by Bill and Melinda Gates Foundation in 2016, the Alliance is a voluntary body that aims to:

- Build consensus and drive the discourse on FSSM at a policy level, and
- Promote peer learning among members to achieve synergies for scaled implementation and reduce duplication of efforts

The Alliance currently comprises 31 organizations across the country working towards solutions for Indian states and cities. The Alliance works in close collaboration with the Ministry of Housing and Urban Affairs (MoHUA) and several state and city governments through its members to support the progress and derive actions towards mainstreaming of FSSM at state and national level. The NFSSM Alliance works on all aspects of city sanitation plans to regulatory and institutional frameworks across the sanitation value chain. The NFSSM Alliance working in collaboration with the Ministry of Housing and Urban Affairs has been instrumental in the passage of India's First Policy on FSSM launched in 2017. This resulted in 19 out of 36 states adopting guidelines and policies for FSSM in India.

The strength of the Alliance lies in its diverse membership, which includes research institutes, academic institutions, think-tanks, quasi-government bodies, implementing organizations, data experts, consultants and intermediaries. This enabled a multi-disciplinary view of urban sanitation, with members building on each other's expertise. The alliance has had enormous success in championing FSSM as a viable solution to the Government of India by broadly focussing on:

1. Influencing and informing policy
2. Demonstrating success through innovation and pilots
3. Building capacities of key stakeholders across the value chain

The collaborative continues to work towards promoting the FSSM agenda through policy recommendations and sharing best practices which are inclusive, comprehensive, and have buy-in from several stakeholders in the sector.

NFSSM Alliance

ASCI	CSTEP	EY	NIUA	USAID
Athena Infonomics	CDD	GIZ	PSI	WASHi
BBC Media Action	CPR	IIHS	RTI International	Water Aid
BMGF	CFAR	ISC	Tide Technocrafts	World Bank Group
Borda	CSE	IWMI	UMC	
CEPT University	Dasra	KPMG	UNICEF	

ABOUT TRAINING MODULE REVIEW COMMITTEE (TMRC)

To ensure quality control in content and delivery of trainings and capacity building efforts, a **Training Module Review Committee (TMRC)** was formed with the collaborative effort of all Alliance partners. TMRC which is a**nchored by National Institute of Urban Affairs (NIUA)**, has the following broad objectives:

- Identification of priority stakeholders and accordingly training modules for Capacity Building
- Development of a Normative Framework – For Capacity Building at State Level
- Standardization of priority training modules – appropriate standardization of content with flexibility for customization based on State context
- Quality Control of Trainings – criteria for ensuring minimum quality of training content and delivery
- Strategy for measuring impact of trainings and capacity building efforts

ABOUT THE TRAINING MODULE

Title	Integrated Wastewater and Septage Management - Design Module
Purpose	The Government of India has made sanitation its priority through the launch of Swachh Bharat Mission. SBM-U 2.0 goes beyond eliminating open defecation in cities, to focus on planning sanitation systems at city-level, through integrated wastewater and septage management targeted at recycle and reuse. Further, the recently announced Atal Mission for Rejuvenation and Urban Transformation (AMRUT 2.0) lays emphasis on creating a circular economy of water by ensuring treatment and reuse of wastewater and faecal sludge. This Module provides participants a holistic understanding of designing of wastewater and septage management solutions, to address the above mentioned priorities under these national missions.
Target Audience	Officials with engineering background and professional experience in wastewater and septage management such as technical faculties from nodal training institutes, technical officials/ engineers from state govt, parastatal bodies and ULBs; consultants from TSU/ PMUs and sector partners.
Learning Objective	1. Understand priorities under various national urban missions for wastewater and septage management to address aspects of circular economy. 2. Gain in-depth knowledge about sanitation systems and to understand the concept and principles of citywide inclusive sanitation. 3. Get hands-on experience in designing wastewater and septage treatment solutions. 4. To leverage various funding avenues and understand contracting mechanisms at city level. 5. Comprehend the aspects of IWSM, such as O&M and sustainability, occupational safety, public awareness and participation.
Structure of the Module	The training is based on Case Method and includes an exercise which will enable the participants to improve analytical skills required to develop wastewater and septage management plans. It also includes a financial modelling tool which helps to calculate Life Cycle Cost of the project using different approaches of waste management. Case studies to demonstrate the learning from the module will be showcased through expert's lecture and handouts. This helps to trainee to apply the knowledge grasped during the session and reinforce it further.
Duration	In a face-to-face training format, this training is conceptualized for two days without site visits and can be adopted for including the site visits depending upon the city where it is being conducted.

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SI Units

Quantity	Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Volume	cubic meter or kilo-litre	m3 or KL

CONVERSION TABLES

Length

	Millimeter (mm)	Centimeter (cm)	Meter (m)	Kilometer (km)
1 millimeter (mm)	1	0.1	0.001	0.000001
1 centimeter (cm)	10	1	0.01	0.00001
1 meter (m)	1000	100	1	0.001
1 kilometer (km)	1000000	100000	1000	1

Mass

	Milligram (mg)	Gram (g)	Kilogram (kg)
1 milligram (mg)	1	0.001	0.000001
1 gram (g)	1000	1	0.001
1 kilogram (kg)	1000000	1000	1

Time

	Second (s)	Min (m)	Hour (h)	Day (d)
1 second (s)	1	1/60	1/3600	1/86400
1 min (m)	1000	1	1/60	1/1440
1 hour (h)	3600	60	1	1/24
1 day (d)	86400	1440	24	1

Volume

	Litre (L)	Cubic meter (m^3) or kilo-litre (KL)	M illion litre (ML)
1 litre (L)	1	0.001	0.000001
1 cubic meter (m^3) or kilo-litre (KL)	1000	1	0.001
1 million litre (ML)	10,00,000	1000	1

The Manual on Sewerage and Sewage Treatment Systems published in November 2013 by Central Public Health and Environmental Engineering Organization elaborates in its Preamble the main cause of water pollution is the challenges faced by ULBs for planning, implementation, procurement of materials, operate and maintain the centralized sewerage system. This exercise is based on Case Method, where the trainee will be working on a town and planning for its wastewater management. The exercise is technology agnostic in terms of collection, conveyance and treatment of septage and sewage emphasizes on selection of appropriate approach and plan for wastewater management at town level without compromising on the environmental sanitation.

Session

01

Baseline Survey & Assessment

1 Baseline surveys and assessment

A municipal town is located at the intersection of two highways and is one of the fastest growing towns of the State. It is the district headquarters and is urbanising at a steady pace due to its strategic location. Its geographical coordinates lie between latitude 24.45'N and 24.45'N and longitude 93.45'E and 94.15'E. As per the 2011 census, it had a total area of 28 sq. km.

There are hills to the north and a wetland to the south east of this town. As the town is located at the foothills, the water table is high. There are two rivers in the town namely, Mahima and Kiruthika. The region is rich in biodiversity and agriculture is practiced largely on the outskirts of the town by the citizens.

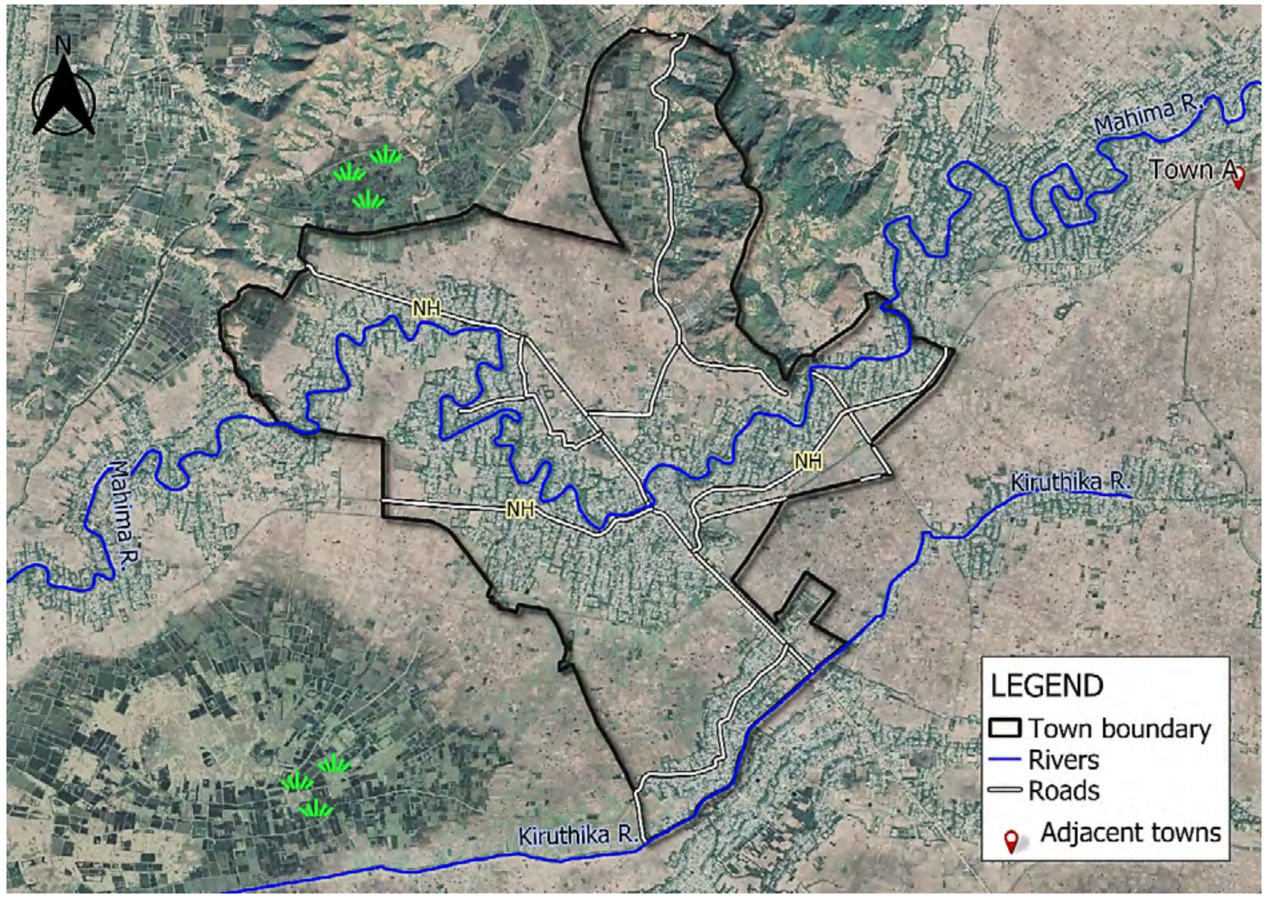

Figure 1: Map showing natural and built environment of the town and its adjoining areas

River Mahima flows through the town and divides the town into approximately two equal halves. The lower half is a densely populated area whereas the upper half was added in the municipal jurisdiction fifteen years ago. River Kiruthika runs along the southern border of the town.

In the 2011 census, the town was recorded to have 18 wards with a total population of 56,200 residing in 12,500 households. Majority of the settlement was along the river banks and then spread out radially around the river banks.

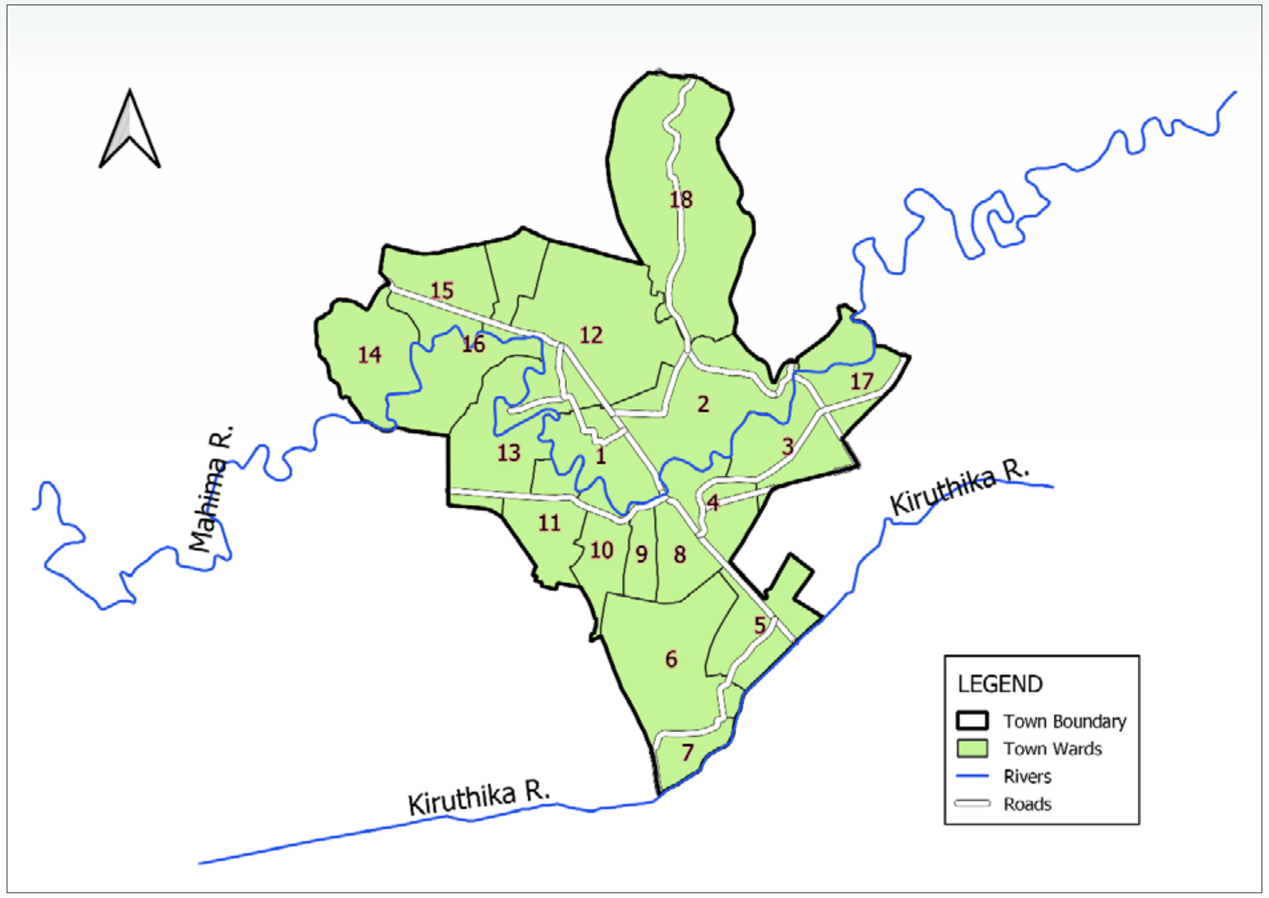

Figure 2: Ward map of the municipal town

The following table provides details on decadal population growth since 1971.

Table 1: Census population for the municipal town

Year	Population	Households
1971	29,300	4,900
1981	34,700	6,300
1991	40,300	8,000
2001	47,100	9,800
2011	56,200	12,500

A socio-economic survey was carried out in the town in 2001, the summary of the survey is tabulated in the following table.

Table 2: Summary of the socio-economic survey carried out in 2011

Ward No.	No. of HH above poverty line	Population	No. of HH below poverty line	Population	Total
1	330	1650	206	1082	2732
2	243	1210	196	1030	2240
3	300	1500	283	1490	2990
4	308	1535	204	1075	2610
5	278	1395	242	1260	2655
6	257	1280	181	955	2235
7	296	1478	235	1220	2698
8	337	1685	308	1590	3275
9	228	1140	117	930	2070
10	215	1070	203	1065	2135
11	412	2055	339	1745	3800
12	282	1400	276	1430	2830
13	294	1475	288	1490	2965
14	233	1160	237	1230	2390
15	232	1155	204	1065	2220
16	264	1320	255	1320	2640
17	366	1825	352	1815	3640
18	81	405	105	570	975
Total	4956	24738	4231	22362	47100

The town is also the main market cum distribution centre of the district. Local agricultural produce is brought to this town, sorted and packed to be sent to the state capital for sale. Handloom and handicraft industry is the most attractive sector in terms of employment. Bedsheets, chadars, mosquito nets, bamboo baskets, mats, fishing nets, furniture, carpentry products, etc. are some of the items which are manufactured and exported to other states. The town has a market hub located in ward 8 and a densely populated slum in ward 9.

1.1 Access to water

The piped water supply scheme has been partially implemented and the access to clean drinking water is found to be an issue. The town lacks a source of clean raw water and is currently planning for installing a raw water treatment plant. The raw water for this plant will be surface water bodies and groundwater aquifer.

Data regarding access to water can be depicted through indicators below:

Table 3: Access to water as per 2011 census

Location of drinking water	Within the premise	25%
	Near the premise	51%
	Away	23%
Main source of drinking water	Tap	37%
	Subsurface	25%
	Surface	38%

1.2 Access to sanitation

Access to sanitation is comparatively better than access to water. As per the 2011 census, 94% of the households had toilets, whereas only 2% of the population was dependent on the community toilet. Remaining 4% of the households were practicing open defecation.

Table 4: Containment units at the household level

Households having access to toilet		11,750
Flush Toilet	Piped sewer system	5%
	Septic tank	47%
	Others	9%
Pit Latrine	With slab/ventilated improved pit	20%
	Without slab/open pit	14%
Insanitary Latrine	Night soil disposed in drain	1%
	Night soil removed human	4%
	Night soil removed by animal	0%

The following pictures show types of toilets and containment units installed at the household level. Referring to figure 4, image on the left shows a toilet linked to a septic tank with a proper drainage system. A piped drain system carries the black and grey water from a household to the stormwater drain situated below the main road. On the other hand, the other image in figure 4 shows an outlet of a septic tank that is allowed to discharge in the open.

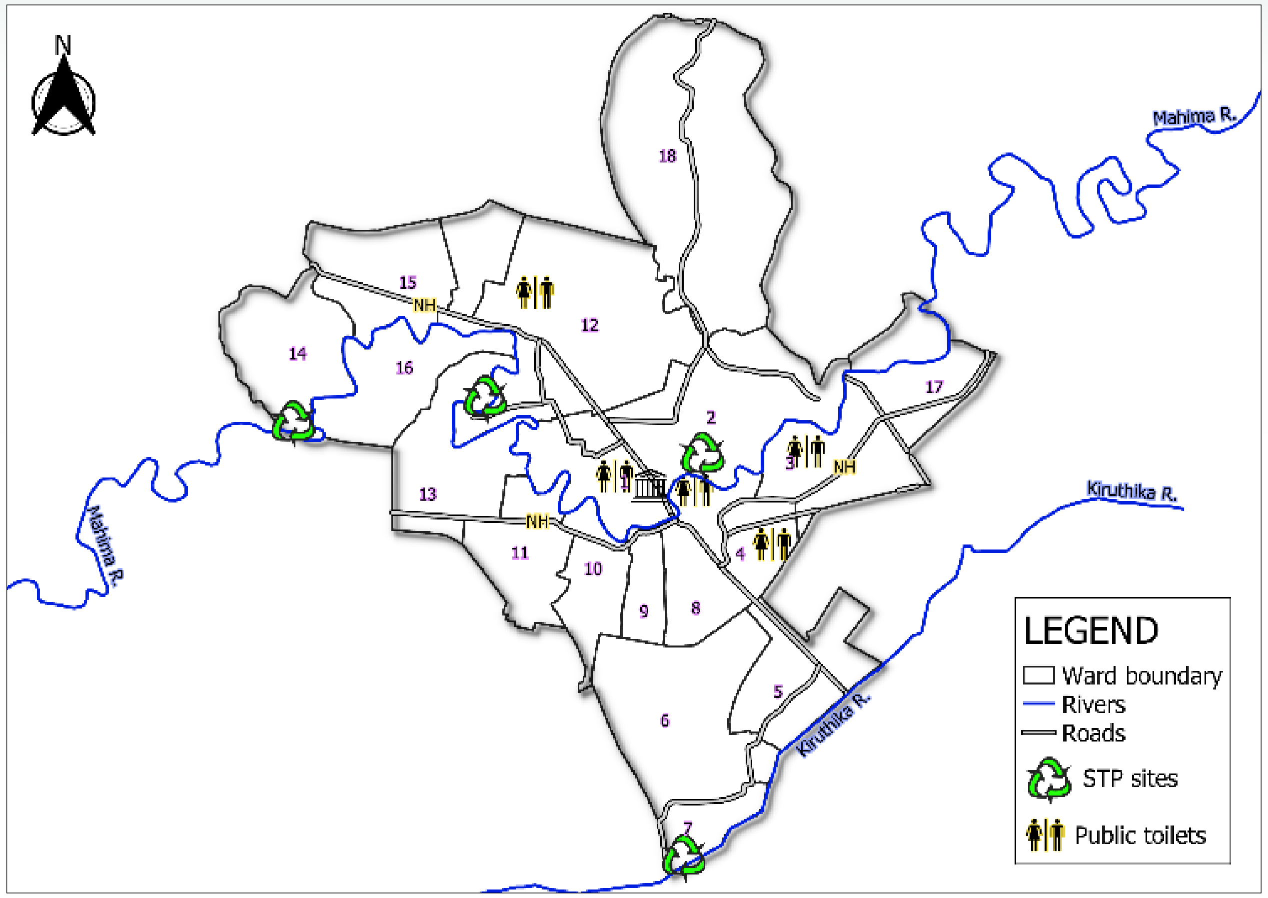

Figure 3: Map showing location of public toilets in the municipal town

Figure 4: Flush toilet linked to septic tank with different types of drainage system

The picture below shows different types of pit-based systems (figure 5). While the image on the left shows a properly constructed twin pit toilet with a cover on the top, the other image shows an insanitary toilet with an open unlined pit. Such pits, when full, are discontinued and a new pit is excavated.

Figure 5: Pit based containment units connected to household toilets

After the first phase of Swachh Bharat Mission, it is expected that the insanitary latrines are converted into sanitary toilets. This essentially means the households connected to septic tanks have increased in number.

The current state of wastewater management is through a network of open surface drains which collect and convey the water to the nearest surface water body such as a nallah or the river.

Table 5: Collection and conveyance of wastewater

Total number of households		12,500
Wastewater outlet connected to	Closed drainage	3%
	Open drainage	56%
	No drainage	41%

Figure 6: Pictures of cesspool vehicle owned and operated by the municipal authorities

The municipal town has one cesspool vehicle which caters to the requests for desludging of septic tanks from the households. The capacity of this cesspool vehicle is 3000 L and it can service a septic tank up to a distance of 100 ft. The municipal authorities mentioned that few households (< 2% of households) situated in the interior of the wards are not accessible to the truck.

1.3 Assessment

This stage is crucial as it lays the foundation for planning of wastewater and septage management. It is recommended that resources should be invested for collection of ward wise data and collate it using GIS and other softwares into visual aids. This helps to highlight the gaps and conceptualise an approach for wastewater management in a phase wise manner.

Creating a base map of town is the first stage. The base map shall highlight the natural (hills, agricultural land, vacant land, surface water bodies etc) and built environment (markets, town halls, gardens, places with religious importance etc) and landmarks of the town.

The selection of an approach for wastewater management is governed by factors such as water consumption, population density, topography etc. The importance and impact of these factors on the technical solution and its design might change on a case-to-case basis.

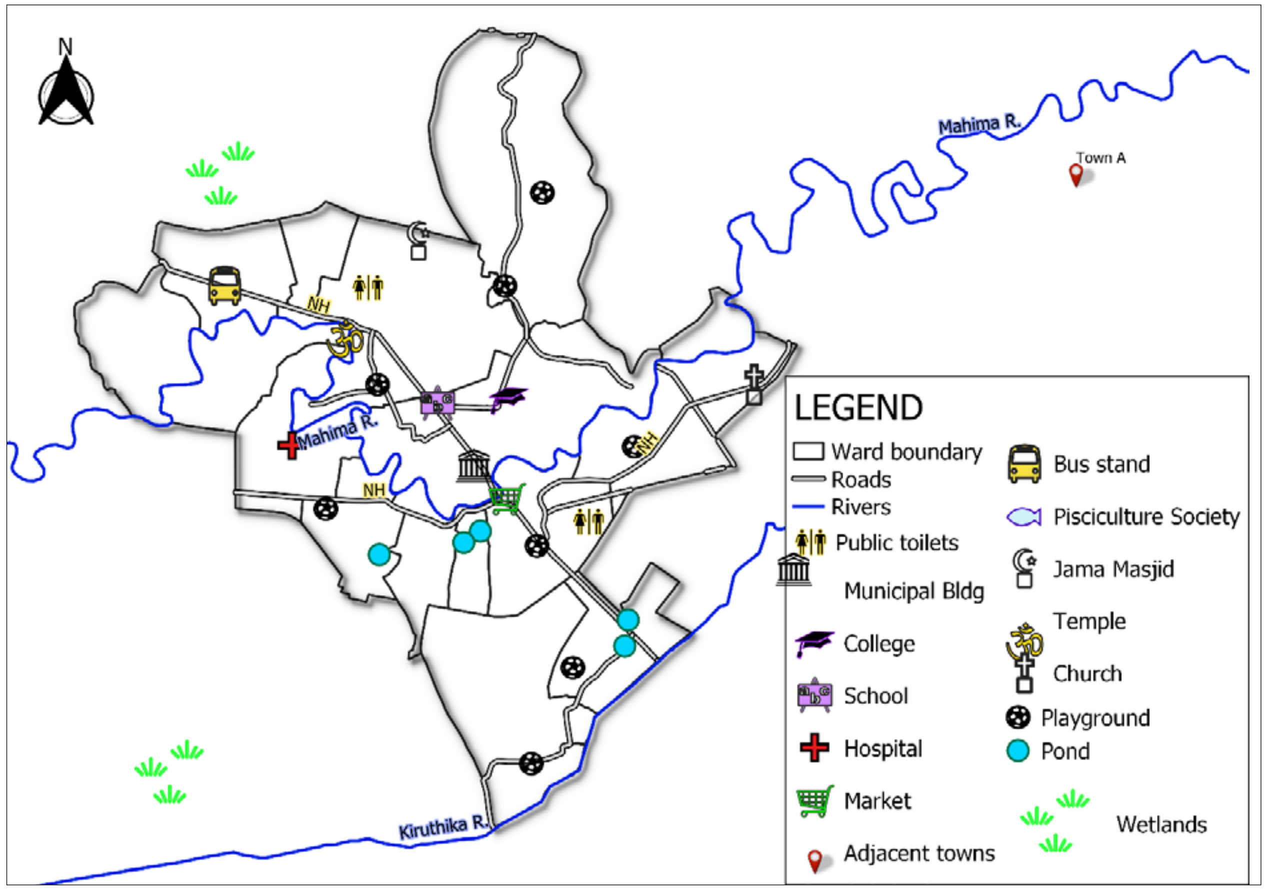

Figure 7: Map showing major landmarks in the municipal town

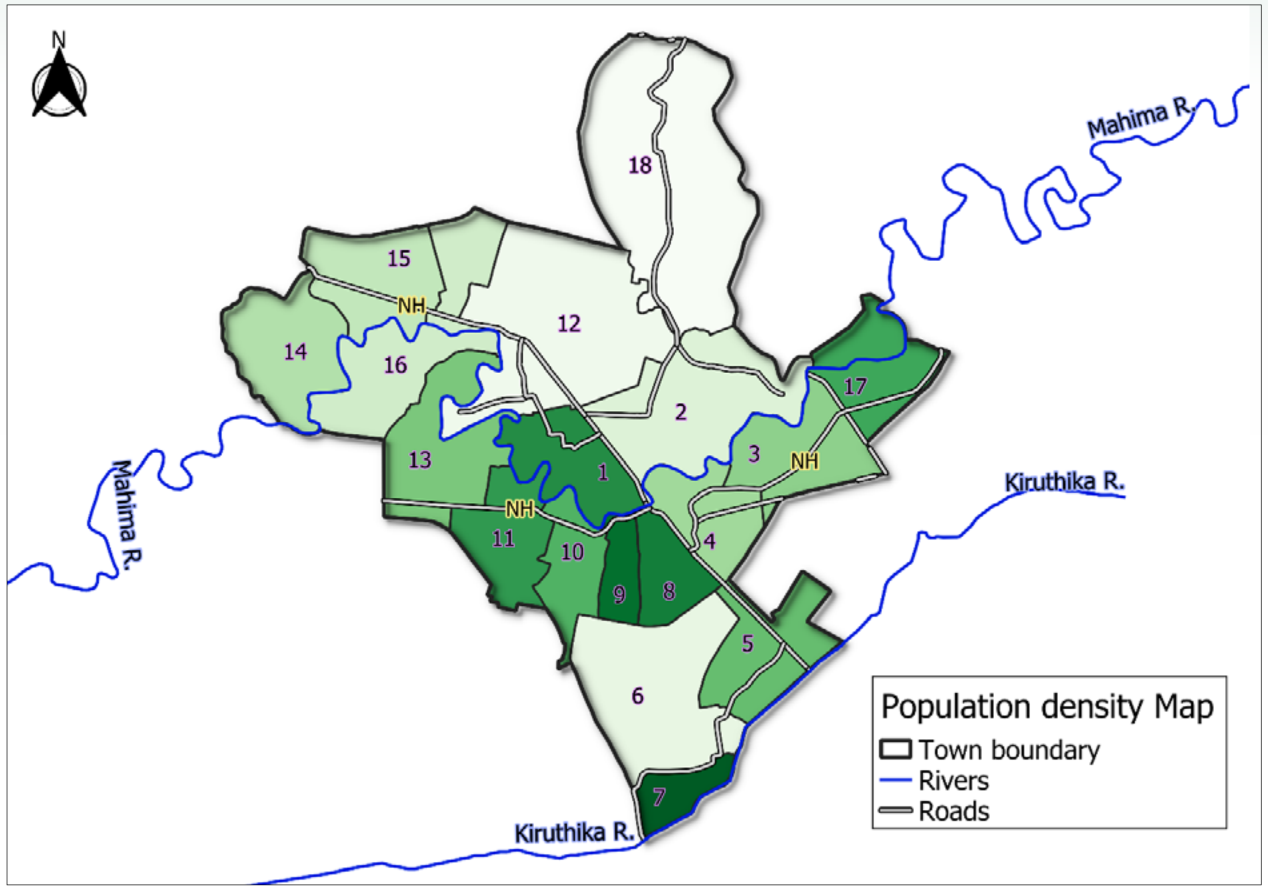

Figure 8: Map of showing ward-wise population density of the municipal town

Figure 9 represents population density for each ward. The dark green colour denotes a high population density. Ward 7, 8 and 9 has the highest population density followed by ward 1, 11 and 17. Such maps help in identifying the zones for preparing the city sanitation plan.

A core sanitation zone (CSZ) in the city is identified. This zone has a high population density area catering to around 50% of the population in approximately 30% of the area. The rest or the areas of the town can be called as Peri-urban Areas (PuAs) which can be further classified based on the population density, water consumption, topography etc.

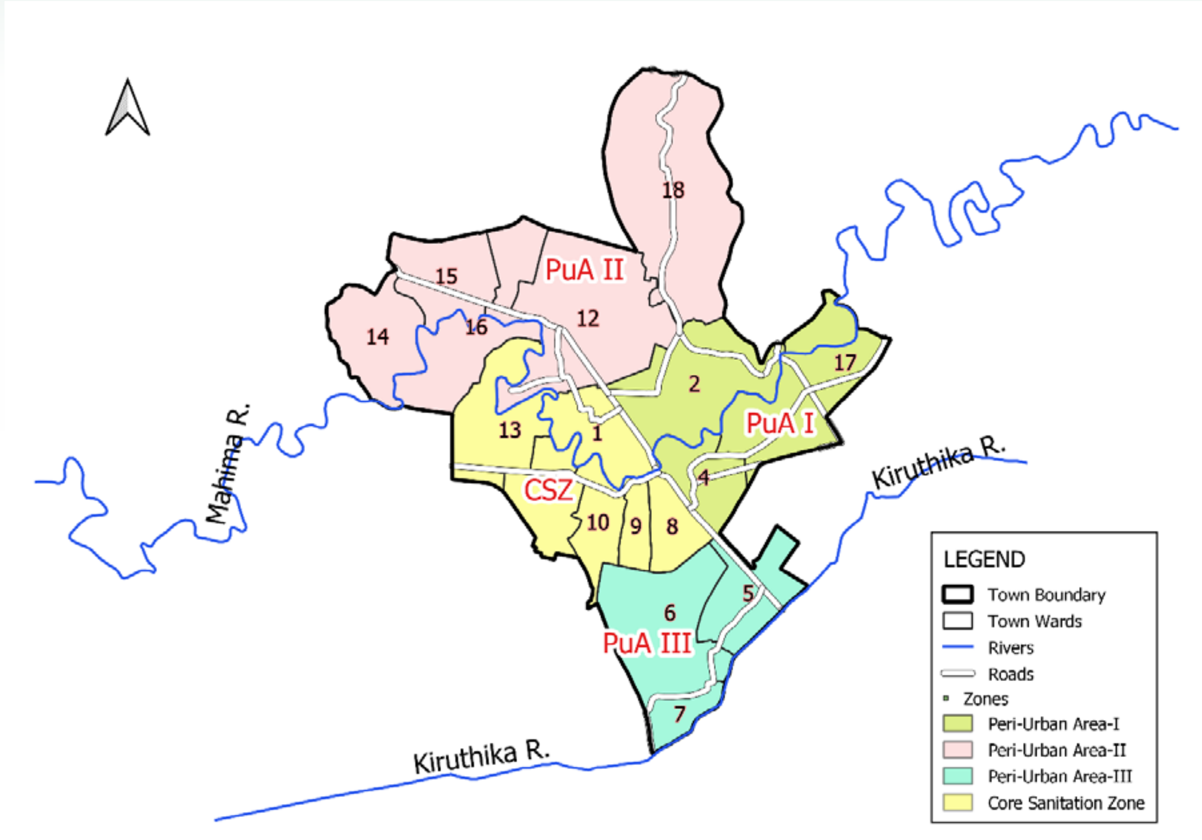

Figure 9: Map showing the classification of zones in the municipal town

The figure above illustrates different classification of the municipal town.

Session

02

Population Projection

2 Population projection

Population projection is an attempt to foresee how the change in population with respect to the present. This is an important step for planning water, wastewater and solid waste management projects. This step always comes after conducting a thorough baseline survey.

Population projections are made using mathematical models. These models of population growth take trends in human development and apply projections for the future. These models use trend-based-assumptions about how the population will respond to economic, social and technological forces to understand how they will affect fertility and mortality, and thus population growth.

First step of any population projection method is to identify the base year and the design year for various components of the sanitation system. A base year refers to the year when the implementation of the DPR will be completed and the project will be commissioned. The design period of non-conventional sewers and STP is 15 years and that for conventional sewers is 30 years from the base year.

Table 6: Base and design year for wastewater management project

Base year	
Design year for unconventional sewers & STP	
Design year for conventional sewers & STP	

For example of the population projection using the three methods, please refer to Manual on Sewerage and Sewage Treatment Systems Part A: Engineering – Appendix A2.2 on page A-47.

2.1 Arithmetic increase method

Calculate the population increase.

Table 7: Arithmetic population projection – population increase

Year	Population	Increase
1971	29,300	
1981	34,700	
1991	40,300	
2001	47,100	
2011	56,200	
Average (*X*)		

Formula for population projection using arithmetic increase method:

$$\textit{Population in 2021} = \textit{Population in 2011} + X \times n$$

where,

n: number of decades (for example, [2021-2011]/10 = 1; round off the answer to one decimal point)

Table 8: Population projection by arithmetic increase method

Year	n	Projected population
2021		
2025 Base year		
2031		
2040 Design year (Unconventional sewers/STP)		
2041		
2051		
2055 Design year (Conventional sewers/STP)		

2.2 Incremental increase method

Calculate the population increase and incremental increase for each decade.

Year	Population	Increase	Incremental increase
1971	29300		
1981	34700		
1991	40300		
2001	47100		
2011	56200		
Average		X =	Y =

Formula for population projection using incremental increase method:

$$Population\ in\ 2021 = Population\ in\ 2011 + (X \times n) + \frac{n \times (n+1) \times Y}{2}$$

where,

n: number of decades (for example, [2021-2011]/10 = 1; round off the answer to one decimal point)

Table 9: Population projection by incremental increase method

Year	n	Projected population
2021		
2025 Base year		
2031		
2040 Design year (Unconventional sewers & STP)		
2041		
2051		
2055 Design year (Conventional sewers & STP)		

2.3 Geometric increase method

Calculate the decadal growth rate (in percentage).

$$Decadal\ growth\ rate\ (\%) = \frac{Increase}{Population\ of\ previous\ decade}\ x\ 100$$

Year	Population	Increase	Decadal Growth Rate
1971	29300		
1981	34700		
1991	40300		
2001	47100		
2011	56200		

Calculate geometric mean of the decadal growth rates:

$$Geometric\ Mean\ of\ m\ numbers = \sqrt[m]{product\ of\ numbers}$$

For example, geometric mean of m1, m2, m3, m4, m5 will be calculated as follows,

$$Geometric\ mean = \sqrt[5]{m1 \times m2 \times m3 \times m4 \times m5}$$

Assuming future population growth follows the geometric mean (R), calculate the future population.

$$Population\ in\ 2021 = Population\ in\ 2011\ \times\ (1+R)^{n}$$

where,

n: number of decades (for example, [2021-2011]/10 = 1; round off the answer to one decimal point)

Table 10: Population projection by geometric mean method

Year	n	Projected population
2021		
2025 Base year		
2031		
2040 Design Year (Unconventional sewers & STP)		
2041		
2051		
2055 Design Year (Conventional sewers & STP)		

2.4 Comparison of population projection by different methods

The results of the above three projection methods have been plotted in the figure below. Identify the curves for each projection method.

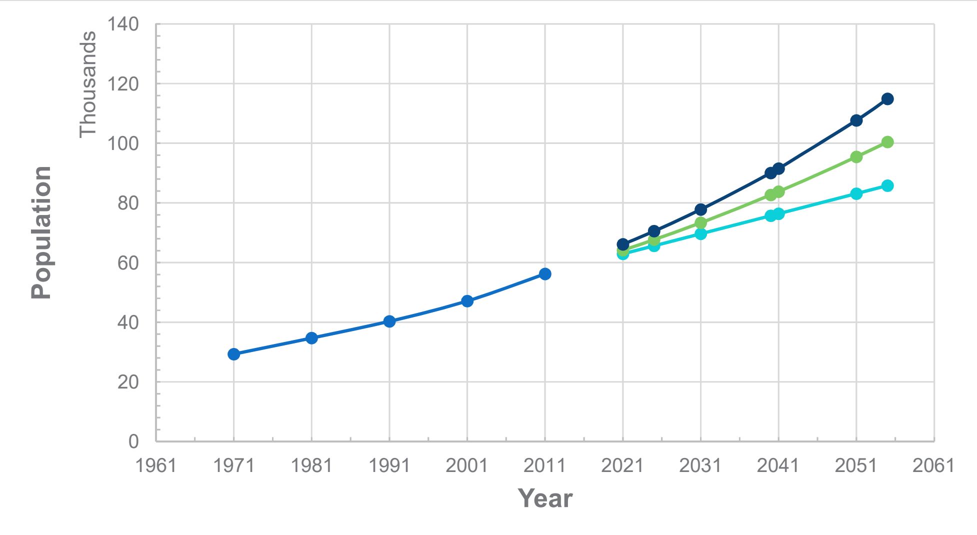

Figure 10: Population projection graphs

Colour of the Curve	Method
(blue)	Census population
(cyan)	
(green)	
(dark blue)	

It is to be noted that the choice of method for calculating population projection is dependent on the character of the city.

- Arithmetic increase method is suitable for large and old towns which are saturated and have no or little scope for expansion.
- Incremental increase method is suitable for an average sized town that has an average or lower than average scope for growth.
- Geometric increase method is suitable for towns with a higher scope of growth and are urbanising at a faster pace. These towns are typically characterised by an increase in population due to people migrating to these towns in search of employment.

2.5 Data inputs

The following table summarises the data for the CSZ and three peri-urban areas. This data is necessary to design the project in the upcoming sessions.

Table 11: Zone-wise data inputs for calculation of project cost

Description	Unit	CSZ	PuA I	PuA II	PuA III
Design Population	no.	49,500	22,500	3,600	14,400
Households	no.	9,900	4,090	900	3,200
Area	sq. km	6	8	8	6
Population density	persons/sq. km	8 _ _ _	2 _ _ _	4 _ _	2 _ _ _
Water consumption	LPCD	135	90	90	90
Cost of land	cr. INR/ha	2.5	2.2	2.0	2.0
Distance from STP site	km	10.00	20.00	5.00	0

Please refer to figure 11 for the identified locations of sites allocated to STPs in the municipal town.

Session

03

Collection & Conveyance System

3 Collection and conveyance system

3.1 Sewerage zones

The delineation of sewerage zones based on topography is an important aspect of wastewater management. For this, the river basins or natural watersheds are taken into consideration. The municipal town is divided into two river basins. Maximum area (upto 80%) of the municipal town (CSZ, PuA I and II) falls in the Mahima river basin and the remaining area i.e. PuA III falls in the Kiruthika river basin.

Identification of the sites for STP(s) is done at this point. It is preferable to consider the land which is already available with the municipal authorities and is adequate enough to accommodate the STP. Location of the sites available for STPs are marked in the figure below.

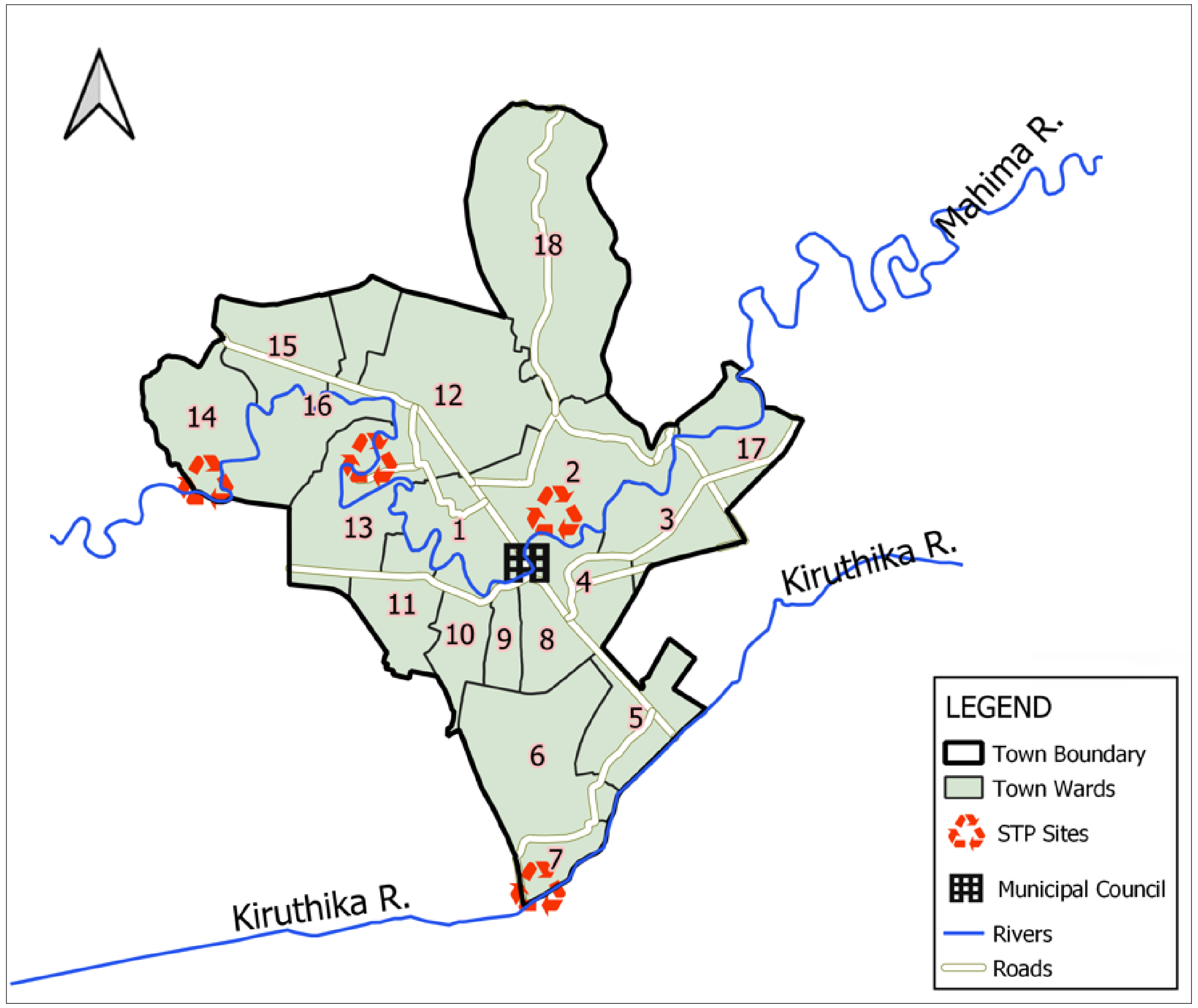

Figure 11: Map showing sites identified for STP in the municipal town

Lift stations are installed within a sewerage zone to lift the water from lower levels and discharge it into the gravity sewers. Sewage pumping stations are used to pump the wastewater from one sewerage zone to another.

The PuA III is disconnected from the main municipal town due to the topography. Hence, it is advisable to plan a separate wastewater management plan for this part of the town. The wastewater management for the three areas (CSZ and PuA I and II) can be planned in various ways of which some are suggested below.

a) All zones are combined using an I&D system containing lift stations and sewage pumping stations that collect and convey wastewater to an STP of large capacity. This is the centralised approach of wastewater management.
b) Each zone is catered to by its own STP. This is known as the decentralised approach of wastewater management.
c) It is also possible to break down a zone into micro-watersheds to eliminate the need of lift stations and set up STPs of smaller capacities. This is done when a relatively large portion of the sewerage zone is still vacant i.e., not yet inhabited by the population. This is known as the cluster approach, where a few selected residential areas with high population density are grouped together to form a cluster for wastewater management.

In order to design the sewerage systems, computer aided design softwares such as SewerGEMS, SewerCAD, etc. can be used and is considered to be very useful. Size of sewer pipes, length of the sewers, number of lift stations & sewage pumping stations, and other sewerage appurtenances such as machine holes etc. can be known by conducting design and modelling exercises. However, for the ease of this exercise, we are providing certain assumptions *(and not thumb rules!)* for understanding the impact of planning approach and population density *(and not population!)* on the cost of wastewater and septage management projects.

3.2 Assumptions

The following assumptions are to be used to do the calculations on the collection and conveyance system in the following sections.

In this exercise, we will be considering two types of sewer systems: (a) separate sewers, and (b) solid free sewers (also known as settled sewers).

Table 12: Assumptions for planning of collection and conveyance system

Description	Unit	Separate sewers	Solid-free sewers
Length of sewer	km/sq. km	8	6
Machine holes	no./km	30	10
Lift stations	no./km	1/50	1/100
Sewage pumping station	no./km	1/100	1/200
I&D with pumping station	no./zone	1	1

It is to be noted that for a properly functioning solid-free sewer system, regular desludging of septic tanks is necessary. Thus, for areas where solid-free sewers option is considered, it is necessary to calculate the number of cesspool vehicles required for practicing scheduled desludging. The assumptions for calculating the number of cesspool vehicles are as follows:

Table 13: Assumptions for planning of FSSM

Description	Unit	Quantity
Desludging period	year	3
Working days in a year	days/year	300
Cesspool vehicle trips	no./day	3
Septage receiving station	no./zone	1

After calculating the length of sewers and number of sewer appurtenances, capital expenditure (CapEx) and operational expenditure (OpEx) will have to be estimated. These estimations will be used in session 5.

Table 14: CapEx for collection and conveyance system components

Description	Unit	Quantity
Sewer	lakh INR/km	80.00
Machine hole	lakh INR/no.	0.35
Lift station	lakh INR/no.	30.00
Sewage pumping station	lakh INR/no.	100.00
I&D with pumping station	lakh INR/no.	150.00
Trunkline	lakh INR/km	120.00
Septage receiving station	lakh INR/no.	80.00
Cesspool vehicles	lakh INR/no.	25.00

Table 15: OpEx for collection and conveyance system components

Description	Unit	Quantity
Sewer	INR/km	7,500.00
Machine hole	INR/no.	1,500.00
Lift station	lakh INR/no.	30.00
Sewage pumping station	lakh INR/no.	80.00
I&D with pumping station	lakh INR/no.	100.00
Trunkline	INR/km	10,000.00
Septage receiving station	lakh INR/no.	10.00
Cesspool vehicle	lakh INR/no.	8.50

3.3 Centralised approach

In this approach, following things are considered:

- Sewerage network to collect and convey wastewater from the households
- I&D system at the end of sewerage network and collected sewage is treated in a centralised STP in PuA II

As the population density of CSZ is relatively high, separate sewers are recommended here. For the PuA I, II and III, solid-free sewers are recommended. In this case, FSSM will also have to be implemented in these zones.

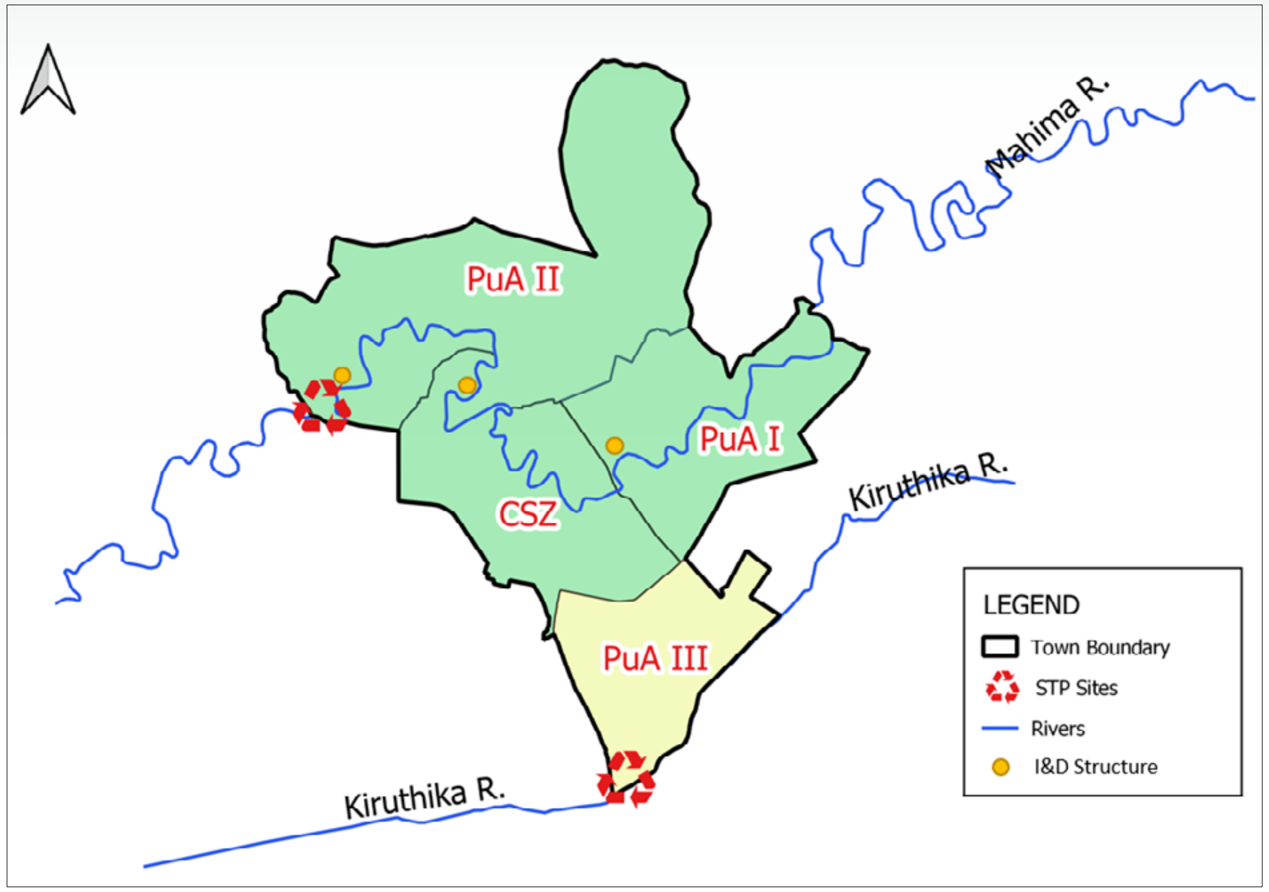

Figure 12: Map showing centralised approach of wastewater management

3.3.1 Sewerage appurtenances

The length of sewers is calculated using the following formula and information provided in Table 11 and Table 12;

$$Length\ of\ sewers\ [km] = Area\ of\ zone\ [sq.km] \times Length\ of\ sewers\ [\frac{km}{sq.km}]$$

Calculate the length of sewers and document it table 16 below.

Number of machine holes is calculated using the following formula and information provided in table 12.

$$Number\ of\ machine\ holes\ [no.] = Length\ of\ sewers\ [km] \times Number\ of\ machine\ holes\ \left[\frac{no.}{km}\right]$$

Similarly, the number of lift stations is calculated using the following formula and information provided in table 12.

$$Number\ of\ lift\ stations\ [no.] = Length\ of\ sewers\ [km] \times Number\ of\ lift\ stations\ \left[\frac{no.}{km}\right]$$

Similarly, calculate the number of sewage pumping stations in each zone and document it in the table below.

Table 16: Sewerage appurtenances for centralised wastewater management

Description	Unit	CSZ	PuA I	PuA II	PuA III
Type of sewerage system	-	Separate system	Solid-free sewers		
Length of sewer	km				
Machine holes	no.				
Lift stations	no.				
Sewage pumping station	no.				

3.3.2 Interception and diversion infrastructure

The wastewater collected from three zones has to be intercepted and diverted to the centralised STP located in the PuA II as shown in the figure 12.

For this, an I&D infrastructure consisting of a pumping station and trunk line conveying the wastewater to the STP has to be designed. Length of the trunk line is equal to the distance between the zones and the STP when measured along the river line.

Table 17: Length of trunkline to be installed for centralised wastewater management

Description	Unit	CSZ	PuA I	PuA II
Length of trunkline	km	10.00	20.00	5.00

3.3.3 Faecal sludge and septage management

FSSM is an important aspect of providing access to safe sanitation to the citizens, reducing pollution of groundwater and rivers as well as maintaining the functionality of solid-free sewers. Hence the zones, where solid-free sewers are implemented, FSSM needs to be ensured.

The faecal sludge and septage has to be collected and conveyed to the pumping station. Each pumping station should be equipped with a septage receiving station. After the preliminary treatment, septage will be added to the wastewater and pumped to the STP for co- treatment.

Calculate the number of cesspool vehicles required for providing scheduled desludging services to the households using the following formula and the information given in table 13.

$$No.of\ cesspool\ vehicles\ [no.] = \frac{No.of\ households\ [no.]}{Desludging\ period\ [years] \times No.of\ working\ days\ \left[\frac{days}{year}\right] \times No.of\ trips\ per\ vehicle\ [\frac{no.}{d}]}$$

Document the answer in table 18.

Table 18: Number of cesspool vehicles required for centralised approach

Description	Unit	CSZ	PuA I	PuA II	PuA III
Septage receiving station	no.	-	1	1	1
Cesspool vehicles	no.	-			

3.3.4 Capital expenditure

Calculate the CapEx for sewer appurtenances and FSSM. Use the answers documented in the section 3.3.1, 3.3.2, 3.3.3 and table 14.

Use the general formula provided below:

$$Cost\ of\ appurtenance\ [cr.INR]$$
$$= No.of\ appurtenance\ [no.] \times Cost\ of\ appurtenance\ [lakh\frac{INR}{no.}]$$

Document the answers in table 19.

Table 19: CapEx for collection and conveyance of centralised wastewater management

Description	Unit	CSZ	PuA I	PuA II	PuA III
Sewer	cr. INR				
Machine hole	cr. INR				
Lift station	cr. INR				
Sewage pumping station	cr. INR	-	-	-	-
I&D with pumping station	cr. INR				-
Trunkline	cr. INR				-
Septage receiving station	cr. INR	-			
Cesspool vehicles	cr. INR	-			
Total	cr. INR	57._ _	66._ _	48._ _	31._ _
Total	cr. INR	204._ _			

3.3.5 Operational expenditure

Similarly, calculate the OpEx for sewer appurtenances and FSSM. Use the answers documented in the section 3.3.1, 3.3.2, 3.3.3 and table 15. Document the answers in the table below.

Table 20: OpEx of collection and conveyance of centralised wastewater management

Description	Unit	CSZ	PuA I	PuA II	PuA III
Sewer	cr. INR/year				
Machine hole	cr. INR/year				
Lift station	cr. INR/year				
Sewage pumping station	cr. INR/year	-	-	-	-
I&D with pumping station	cr. INR/year				-
Trunkline	cr. INR/year				-
Septage receiving station	cr. INR/year	-			
Cesspool vehicles	cr. INR/year	-			
Total	**cr. INR/year**	1._ _	1._ _	1._ _	0._ _
Total	**cr. INR**	4._ _			

3.4 Decentralised Approach

In this approach, the following things are considered:

- Sewerage network to collect and convey the wastewater from the households
- STP is planned for each zone

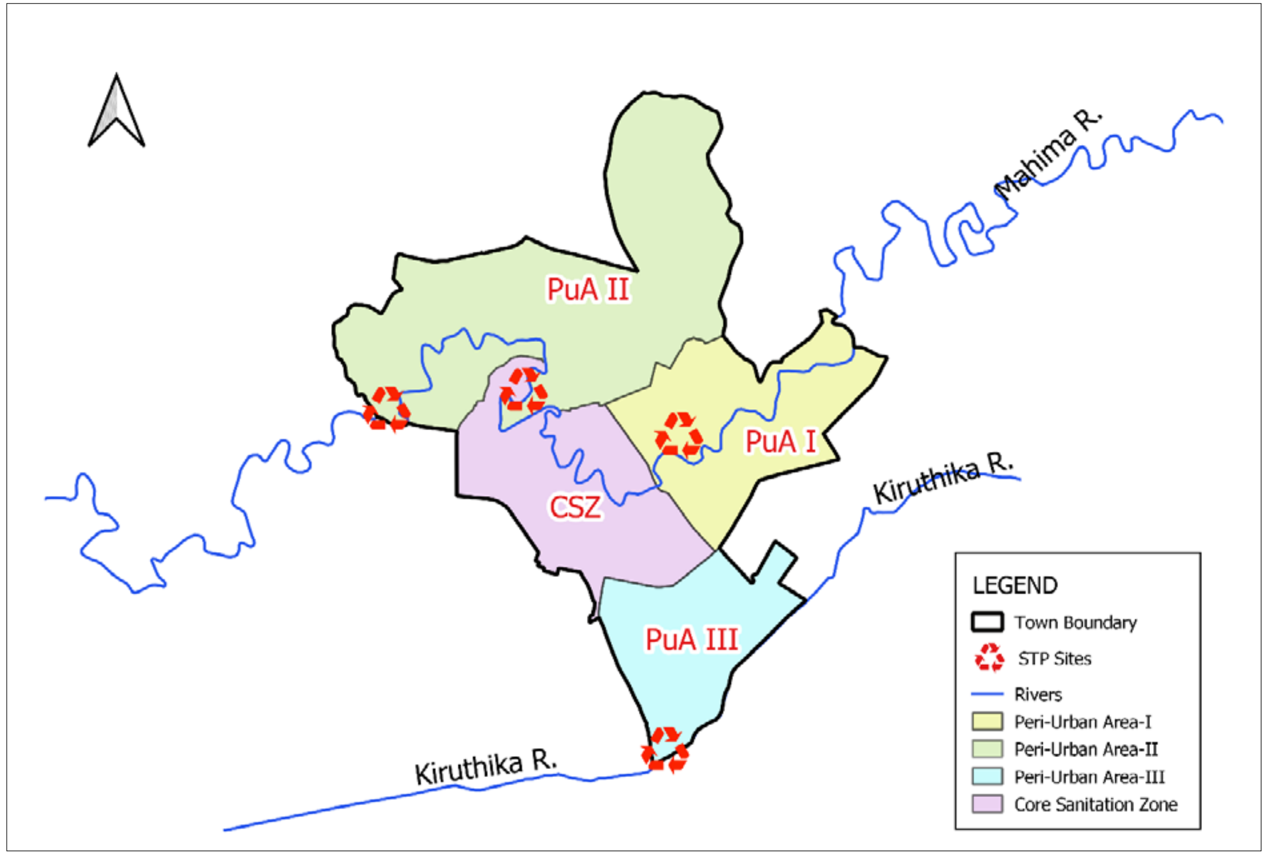

Figure 13: Map showing decentralised approach for wastewater management

To understand the impact on cost of collection and conveyance systems, it is proposed to plan for separate sewers in PuA III. This will help us to analyse how the cost of the project per unit volume of wastewater managed [INR/KL] and per person [INR/person] varies and affects the affordability of the infrastructure.

3.4.1 Sewerage appurtenances

Use the approach given in the section 3.3.1, to calculate the number of sewerage appurtenances for zone PuA III.

Table 21: Sewerage appurtenances for decentralized wastewater management

Description	Unit	CSZ	PuA I	PuA II	PuA III
Type of sewerage system	-	Separate system	Solid-free sewers		Separate system
Length of sewer	km	48	48	48	
Machine holes	no.	1440	480	480	
Lift stations	no.	1	0	0	
Sewage pumping station	no.	0	0	0	

Compare the values calculated in table 16 with table 21.

3.4.2 Faecal sludge and septage management

The type of sewerage system is not changed in zones CSZ, PuA I and II. So, the number of cesspool vehicles in these zones remain unchanged.

Table 22: Number of cesspool vehicles required for decentralised approach

Description	Unit	CSZ	PuA I	PuA II	PuA III
Septage receiving station	no.	-	1	1	-
Cesspool vehicles	no.	-	2	1	-

Compare the values calculated in table 18 with table 22.

Faecal sludge and septage has to be collected and conveyed to the respective STP in each zone. Each STP should be equipped with a septage receiving station. After the preliminary treatment, septage will be added to the wastewater and pumped to the STP for co- treatment.

3.4.3 Capital expenditure

Calculate the CapEx for sewer appurtenances and FSSM. Use the answers documented in the section 3.4.1, 3.4.2 and table 14.

Use the formula provided below:

$$Cost\ of\ appurtenance\ [cr.INR] = No.of\ appurtenance\ [no.] \times Cost\ of\ appurtenance\ [lakh\frac{INR}{no.}]$$

Document the answers in the table below.

Table 23: CapEx of collection and conveyance of decentralised wastewater management

Description	Unit	CSZ	PuA I	PuA II	PuA III
Sewer	cr. INR	38.40	38.40	38.40	
Machine hole	cr. INR	5.00	1.70	1.70	
Lift station	cr. INR	0.30	-	-	
Sewage pumping station	cr. INR	-	-	-	-
Septage receiving station	cr. INR	-	0.80	0.80	-
Cesspool vehicles	cr. INR	-	0.50	0.25	
Total	cr. INR	43.70	41.40	41.15	43._ _

Compare the values calculated in table 19 with table 23.

3.4.4 Operational expenditure

Similarly, calculate the OpEx for sewer appurtenances and FSSM. Use the answers documented in the section 3.3.1, 3.3.2, 3.3.3 and table 15. Record the answers below.

Table 24: OpEx of collection and conveyance of decentralised wastewater management

Description	Unit	CSZ	PuA I	PuA II	PuA III
Sewer	cr. INR/year	0.04	0.04	0.04	
Machine hole	cr. INR/year	0.22	0.07	0.07	
Lift station	cr. INR/year	0.30	-	-	
Sewage pumping station	cr. INR/year	-	-	-	-
Septage receiving station	cr. INR/year	-	0.10	0.10	-
Cesspool vehicles	cr. INR/year	-	0.17	0.09	-
Total	cr. INR/year	0.56	0.38	0.30	0._ _

Compare the values calculated in table 20 with table 24.

Session

04

Wastewater Treatment

4 Wastewater treatment

Wastewater treatment is more than simply selection of a treatment technology. For a town to be able to sustain the sewerage project through its design life, following points need to be considered.

1. Location of STP and cost of land

While planning for wastewater management, all the suitable sites for STPs shall be considered. Even if land is available with the municipal authorities, cost of land should be factored into the life cycle cost of the project. Cost of land in rapidly urbanising cities is increasing. As a result, the cost of land on which the STP is located is far valuable for some other project in the future. If selecting land for STP is away from town or on the outskirts, the cost of land reduces and also allows selecting non-mechanised treatment technologies such as waste stabilisation ponds. This has a positive impact on the life cycle cost of the project.

2. Characteristics of wastewater

Characteristics of influent wastewater is very critical. Variation in the organic loading impacts certain treatment units more than others. Ideally for a low strength wastewater, aerobic biological processes are recommended whereas for high strength wastewater, aerobic biological processes should be preceded by an anaerobic biological process. A high variation in the organic loading results in imbalance of secondary treatment unit affecting the efficiency of treatment and increasing the cost of treatment.

3. Life cycle cost of the wastewater treatment

Non-mechanised technologies (popularly known as nature-based technologies) do have higher capital cost, however the operation and maintenance cost of such technologies over a period of design life is far less when compared to the mechanised technologies.

4.1 Sewage generation

As suggested in sessions 5 and 6 of the module, a thorough understanding of the ground situation is required in calculating the design flows. This can be understood through many factors like groundwater infiltration, interception factor, etc. These factors vary on a case-to-case basis.

For keeping this exercise and calculation simple, we use a thumb rule that 80% of water consumed by the population is converted into wastewater. The groundwater infiltration is considered to be 10% of the estimated sewage generation.

Calculate the sewage generation in each zone using the following formula.

$$Sewage\ generation\ [MLD] = Design\ population\ [no.] \times Water\ consumption\ [LPCD] \times 80\%$$

$$Groundwater\ infiltration\ [MLD] = Sewage\ generation\ [MLD] \times 10\%$$

$$\begin{aligned} &Total\ sewage\ generation\ [MLD] \\ &\quad = Sewage\ generation\ [MLD] + Groundwater\ infiltration\ [MLD] \end{aligned}$$

Document the answers in the table below;

Table 25: Zone-wise sewage generation in the municipal town

Description	Unit	CSZ	PuA I	PuA II	PuA III
Total sewage generation	MLD				

4.2 Assumptions

The following assumptions are to be considered while calculating and designing wastewater treatment systems in the further sections. The data is provided for four different types of treatment technologies to be selected for the STPs.

1. **Waste stabilisation pond (WSP)** – This refers to a completely non-mechanised system. A series of ponds are provided to perform anaerobic and aerobic treatment to the wastewater in the secondary stage. WSP is a very robust technology and can handle variation in the organic and solids loading.
2. **Hybrid system** – This refers to a mixture of mechanised and non-mechanised treatment unit/s in the secondary stage of the STP. Example of technologies which can be classified as hybrid system are anaerobic baffled reactor (ABR), anaerobic filter (AF), constructed wetland (CW), extended aeration ponds, phytorid technology, soil-scape filter, soil bio-technology (SBT), etc. The combination of different treatment units are done to reduce the area requirement as compared to a fully mechanised system.
3. **Moving bed biological reactor (MBBR)** – This refers to a very popular mechanised treatment system which provides aerobic treatment of wastewater using a media made of PVC or PP. This is a continuous and completely mixed reactor wherein the dissolved oxygen level is maintained in the reactor to balance the MLSS count and F/M ratio. MBBR is robust towards variation in the incoming sewage.
4. **Sequential batch reactor (SBR)** – This refers to another very popular mechanised treatment system which provides aerobic treatment to the wastewater. This is batch reactor in which all cycles of fill, mix, aerate, still and decant are done in one or more tanks. The biggest advantage of this technology is that the operator can optimise the process for each batch of wastewater.

Table 26: Assumptions for wastewater treatment technologies

Treatment technology	Unit	WSP	Hybrid	MBBR	SBR
Area	ha/MLD	1.50	0.80	0.25	0.15
Cost of construction	cr. INR/MLD	1.20	3.00	2.10	2.20
O&M cost of STP	lakh INR/MLD	2.50	3.00	12.00	10.00

4.3 Centralised Approach

As mentioned in Section 3.3, there will be two STPs. A centralised STP of design capacity **8 MLD** will be located in the PuA II and will cater to the sewage generated in CSZ, PuA I and PuA II. The second STP of design capacity **1.10 MLD** will be located in PuA III.

4.3.1 Choice of technology

In the I&D project, the STP should be located on the downstream end of the zones along the river. In case of the centralised STP, availability of the land increases and the cost of the land decreases as the location of STP shifts away from the habitable areas. This provides us with an opportunity to choose hybrid technology which significantly reduces the O&M cost of the plant. For the second STP in PuA III, a waste stabilisation pond is recommended.

4.3.2 Area requirement

Calculate the area requirement for both STPs using the information provided in table 26 and the information given in section 4.3.

$$Area\ required\ for\ STP\ [ha] = Design\ capacity\ [MLD] \times Area\ required\ \left[\frac{ha}{MLD}\right]$$

Note the answers in the following table. These data will be required for calculating the cost of the land acquisition of the STPs.

Table 27: Area required for STPs in centralised approach for wastewater treatment

STP location	Unit	Area
PuA II (catering to CSZ, PuA I and II)	ha	6._
PuA III (catering to PuA III)	ha	1._

4.3.3 Capital expenditure

For calculating CapEx of the wastewater treatment, cost of land acquisition and cost of construction of STP needs to be determined.

Calculate the cost of land acquisition using information provided in tables 11 and 27.

$$Cost\ of\ land\ acquisition\ [cr.INR] = Area\ of\ land\ [ha] \times Cost\ of\ land\ \left[\frac{cr.INR}{ha}\right]$$

Similarly, calculate the cost of STP construction using information in section 4.3 and table 26.

$$Cost\ of\ construction\ [cr.INR]$$
$$= Design\ capacity\ of\ STP\ [MLD] \times Cost\ of\ construction\ [\frac{cr.INR}{MLD}]$$

CapEx of wastewater treatment will be the total cost of land acquisition and cost of construction.

Document the CapEx for wastewater treatment in the table below.

Table 28: CapEx for wastewater treatment in centralized approach of wastewater management

STP location	Unit	CapEx
PuA II (catering to CSZ, PuA I and II)	cr. INR	36._ _
PuA III (catering to PuA III)	cr. INR	4._ _

4.3.4 Operational expenditure

Calculate the OpEx for STPs using the following formula and the information given in section 4.4 and table 26.

$$O\&M\ cost\ \left[\frac{cr.INR}{annum}\right] = Design\ capacity\ of\ STP\ [MLD] \times O\&M\ cost\ \left[\frac{cr.INR}{MLD}\right]$$

Document the OpEx for wastewater treatment in the table below.

Table 29: OpEx for wastewater treatment in centralized approach of wastewater management

STP location	Unit	OpEx
PuA II (catering to CSZ, PuA I and II)	cr. INR/annum	0._ _
PuA III (catering to PuA III)	cr. INR/annum	0._ _

4.4 Decentralised Approach

As mentioned in section 3.4, there will be four STPs with one in each zone. The zones where solid-free sewers are planned i.e. PuA I and PuA II, will have the STP equipped with a facility to co-treat faecal sludge and septage with sewage.

4.4.1 Choice of technology

In case of decentralised approach, each zone i.e., CSZ, PuA I, II and III will have an STP of design capacity 5.90 MLD, 1.80 MLD, 0.30 MLD and 1.10 MLD, respectively.

The recommended treatment technology is based on the area availability in the specific zone. The technology recommended is as follows:

- STP catering to CSZ – 5.90 MLD – SBR
- STP catering to PuA I – 1.80 MLD – MBBR
- STP catering to PuA II – 0.30 MLD – WSP
- STP catering to PuA III – 1.10 MLD - WSP

4.4.2 Area requirement

Calculate the area requirement for all four STPs using the information provided in table 26 and section 4.4.

$$Area\ required\ for\ STP\ [ha] = Design\ capacity\ [MLD] \times Area\ required\ \left[\frac{ha}{MLD}\right]$$

Note down the answers in the following table. These values will be required for calculating the cost of land acquisition for the STPs.

Table 30: Area required for STPs in decentralised approach for wastewater treatment

STP location	Unit	Area
CSZ	ha	0.8 _
PuA I	ha	0.4 _
PuA II	ha	0.4 _
PuA III	ha	1._ _

4.4.3 Capital expenditure

For calculating CapEx of the wastewater treatment, cost of land acquisition and cost of construction of STP needs to be determined.

Calculate the cost of land acquisition using the information provided in tables 11 and 30.

$$Cost\ of\ land\ acquisition\ [cr.INR] = Area\ of\ land\ [ha] \times Cost\ of\ land\ \left[\frac{cr.INR}{ha}\right]$$

Similarly, calculate the cost of STP construction using the information provided in section 4.4 and table 26.

$$Cost\ of\ construction\ [cr.INR] = Design\ capacity\ of\ STP\ [MLD] \times Cost\ of\ construction\ \left[\frac{cr.INR}{MLD}\right]$$

CapEx of wastewater treatment will be the total cost of land acquisition and cost of construction.

Note the CapEx for wastewater treatment in the table below.

Table 31: CaPex for wastewater treatment in decentralised approach of wastewater management

STP location	Unit	CapEx
CSZ	cr. INR	15._ _
PuA I	cr. INR	4._ _
PuA II	cr. INR	1._ _
PuA III	cr. INR	4._ _

4.4.4 Operational expenditure

Calculate the OpEx for STPs using the following formula and information provided in section 4.4 and table 26.

$$O\&M\ cost\ \left[\frac{cr.INR}{annum}\right] = Design\ capacity\ of\ STP\ [MLD] \times O\&M\ cost\ [\frac{cr.INR}{MLD}]$$

Document the OpEx for wastewater treatment in the table below.

Table 32: OpEx for wastewater treatment in decentralised approach of wastewater management

STP location	Unit	OpEx
CSZ	cr. INR/annum	0.5 _
PuA I	cr. INR/annum	0.2 _
PuA II	cr. INR/annum	0.0 _
PuA III	cr. INR/annum	0.0 _

Session

05

Financial Modelling

5 Financial modelling

Financial modelling is one of the last stages of the project design. In this exercise, the capital and operational expenditure of the two project scenarios i.e., centralised approach and decentralised approach for wastewater management are used for calculating life cycle cost of the project.

Life cycle cost of the project helps to calculate the average cost of wastewater management in two ways: (a) cost per unit volume of wastewater, and (b) cost per person. It is also possible to calculate the conservancy tax for each scenario that gives an idea of service affordability by the households and the municipal town.

5.1 Assumptions

5.1.1 Centage and establishment cost

To calculate the total cost of the project, cost of DPR preparation and project monitoring during the implementation stage shall also be included. Cost of DPR preparation includes cost of survey conducted for gathering data, cost of site investigation, preparation of DPR, etc. This is known as centage and is typically considered at 10% of the capital expenditure. Similarly, project monitoring cost includes cost of human resources employed, quality control tests, freight charges, etc. and it is known as establishment cost. The establishment cost is around 15% of the capital expenditure.

Centage – 10% of the CapEx

Establishment Cost – 15% of the CapEx

5.1.2 Classification of capital expenditure

The total capital expenditure can be classified into three categories namely: (a) civil component cost, (b) electro-mechanical component cost, and (c) electrical and plumbing cost. In a real life scenario, these individual costs have to be estimated accurately during the preparation of DPR. Here, the assumed values of these costs are provided in table 33 for solving this chapter. The percentages are based on the technology selected for wastewater treatment.

Table 33: Classification of capital expenditure of the project

Capital expenditure	Unit	Type of STP	
		Mechanised	Non-mechanised
Civil component cost	%	60%	80%
Electro-mechanical component cost	%	30%	15%
Electrical and plumbing cost	%	10%	5%

5.1.3 Life of components

For analysing the life cycle cost, it is important to know the service life of civil components, electro-mechanical components and electrical and plumbing. This is because their service life is different and service life is an important aspect for cost estimation. The life of the components is given in the table below.

Table 34: Life of different components of the project

Type of component	Unit	Service life
Civil component	years	25
Electro-mechanical component	years	15
Electrical and plumbing component	years	10

The service life of the component also plays a major role in determining the repair and renewal cost that will be incurred during the operation and maintenance of the project.

5.1.4 Repair and renewal cost

The repair and renewal (R&R) cost of the components is estimated as a certain percentage of the component cost in the base year. The following table provides details of the R&R cost as a percent of the cost of the component.

Table 35: Repair and renewal cost for different components in the project

Type of component	Unit	R&R cost as % of CapEx
Civil component	%	10%
Electro-mechanical component	%	60%
Electrical and plumbing component	%	40%

5.1.5 Inflation and discount rate

Inflation rate is used to calculate the future cost of operation and maintenance (O&M) for each component of the project during the service life. The discount rate is used to calculate the net present value (NPV) of the components. Here, discount rate is further used to calculate the life cycle cost of the component using the equivalent annual cost (EAC) method.

Inflation rate – 4%

Discount rate – 6%

5.1.6 Conservancy tax

The conservancy tax is the charges levied by the service provider to ensure financial viability of the wastewater management system. Following are the three ways in which the conservancy tax can be determined depending upon the funding pattern.

Table 36: Conservancy tax calculation for a project

Funding pattern	Formula to calculate conservancy tax
Project to be carried out on external loan	$\frac{EAC\ of\ the\ project}{Total\ number\ of\ households}$
CapEx is covered through program funds	$\frac{EAC\ O\&M\ Cost + EAC\ R\&R\ Cost}{Total\ number\ of\ households}$
O&M is not covered through program funds	$\frac{EAC\ O\&M\ Cost}{Total\ number\ of\ households}$

5.2 Centralised approach

Calculate the total capital expenditure for the centralised approach of wastewater management using the formula below and the information from tables 19 and 28.

$$CapEx\ of\ project\ [cr.INR] = \\ CapEx\ for\ collection\ and\ conveyance\ [cr.INR] + \\ CapEx\ for\ wastewater\ treatment\ [cr.INR]$$

Table 37: Capital expenditure for centralised approach of wastewater management

Description	Unit	CSZ, PuA I and II	PuA III
Capital expenditure	cr. INR		
Centage @ 10%	cr. INR		
Establishment charges @ 15%	cr. INR		
Total	cr. INR	261._ _	45._ _

Calculate the total operational expenditure of the centralised approach of wastewater management using the formula below and the information given in tables 20 and 29.

$$OpEx\ of\ project\ [cr.INR] \\ = OpEx\ for\ collection\ and\ conveyance\ [cr.INR] \\ + OpEx\ for\ wastewater\ treatment\ [cr.INR]$$

Table 38: Operational expenditure for centralised approach of wastewater management

Description	Unit	CSZ, PuA I and II	PuA III
Operational expenditure	cr. INR	4._ _	0.3 _

5.2.1 Life cycle cost analysis

Use the excel based tool provided with the module for performing life cycle cost analysis by the EAC method. All the figures are in crore Indian Rupees unless and until specified. Fill the information from tables 37 and 38 in the cells marked in yellow and information from section 5.1 in the cells marked in green. The cells marked in grey are already filled based on the information from section 5.1.

The tool will automatically calculate the inflation for the O&M Cost and the repair and renewal cost. Further, it will also calculate the NPV value for the O&M cost and R&R cost.

Note down the answers in the table below.

Table 39: NPV of project based on centralised wastewater management approach

Description	Unit	CSZ, PuA I and II	PuA III
NPV O&M cost	cr. INR		
NPV R&R cost	cr. INR		
CapEx	cr. INR		
NPV of project (zone-wise)	**cr. INR**	**3 _ _ . _ _**	**5 _ . _ _**
NPV of total project	**cr. INR**	**3 _ _ . _ _**	

The next step is to calculate the EAC for each cost. Check the tool and it has estimated these values. Document the answers in the table below.

Table 40: EAC of project based on centralised wastewater management approach

Description	Unit	CSZ, PuA I and II	PuA III
EAC CapEx	cr. INR/annum		
EAC O&M cost	cr. INR/annum		
EAC R&R cost	cr. INR/annum		
EAC of project	**cr. INR/annum**	**2 _ . _ _**	**4. _ _**

Using the information provided in tables 39 and 40, calculate the cost of the project as shown in the table below.

Table 41: Project cost for centralised wastewater management

Description	Unit	Formula	CSZ, PuA I and II	PuA III
Cost of project	$\frac{INR}{person}$	$\frac{NPV\ of\ Project}{Design\ population}$		
Cost of project	$\frac{INR}{KL}$	$\frac{EAC\ of\ Project}{Design\ capacity\ of\ STP\ \times 365}$		

5.2.2 Conservancy tax

Use the EAC values and the formula provided in table 36 to calculate the conservancy tax and document in the table below.

Table 42: Conservancy tax for project based on centralised wastewater management approach

Funding pattern	CSZ, PuA I and II	PuA III
Project to be carried out on external loan		
CapEx is covered through program funds		
O&M is not covered through program funds		

5.3 Decentralised Approach

Calculate the total capital expenditure of the decentralised approach of wastewater management using the formula below and the information from Table 23 and Table 31.

$$CapEx\ of\ project\ [cr.INR] = CapEx\ for\ collection\ and\ conveyance\ [cr.INR] + CapEx\ for\ wastewater\ treatment\ [cr.INR]$$

Table 43: Capital expenditure for decentralised approach of wastewater management

Description	Unit	CSZ	PuA I	PuA II	PuA III
Capital expenditure	cr. INR				
Centage @ 10%	cr. INR				
Establishment charges @ 15%	cr. INR				
Total	**cr. INR**	**73._ _**	**57._ _**	**53._ _**	**60._ _**

Calculate the total operational expenditure of the decentralised approach of wastewater management using the formula below and the information from Table 24 and Table 32.

$$OpEx\ of\ project\ [cr.INR] = OpEx\ for\ collection\ and\ conveyance\ [cr.INR] + OpEx\ for\ wastewater\ treatment\ [cr.INR]$$

Table 44: Operational expenditure for decentralised approach to wastewater management

Description	Unit	CSZ	PuA I	PuA II	PuA III
Operational expenditure	cr. INR/annum	1._ _	0.5 _	0.3 _	0.5 _

5.3.1 Life cycle cost analysis

Use the excel based tool provided with the module for performing life cycle cost analysis by the EAC method. All the figures are in crore Indian Rupees unless and until specified. Fill the information from tables 43 and 44 in the cells marked in yellow and information from section 5.1 in the cells marked in green. The cells marked in grey are already filled based on the information from section 5.1.

The tool will automatically calculate the inflation for the O&M Cost and the repair and renewal cost. Further, it will also calculate the NPV value for the O&M cost and R&R cost.

Note down the answers in the table below.

Table 45: NPV of project based on decentralised wastewater management approach

Description	Unit	CSZ	PuA I	PuA II	PuA III
NPV O&M Cost	cr. INR				
NPV R&R Cost	cr. INR				
CapEx	cr. INR				
NPV of Project	**cr. INR**	**1 _ _ . _ _**	**8 _ . _ _**	**6 _ . _ _**	**7 _ . _ _**
NPV of Project	**cr. INR**	**3 _ _ . _ _**			

As done earlier, the EAC is to be estimated next. Again, the EAC values have been estimated in the tool. Record the values in the table given below.

Table 46: EAC of project based on decentralised wastewater management approach

Description	Unit	CSZ	PuA I	PuA II	PuA III
EAC CapEx	cr. INR/annum				
EAC O&M cost	cr. INR/annum				
EAC R&R Cost	cr. INR/annum				
EAC of Project	**cr. INR/annum**	**8._ _**	**6._ _**	**5._ _**	**6._ _**

Using the information provided in tables 45 and 46, calculate the cost of the project as shown below.

Table 47: Project cost for decentralised wastewater management

Description	Unit	Formula	CSZ	PuA I	PuA II	PuA III
Cost of project	$\frac{INR}{person}$	$\frac{NPV\ of\ Project}{Design\ population}$				
Cost of project	$\frac{INR}{KL}$	$\frac{EAC\ of\ Project}{Design\ capacity\ of\ STP}$				

5.3.2 Conservancy tax

Use the EAC values and the formula provided in table 36 to calculate the conservancy tax and document in the table below.

Table 48: Conservancy tax for project based on decentralised wastewater management approach

Funding pattern	CSZ	PuA I	PuA II	PuA III
Project to be carried out on external loan				
CapEx is covered through program funds				
O&M is not covered through program funds				

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06

Project Planning

6 Project planning

This section elaborates on selection of approaches and phasing of the wastewater management project in order to achieve safe and effective sanitation in a sustainable manner. In the case of this municipal town, after comparing the NPV of two approaches, it is observed that a decentralised approach is economical. Thus, by using a decentralised approach, the municipal authorities can proceed to the DPR preparation stage for wastewater management.

For understanding the phasing of the project, let us assume that the O&M of the project is not covered through any program funds. A socio-economic survey of the zones will help in understanding the affordability of the conservancy tax that can be levied to end users. Stakeholder consultations shall be arranged at this stage to avoid any issues and challenges at a later stage. For stakeholder consultation, the elected representatives can be mobilised by providing information about the project – objective, benefits, goal to be achieved.

The socio-economic survey and subsequently the stakeholder consultation showed that INR 2000 per household per annum to be paid quarterly was acceptable to the citizens.

The project for wastewater management in the CSZ, PuA I and PuA III can successfully move to the next stage of DPR based on the selected technologies.

The conservancy tax will not be affordable for the households residing in PuA II and hence, it is recommended that non-sewered sanitation – i.e. onsite sanitation system be promoted and practiced in this zone for the next 30 years. This will eliminate the need for implementing a sewerage network and the septage from the households can be co-treated in the nearest STP.

Table 49: Zone-wise selection of technologies for wastewater management

Functional group	CSZ	PuA I	PuA III	PuA II
Collection and conveyance (Wastewater)	Separate sewers	Solid-free sewers		-
Collection and conveyance (Septage)	-	Cesspool vehicles		
Wastewater treatment	SBR	MBBR	WSP	-

6.1 Phase 1

Phase 1 will start from the base year to year 5. Until the base year, the municipal town shall:

1. Plan and implement the separate sewers and STP based on SBR in the CSZ.
2. Plan for solid-free sewers and implement I&D of surface drains along with STP based on MBBR in PuA I.
3. Plan for solid-free sewers and implement I&D of surface drains STP based on WSP in PuA III
4. Implement non-sewered sanitation in PuA I, II and III until solid-free sewers are implemented in PuA I and III.
5. Develop and enforce the byelaws for constructing the septic tanks and soak pits/soakaway zones as per IS 2470 Part A and B in PuA I, II and III.
6. Develop and implement IEC campaign for generating demand organically for regular desludging of septic tanks (one in three years as per the ODF ++ protocol, May 2020) in PuA I, II and III.
7. Formalise the desludging service providers in the city through licensing, contracting and improve the quality of services given to the household.

6.2 Phase 2

Phase 2 will start from year 6 to year 15. During this period, the municipal town shall:

1. Implement the solid free sewers in PuA I and III and treat the wastewater at the respective STPs.
2. Ensure regular desludging of septic tanks in order to maintain efficiency of the solid free sewers.
3. Increase the conservancy tax to be able to operate and maintain the solid free sewers
4. Continue promoting and practicing non sewered sanitation in PuA II.
5. Reassess the adequacy of the STPs in CSZ, PuA I and III. Develop plan/DPR for augmentation of the wastewater treatment capacities.

6.3 Phase 3

Phase 3 will start from Year 16 to Year 30. During this period, the municipal town shall:

1. Reassess the situation in PuA II and based on the inferences, decide if non-sewered sanitation needs to be continued or sewered sanitation can be implemented.
2. Depending upon the plan of augmentation of treatment capacity, implement the DPR for CSZ, PuA I and III.

The municipal town shall also plan for capacity building of its officials from time to time in improving wastewater management in the town. The capacity building can focus on various topics such as operation and maintenance, contracting and licensing, managing municipal finances and occupational health and safety in sanitation.

The desludging operators shall also be asked to provide training to its employees on standard operating procedure of desludging of septic tanks and maintaining sewerage networks. Occupational health and safety should also be given priority. Personal protective and safety equipment should be provided by the operators to its employees along with training to use and maintain the equipment at least once a year.

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07

Summary

7 Summary

The exercise takes a municipal town and classifies it into different zones depending upon the topography, population density etc. Furthermore, the wastewater management in the town is proposed to be implemented through two approaches. These are the centralised and decentralized wastewater management. By using certain assumptions, the calculation for key financial aspects such capital and operational expenditure, conservancy tax, etc. were estimated.

This exercise is an attempt to showcase how the selection of a wastewater management approach can be done using pragmatic indicators such as life cycle cost of project and affordability of the infrastructure by the end users. Any mis-step in selection of the approach for wastewater management will result in errors in selection of inappropriate technology for collection, conveyance, and treatment of wastewater leading to the overall failure of the project. This should be avoided at all costs even when the capital expenditure of the project is covered through funds or grants.

The following are key take away points from the exercise:

1. Population density has a huge impact on the project cost. This can be confirmed from the cost of the project for PuA III in table 41 and PuA II from table 47. For the same type of collection and conveyance system and wastewater treatment system, the cost of the project for a zone with higher population density is significantly less.
2. Selecting the right approach to the collection and conveyance system can reduce the financial aspect of the project and improve its affordability. This can be confirmed from the cost of the project for PuA III (tables 41 and 47). For the same population density and same wastewater treatment system, the cost of a project with solid-free sewers is lower in comparison to the project with separate sewers.
3. Life cycle cost analysis helps to determine the conservancy tax to be recovered from the end users. This can be used to determine if the infrastructure is affordable and plan the O&M aspect accordingly in order to have continuous and uninterrupted services.
4. Creating a cluster of zones with centralised STP for a municipal town is only recommended when all the zones have consistently high population density, topography supports creating clusters, there is a minimal requirement of pumping and the rising main is not too long.
5. Cost of land should also be considered while calculating the cost of the project. Given the rising cost of land in the municipal towns, centralised STP outside the municipal limits might be a cheaper option.
6. When the collection and conveyance system become unaffordable to the households, it is recommended to promote onsite wastewater management using soak pits and soak away zones after the septic tank. Desludging cost of septic tanks will still have to be borne by the households. However, the cost per capita per year of desludging if done regularly will come out to be a fraction of the cost of offsite wastewater management.

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- Dissemination of FSSM research, advocacy and outreach to State governments and ULBs.

Its strength is its ability to bring together partners to contribute towards developing state sanitation policy, training of trainers and training content development, technical and social assessments, training programme delivery, research and documentation.

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INTEGRATED WASTEWATER AND SEPTAGE MANAGEMENT—DESIGN MODULE

PART C: WORKBOOK