STM JOURNALS

Journal of
Water Resource Engineering and Management

ISSN: 2349-4336
Volume 9, Issue 2, 2022
DOI (Journal): 10.37591/JoWREM

http://engineeringjournals.stmjournals.in/index.php/JoWREM/index

Research JoWREM

Rejuvenation and Beautification of River and Nala

Rutuja Kendre[1,*], L.G. Patil[2], Sandeep Zade[3]

Abstract

Nowadays almost all water bodies in India are getting more and more polluted and facing with three major problems which are likely to be Untreated Sewage, Solid waste and abetting encroachment or slums areas along the bank of River, nala or any water body. Due to population development, outdated storm water drainage systems, climate change, and poor management of utility infrastructures, significant damage has recently been done to urban areas, including Hyderabad City, the capital of Telangana. One of the most practical methods to manage these complex urban systems is using process of Rejuvenation of the Nala and pollution abetment works by diverting the incoming Sewage leading to Nala in the Designed Sewerage Systems. In this research work, the framework is prepared for Rejuvenation of Polluted Nala channel and Designing Sewerage System for sewage outfall from the abetting slums including effective management of the nala system. This study is divided into three main parts which consists of 1. Contribution of Upstream Catchment area-Determination of the contribution of Catchment flow from Upstream to Confluence point of Nala and delineation of the Catchment area. 2. Nala Channelization-The Inlet flow has been intercepted and diverted to STP and total carrying capacity of Nala is found and check has been determined. 3. Design of Sewerage System-Determining the Sewage flow generation beside the Nala and four Inlets joining the Nala. For the first stage various Design Software like Civil 3D, Power Civil, Infraworks were used to simulate the existing catchment flow leading at the Confluence point then by using capabilities of QGIS 3.16.11 software application the Drainage networks, stream orders and elevation details has been achieved. In the Second stage the carrying capacity of storm water Nala is been determined by making calculation check for total of upstream flow, storm water flow and Inlet flows. Finally the third stage determines the generation of Sewage flow tapping and diverting it to the Sewer System by Designing and optimizing it in SewerGEMs select-series 4 Software which will get carried to the Sewage Treatment Plants, thereby treating the water as per CPCB-NGT norms. The proposed strategic approach is able to abate the pollution in Nala, maintain the ecological flow and conserve the public realm along the river.

Keywords: Catchment Delineation, storm water flow, Nala Channelization, Pollution abatement, Sewerage system, Sewage Treatment Plant, civil 3D, SewerGEMS, QGIS.

***Author for Correspondence**
Rutuja Kendre
E-mail: 2020mcw006@sggs.ac.in

[1]Student of Civil Engineering Department, SGGSIE&T, Nanded, Maharashtra, India
[2]Professor of Civil Engineering, SGGSIE&T, Nanded, Maharashtra,, India
[3]CTO of Tandon Urban Solutions Pvt. Ltd., Mumbai, Maharashtra, India

Received Date: August 16, 2022
Accepted Date: August 24, 2022
Published Date: August 30, 2022

Citation: Rutuja Kendre, L.G. Patil, Sandeep Zade. Rejuvenation and Beautification of River and Nala. Journal of Water Resource Engineering and Management. 2022; 9(2): 1–12p.

INTRODUCTION

River rejuvenation is the process of returning to a previous state to create healthy state of ecosystem. In addition to serving as important sources of groundwater infiltration and water table recharge, water bodies like lakes, rivers, and underground streams are also capable of receiving domestic sewage and industrial effluents from the catchment and can function as locations for the disposal of waste water. These water sources are one of the most important for human needs and are most useful for development activities in the areas where they are present. Due to a variety of pollutants, residential and industrial sewage is contaminating many rivers and natural water bodies throughout the world. Some of the pollutants are environmental toxins that are stable and persistent. Be it rivers or groundwater, the rapid rate of water contamination is increasing the concern. Without an emphasis on clean rivers and other water sources, no attempt to protect the environment would be complete. Success in conserving all other areas depends on having enough potable water. Thus keeping in view the critical nature of the drainage system throughout the world, it is very necessary to have a proper connecting network for safe transport of the sewage [1–5].

Necessity of Rejuvenation Project

As part of rejuvenation of Kukatpally Nala it is found that, multiple entries of uncontrolled sewage discharging into it is a major problem. The topography of the area has a slope, undulations and of rocky terrain, which endorsing various problems like hot spots flooding, bottlenecks, and obstructions of bushes and greeneries which are developed within the Nala. Prominently there are many points where the sewage is directly getting discharged into the nala without any treatment. The Nala segment is also impacted with large scale sediments through storm water run-off, Sewage of urban areas and direct dumping of domestic and small scale industrial waste, garbage, plastic waste, and other debris in the Nala besides. It is the need of the day to lay the utmost importance to the preservation and further development of the Kukatpally Nala and their Tributaries. The untreated chemical compounds and pathogens present in the wastewater can harm the ecosystem. It is also contaminating the nala water and affecting the human health. The treatment of Wastewater is essential to protect the ecosystem [6–13].

Benefits of the Project

1. Treatment of Catchment area contributing to Kukatpally Nala.
2. Enhance ecological restoration and moisture conservation.
3. Controls the erosion of soil.
4. Reduces the risk of Flood.
5. The quality of water and atmospheric temperature is maintained.
6. Recreation of waterbody is created for the people around.

Objectives of the Project

1. To study Kukatpally Nala with its upstream catchment details.
2. To determine Catchment flow contributing at Confluence Point of Kukatpally Nala.
3. To determine Carrying Capacity of channel having Treated Effluent Flow and Storm water.
4. To design Sewage Carrying System for sewage coming from the Inlets and slums beside the nala leading to Kukatpally Nala.
5. To recommend suitable capacity of STP with type of treatment.

SCOPE OF STUDY AREA

Kukatpally Nala is located in the north western part of Hyderabad in the Telangana State. The scope of the project starts at 17°27'52.10"N & 78°26'56.03"E and ends by meeting Hussainsagar at 17°26'13.87"N & 78°28'10.54"E approximately. The total length of Kukatpally Nala is 25.53 and the scope of project is of 3.895 km. The scope of project starts from Confluence point of Kukatpally Nala and Jeedimetla Nala. The major inflow inlets of Kukatpally Nala are B.K. Guda nala, Yusufguda nala, Dwarkadas nala and Prakashnagar nala. The sewage generated from the catchment of Jeedimetla and Kukatpally are flowing through the Kukatpally Nala leading to the Hussainsagar Lake. About 75% of wastewater flows into Hussain Sagar Lake is through Kukatpally nala. Kukatpally Nala feeds the major incoming sewage discharge to Hussain Sagar Lake comes from Kukatpally Nala Figures 1–2 [14–22].

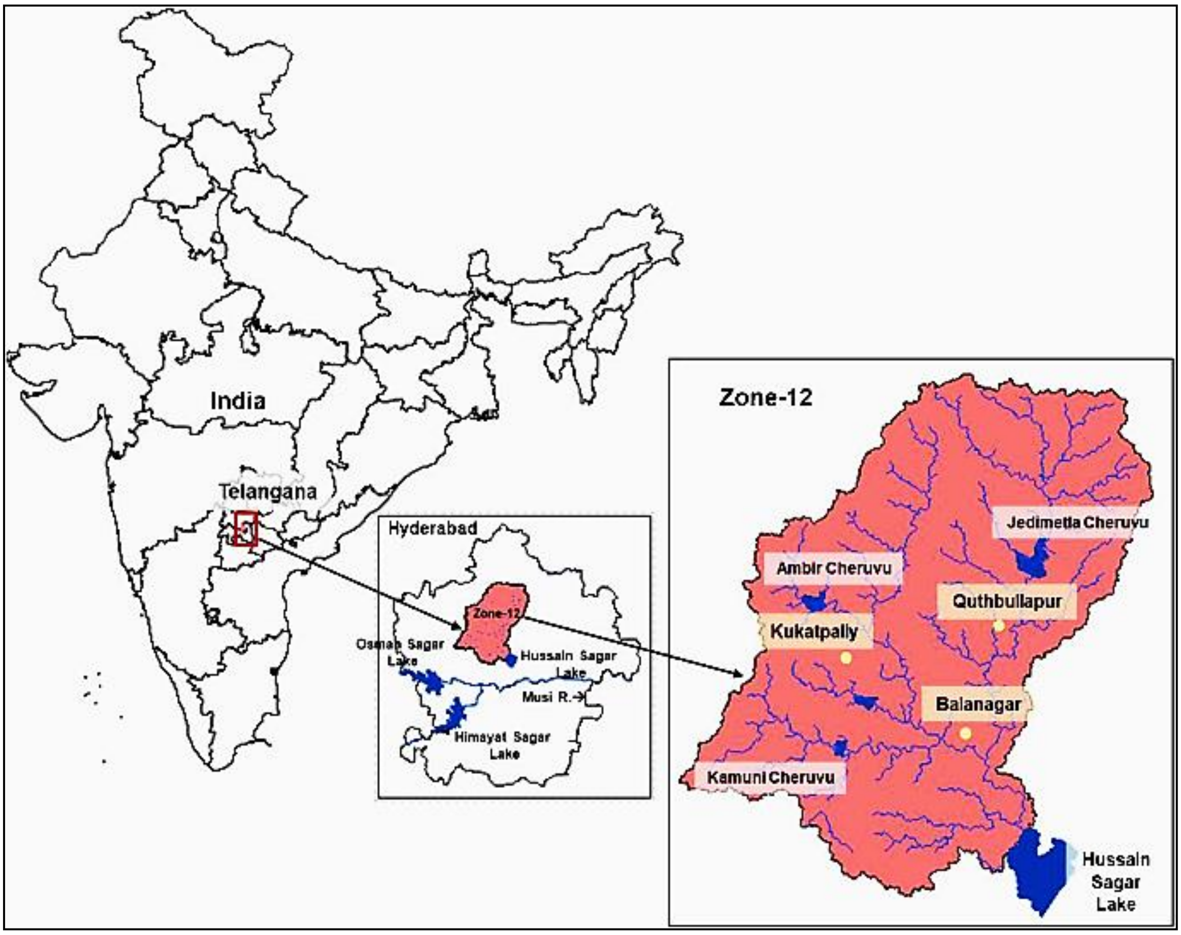

Figure 1. Geographical Location Map of Kukatpally Nala contributing to Hussain Sagar Lake.

METHODOLOGY

The methodology for Rejuvenation of Nala project includes Nala Channelization and Design of Sewerage System. The first part of study includes Watershed Analysis and Computation of Carrying Capacity of Nala whereas second part of study includes Design of Sewerage network and preferring suitable STP technology.

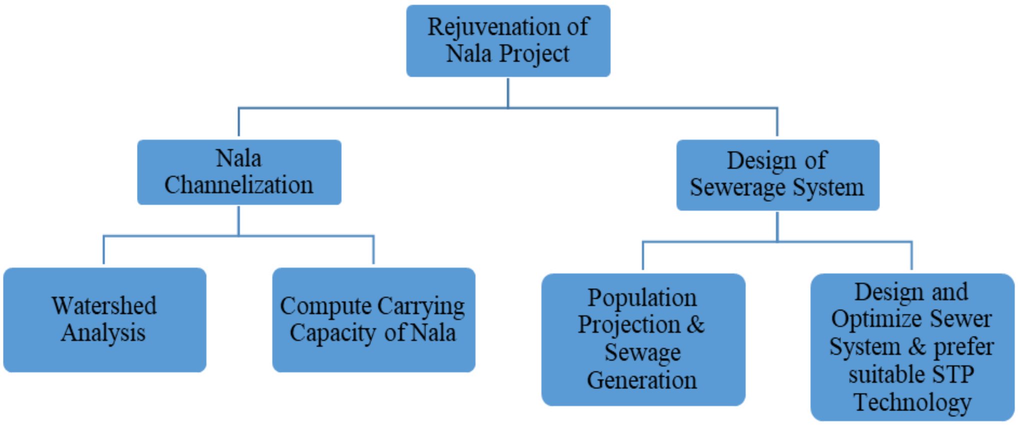

Figure 2. Methodology graph.

Nala Channelization

The existing Nala is unlined, the profile has sloping undulations, bottlenecks points, and there are high risks of floodings issues due to undulated sloping. To maintain carrying capacity of the Nala the proper Nala channelization is required so that an ecological flow is maintained throughout its length. The sewage flow coming from the Inlets is discharged directly in the Nala creating a wastewater Nala. The Nala Channelization also includes intercepting the Sewage flow and diverting it to the Sewage Treatment Plants, so the treated effluent will flow in the Nala by conserving the ecosystem [21–23].

Watershed Analysis

The Watershed analysis comprises the process of using Digital Elevation Model (DEM) and raster (tif file format) to delineate the watersheds of the particular area. The output of this function derivers features such as streams, stream network, catchment basin areas etc. Watershed analysis can be conducted on varying dimensional scale. A total large watershed computed comprises of an entire stream network, within that large watershed there may be smaller watersheds, one for each tributary in the stream. Delineation of watershed can be determined by two methods which are area based and point based method. An area based divides the study area into a series of watershed, one for each stream network and Point based method derives watershed analysis for each selected point, and selected point may be an outlet, a gauge station or a dam. Watershed Analysis has been derived at selected point as shown in Figures 3–4. The point shown is Confluence point of Kukatpally & Jeedimetla Nala.

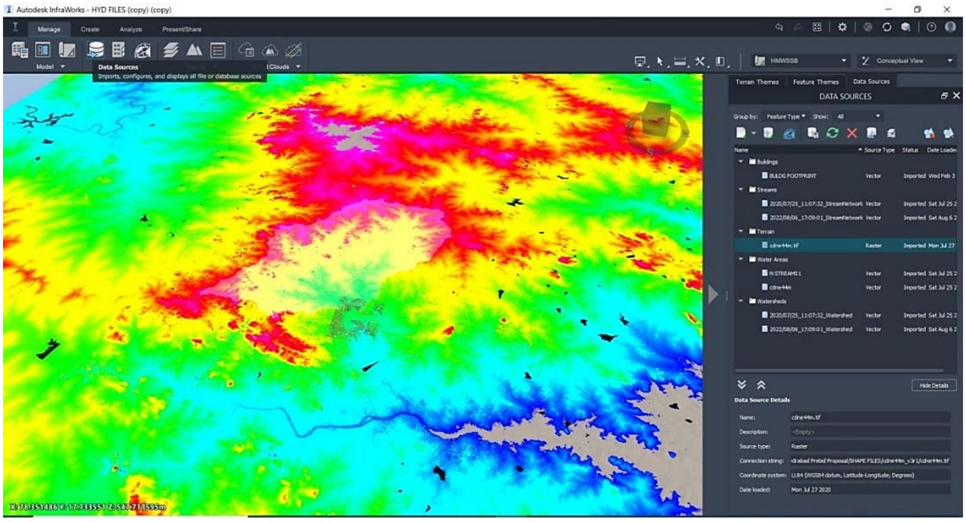

Figure 3. Watershed Demarcation at Selected Point.

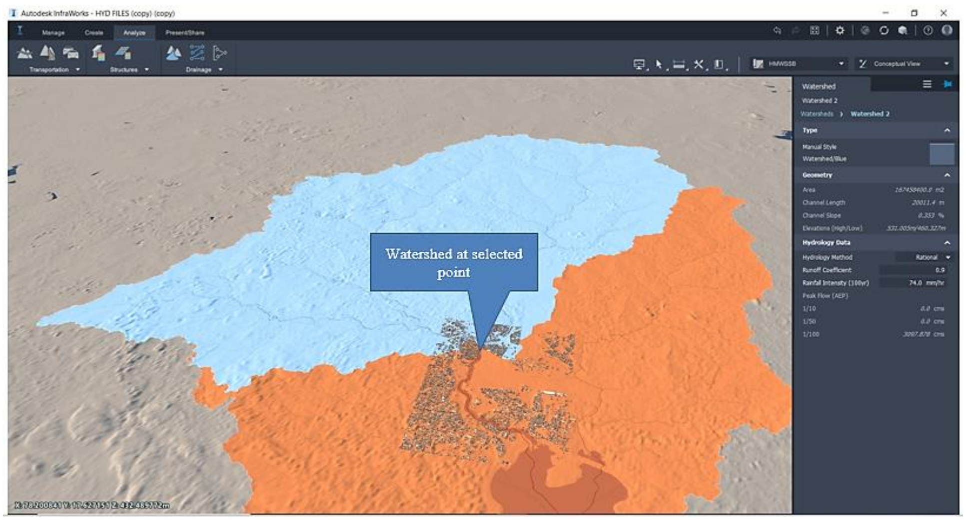

Figure 4. Output results of Watershed Analysis.

Journal of Water Resource Engineering and Management
Volume 9, Issue 2
ISSN: 2349-4336

The raster file of tif format from Bhuvan Portal of Kukatpally Nala, Hyderabad location has been imported. After analyzing the output results are such as, the demarcated area is 167 sqkm, Channel length 20011.4 m, Channel slope is 0.353% and Elevations are in from 531.05 m to 460.327 m (High/Low). For Hydrology data the runoff coefficient is 0.9. The rainfall intensity (100 yr) is 74.0 mm/hr Figures 5–7.

Catchment Delineation

1. DEM acquisition
2. Adding DEM and Projecting
3. Filling Sinks
4. Strahler Order
5. Channel Network
6. Catchment areas/Drainage basins

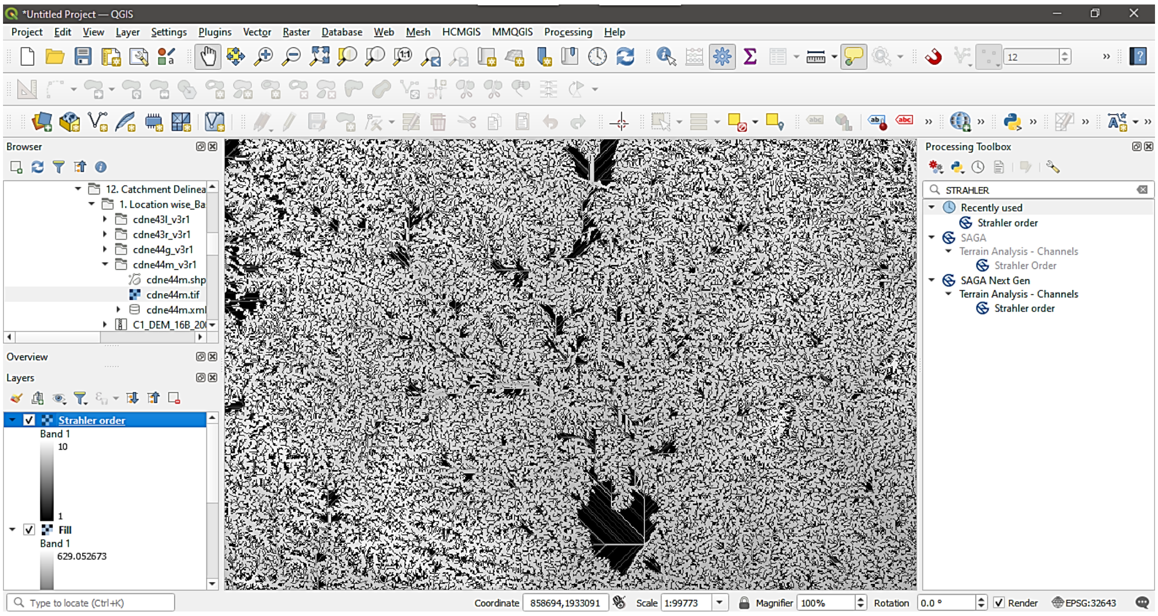

Figure 5. Catchment Delineation.

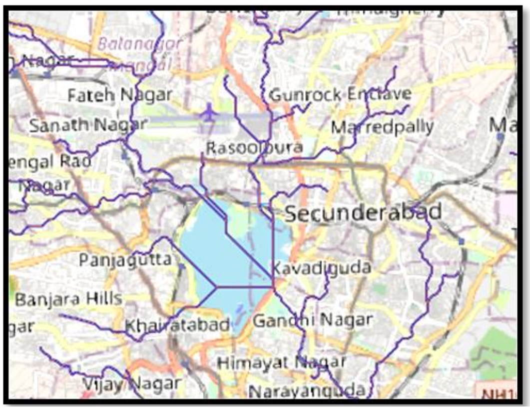

Figure 6. Drainage Network with OSM Standard map.

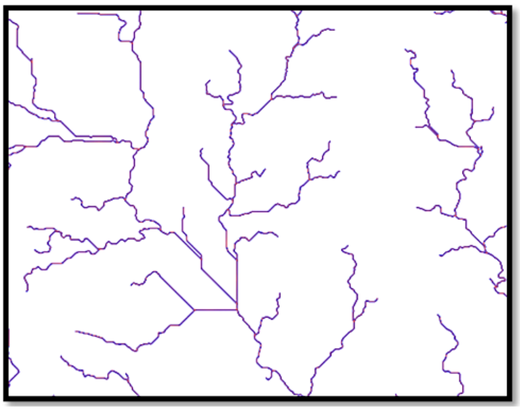

Figure 7. Catchment area showing Stream orders.

Carrying Capacity of Nala

For this project it is assumed that, at Zero Chainage (i.e. confluence of Kukatpally & Jeedimetla Nala) which is starting point for the scope of work, all the flow coming from upstream is treated effluent and will carry no sewage from the zero Chainage point towards the downstream (Hussain Sagar).

Total treated effluent coming to zero Chainage from various STPs (STP-01 to STP-12) on upstream of Kukatpally & Jeedimetla Nala = 269.0 MLD. Out of that 169.5 MLD is coming at 0 + 000 Chainage and other remaining will come at 0 + 600 where 100 MLD of STP is located at Fathenagar. Also 15 MLD treated effluent will come from inlets joining Kukatpally Nala from 3 STP's. Therefore total treated effluent flowing through Design Treated Effluent Channel is 285 MLD Tables 1–4.

Carrying Capacity of Designed Treated Effluent Channel:

- Carrying Capacity of Designed Dry Weather Flow Nala Section = 350 MLD
- For Designed DWF channel of 10 m wide and 0.5 m depth, assuming velocity of flow as 0.8 m/sec
- Therefore total carrying capacity will be = 10 m × 0.5 m × 0.8 m/sec = 4 m^3/sec
- Equivalent carrying capacity in mLD = is 4 m^3/sec × (1000/10^6) × (60*60*24) = 345.6 MLD, Say 350 MLD.

Table 1. Total Treated Effluent in Channel.

S.N.	Treated effluent into Treated Effluent Designed Channel	MLD
1.	From U/s of Confluence i. 169.5 MLD coming from u/s of 0+000 Chainage ii. 100 MLD at Fathenagar STP	270
2.	Proposed Small STPs (3 STP of 5 MLD) i At B.K. Guda ii At Yusufguda iii At End Point	15
	Total flow for DWF channel	*285*

Table 2. Nala Channelization.

Storm Catchment Location (From-To)	Chainage	Length m	Size		Velocity	Design Q (m^3/sec)	Calculated Q (m^3/sec)	Check
Kukatpally & Jeedimetla Nala-Fathenagar	0+000 to 0+600	600	20	3	0.8	48	501.90	TRUE
Fathenagar-BK Guda Nala	0+600 to 1+470	870	30	4	0.8	96	995.80	TRUE
BK Guda Nala-Yusufguda Nala	1+470 to 2+530	1060	45	3	0.8	108	1082.00	TRUE
Yusufguda Nala-Dwarkadas & Prakashnagar Nala	2+530 to 3+540	1010	50	3	0.8	120	1264.60	TRUE
Dwarkadas Nala-Hussainsagar	3+540 to 3+895	355	55	3	0.8	132	1338.50	TRUE
		3895						

Table 3. Population projected by Decadal Growth method.

Catchment for Sewage Collection	Area (sqm)	Area (sqkm)	Density	Population 2021	Decadal growth	Population 2036	Population 2051
A-1	256950	0.26	19000	4882	2.97%	5102	5330
A-2	75744	0.08	19000	1439	2.97%	1504	1571
A-3	53298	0.05	19000	1013	2.97%	1058	1106
A-4	182944	0.18	19000	3476	2.97%	3632	3795
A-5	318227	0.32	19000	6046	2.97%	6318	6601

Source: https://www.census2011.co.in/census/district/122-hyderabad.html

Table 4. Sewage flow calculation.

Catchment for Sewage Collection	Water Supply Rate (LPCD)	Sewage Generation (MLD) = 80% of Water Supplied			Infiltration	Total Intermediate Flow 2021 (MLD)	Total Intermediate Flow 2036 (MLD)	Total Ultimate Flow 2051 (MLD)
		2021	*2036*	*2051*				
A-1	135	0.53	0.55	0.58	10%	0.580	0.606	0.633
A-2	135	0.16	0.16	0.17	10%	0.171	0.179	0.187
A-3	135	0.11	0.11	0.12	10%	0.120	0.126	0.131
A-4	135	0.38	0.39	0.41	10%	0.413	0.432	0.451
A-5	135	0.65	0.68	0.71	10%	0.718	0.751	0.784
Total	*135*	*1.82*	*1.90*	*1.99*	*10%*	*2.003*	*2.093*	*2.186*

Design of Sewerage System

Population Projection

The method used for Population projection is Method of Density.

In method of Density, the drift in rate of increase in population density for each division of a city is determined and population is forecast for each division based on the above approach. Summation of population division wise, gives the population of the city. This approach is based on the assumption that the percentage increase in population from decade to decade remains constant. In this method the average percentage of growth of last few decades is determined and the population forecasting is done on the basis that percentage increase per decade will be the same.

- Decadal Growth Rate:

$$\text{Decadal Growth Rate } = \frac{\text{P1}-\text{P0}}{\text{P0}} \times 100$$

Whereas, P1 = Current year Population
P0 = Previous year population

- Population Projection:

Population Projection = P1 + (P1 × d)

Whereas, P1 = Last ten years (decade) Population
d = Growth in decade

Design of Sewage Flow

The design flow is based as per the wastewater expected to be generated in the year 205. The wastewater generally includes wastes from domestic use in residential, commercial and institutional utilities.

Average Design Dry weather flow (DWF) [Q avg.] = [Population (P) × Sewerage Flow (Water Supply in LPCD) × Expected Sewer 85%].

For Design purpose, the wastewater generated is calculated considering population and water supply rate as 135 LPCD for residential population. It is presumed as 80% of the water supply with infiltration allocation to reach the sewers.

Design and Optimization in SewerGEMS

Design Criteria suggested by CPHEEO guidelines for design of sewage system. Important criteria are mentioned below:

1. Pumping machinery is designed for 15 years period i.e. for intermediate population of the year 2036.

2. Collection systems, Sumps and Wet well, Sewage treatment plant are proposed for 30 years period i.e. for projected population of the year 2051.
3. The Sewage flow is considered as 80% of the water supply, thus ((4883 × 135)/10^6 × 0.80) = 0.527 MLD say 0.53 MLD.
4. The infiltration of Ground water is taken as 10% of the flow. Thus, flow in sewers is 0.53+ (0.53 × 0.1) = 0.58 MLD.
5. As per CPHEEO manual peak factor for trunk/main sewers is 3 for contributory population upto 20,000 (Page No 3 of Chapter 3-CPHEEO Manual). In the optimal design of sewer network, an average peak factor of 3.0 is considered.
6. Manning’s formula is used for velocity calculations in sewers. Manning’s roughness coefficient for RCC pipes with collar joints is taken as 0.011
7. For ultimate flow recommended minimum self-cleansing velocity in sewer is 0.6 m/s. This is to assure a minimum self-cleansing velocity of 0.6 m/s for present peak flow and the maximum velocity is 3.0 m/s.
8. Minimum diameter for DWC sewer is 150 mm and for RCC sewers the minimum diameter is 525 mm. In the design, only laterals, branch and main sewers are considered. Therefore, minimum diameter for them is considers as 150 mm.
9. Manholes are considered at every change in direction and at 30 m c/c on straight lines.
10. Minimum cover is considered as 1.0 m and maximum depth of excavation is limited to 5.0 m below ground level considering groundwater table.
11. Sewage network is designed such that depth of excavation is minimized, i.e. sewers are laid parallel to ground surface as far as possible.
12. Capacity calculations for Sewage treatment plants are provided. Conventional treatment plants are suggested to meet effluent standards for disposal into inland water bodies, i.e. BOD less than 3 mg/L and Suspended Solids less than 50 mg/L.

DESIGN OUTPUTS

The results obtained from the software SewerGEMS are in the form of Output Table 5 where we get the following Figures 8–12:

- Velocity of Sewage flow through each pipe.
- Rim and Invert slope.
- Excavation depth at each node.
- Appropriate Diameter for each pipe.

Table 5. Output Results of Design and Optimization.

Conduit Counts	Manholes Counts	Outfall Count	Diameter Ranges (mm)	Velocity ranges (m/s)	Slope ranges (1/S)
101	101	04	150–200	0.32–0.71	100–250

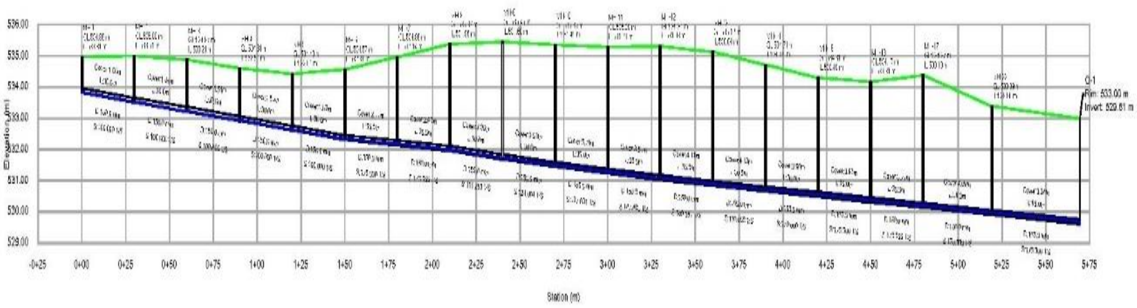

Figure 8. Engineering Profile–Profile 1.1.

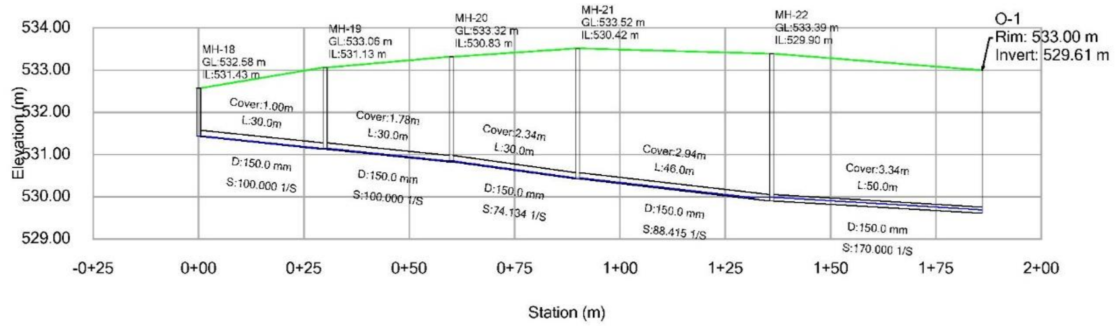

Figure 9. Engineering Profile–Profile 1.2.

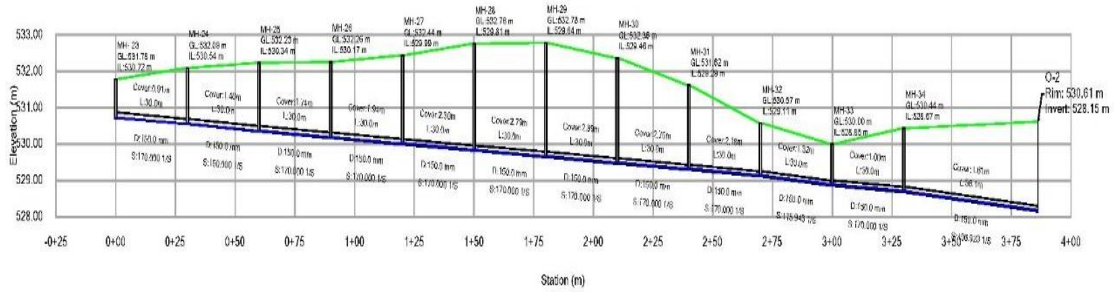

Figure 10. Engineering Profile–Profile 2.

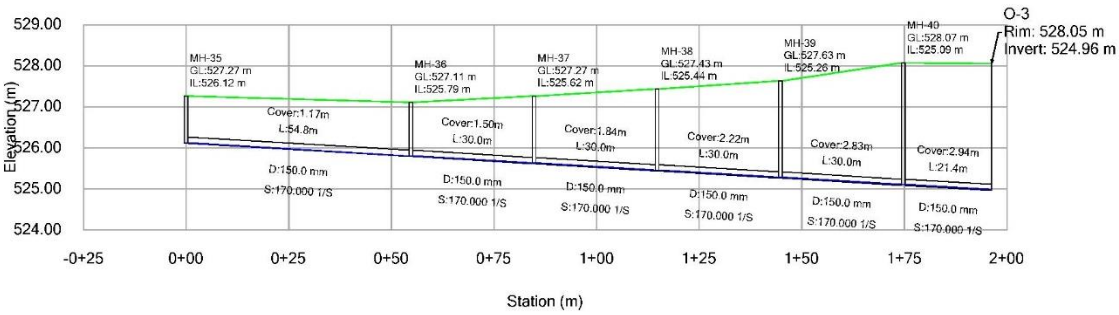

Figure 11. Engineering Profile–Profile 3.

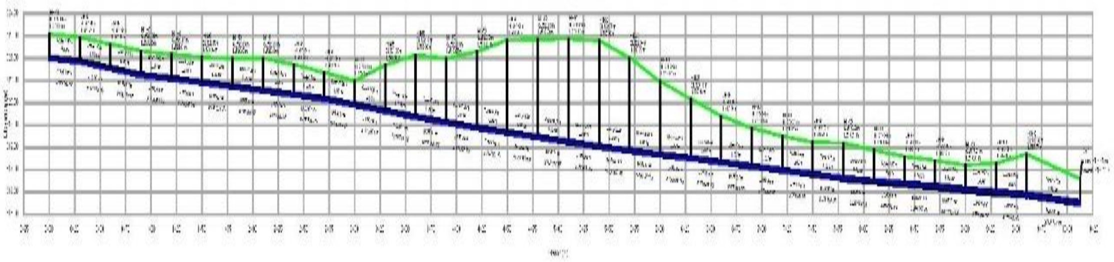

Figure 12. Engineering Profile–Profile 4.

Approached Sewage Treatment Plant [STP] Technology

The approached Sewage Treatment Plant technology adopted is Membrane bioreactor [MBR]. It consists of membrane processes like ultrafiltration or microfiltration with a biological wastewater treatment process, the activated sludge process. This technology is widely used for municipal and industrial wastewater treatment. The MBR supports a concentration between 6000–10000 mg/l of MLSS with the aid of membranes which draw out or force out water while retaining the biomass in the bioreactor. This implies that the secondary clarifiers and tertiary filtration become redundant.

The high microbial mass concentrations suspended in the reactor decelerate the oxygen transfer. Savings from the elimination of the secondary clarifier and tertiary filtration are more than offset by the cost of membranes which is an order of magnitude higher. MBR Requires the least footprint area and also can handle varying loads and still give a consistent desired output.

Merits of adopting MBR Technology

1. To achieve the stringent norms directed by National Green Tribunal (NGT), MBR Technology is suitable to achieve the desired output Tables 6–7.
2. The Nala stretch consists of encroachments and bottlenecks, due to which there are space restrictions and MBR technology has minimum footprint area as compared to other technologies which guides us to adopt MBR technology.
3. The MBR technology results in production of effluent of good quality.
4. The generation produced is of low excess sludge.
5. There is the ease of automatic control of processes.
6. There are higher volumetric loading rates and shorter hydraulic retention times (HRT).

Reuse and Recycle of Treated Effluent

Table 6. STP Capacity as per Projected Flow.

Catchment for Sewage Collection	STP	STP Capacity (Ultimate Average Flow-2051) MLD	Proposed STP (MLD)
Total (A1)	HMWSSB STP	1	100
Total (A2)	STP-1	0.2	5
Total (A3)	STP-2	0.2	5
Total (A4 + A5)	STP-3	1.3	5

Table 7. Water Quality Standards requirements as per NGT/CPCB Norms.

S. N.	Parameters	Toilet Flushing	Fire Protection	Vehicle exterior washing	Non-contact impoundments	Landscaping, Horticulture & Agriculture			
						Horti-culture, Golf course	*Crops*		
							Non nutritious crops	*Crops which are consumed*	
								Raw	Cooked
1	Turbidity (NTU)	<2	<2	<2	<2	<2	AA	<2	AA
2	SS	0	0	0	0	0	30	0	30
3	TDS	2100							
4	pH	6.5 to 8.3							
5	Temperature(°C)	Ambient							
6	Oil and Grease	10	0	0	0	10	10	0	0
7	Minimum Residual C	1	1	1	0.5	1	0	0	0
8	Total Kjeldahl Nitrogen as N	10	10	10	10	10	10	10	10
9	BOD	10	10	10	10	10	20	10	20
10	COD	AA	AA	AA	AA	AA	30	AA	30

11	Dissolved Phosphorus as P	1	1	1	1	2	5	2	5
12	Nitrate Nitrogen as N	10	10	10	5	10	10	10	10
13	Fecal Coliform in 100 mm	0	0	0	0	0	230	0	230
14	Helminthic Eggs/Lit.	AA	AA	AA	AA	AA	<1	<1	<1
15	Color	Colorless	Colorless	Colorless	Colorles s	Colorless	Colorless	Colorless	Colorless
16	Odor	Aseptic which means not septic and no foul order							
All units are in mg/l unless specified, AA-as rising when others parameters are satisfied									

CONCLUSIONS

The various concluding steps for rejuvenation are as under:

1. The existing catchment area leading at the Confluence point of Kukatpally Nala and Jeedimetla Nala has been demarcated which is 167 sqkm with the help of various softwares such as civil 3D and Infraworks.
2. The assessment of Drainage networks, stream orders and elevation details has been achieved using capabilities of QGIS.
3. The total Nala inlet flow has been trapped and diverted to the STP for treatment using Interceptors. Thus the total carrying capacity of 285 MLD in the Nala which includes 270 MLD of treated effluent of upstream and 15 MLD from 3 STPS which includes Sewage generation from Slums and Nala Inlets has been determined. The Check of Nala channelization has been done for the smooth flow throughout the nala avoiding all flooding risks.
4. The entire trapped sewage of 2.186 MLD coming from slums beside the Nala has been treated by diverting it to the proposed Sewerage system and then connecting it to the Sewage Treatment Plant.
5. The Nala stretch consists of encroachments and bottlenecks, due to which there are space restrictions and MBR technology has minimum footprint area as compared to other technologies which guides us to adopt MBR technology of 5 MLD capacities at 3 locations as per the sewage generation from slums and Nala Inlets. As per NGT/CPCB order dated 17-08-2020 effluent standards shall be maintained within the flowing water body accordingly the MBR technology.

REFERENCES

1. Katti Murugesh, Krishna B. M, Manoj Kumar B, (2015), “Design of Sanitary Sewer Network using Sewer GEMS V8i Software” IJSTE-Volume 2-Issue 01-July 2015
2. Manaye Teshome, (2020) “A Review of Recent Studies on Urban Storm water Drainage System for Urban Flood Management” October 2020
3. Nishant Sourabh & PV Timbadiya, (2018), “Hydraulic and Condition Assessment of Existing Sewerage Network: A Case Study of an Educational Institute”, Journal of the Institution of Engineers (India):Series A-April 2018
4. Shraddha Tiwari & Mangesh Bhorkar (2020), “Design of Under Ground System for Rural Area.”
5. P. Mahammed Rafi & Acharya Jyothi Kusum, (2018) “Review of Hussain Sagar Lake Pollution, Hyderabad, India”, IJEAB, Volume 3, Issue – 2, Mar-Apr 2018
6. Prof. Dr.-Sc.techn. Peter Krebs, (2009), “GIS Based Estimation of Sewer Properties from Urban Surface Information”, December 2009
7. Abhishek Pawar, Yogesh Patil & Prof. Sachin Mane (2021), “Design of Sewer System for Village using SewerGEMS”, IRJET, Volume:08, Issue:07, July 2021
8. D.S Parihar, “Need of River Rejuvenation in India”, International Journal of Advanced Research
9. Baisakhi Chakraborty, Pravat Kumar Shit, “Cleaning the river Damodar (India): Impact of COVID-19 lockdown on water quality and future rejuvenation strategies.”
10. Ar. Aatmika Rathore, Dr. S.S. Jadon, “A sustainable approach for urban Riverfront development.”

11. Mohammad Alhumaid, Abul Razzaq Ghumman, Yousry Mahmoud Ghazaw, “Sustainability Evaluation Framework of Urban Storm water Drainage Options for Arid Environments Using Hydraulic Modeling and Multicriteria Decision-Making”
12. Pedro L. Iglesias-Reya, Vicente R. Navarro-Planasa, “Pseudo-genetic model optimization for rehabilitation of urban storm-water drainage networks”
13. Engineering Hydrology–Third Edition by K. Subramanya
14. Flow in Open Channels–Third Edition by K. Subramanya
15. Environmental Engineering Water Supply–Book by Santosh Kumar Garg (Vol. 1)
16. Sewage Waste Disposal and Air Pollution Engineering–Book by Santosh Kumar Garg (Environmental Engineering Vol. 2)
17. Wastewater Engineering Treatment Disposal Reuse–Book by George Tchobanoglous and Metcalf & Eddy
18. Design of Canals-revised design procedure, Government of Maharashtra Water Resources Department Government Circular No. MIS-2015/(CR. No.253/15)/MP Annex Mantralaya, 2nd floor, Mantralaya, Mumbai-400 032 Dated 01/09/2015 Ref. Govt. Circular No. MIS 1094/(156/94) MP (A), Dated: 10.02.1995
19. Manual on Sewerage and sewage treatment–CPHEEO May 2012
20. Manual on Storm water Drainage Systems–CPHEEO August 2019
21. Guidelines of Road Drainage (First Revision) IRC: SP: 42-2014.
22. Indian Standard criteria for design of lined canals and guidance for selection of type of lining (First Revision)
23. The National Green Tribunal Southern Zone, Chennai, Original Application No. 85.

