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STORM WATER DRAINAGE SYSTEM OF BHOPAL CITY

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ABSTRACT

Many cities in India ranging from large metropolitan to small transitional cities lack effective storm drainage systems and face problems due to illegal, unplanned development and encroachment often on natural areas and drainage systems/ways. As the cities develop and grow, benefits from important environmental functions (natural water ways/areas) are often ignored and overlooked because of which natural areas are degraded and damaged. This along with increase in built up area results in increase in incidences of flooding and accompanied ill effects. The densification of cities is leading to construction of roads, buildings which has resulted in increase in impermeable areas. Thus, often permanent changes to the catchment are caused, leading to changes in runoff patterns, which affect the magnitude, frequency and occurrence of flooding. This necessitates adoption of sustainable storm water management practices in cities. The study and the field observations stress on an urgent need for improvement of storm water Drainage system of Bhopal city as the town is facing water logging problems. Once the drainage network of town is improved and outfall of drains ensures the safe disposal of storm Water.

INTRODUCTION

A storm drain, storm sewer, storm water drain or drainage well system or simply a drain or drain system is designed to drain excess rain and ground water from paved streets, parking lots, sidewalks and roofs. Storm drains vary in design from small residential dry wells to large municipal systems. They are fed by street gutters on most motorways, freeways and other busy roads, as well as towns in areas which experience heavy rainfall and flooding. Many storm drainage systems are designed to drain the storm water, untreated, into rivers or streams.

Over the years, there has been continuous migration of people from rural and semi-urban areas t**o** cities and towns. The proportion of population residing in urban areas has increased from 27.8% in 2001 to 31.80% in 2011. The number of towns has increased from 5,161 in 2001 to 7,935 in 2011. The uncontrolled growth in urban areas has left many Indian cities deficient in infrastructural services as water supply, sewerage, storm water drainage, and solid waste management.

Most urban areas inhabited by slums in the country are plagued by acute problems related to indiscriminate disposal of wastewater (sewage & drainage). Due to deficient efforts by town/city authorities, wastewater and its management has become a tenacious problem and this is not withstanding the fact that the large part of the municipal expenditure is allotted to it. It is not uncommon to find that substantially a large portion of resources is being utilized on manning wastewater management system by Urban Local Bodies (ULBs) for their operation and maintenance.

OBJECTIVES

Storm water drains called collector drains, are designed to evacuate rain water. The drains are generally laid along building lines. These are constructed either in open rectangular channels in brick work, in situ concrete or in precast concrete precast. In metro cities these are of circular concrete pipes under the road surface away from sewer lines. The capacity of drains in based on rainfall frequency, intensity & estimated storm water inflow. Combined sewer and treatment for reuse are issues of attentions. It is seen that storm water drains are also be causing career of waste water from non point sources of discharge of wastes.

STATE PROFILE

Madhya Pradesh is a state in central India. Bhopal is the capital and the largest City is Indore. Madhya Pradesh is called as Heart of India due to its geographical location. Madhya Pradesh is the second-largest state in the country by area. With over 75 million inhabitants, it is the fifth-largest state in India by population. Madhya Pradesh is surrounded the states i.e. Uttar Pradesh in North-East, Chhattisgarh in South-East, Maharashtra in South, Gujrat in West and Rajasthan in North-West. This state was the largest in India by area until 2000, when its south-eastern Chhattisgarh region was made a separate state. In recent Years, the GDP of the state has been above the national average. Rich in mineral resources, MP has the largest reserves of diamond and copper in India. More than 30% of its area is under the forest cover. Its tourism industry has seen considerable growth, with the state topping the National Tourism Awards in the year 2010.

The scenario in Madhya Pradesh suggests that urban development is critical for the State to achieve overall development goals. The status of urban Madhya Pradesh, presents a significant opportunity to develop urban centres as engines of economic growth and enable a pivotal role in the overall development of the state. The Urban Administration & Development department in Madhya Pradesh aims to initiate and accelerate urban reforms to address challenges for urban development and contribute significantly to the continuum of sustainable development in Madhya Pradesh.

Location

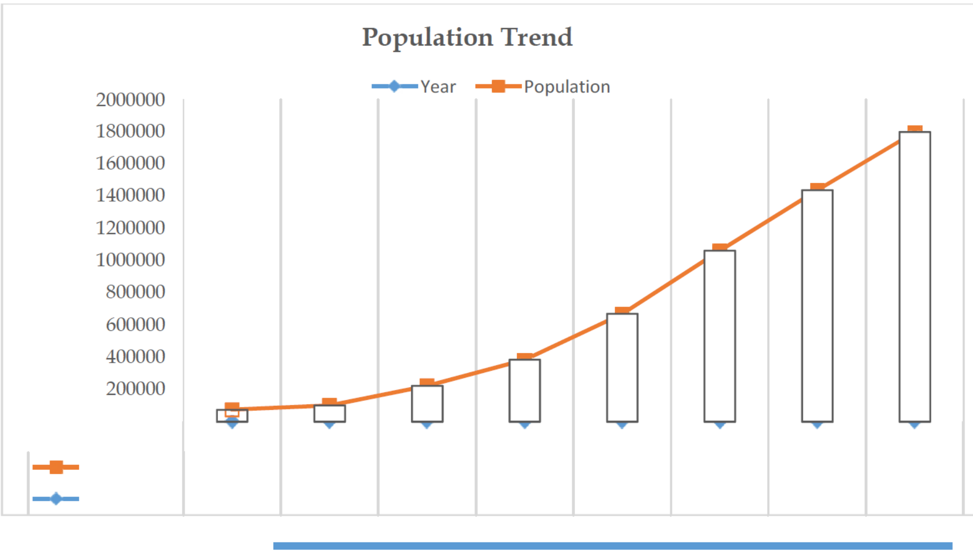
The Madhya Pradesh state is located between 23.25° N latitude and between 77.417°E longitude. The highest point in Madhya Pradesh is Dhupgarh, with an elevation of 1,350 m (4,429 ft.). The state straddles the Narmada River, which runs east and west between the Vindhya and Satpura ranges; these ranges and the Narmada are the traditional boundary between the north and south of India. The total area covered by the state of Madhya Pradesh is 308,245 sq. km.

Climate

Madhya Pradesh has a subtropical climate. Madhya Pradesh is mildly cold in the winter the lowest temperatures being around 5 to 10 degrees Celsius. Winter months are December and January. It is hot in the summer (with average highs around 35-40 Celsius). April to mid-June is the hot period. The monsoon months of July, August, and September experience good rainfall. October & November and February & March have pleasant climate. Average rainfall in mm has been recorded as 1,371 (54.0 in).

Climate and Rainfall

Bhopal has a humid climate and summer start in late march and same is extended upto mid june. May is the hottest month with the mean daily maximum temperature at 40°c and mean daily minimum at 30°c. Days are extremely hot with temperature rising to 45°c. The mansoon period start in late june and end in September and during this period about 1010 mm average rainfall observed (based on available data from 1970 to 2011) varying from a low of 638 mm to 1837 mm as per available data from IMD Pune.



	1	2	3	4	5	6	7	8
Population	75228	102333	222948	384859	671018	1062771	1437354	1798218
Year	1941	1951	1961	1971	1981	1991	2001	2011

The Rainfall data collected from IMD is given below.

Table: Annual Rainfall of Bhopal for 33 years

S. No.	Year	Annual Rainfall (mm)	S. No.	Year	Annual Rainfall (mm)
1	1970	1573.9	18	1987	979.2
2	1971	1161.8	19	1988	1003.7
3	1972	673.8	20	1989	897.3
4	1973	1837.2	21	1990	1454.5
5	1974	1316.3	22	1991	978.2
6	1975	1242.1	23	1992	800.6
7	1976	1044.3	24	1993	856.5
8	1977	595.1	25	1994	1429.5
9	1978	1381.5	26	1996	21.7
10	1979	638.1	27	1998	1020.5
11	1980	922	28	1999	1321.4
12	1981	696.6	29	2000	845.5
13	1982	1218.3	30	2007	877.6
14	1983	9.4	31	2008	326.9
15	1984	986.8	32	2009	1095.3
16	1985	1314.4	33	2011	1170.7
17	1986	1625.7			

**Source: Data procured from IMD, Pune*

BHOPAL DEVELOPMENT PLAN 2021

The Bhopal development plan 2021 is notified document being adopted for all urban development plans. It is a vision document prepared by Directorate of Town & Country Planning M.P. published under provisions of Madhya Pradesh Nagar Tatha Gram Nivesh Adhiniyam, 1973. The key highlights of this guiding document are as follows:

The estimated population of Bhopal as per Bhopal Development Plan (BDP) 2021 is 2.20 Million however it is planned for a population of 3.2 Million. The Incremental Increase Method is found to be appropriate. The projected population for the year 2021, 2025 is 21.9 and 24.09 Lakhs respectively.

Table : Data showing Population Forecast for various years

S. No	Method of Forecasting	1991	2001	2011	2021	2025
1	Arithmetic Increase	1062000	1454000	1724400	1994800	2114978
2	Geometric Increase	1062000	1454000	2525300	4307190	5687662
3	Incremental Increase	1062000	1454000	1792400	2198800	2409444
4	Exponential Method	1062000	1454000	2913675	4510799	5464602
5	Forecast function Method	1062000	1454000	1606133	1652089	2102686
6	Trend	1062000	1454000	1606133	1952089	2102686

Design Methodology

The design methodology is based upon the guidelines laid by CPHEEO (Center Pollution Health Environmental Engineering Organisation). For this, rainfall data of previous 33 years has been collected and analysed for estimating the quantum of storm runoff that has to be considered for the design. Base year considered is 2019 considering time for execution and scheme to be more realistic.

Design Principle

Urban storm water hydrology includes the information and procedures for estimating flow, volumes and time distributions of storm water runoff. The analysis of these parameters is fundamental for the design of storm water management facilities, such as storm drainage systems for conveyance of surface runoff and controls. In the hydrologic analysis of a development, there are number of variable factors that affect the estimation of storm water run-off from the site. The factors that are considered in design include:

- Intensity and storm duration;
- Drainage area size, shape and orientation;

- Ground cover and soil type;
- Slopes of terrain and stream channel;
- Characteristics of the local drainage system.
- Existing drainage network (Natural Drain, Primary, Secondary & Tertiary drain)

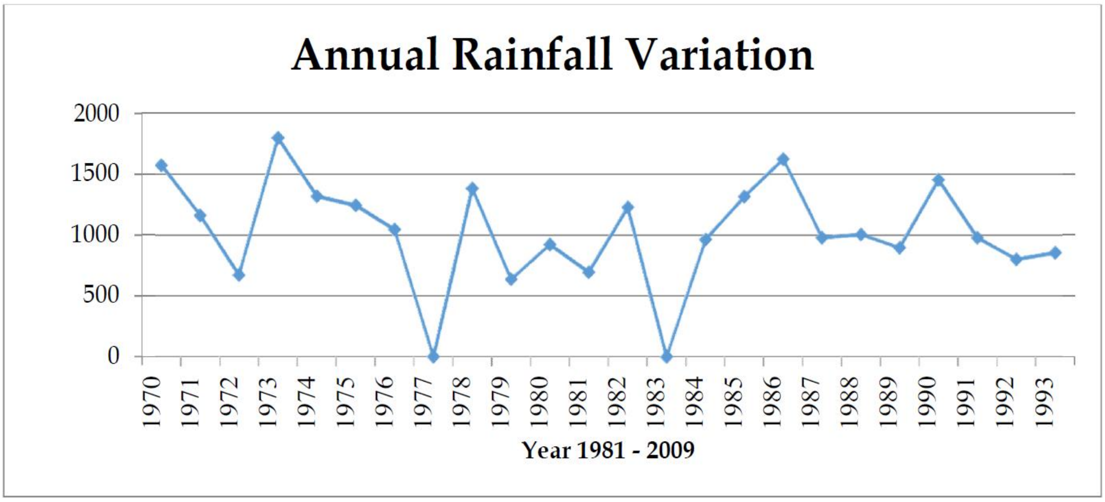
The adopted design Principles for design of storm Water Drainage System for selected area of Bhopal town is as follows:

The adopted design Principles for design of storm Water Drainage System for Bhopal town is as follows:

- The selection of catchment is based on the topography of the project area, land use plan, existing and proposed development of areas, contours of the project area, local prevailing conditions to drain off the storm water runoff from the project area. The Town has been divided into Drainage Zones with independent Outfall to cater the surface runoff and its disposal from the entire project area.
- The total project area of is being taken-up under while project preparation for designing / remodelling of the existing drains so that there should not be any water logging in the project area.
- The drain section should be economical and the velocity generated is non-silting and non-scouring in nature.
- For accomplishing storm water drainage efficiently, storm water is collected in the street and admitted into the link drains through inlets, which in-turn discharge into the primary drains; the primary drains finally discharging into trunk drains in the project area. These trunk drains discharge the storm to the water bodies through an Outfall arrangement.
- Ground & Invert levels of drain between any two nodes (Upstream & Downstream) are interpolated (through software) on designed drain slope & number of drops provided. Actual invert levels between upstream and downstream of node have been calculated at the time of detailed design and drop height being adjusted from 0.1m to 0.6m depending on site conditions. It is proposed to provide the first drop on upstream node and thereby at equidistance up to downstream node i.e. if there are 10 drops in a 100-metre length of drain, it is proposed to provide first drop at upstream node & thereby at every 10m interval. The drop height is provided as 0.5m in design.

Rainfall Data

I. Rainfall data is obtained from the Indian Metrological Department (IMD), Pune The continuous 60-minute rainfall data recorded by Automatic Rain Gauge has been collected from IMD, Regional Centre, Pune. By Automatic Rain Gauge a graph is plotted as per the variation in rainfall over the time. A sample of annual rainfall is shown below. In this graph, vertical scale represents depth of Rainfall in millimetres (mm) and horizontal scale represents the time (year). Further, one unit on vertical scale is equal to 500 mm of rainfall and one unit on horizontal scale is equal to one year time interval.



Annual Rainfall

The continuous rainfall data is tabulated and sorted for annual rainfall. The above table shows thirty-three years annual rainfall of the town. The minimum rainfall has been recorded in 1982 i.e. 508.1 mm while the maximum rainfall has been recorded in 1987 i.e. 1744.9 mm. The average annual rainfall is 931 mm.

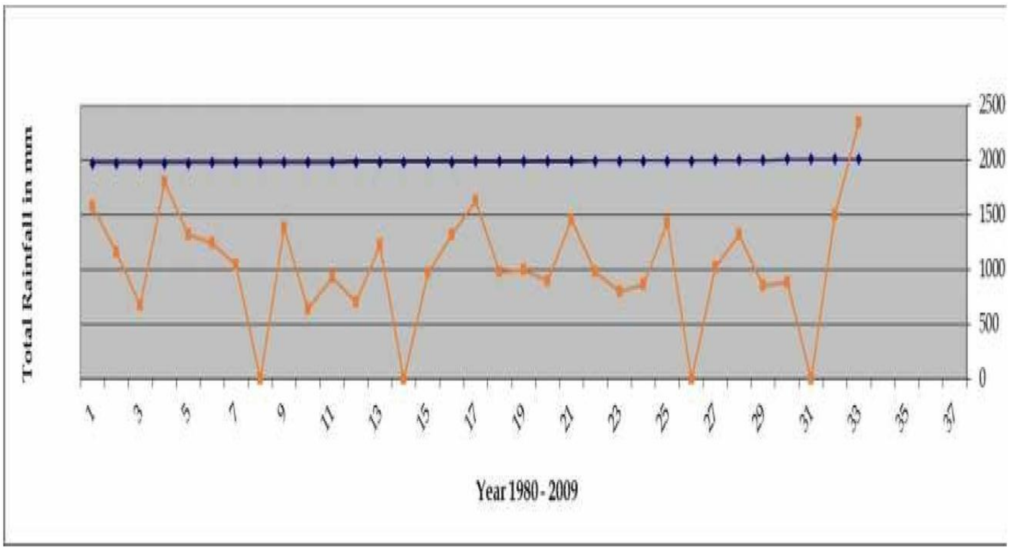


Figure : Annual Rainfall Graph

Design Parameters

Hydraulic Design Criteria

The rationale for hydraulic design is evolved after detailed study on the characteristics of the drainage system that typically constituted a diligent interfacing of the following domains:

- Topography;
- Drainage area;
- Location of disposal facilities;
- Highest flood level (HFL) of the storm-water receiving bodies;
- Sub-soil water level;
- Intensity of rainfall;
- Inlet time (time taken from farthest point in the catchment area to the inlet point under consideration) to be determined. The actual time of concentration is dependent on the farthest point of catchments, length of the drain, catchment slope and type of land use;
- Imperviousness factor and runoff coefficient to be considered as per guidelines mentioned in CPHEEO Manual. The catchments were bifurcated for different land use and based on the distribution of land use the 'C' value has been assigned.
- Storm water run-off;
- Manning's equation is being adopted to design the hydraulic section of drainage system;
- Minimum velocity of 0.6m/s to be adopted to avoid siltation, while maximum velocity to be kept below 3.0m/s to avoid scouring of drain sections;
- At road crossing, pipe/ slab culverts are proposed;
- Rectangular drain section is being considered; and
- Full supply level (FSL) / Invert level of the proposed drain shall be kept more than the highest flood level (HFL)/Invert level of the main drain

RATIONAL METHOD

The runoff reaching the drain is given by the below expression. Rational Method is more commonly used.

$Q=1\times C\times I\times A$

Where,

Q: runoff in m^3/hr

C: Dimensionless runoff coefficient

i: Intersity of rainfall in mm/hr

A: area of drainage district in hectares

It may be reiterated that *Q* represents only the maximum discharge caused by a particular storm.

Minimum Velocity & dry Weather Flow

The velocity of flow in a drain shall not be lower than 0.6 m/s for self-cleansing action to take place. However, the flow rate during dry weather may fall to a low level where this minimum velocity cannot be achieved. The problem can be solved by introducing a small channel in the drain to confine the dry weather flow to a smaller flow section.

Maximum velocity

The velocity of flow in a drain shall not be too high to cause excessive scouring or hydraulic jumps. Hence, the velocity of flow in a concrete-lined drain shall be limited to a maximum of 3.0 m/s or below the critical velocity, whichever is lower.

Free Board

Manual of CPHEEO is non-specific about free board. However, storm water drains are designed to flow full. Therefore, in order to restrict depression of invert levels & effect economy, a nominal freeboard of 50mm in case of drains with water depth upto 0.5m, 100mm in case of drains with water depth upto 0.8m and 150mm in case of drains having water depth more than 0.8m have been provided for roadside drains and a Free-board of 750mm has been adopted in design of natural drains.

Backfill

All Backfills shall be manually/ mechanically compacted and compaction density measured up to acceptable levels or as specified based on soil analysis.

Review of the Existing Drainage System

The comprehensive Storm Water Master Plan was prepared by M/s MEINHARDT in 2012 for complete municipal area of Bhopal and same was approved. The total cost of project was estimated Rs 1608.78 crores. Due to lack of funds, the Project has not been implemented. Now the same project has been taken under AMRUT Scheme for implementation. Accordingly, the assessment of existing system has been made and topographical survey conducted for new and existing drainage network.

The town does not have a comprehensive Storm Water Drainage Scheme that would collectively carry the storm water from entire town to the river. Presently, few Major drains, Medium Drains and Minor drains exist in almost the town but their channelization is inadequate to carry the entire the flow in a proper way. The issues pertaining to drainage system of these project areas are lack of master plans, improper and inadequate drainage channels, periodic and serious town flooding especially in low lying areas due to monsoon, use of open drains for disposal of sewage and toilets waste, lack of capacity of pumping stations to clear flooding from monsoon rains, lack of an intermittent power supply for drainage pumping stations, narrow crowded streets and insufficient space for storm water drains pipes and box culverts particularly in crowded part of town, lack of investment for drainage infrastructure, lack of drainage management, and trained staffs and effect on environment and public health effects of flooding and use of drains and ditches for sanitation.

Major issues observed, *related to existing drainage system*, in the town are as follows:

- Storm water drains; open drains and storm outfall carry sullage, septic tank effluent and even untreated sewage. Hence, there is a need for provision of separate sewerage and drainage system.
- The major portion of storm drainage system is open and gets silted.
- The construction of unplanned colonies is further aggravating the water logging and is source of health hazards.
- The encroachments; solid waste dumping and silt deposition in the drains are causing choking of the system which results non-functioning of the drainage system. This leads to water logging in low lying areas as well on roads at some places.
- Involvement of multiple agencies in planning, implementation and operation &maintenance of drainage system has led confusion on responsibilities of different agencies resulting mismanagement of the system.
- The Natural drains area has been encroached and building has been constructed and garbage is dumping in the drain. Due to water carrying capacity has been reduce and most of the area flooded during heavy rain.
- Primary drain also not connected properly with natural drain. Due to this reason, the colonies remain flooded for longer time.
- To avoid loss to the existing drains, their suitability has been checked and a provision for their cleaning and re-constructing as per hydraulic design has been proposed in this report. The design statement has been prepared for complete Project area by evaluating

the number of existing drains having adequate section along with the ones with in-adequate sections. The existing drains with inadequate sections have been proposed to be dismantled and designed section is proposed to be provided. The existing drains with Adequate sections have been incorporated with proposed design sections to ensure proper channelization of the storm run-off.

SELECTION OF DRAIN SECTION

Ground Slope has been adopted as the design slope for all the drains. The drains with very lean ground slope have been designed at a slope appropriate enough to have self-cleansing velocity of 0.6m/s and the drains with very steep slope have been laid at a curtailed design slope generating scouring velocity of 3.0m/s. The drains that are found to be adequate are proposed to be cleaned and dredged to ensure full-running capacity. A cost estimate has been prepared considering all costs to be incurred in construction of new drains, cleaning of adequate existing drains and allied ancillary works. The details are given based on varying Storm Frequency.

CONCLUSION & RECOMMENDATIONS

The rainfall analysis has been done as per the guidelines laid by CPHEEO. As per CPHEEO guidelines, the rainfall data (last 33 years) of 15 minutes interval needs to be procured for carrying out runoff calculations. For this, detailed consultations have been carried out with Indian Meteorological Department and the nearest rain gauge station has been identified for the same. In case of Bhopal, the nearest rain gauge station is located in Bhopal. The hourly rainfall data of Bhopal for last 33 years (as available with IMD) has been collected. The rainfall data for 1 year i.e. 1977, 1983, 1996 and 2008 is missing/in-sufficient. Therefore, **the rainfall data of Bhopal for last 29 years has been analysed for various calculations and the design purpose by plotting the IDF curve for Bhopal Town**.

Estimation of runoff reaching the storm sewers/drain therefore is dependent on intensity and duration of precipitation, characteristics of the tributary area and the time required for such flow to reach the storm sewer/drain. More the intensity of rain, the higher will be the peak runoff rate. The storm water flow for this purpose may be determined by using the rational method, hydrograph method, rainfall-runoff correlation studies, digital computer models, inlet method or empirical formulae. The empirical formulae that are available for estimating the storm water runoff can be used only when comparable conditions to those for which the equations were derived initially can be assured.

A rational approach, therefore, demands a study of the existing precipitation data of the area concerned to permit a suitable forecast. Storm sewers are not designed for the peak flow of rare occurrence such as once in 10 years or more but, it is necessary to provide sufficient capacity to avoid too frequent flooding of the drainage area.

REFERENCES

The following guidelines have been followed while preparation of the project report:

1. Manual on Sewerage and Sewerage Treatment, (CPHEEO), GOI, 2012.
2. Indian Road Congress Special Publication 50, Guidelines on Urban Drainage, 1999.
3. Indian Road Congress Special Publication 13, Guidelines for the Design of Small Bridges and Culverts, 2004.