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Integration of Stormwater Drains with Lakes: Expectations and Reality - A Case of Raipur, India

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Abstract

Recently one of the most prominent activity focusing in Indian cities is the retrofitting the urban drainage system. Millions of rupees spent on the construction of stormwater drains in towns and cities to prevent flooding during the rains. These drains that extend several kilometers across the town or city are expected to feed all the collected surface runoff into the nearest surface water body such as a lake or a river. Recently a case study was done by Royal HaskoningDHV, a premier engineering and consultancy organization of Netherlands in association with German funding agency - GIZ on improvement of the stormwater management of Raipur city in India. The study suggested that flooding can be prevented in the city by interlinking of stormwater drain with the existing lakes in the city. The lakes can act as the storage reservoirs which dampen the effect of flooding and also reduce the chances of getting lakes dried during summer. Site reconnaissance revealed that most of the drains damaged and the sewage also entering to lakes. The sewerage system in the city observed very poor, creating health and safety issues for the general public. The city municipal corporation is making an effort in restoring these systems. This technical article will try with the following describe and provide with a glimpse into the massive efforts that the Raipur City undertook in order to inspect and clean its drainage and sanitary sewer systems.

Keywords: Urban drainage; Stormwater management; Lakes; Sustainability; Flooding

Introduction

An effective management of stormwater assumes more and more importance, the retrofitting of existing infrastructure becomes critical. Stormwater retrofit programs are essential to correct existing situations and to effectively manage stormwater. Urban stormwater management is one of the prominent basic infrastructure facilities growing fast in India. The fast infrastructure development has not included the proper drainage system. These critical issues must be addressed in parallel to any infrastructure development plan and a comprehensive plan on urban drainage and sanitation must be organized and implemented accordingly. Moreover, these issues become even more important for such cities having natural water bodies like lakes/ or ponds.

Raipur is the capital of Chhattisgarh state in India stretches from 21.201° and 21.324° latitude and 81.586° and 81.683° longitude [1]. It is situated on the Howrah-Nagpur-Mumbai railway line of the Indian Railways and is well connected with almost all major cities like New Delhi, Mumbai, and Kolkata. Raipur has an area of about 140 km^2 falls under the municipality of Raipur (RMC). Raipur has about 190 Talab (Lake) natural/ or artificial origin and some of them are very large in size. The water quality of these lakes is gradually deteriorating due to poor drainage system and discharge of untreated sewage [2]. The municipal authorities are now-a-days greatly concerned for proper management and protection of these water bodies.

According to 2011 census, the population of the city under Municipal Corporation was 1,010,087. The municipality has 70 wards and each ward is divided into 8 separate zones. Raipur has a warm and dry climate with moderate temperature range throughout the year. The temperature rises up to 48°C during March to June and becomes very hot. The city receives about 1300 mm of annual rainfall during monsoon period from June to August. Evaporation rates are high. Kharun River is only source of water which is flowing through the south-western part of the city [2].

This paper examines real-life examples of Raipur city how the municipality has facing the problems from unorganized drainage pattern and making an attempt to retrofit existing infrastructure by using its natural resources like lakes by integrating lakes into their stormwater management project.

Complexity of stormwater management

The implementation of sustainable and well developed master plan on urban drainage of any town/ or city is highly depend on the adaptability of the drainage principles to real situation of the city [3]. Many issues such as legal, social and financial, hamper the adoption of the real principles to implement innovative alternatives. These experiences are common in developing countries like India. The recent experience on the development of stormwater management for Raipur city has showed the problems of the appropriate data available, cooperation of municipal authorities and the uncontrolled urban expansion.

Hydrological data availability

The hydrological data such rainfall, evaporation, water balance of existing water bodies such as lakes (natural and artificial), paved and unpaved area, existing drainage network and hydraulic capacities are few that needs for development of sustainable stormwater management. Raipur city lacks proper data availability and observed difficulties to find proper hydrological data such as water flow in natural and manmade

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drains [4]. In this scenario, the designers/ engineers compelled to use modeling calibration processes, such as the use of inundation marks.

The majority of the rivers are not monitored in India, bringing difficulty for the flow estimation. In Raipur, there are few different IDF curves are available. Although they are not evenly distributed in order to properly represent the different characteristics of the rainfall. These curves show that there is a great spatial variability in the rainfall distribution in the city limits. In this way they are very helpful to bring bigger reliability to the structures design so that the rainfall characteristics frequently have to be obtained by data from other neighboring regions. Only a limited number of cities in India present a record of the existing drainage network. Even in the cities where this record is available, it presents several restrictions such as inconsistencies in records and actual field data.

Uncontrolled urban expansion

The expansion of cities haphazardly obstructs the determination of flow limits for future occupation due to the difficulty to forecast permeability soil rates. Residences located by rivers and water bodies with direct sewage discharges to the water body are frequently observed (Figure 1). This haphazard urban expansion tends to bring difficulties to forecast the real figures on land use pattern and occupation in future [5]. The hydrologic modeling greatly depends on the land use pattern which brings great uncertainties in prediction of stormwater flows.

Methods

Study area

Raipur has about 155 lakes of natural or artificial origin within its municipal boundary and a few are very large in size covering a total area of 3,810,000 m². Gradual deterioration of water quality in lakes and proper management and protection of these water bodies has been a concern for the civic authorities. About 100 lakes are larger than 1000 m². The most significant lakes are Budha Talab, Telibandha Talab, Maharajbandh Talab and Saryabandha Talab. They are several hundred years old and have been traditionally used for drinking and irrigation purposes. 51 lakes lies within limestone areas, which are supposed to be effective, recharge structures. The bottom of the lakes located in shale, by all accounts, do not allow particular percolation. Some of the lakes are overflowing during the rainy season. Due to anthropogenic and ecological pressure of the fast growing city, water quality in the lakes is poor. The major problems are the influx of sediments from the catchments, nutrients from agricultural areas, and the disposal of mainly untreated sewage water.

The city has a linear form bounded on the west and on the east by gently rolling hills. The city is fairly flat, the average altitude above MSL being 150 m. The quantity of rainfall in Raipur is due to the southwest monsoon, which is very active from June to October. The average number of rainy days is 160 in Raipur. Excessive falls of rain during June to August cause frequent floods in the rivers and canals submerging low lying areas. The average annual rainfall in the city is 1282 mm. The low lying areas of the Raipur will be flooded, when the rainfall exceeds 100 mm in a day. When the daily rainfall exceeds 150 mm, 20% of the residential areas and 30% of the roads and several other facilities of the city are affected. The main reason for the problem to be so acute is the poor drainage network in the city. Absence of drainage network also results in the indiscriminate discharge of wastewater in to the water bodies.

Reconnaissance survey

The field reconnaissance conducted for identification and verification of existing drainage conditions, connectivity of existing lakes, and their hydrological characteristics to validate a drainage pattern. The principle purpose of site visits was to verify the inlet and outlet of lakes/ or drains entering and leaving the lakes in whole city. In order to study a proper drainage pattern and lakes connectivity, consortium of three large lakes were selected and proposed a system which will be adopted for further review and modeling and putting forward the recommendations for a sustainable stormwater management system. In order to assess the existing conditions of drainage pattern of the city a number of field visits were made.

An assessment of existing drains and natural drainage pattern were made over some important catchments in preliminary site exploration. The aim of this preliminary site investigation was to decide how to carry out the further study, collection of data on rainfall, evaporation etc.

After data (on rainfall, evaporation, flow, drainage maps etc.) analysis and reviewing of drainage maps provided by Municipal Corporation, it was decided to consider the larger lakes for further study i.e. for modeling. These large lakes are situated in the heart of the city. The most elevated lakes in a catchment were considered for modeling so as to minimize the errors and a model could be applied efficiently. Such assessment was first done on available maps and was later supported by verification in the field and enquiry from concerned officials and local residents.

During February 2013, again a site visit was made for further review of existing drainage pattern and specifically addresses the gaps identified. The field observations revealed that the open rectangular drains (plain cement or stone masonry drains) acts as sewage drains since no proper sewerage network exist in the city and presently are

Figure 1: Unplanned House Clusters Discharging Sewage Directly into Storm Drains.

now under construction in each ward especially along the periphery of the lakes. The inlets of drains (either natural or manmade) have been closed and prevent the entry of sewage to lakes. However, in some cases, these channels are diverted and connected to the side drain in order to prevent the discharge of wastewater/ sewage into the lakes. This relatively helps preventing the water pollution of the lakes. The outlet exists at almost all lakes to drain off the excess water get filled during rainy season. The outlets at some lakes might get clogged due to dumping of waste and poor flow of water due to insufficient volume of water available in these lakes. Some outlets are properly constructed in order to drain off the excess water from the lakes to natural drain or PC drain by gravity; recently built adjoining the lakes. Field observations revealed that certain lakes have earthen outlet made by cutting the side bunds (Figure 2).

Following a visual identification and reconfirmation from the field reconnaissance, presently most of the lakes in different zones do not have direct entry of any kind of drain; however, certain lakes surrounded by slums, getting house waste or sewage discharges into these lakes as shown below.

Field observations also revealed that these lakes usually used for bathing and washing purposes and dried up during summer season. Surface runoff becomes only source of water for these lakes during rainy season.

Investigations at site survey also revealed the interconnectivity of lakes following the natural gradient or topography of terrain. Sometimes, 2 or 3 lakes are well connected through pipes to carry the surface runoff and drain off the excess water to lower gradient drain. Moreover, at some lakes the connectivity is badly hampered due to encroachments by locals, dumping of wastes by slum dwellers, heavy siltation, etc. A few identified locations and sample photographs of such reconnaissance done are given below.

Enquiries were also made on extent of local flooding, variation of water level in lakes over the year, religious significance of the lakes (if any), use of water by local community, reason for intentional blocking of existing outlet structure of some lakes, any identifiable stream of wastewater finding its way to these lakes, etc. The condition of roads, overall natural slope of the terrain, and socio-economic condition of the stakeholders living inside such catchments were also reviewed.

The effort of this field reconnaissance had to be focused on a specific area of the city to check and validate the selected model for its drainage pattern.

Modeling protocol

For hydraulic modeling and analysis, a catchment was selected which includes prominent lakes like Kankali Talab, Budha Talab, Maharajaban Talab, Nariya Talab, Sarjubandha Talab and Bhaiya Talab (Figure 3). This lake consortium was selected based on consideration of site investigation, physical features of these lakes like area, volume and water elevation, catchments, drain sizes, data availability, social and religious importance and replicable to other lakes and data availability such as base map of the lakes.

The primary aim of this study is integrate the existing lakes to storm drainage network. The feasibility of connecting drains with lakes in a catchment should be verified by application of simulation model. The modeling studies were carried out to a representative lake system in a catchment which can be replicated to other lakes and explore the options of integrating these lakes with stormwater drainage system to

Figure 2: Side Drains,Inlets & Outlets, Bathing Ghat & Solid Waste Dumping to different Lakes (adapted from site survey).

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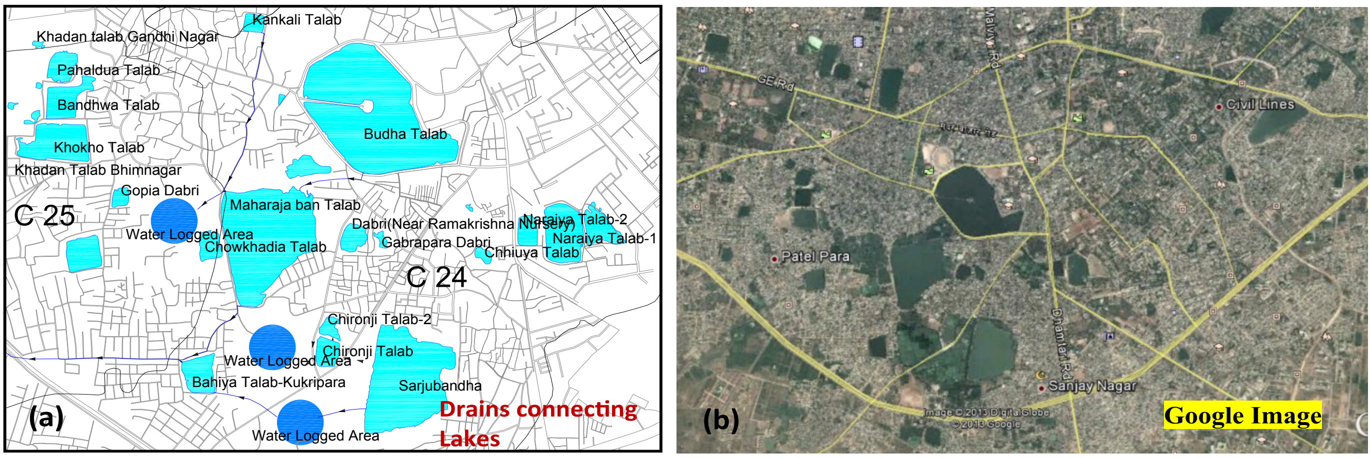

Figure 3: Consortium of Lakes for Modeling Study (a) Kankali Lake System (b) Google Earth Image of Kankali System (Adapted from GIS base map of Raipur City and Google Earth).

improve the lake water balance and reduce the flooding in the city by harvesting the surface runoff.

Various models are now available for stormwater modeling and flood assessment. United States Environmental Protection Agency (US EPA) has developed Stormwater Management Model (SWMM) for estimating the surface runoff, flooding and for analysis of flow conditions.

Due to its precision and accuracy, SWMM was used to model the storm drainage network and to assess the level of water stagnation, its duration, extent and time.

Restoring the lakes through integration of stormwater drains

Site reconnaissance suggests that drains could be integrated with lakes for the specific purpose of harvesting most stormwater/ urban runoff for recharge of lakes, infiltration and drain off the remaining amount of runoff to downstream lakes and channels in a catchment.

The modeling studies suggest that no flooding observed if stormwater drains integrating with lakes in most of the lake systems and BMP of stormwater management could be achieved by harvest urban runoff through integration of lakes with stormwater drains and could reduce the flooding.

Moreover, a paradigm of runoff being viewed as a wastewater now shifted to a new paradigm of viewing runoff as a local natural resource for reuse. For dry weather urban runoff, the city administration must consider to promote the reuse of this resource. This strategy could accomplish the present goal of preventing flooding and maintaining water balance in lakes by harvesting urban runoff.

This presentation will demonstrate the principle of environmental health improvement, water capacity of lakes and reduce the flooding. The systems of interconnectivity of drains with lakes and construction and designed of infiltration chambers, porous paving, and cisterns within catchment area to harvest runoff for diverting water to lakes and improve water quality.

Existing design standards

The existing drainage system of Raipur is inadequate to meet the growing demands of civic infrastructure needs in terms of coverage of the area and catchment of Raipur municipal Corporation (RMC). For successful functioning of drainage system, it is imperative to highlight the design principles for formation drainage system and stormwater management.

In the hydrologic analysis, there are number of variable factors that affect the estimation of stormwater runoff from the site. The factors that were considered in the design include:

- Rainfall intensity and storm duration
- Drainage area, shape and orientation
- Ground cover and soil type
- Slopes of terrain and stream channel
- Characteristics of local drainage system

Modeling analysis

The modeling study were carried out for a sub-catchment having Kankali System which is the most appropriate systems to be adopted for hydraulic modeling. The applicable hydrological parameters like evaporation, infiltration, rainfall events were required to obtain for simulation. Certain assumptions have to be made in running the model for interested lake system and some are given below:

- The rate of evaporation rate assumed constant throughout the year.
- Percolation through bottom of lakes and infiltration to the lakes were assumed to be negligible.
- No wastewater intrusion and groundwater infiltration was considered in the system.
- The network was assumed to be carrying only stormwater run-off. However, in the field, separate system for sewage and storm run-off is yet to be implemented and maintained.
- The connecting drains were assumed cleaned.
- The Manning's coefficient (n) was considered as 0.011 and 0.017 for new and existing concrete drains (for rectangular shapes) respectively.
- Initial inflow in the system is assumed to be zero.
- Imperviousness factor of the sub-catchment is 70%, irrespective to its differential land-use pattern.

- N-value of the imperviousness and pervious area of the sub-catchment was assumed 0.01 and 0.1 respectively.

Table 1 indicates the various rainfall events that were applied for simulation of model.

From application and simulation of hydrologic model, results suggest that the integration of drainage system into lakes have advantage in reducing the flooding. The flooding can be reduced by 34% and a reduction of 59% in volumetric load on outfall drain can be achieved which leads to economize the drainage system. Different return period of 2 and 5 years with rainfall intensity for 30 minute duration and 50 year return period with one hour duration of rainfall has been considered in this study. The study revealed that no flooding observed in any lake. The flooding mainly observed in outfall drains of the system which could be eliminated after minor modifications in drains sizes.

Proposed solutions

The sustainable urban stormwater management could be adopted by

- Establish a feasible and cost effective stormwater management plan.
- Overcoming of social and institutional issues by establishing steering committee comprised representative from administrative bodies, academic institutions and policy makers to help city implement its stormwater management goals.
- Integration of administrative organs of the cities with academic and research institutes aiming to promote the awareness for maintenance of water bodied.
- Long-term planning of effective stormwater management system.
- Implementation of laws and publicize the stormwater management guidance manual.

Rainfall Events	Rainfall Intensity	Rainfall Duration	Model Run Period	Remarks
Event –A	40 mm/hr.	30 min.	23 hrs.	Run-1 Existing drainage system within the watershed without linking lakes Run-2 – Existing drainage system within the watershed with linking lakes
Event –B	26 mm/hr.	75 min.	23 hrs.	Run-1 Existing drainage system within the watershed without linking lakes Run-2 – Existing drainage system within the watershed with linking lakes
Event –C	16 mm/hr.	120 min.	23 hrs.	Run-1 Existing drainage system within the watershed without linking lakes Run-2 – Existing drainage system within the watershed with linking lakes
Event –D	Year long representative rainfall considered as 1412 mm.		1 (one) representative year	Proposed drainage system within the watershed linking all lakes Average evaporation rate of 5.4 mm/day adopted throughout the year.
A rainfall intensity for 2, 5 and 50 year return period has been assumed.				

Table 1: Rainfall Events for Simulation.

In terms of education, it is necessary to favor the knowledge transfer, at different levels:

- Technical information to the designers/ engineers/ technicians.
- Information to legislators and decision makers, in order to inform about the existence of other solutions.
- And environmental education to the general public, in order to impart an importance of the sustainable approach.

Experimental studies should be used to present demonstrative effects of the advantages of the sustainable approach. Although educational campaigns were being organized in Raipur (by GIZ a German funding agency), where various sectors of the society Municipal Engineers, Consultants of reputed organizations and local politicians together to inform the population on the advantages of the use of stormwater quantitative and qualitative control.

Conclusions

This paper presented stormwater management concept, its reality and expectation by retrofitting/ renovation of old and new drainage system into existing lakes. Many issues/ or problems were faced during the study for due to limited information. The adoption of a sustainable approach for the urban stormwater management faces many challenges especially in developing countries like India, mainly due to absence of proper data, uncontrolled urban expansion, lack of knowledge, legal issues and hydrologic information on infiltration, rainfall, evaporation, volume of water bodies, water quality and finally discharge.

During field investigations and reconnaissance lack of hydrologic data, proper drainage network records and difficulties for urban occupation forecast were identified.

Experience gained during workshop and field trips, people showed great interest to the adoption/ or maintenance of lakes since they has bad experiences mainly related to the presence of clandestine sewage connections, solid waste dumping, sediments influx and lack of appropriate maintenance.

The integration of drains with lakes could prevent flooding; improve the lake water quantity, increasing opportunities for recreation, and restoring ecosystems and water quality as well. The integration of drainage system with lakes could have been effective, but it serves a single purpose and the opportunities for the highest marginal returns on water quality improvement have largely been exhausted.

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References

1. Raipur, Wikipedia, the free Encyclopedia.
2. DPR (2011) Meinhardt Singapore Pvt Ltd New Delhi.
3. Goldenfum JA, Tassi R, Meller A, Allasia DG, André L. da Silveira (2007) Challenges for the sustainable urban storm water management in developing countries: from basic education to technical and institutional issues. Proceedings, 6th International Conference on Sustainable Techniques and Strategies in Urban Water Management, Lyon, France.
4. FU Berlin Report (2012) Water balances of Maharajbandh Talab, Budha Talab and Narayia Talab in Raipur city, India.
5. Rahman A (2004) The state of urban drainage conditions and management in Aligarh city, India. In: Proceedings of the 5th Novatech conference on Innovative Technologies in Urban Storm Drainage 1303-1310.