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URBAN FLOODING AND DRAINAGE

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Abstract *Urban flooding is a result of the decision of urban communities to provide only partial protection from flooding in the cities. The location of urban communities in relation to large rivers, sea and drainage networks of rural basins is another important factor contributing to urban flooding. Urbanization increases peak discharge, reduces response time and base length of the unit hydrographs. This in turn reduces the level of protection, which was provided at the time of laying down the drainage network wherever urbanization has occurred in upstream areas. The net effect of the increased urbanization is increased flooding unless the capacity of the existing network is increased. The most important management function is to ensure that the drainage network is free from silting and all portions of the network are maintained as per design specifications. Once the infrastructure is in position, flood depth frequency maps need to be developed for involving and educating the people about the dangers of flooding, identifying trouble spots and developing local solutions for providing additional drainage. Scientific analysis for achieving these goals require static data about the system, spatial and temporal distribution of rainfall in the urban area and simulation models.*

INTRODUCTION

Urbanization substantially alters rainfall-runoff relations compared with those of natural drainage as increase in the impervious area that accompanies urbanization reduces infiltration and evapotranspiration in the catchment. Surface detention storage characteristics which also change drastically result in changed values of ground water recharge. All these factors collectively increase surface runoff. Urban communities face flooding in case the transport system gets overloaded. The reasons for the overloading/flooding are:

(a) Low capacity of urban storm sewerage systems.
(b) Location of the urban community vis-à-vis natural drainage systems and sea.
(c) Ground water level increase in the area.

Inadequate Capacity

Urban flooding is a result of the decision of urban communities to provide only partial protection from flooding in the cities. The reason for this decision is the inability to find funds for building the urban sewer/drainage network to cope up with the runoff generated by higher return period rainfall. The network is designed for partial protection, knowing fully well that it will be taxed infrequently. The capacity also decreases because of silting of the network and the storage structures, thus reducing the level of protection still further.

Location

The location of urban communities in relation to large rivers, sea and drainage networks of rural basins is another important factor contributing to urban flooding. These locations give rise to urban flooding in the following ways:

(i) Penetration of surface water from rivers, and other streams and drains in the city because of failure/overtopping of embankments on these rivers thus flooding the adjoining streets.
(ii) Inability of natural and man made drainage in the city to discharge its water to the river because of higher levels in these rivers during the passage of flood through them, and thus creating reverse flow/flooding in the urban areas.
(iii) Unauthorized settlements in between the embankments/banks of the drainage network below the designed flood level.
(iv) Flooding caused by high tides and wind induced waves.
(v) Floods originating from upstream basin and flowing through drainage network incapable of safely passing higher return period floods through urban areas.

Increase in ground water levels

Large-scale irrigation in some areas has increased water levels. This in turn causes waterlogging conditions in low-lying urban communities during the wet season. Such situations are usually managed by lowering the water level by either large scale pumping in the area or by providing bio-drainage.

The consequences of urban flooding range from clearly assessable property destruction and loss of lives to annoying inconvenience. The focal theme of this paper is urban hydrology, therefore, questions relating to flooding, because of low level of protection provided in the design or urban storm water drainage systems, are discussed in the following paragraphs. Urban flooding because of rivers and streams passing through the cities require comprehensive structural and non-structural measures – a subject in its own right which needs to be dealt with separately.

SELECTION OF FREQUENCY OF RAINFALL INPUT

The selection of rainfall input used for computing urban runoff decides the level of protection that is provided to the users from urban flooding. This requires the knowledge of Rainfall Depth-Area-Duration-Frequency relationships for the urban area, surface runoff quantity model, land use plans and existing/planned storm drainage network indicating flood storage, off channel storage, pumping stations, weirs and other structures. These data are used to work out cost of providing drainage network for various frequencies of rainfall and damages due to flooding associated with this choice during the life of project. This study is used by the planners/decision makers to decide the level of protection for which the community is willing to pay against flooding in the area. In most cases the recurrence interval chosen for design of the urban storm sewerage system/drainage ranges from 2 to 5 years.

RUNOFF ESTIMATION IN URBAN AREAS

Once the decisions of the level of protection which is to be provided to the urban area has been decided, runoff hydrographs need to be estimated at each node (where two sewers/drains meet) for sizing the drainage network.

Factors Affecting Runoff

The main factors affecting runoff for a given rainfall are:

(a) Catchment area
(b) Topography
(c) Shape of the catchment
(d) Natural or man made storage
(e) Type of soils
(f) Land use
(g) Urbanization

Of these, land use and urbanization are continuously changing factors. Their dependence is best explained by Stankowski (1972). According to him urbanization usually begins with the occupation of rural lands by small, concentrated communities with close groupings for homes, schools, and commercial activities. Further growth is characterized by large residential subdivisions, additional schools, shopping centres etc. and an enlarged network of streets and sidewalks. The process continues until all such structures and developments occupy all or most of the former rural land area.

Impact of Urbanization on Hydrologic Response

These developments have a significant effect on the hydrologic response because the impervious area is drastically changed and conveyance systems for drainage are often not properly installed. The increase in impervious areas increases the runoff volumes. The change of shape of the flood hydrographs have been analysed by researchers by relating it to the characteristics of resulting unit hydrographs. According to them (NIH, 1994) urbanization increases peak discharge, reduces response time and base length of the unit hydrographs. This in turn reduces the level of protection, which was provided at the time of laying down the drainage network wherever urbanization has occurred in upstream areas. The net effect of the increased urbanization is increased flooding unless the capacity of the existing network is increased. The increase of flooding frequency can be reduced by increasing the time of travel of surface runoff on grass surface (providing opportunity for infiltration) before the roof water joins the storm drain and or providing storage through temporary detention in recreational areas by incorporating it in land use plans.

Methods for Computing Runoff Hydrographs

The methods available for computing runoff hydrographs have been reviewed in the National Institute of Hydrology (NIH) Report No. TN-49 (NIH, 1988-89) entitled 'Storm Drainage Estimation in Urban Areas'. Another report (NIH, 1991-92) on the 'Effect of Urbanisation on Runoff' is an updated version of the 1988-89 report. The present status of research in various countries has been reviewed in status report on Urban Hydrology published by NIH in 1992-93.

These reviews have concluded that:

1. Existing practice of urban runoff estimation in India is mostly empirical in nature and not reliable for analysis and design of complex drainage systems.
2. Tested and verified models developed elsewhere for estimation of urban runoff need to be applied in India with suitable modifications, if required.
3. The urban instrumentation network both in terms of assessing quantity and quality of urban runoff is very poor.

The hydrological properties of overland flow component of selected physically based models, Unit hydrograph based urban surface runoff models and comparison of some major model characteristics are also given in the TN-49 report. Some of these models are comprehensive package comprising of Surface Runoff Quantity Model, Surface Runoff Quality Model, Transport Quantity Model and Transport Quality Model, capable of computing time history of flows and water surface elevations as well as pollutographs and time history of concentrations, at locations within the drainage systems and at outfalls. Simulation models for the examination and redesign of many inadequate and worn out sewer systems of the old towns which may include storm overflows, bifurcations, inverted siphons, on or off line storages, pumping stations and outfall flaps are also presented in these reports.

Flood Depth- Duration-Frequency Maps

It is important that the community is informed of the probability of flooding of the areas surrounding the drainage network. This requires spatial data on storms which have been recorded in the past. This storm data in conjunction with the simulation model can be used to develop these maps. The flooding depth and its frequency be painted on the boards in local language for the information of the community at all nodal and interest points so that they are aware of the danger that they are facing from flooding. In literature it is mentioned that there is low fiscal priority for drainage investment. It will remain low as long as the complete information on the likelihood of flooding of various areas is not made public. Once the community becomes aware of the dangers it will find funds to sort out the problem of flooding by providing appropriate fiscal priority in drainage investment schemes. In most of the Indian cities storm water is carried in open drains which were draining the rural basins prior to urbanization of the area. Over the years the cross section of these drains is reduced to recover land for urbanisation. Lining of the drains is resorted for maintaining the same gauge discharge curve. The loss of storage because of these modifications and consequent increase of flood peaks in the down stream reaches and therefore increased frequency of flooding is never made known to the public. Another major reason of reduction of the capacity of the drains is lack of maintenance of even the designed sections as these drains are used as garbage disposal sites.

URBAN FLOODING – A MANAGEMENT PROBLEM

The urban sewer/drainage system is designed to drain runoff resulting from low return period rainfall. It is expected that the system will be overloaded/flooded for some time when the urban areas receive higher return period showers. It is also known that spatial and temporal distribution of rainfall is not uniform thus, limiting the overloading to areas that experience more than the design rainfall. Some areas are more prone to flooding than the other areas. Such areas require additional pipes or loops to reinforce the network. Others require continuous monitoring of the formation and disposal of runoff. The disposal could be either by pumping the water or draining it through surface drains if the topography permits. The most important management function is to ensure that the drainage network is free from silting and all portions of the network are maintained as per design specifications.

In countries, where the economic cost of dislocation of the area transportation network is very high, private/public radio station give a continuous broadcast of the status of roads in the area. Some of these countries use Doppler Radar to continuously monitor the spatial and temporal variation of rainfall and provide information to the community of the impending dangers in a readily usable format.

IMPACT OF ROOF WATER HARVESTING ON URBAN FLOODING AND DRAINAGE

All major cities in India face shortage of drinking water especially during the summer months. Ground water is the main source of drinking water in many of these cities. With increased urbanization the recharge to the underlying acquifers has decreased and demand of water for the city has increased leading to mining of ground water and rapidly falling ground water table. The cities are coping up with this problem by enacting laws requiring builders, housing societies and public institutions to harvest roof water for household use or for recharging the underlying aquifers. This roof water catchment amounts to adding storage to the existing drainage networks thus reducing the incidence of flooding. The capacity of storage so added will improve protection from urban flooding in these areas.

CONCLUSIONS

The scale of development of the urban storm drainage system is a function of the fiscal capacity of the community to invest in drainage infrastructure. The fiscal capacity and land use plans determine the level of protection that can be provided to the community from urban flooding. Once the infrastructure is in position, flood depth frequency maps need to be developed for involving and educating the people about the dangers of flooding, identifying trouble spots and developing local solutions for providing additional drainage. Scientific analysis for achieving these goals require static data about the system, spatial and temporal distribution of rainfall in the urban area and simulation models. Efforts need to be made to install necessary instrumentation to collect data on spatial and temporal distribution of rainfall and the resulting runoff at various points on the network so that Urban Catchment Models, such as the one described in the report by National Institute of Hydrology (NIH, 1997-98), can be verified and made available to designers of urban storm systems.

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