Urban drainage in developing countries – challenges and opportunities

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Wastewater, the 'unwanted' water of a city, includes all types of domestic, commercial and industrial effluent as well as stormwater runoff during times of rainfall. This article highlights some of the challenges for urban planners and engineers in the design of effective urban drainage and stormwater management systems in developing countries.

In the cities of the developing world, the urban poor often inhabit marginal land that has less commercial value but is the only available land where they can afford to live. This includes land that is poorly drained and floods frequently, or on steep hillsides that are prone to landslides. The benefits of living nearer sources of employment and urban services usually outweigh the disadvantages associated with flooding, which is generally perceived as a natural and seasonal event.

The consequences of flooding can sometimes be devastating, especially for poor communities who lack the financial resources to rebuild their homes. Nevertheless, flooding tends to be accepted as a fact of life for these communities, who develop coping strategies for dealing with the consequences of inundation (see Box).

Coping with floods

In response to flooding, households and small enterprises in Indore, India, make structural adaptations to their houses that involving raising plinth levels, paving courtyards, using landfill, and using materials which resist flooding. They use furniture that is less likely to be washed away and ensure that shelving and electric wiring are high up the walls, above expected water levels. Roofing may not be attached to a house, so it can be quickly removed if the structure is in danger of being swept away.

Residents have also developed flood prediction and protection systems and contingency plans for evacuating persons and possessions. During the monsoon season, families are prepared to move the elderly, children and animals to higher ground in response to the threat of severe floods, and many households have trunks so that valuable possessions can be carried away.[1]

Urban drainage and environmental health

Although flooding problems are prominent during the wet season, other effects of poor drainage are perennial and intrinsically linked to deterioration in sanitation and environmental health conditions. The implications of these problems are less tangible than inundation by stormwater but the effects have major implications on the health and livelihoods of urban populations.

In poorly drained areas, urban runoff mixes with sewage from overflowing latrines and sewers, causing pollution and a wide range of problems associated with the increased risk of waterborne diseases.

Infiltration of polluted water into low-pressure water-supply systems can contaminate drinking water, and is frequently a source of gastro-intestinal disease. Poor drainage creates faecally contaminated wet soils that are ideal conditions for the spread of intestinal worm infections such as roundworm and hookworm.

Open drains carrying sewage or sullage water are potential sources of infection to children who play in them, and flooded septic tanks and leach pits provide breeding sites for mosquitoes that are responsible for the spread of a number of diseases. While *Anopheles* mosquitoes are responsible for the transmission of malaria, the *Culex* mosquito transmits filariasis, and the *Aedes* mosquito spreads both yellow and dengue fever.

These problems can reach epidemic proportions. In Brazil, a recent outbreak of dengue fever is reported to have caused 430 000 occurrences of people falling ill, and to combat the epidemic the government has mobilized firefighters and soldiers to fumigate areas and remove stagnant waters.[2] However, these problems can be avoided without investments in large-scale drainage infrastructure, if people eliminate breeding sites for the *Aedes* mosquitoes, such as water containers, old tyres, urns and other water recipients.[3]

Investments in smaller-scale infrastructure for drainage at the household and community level, combined with health education – so that people understand the effects of poor drainage – may therefore be a more cost-effective means of improving problems associated with poor drainage than investments in large-scale flood alleviation infrastructure. However, Jo Lines makes the important point in his article that the relevant measures to take are specific to the region and the particular mosquito species.

The impacts on the environment associ-

Solid waste blocking an open drain in Kathmandu, Nepal

'all too often, engineering designs take little account of waterways and wetlands'

ated with poor drainage and wastewater management are also widespread. The pollution of natural watercourses from the discharge of untreated wastewater may threaten the livelihoods of poor communities who depend upon water resources for subsistence farming. In Asia, wetland areas are particularly vulnerable as they are traditionally used for paddy fields and for the harvesting of fish, invertebrates and plants. Although many of these practices continue today, they are decreasing, owing to the physical destruction of wetland habitat and pollution from untreated sewage.

Design of urban drainage systems

One of the basic problems of drainage system design in developing countries is a lack of appreciation of the differences in rainfall distribution patterns and urban hydrology in different parts of the world. Many developing countries lie in humid tropical regions where annual rainfall distribution is characterized by a monsoon season, with much higher rainfall intensities than those in temperate regions, and the rain concentrated during a few months of the year. Global warming may result in further impacts upon rainfall distribution adding further uncertainty to drainage system design and flood prediction.

The rate and volume of stormwater runoff from urban surfaces is dependent on hydrological factors such as the surface depression storage (dips in the surface that can store water and form puddles) and the antecedent rainfall conditions relating to the wetness of the catchment. Urban catchments in developing countries typically have significantly different physical characteristics from those in industrialized countries, which cause wide variations in the rainfall–runoff response and the resultant volume of runoff and peak flows.

Although the effects of urbanization on rainfall–runoff relationships have been quantified, the various formulae derived from individual studies may not be applicable to developing countries in the humid tropics. Inadequate data for computing design parameters, and the use of various assumptions and mathematical formulations more relevant to developed countries have created more complex problems rather than solutions to drainage problems in developing countries. Much work remains to be done to develop practical local alternatives to these formulae and approaches.

Drainage engineers are notoriously unsympathetic to the use of natural drainage patterns and, all too often, engineering designs take little account of the existence of waterways and wetlands. These factors have led to a re-evaluation of the conventional approach to drainage system design and the development of an alternative approach based upon the planning and design of sustainable urban drainage systems (SUDS) which attenuate stormwater runoff and reduce flooding by using natural drainage pathways and floods. Infiltration of relatively uncontaminated runoff from rainfall can help maintain base flows in rivers, and rainwater harvesting can reduce peak flows of stormwater runoff as well as offering benefits in terms of water supply.

Advances in technology and its application

Recent advances in computer technology enable better analysis of the complex interactions of the urban hydrological cycle. Computer models offer the drainage engineer powerful simulation tools to analyse existing drainage problems and various alternatives for a new design. These models have been widely applied in the developed world and there is considerable scope for their application in the developing world.

Modelling of urban flooding with the interaction between the pipe system and the surface flooding is feasible and this raises new possibilities for managing urban flooding problems. The example described by Ole Mark et al. shows how a simulation model may be used to compare alternative strategies for pollution control in bathing waters following heavy rainfall on Pattaya Beach in Thailand.

In general, the successful application of computer models is often constrained by a lack of data describing the catchment and the existing drainage system, a lack of reliable local data on rainfall and runoff (for calibration and verification). There is scope to utilize remote sensing and geographical information systems (GIS) for planning and design of urban drainage

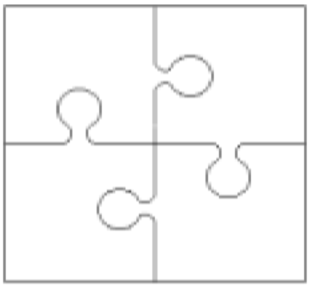

Figure 1
Drainage as an integral component of sanitation

systems, but this is often constrained by the expense of the technology and a lack of suitably skilled technicians. For these reasons, it is important to choose the right model for the purpose and there is always a danger that large resources are invested in developing complex computer models without due consideration of the wide range of problems described below.

Operational performance and maintenance requirements

From a technical perspective, the design and construction of urban drainage systems is relatively straightforward, but subsequent operation and maintenance remain major challenges to urban authorities who are often ineffective in dealing with the scale of the problem. Uncollected solid waste often finds its way into surface drains and sewers; these drains, blocked with rubbish, then have less capacity than clean ones, and are more likely to flood during large storms.

The problem of litter in the stormwater drainage systems is at its worst where modern technologies, such as the plastics industry, have been introduced before the development of a strong environmental lobby or authority to police the waste.[4] These problems have become so severe in Dhaka that the municipal authorities have recently banned plastic bags. At least 5.5 million plastic bags were being discarded every day which led to 30 per cent of the city's sewerage system becoming clogged and the formation of a 3-metre layer of polythene on the bed of the Buriganga River that runs through the city.[5]

'Dhaka's authorities recently banned plastic bags when it was discovered that a 3-metre layer of polythene had formed on the bed of the Buriganga River'

The operational problems caused by poor solid waste management are exacerbated by a lack of effective arrangements for drain cleaning. These tend to be related to a lack of resources and manpower, and inappropriate equipment. But, to make matters worse, the department responsible for solid waste management is often separate from that responsible for drain cleaning and coordination between different urban authorities is generally very poor. An integrated approach to drainage is therefore recommended in which management of stormwater is seen as an integral component of sanitation.

Institutional arrangements for urban drainage planning

Urbanization and new housing and commercial developments exacerbate urban drainage problems by increasing urban runoff from impermeable areas. In many cities in the developing world, there is often no real control over new developments due to deficiencies in the administrational systems for urban planning and control. In these situations, buildings are constructed with no consideration for drainage of stormwater and, where these occupy floodplains or natural drainage pathways, the problems of stormwater drainage are increased due to downstream flow constrictions.

Urban drainage systems cannot be designed in isolation from the communities that they serve. For example, where communities construct houses on drainage pathways and floodplains, it may be necessary to relocate some of the houses for the construction of drains. However, experience has shown that large-scale eviction and forced relocation often exacerbates social problems, which can be more severe than the original drainage problem. In Carlos Tucci's article, the plan for the Iguacu River includes building a park in the river's floodplain to take the floodwater during times of heavy rainfall. However, to discourage further illegal invasions and squatter settlements, it was considered essential to build sports amenities on this park.

Increasingly urban authorities have adopted an alternative approach towards urban upgrading in which informal settlements and squatter communities are seen to be an integral part of the social, economic and physical fabric of urban society. For example, in India, 'slum networking' is an innovative concept, which exploits the linkage between the slums and the natural drainage paths that influence the urban infrastructure and environment of the city.[6]

This approach, which is also described in the article by Shaleen Singhal and Amit Kapur, aims to solve problems of flooding for the city as a whole, whilst concurrently providing services for the slum dwellers in low-lying areas adjacent to natural drainage paths.

Implications for policy and practice

Advances in technology provide improved tools for planning and design, but for investments in urban drainage systems to be cost-effective and operationally sustainable, greater emphasis needs to be placed upon communication, between professionals responsible for drainage, to promote

Conventional engineers often take no account of the benefits of natural wetlands for flood control – Vientiane, Laos

new ways of thinking.

The effectiveness of stormwater management systems can be directly linked to the efficacy of urban management. Hydrological systems are not constrained by administrative boundaries. Effective drainage area and catchment planning requires careful coordination between the relevant institutions responsible for water supply, sewerage, drainage and solid waste management.

The financing and cost-recovery of urban drainage systems remains a challenge and it is necessary to develop an appropriate system to pay for these services. The overall planning framework needs to be considered in relation to land use in the urban and peri-urban areas and, in particular to the communities that inhabit this land. In order to achieve this, collaboration between government agencies and non-governmental organizations, as well as consultation with communities is essential.

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webwatch

These five websites cover most of the resources on the web about urban drainage.

■ **Sustainable urban drainage systems**
CIRIA is a UK-based research association concerned with construction and the environment, and it leads research on sustainable urban drainage. This website provides an introduction to Sustainable Urban Drainage Systems (SUDS) and updates on current good practice in their use.
http://www.ciria.org.uk/suds/

■ **Stormwater management on 'Sanitation Connection'**
Stormwater management is one of the themes in Sanitation Connection prepared by GHK Research and Training. This page includes a range of resources, inlcuding websites, online publications and mailing lists.
http://www.sanicon.net/titles/topicintro.php3?topicId=5

■ **Urban drainage mailing list**
This is a discussion and information exchange network concerning the planning, design, operation and modeling of urban drainage systems. Postings concerning the sustainability of urban drainage systems, the long-term effects of their operation on natural ecosystems, and the transfer of technology to developing and devastated countries are welcomed.
http://www.jiscmail.ac.uk/lists/urban-drainage.html
for subscription details.

■ **Scottish Environment Protection Agency SEPA: Sustainable Urban Drainage Bibliography**
Essential reference material plus useful papers and websites.
http://www.sepa.org.uk/guidance/scontrol/bibliography.html

■ **IWA Specialist Group on Urban Drainage**
This group aims to foster fundamental and applied research in urban storm drainage, taking account of meteorological, hydrological, hydraulic and pollution aspects. The Group has a triennial international conference and many specialised conferences.
http://www.iawq.org.uk/template.