Sustainable Urban Drainage in Low-income Countries ~ a Scoping Study

Project report

Brian Reed

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Water, Engineering and Development Centre
Loughborough University Leicestershire
LE11 3TU UK

Water, Engineering and Development Centre
Loughborough University
Leicestershire
LE11 3TU UK

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The Water, Engineering and Development Centre (WEDC) is one of the world's leading institutions concerned with education, training, research, and consultancy relating to the planning, provision, and management of infrastructure for development in low- and middle-income countries.

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Contents

Besides this Project Report, other outputs include:

- a set of training materials; which includes two briefing notes, one for a technical audience and one for local policy makers.

As part of the research process the project team also produced:

- a literature review; and
- a series of reports from workshops in Uganda, Brazil and Vietnam.

Executive Summary

This short research project looked at the scope for using "Sustainable Urban Drainage Systems" (SUDS) in low-income countries. Poorly managed urban drainage has many impacts on the lives of urban residents, especially the poor who are living in areas prone to flooding, water pollution or landslides. SUDS have been developed in a variety of countries, most notably the USA, Australia and now the UK. They take an holistic approach to drainage design and management.

Conventional drainage systems aim to remove water from the built-up area as rapidly as possible, transferring flooding and pollution downstream. They have detrimental impacts on water resources and the wider environment. In low-income countries, channels are often used instead of pipes, but the same design philosophy is used. The use of piped sewerage is now recognised as inappropriate for excreta disposal in many locations of the developing world, but an urban drainage equivalent of the pit latrine and septic tank has not been developed or promoted. This project aimed to see if SUDS could fill this gap.

Findings

SUDS mimic nature, using man-made features such as soakaways, ponds and gently sloping channels (swales) to attenuate and treat urban runoff. They focus on prevention of runoff and source control rather than end- of pipe solutions. <u>The research established that not only was there potential to use SUDS in low-income areas, but they are actually being used, often informally</u>.

Other findings of the research demonstrated that the problems encountered with drainage developments in the UK are also encountered in low-income countries, but to a greater degree. <u>Water pollution is one clear example of the adverse impact of poorly managed urban drainage, leading to disease and poor drinking water quality</u>. One important aspect is the quantity of silt in drainage systems, requiring significant maintenance. Conventional drainage design practice developed in industrialised countries does not address this problem to a sufficient extent and thus, this is a major area of failure of drainage systems in low-income countries. <u>Other problems include qualified and knowledgeable staff and adequate budget arrangements</u> (in terms of institutional distribution and timing).

However <u>the most significant issue to arise during the project was the widespread lack of focus on urban drainage problems</u> (using any technique). Given the accepted impacts of poor drainage on health, the economy, physical infrastructure and society (especially vulnerable groups such as women and the poor), there does appear to be a lack of appropriate guidance, funding, training and political support. Actions are reactive and short-term. Urban drainage

management has to be multidisciplinary, with sanitation engineers, water supply staff, environmentalists, road engineers and communities all having a role to play, however, lack of co-ordination and even conflicting institutional aims appear to be widespread.

Recommendations

Recommendations centre on the need to raise awareness of the importance and range of appropriate options for drainage amongst policy-makers and decision-makers in urban areas at all levels. Urban drainage needs to be included as standard component in water and sanitation interventions. They have an important contribution to make to the millennium development goals – especially the environmental goal.

Millennium development goal number 7
Ensure Environmental Sustainability

The environment provides goods and services that sustain human development so we must ensure that development sustains the environment. Better natural resource management increases the income and nutrition of poor people. Improved water and sanitation reduce child mortality, and better drainage reduces malaria. It also reduces the risk of disaster from floods. Managing and protecting the environment thus contribute to reaching the other Millennium Development Goals. Fortunately, good policies and economic growth, which work to improve peoples' lives, can also work to improve the environment.

Target 9 Integrate the principles of sustainable development into country policies and programmes and reverse the losses of environmental resources.

Target 10 Halve by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation.

Target 11 Have achieved by 2020 a significant improvement in the lives of at least 100 million slum dwellers.

http://www.developmentgoals.org/

Other recommendations of the study include further research, mainly to look at institutional arrangements, human resource requirements and performance indicators for urban drainage that go beyond simplistic flooding standards.

Technical research is needed to support physical interventions, especially for the design of drainage systems that can cope with silt and also for the development of design procedures where there is limited data and staff with limited drainage expertise.

1. Introduction

This chapter sets out the rationale and methodology of the project.

Readers are reminded this is a scoping study and only introduces the subject rather than aiming to present a finished outcome. References to possible subsequent work are for information and planning purposes (e.g. completion of log frame). These subsequent stages are subject to the outcome of the scoping study and would require additional funding. Potential future activities are shown in italics in the Logical Framework.

1.1 Goal, purpose and aims

The goal of the research strand under the DFID Knowledge and Research programme that this project was submitted under was to *"Combat the degradation of water resources".*

1.1.1 Purpose and Outputs

The purpose was to outline the scope (if any) for using sustainable urban drainage systems (SUDS) in low-income countries. SUDS have the potential to help prevent degradation of water resources through sustainable, environmentally balanced methods to reduce flooding, pollution, soil erosion and siltation and increase the value of aquatic habitats, aquifer recharge and low flows in watercourses.

However, taking a narrow view of the purpose (to only examine water resource degradation) would have limited the value of the research as the benefits and problems with urban drainage span many disciplines (e.g. health, social exclusion, urban planning) and so a wider perspective was taken.

The outputs of the project are designed at three levels:

- Reporting on the scope for more sustainable approaches to urban drainage and, if appropriate, steps that would be needed to promote uptake on a wide scale. The output is this final report and recommendations for further work
- Promotional and educational material explaining the concepts behind SUDS. These outputs will be able to be used after the scoping study for wider dissemination to practising (municipal) engineers, so will be developed in a self/ distance learning format, based on the demands of the collaborators. Outputs include:

- ? training material
- ? short briefing note for technical staff
- ? short briefing note for policy-makers and planners
- ? website containing material for use at national level

- Research materials, that were produced as part of the project; whilst these are not outputs, they will be made available via the website. These include:
  - ? literature review
  - ? reports from country workshops
  - ? photographs of drainage issues.

1.1.2 Research Overview, Approach and Implementation

As a scoping study, a broad perspective was required before any specific issue was tackled in depth. In addition, taking the viewpoint of drainage managers in urban areas in low-income countries, the project would concentrate by looking to see what resources are available to them rather than the latest academic research.

Background including, demand for the research, researchable issues and constraints

Urbanisation disrupts natural drainage patterns; natural watercourses are destroyed, natural retention of runoff by plants and soil is removed and the creation of impervious surfaces increases the amount of runoff. This runoff becomes polluted as solid waste, silt and contaminants are washed off roads. The increase in volume and rate of runoff causes erosion and siltation. All these factors have an adverse impact on the natural environment, leading to flooding and the pollution of water supplies and aquatic habitats.

> *"India's urban population is increasing rapidly and is expected to reach 550 million, or over 40 percent of the total population, in 20 years. Inadequate urban infrastructure and a deteriorating environment are constraining development and adversely affecting the quality of life. The annual cost of environmental degradation to the economy is nearly 5 percent of GDP. Of this, 60 percent is due to water pollution..."*
>
> Asian Development Bank, 1999

Uncontrolled drainage has an adverse impact on the poorest members of society living in marginal areas, such as low-lying areas that flood, or steeply sloping areas that are subject to erosion and flash floods. They may not have access to potable water and so have to rely on surface or shallow groundwater sources that are polluted. Poor drainage of rainwater can lead to the creation of breeding sites for disease vectors. Lack of political power and resources means that drainage infrastructure is not provided.

Conventional drainage systems are designed to just remove water from one area as rapidly as possible. However, this can lead to increased flooding, erosion and pollution at the eventual outfall. Urban runoff is very difficult treat at the end of the pipe, due to its rapidly varying quantity and quality. The rapid removal of runoff can also reduce the recharge to aquifers and disturb the natural flow regimes in water bodies. Conventional systems rely on pipes or channels, which have to be kept clear of blockages or flooding can occur. The pipes are relatively expensive, require skilled designers, production, construction and maintenance and capacity cannot be readily increased. Piped surface water is sometimes mixed with foul sewage (intentionally or through misconnections).

"Some cities in the developing world are already facing critical environmental degradation. This is the result of overload on water sources, improper waste disposal, contamination of rivers and streams, the reckless extraction of water from depleted aquifers... "

Maggie Black/ WaterAid

Conventional drainage systems are very focused, being designed to just remove water from one site, rather than taking a holistic approach dealing with pollution, downstream flooding and wider environmental impacts. Appropriate, community based methods (e.g. locally managed retention ponds) have not been widely researched or promoted.

In view of the problems with conventional drainage systems, alternative techniques have been developed. Called Sustainable (urban) Drainage Systems (SUDS) in the UK (Best Management Practice – BMPs in the USA and Urban Stormwater Management in Australia), this approach uses a different drainage philosophy. The aim is to maintain the natural characteristics of the runoff, both in quantity, rate and quality. Source control is advocated, involving pollution prevention, minimisation of directly drained areas and on-site retention and infiltration. If the site has limited capacity to control the runoff, off-site measures may be required, such as conveyance in swales, retention in ponds and infiltration in basins. If pollution cannot be prevented, local treatment using filter strips, settlement ponds or even constructed wetlands can be used. Despite the title, SUDS also have applications in peri-urban and rural locations, especially in the role of filter strips to protect watercourses from agricultural runoff. Flow control and pollution prevention at source is cheaper than conveyance followed by attenuation and treatment.

A UK scoping study and subsequent best practice report recognised the value of SUDS in combating flooding and the degradation of aquatic habitats and the positive role they can have in the urban environment (e.g. rainwater harvesting, wildlife provision, social amenity), but found that the main constraints were institutional and due to perception issues rather than technical problems. This research proposed to investigate the potential scope for using more sustainable approaches to urban drainage in low-income countries. It was envisaged that similar institutional and perception problems may occur when the technology is transferred to other countries. Preliminary research was required before large-scale applications could be promoted.

In pre-independence Uganda, gutters were prohibited on houses, to prevent mosquitoes breeding if the gutter was blocked. Instead, the rainwater fell from overhanging eaves onto the surrounding ground and soaked away

1.1.3 *Intended impacts of the research*

This project was limited to scoping the potential for SUDS as a potentially more appropriate form of urban drainage. Practical implementation of these concepts will be required before any potential direct impacts on the poor living in flood prone areas or using polluted aquatic environments for water and natural resources.

However, drainage schemes are not without their negative impacts, for example community participation does involve increased workload on the local population, before any benefits are realised. This is the reason for having a scoping study, to identify and maximise potential benefits and plan the implementation of SUDS around the needs of people, before advocating their use.

There are existing burdens on the poor, from flooding, pollution and environmental degradation, but the benefits of improved environment should not be outweighed by the costs to society – especially socially excluded groups such as women, who may be expected to take on much of the responsibility for maintenance. Issues such as this need to be resolved during the scoping study, balancing up the impact on each of the stakeholders before any practical projects are implemented.

This scoping study had no impact on the environment, as no implementation was directly carried out. Subsequent work in this area should have a net benefit through reduced pollution, reduced flooding and erosion and enhancement of natural drainage features, leading to reduced degradation of water resources.

Cross cutting themes

The environment and sustainability issues were at the core of this project. The goal of combating the degradation of water resources focused the project on sustainable, environmentally acceptable solutions to the problems created by poorly managed urban runoff. Involving stakeholders and placing institutional issues at the start of the project ensured that the socio-economic factors support the possible long-term implementation and operation of suitable technologies. Using drainage methods based on natural runoff patterns should work with the environment rather than imposing potentially damaging drainage techniques in urban areas.

Sustainability and socio-economic impact

The term "sustainable" in sustainable urban drainage systems is a relative measure. These systems should be more sustainable than conventional drainage systems in a variety of ways. The following overview uses a sustainable livelihood framework to indicate some of the ways in which these systems can be more sustainable than other options. Whilst it is not a definitive view of sustainability, it does indicate some of the areas that were considered.

Physical impacts

Man-made drainage systems have finite lives; they deteriorate over time, break and need replacing. They may even require replacement whilst they are still in good condition, as piped systems have a limited capacity and can become surcharged. Natural systems do need "refreshing" (dredging ponds, cutting wetlands) to restore them to full capacity, but these tasks are not as onerous as re-building a whole system. The construction and maintenance methods rely on simple techniques (pond digging, grass cutting/ animal grazing) rather than more expensive pipe laying, casting of concrete channels and sewer rodding.

Financial impacts

The use of labour-based construction and minimising reliance on (imported) materials can reduce the cost of SUDS drainage systems. The implementation can be carried out using a progressive, incremental programme, so spreading the costs over time. Conventional systems need to be completed in a single operation, or any drainage problem is only moved rather than solved.

Maintenance costs follow a different pattern for SUDS, compared to conventional systems. They require simple, regular basic maintenance (such as cutting grass), managed locally, rather than occasional, expensive repair and refurbishment by a central authority. This fits in better with the cash flow of poor communities. Another positive feature of source control is the inherent “polluter pays” – if source controls are not maintained, the local area will be flooded, rather than piped systems, where lack of integrated design impacts on people downstream. Source control can promote expenditure on maintenance by those best placed to carry it out.

Social impacts

Source control techniques are a technical example of subsidiarity – where responsibility is devolved to the most local level that is reasonable. This puts the power into the hands of the community, rather than having to rely on external powers. However, many flooding and pollution problems arise due to poor drainage practice upstream. Therefore, a key stakeholder will be the municipal engineer with responsibility for drainage in all areas. The institutional aspects of this person’s role are seen as an important component in implementing SUDS. This is likely to be a weak link in the complex matrix that affects the sustainability of the drainage systems and it is in this area that the research will initially focus on.

Human impact

Sustainable urban drainage systems do not require such high levels of skill to design and construct local drainage features as conventional systems. Simple source control techniques can be implemented at the householder level, whilst larger site control methods can use labour intensive construction more readily than engineered pipe systems. Designers do not need complex computer analysis to design a system, but can enable a drainage system to evolve, choosing from a palette of control techniques.

Maintenance of piped systems does require skills and specialist equipment to prevent and remove blockages. Open channels are an improvement, but repairs and extensions do require technical expertise. Natural drainage methods can be understood more readily and so can be monitored, maintained and refurbished without relying on highly trained personnel.

Natural impact

SUDS require lower material inputs to construct the drainage system (e.g. limited use of pipe work, concrete). The construction techniques also require lower inputs. Wetland habitats that may be destroyed by conventional drainage systems should be conserved for their potential contribution to the drainage system. The multi-faceted aspects of SUDS (controlling water quantity, quality and environmental impact) have more potential for environmental protection than conventional systems that only control water quantity.

Some of the initial drivers for SUDS were related to improving the impact of drainage systems on the natural environment. These include reduced pollution and erosion, as well as maintenance of natural flow regimes. The opportunity for environmental enhancement and restoration of depleted wetland environments adds to the value of SUDS.

The emphasis on local control, decentralised management, low-costs, naturally occurring processes and readily understood techniques gives SUDS a greater resistance to shocks and a greater adaptability to trends and seasonal variations than more conventional techniques. They do however require institutional processes and structures to support and encourage their uptake.

The sustainability and socio-economic issues are therefore integral to the implementation of SUDS and so have to be addressed throughout the report, rather than treating them as a separate issue. The wide variation in sustainability and socio-economic issues outlined above necessitates a multi-disciplinary approach.

1.2 Research methodology

Research approach and methods

Due to the scarcity of work on urban drainage and sustainable urban drainage in low-income countries in particular, this project will research the broad scope for the use of SUDS techniques under such conditions, rather than specific applications. Methods to explore the scope included:

- a review of existing literature
- a series of stakeholder workshops, focussing on municipal engineers, planners and those working in urban upgrading projects in low-income areas, as well as environmental protection staff
- a series of semi-structured interviews based on field situations
- an examination of the planning and regulation issues relating to urban drainage.

These activities were carried out in contrasting situations, both from a climatic/hydrological point of view and from an institutional/ planning perspective. They were designed to find out whether the main implementers of urban drainage projects see if there was potential for more sustainable approaches to runoff management and, if in their view, these systems would improve the livelihoods of those who may benefit from such schemes.

Background to research approach

The reason for commencing this research with a scoping study was to examine the potential for using more sustainable methods in urban drainage. This research identified opportunities for further work, and has recommended possible future activities. Sustainable urban drainage systems (SUDS) are not a new technology or system, but their use has not been widely promoted in low-income countries. Many of the issues that relate to their increased use are not directly technical, but educational, institutional, managerial or related to issues such as ecology or maintenance. The study will identified constraints to the application of such systems and recommends priorities for work to overcome these potential barriers.

Similar research in the UK adopted the following pattern.

- A scoping study looking at the technical, legal and planning issues around the need and potential for the local control for urban runoff and proposals for further work (CIRIA 1992 and again in 1996)
- Video on natural drainage techniques (IAWQ 1996). Promotional material for construction and planning professionals (Scottish Environment Protection Agency/ Environment Agency)
- Documentation, analysis and promotion of construction projects that are using sustainable urban drainage techniques (CIRIA commenced 1998 and on-going)
- Report on best practice in the technical design of these drainage systems (CIRIA 2000) and best practice in the planning, implementation and management of sustainable drainage systems (CIRIA, 2000).
- Detailed research on pollutant mobilisation, financial aspects of maintenance, design details, implementation (various, on-going)

In terms of this research, the pattern of development of SUDS moved from concepts to details, with an early emphasis on education, dissemination and involvement of stakeholders. Regulators and researchers were actively involved from the start, but the concerns of practitioners (designers, developers and planners) had to be identified, addressed and disseminated before any real progress was made. Although technical professionals raised many of the initial questions, the wider and longer-term concerns relate to the managers of urban drainage e.g. planners and municipal engineers.

Learning the lessons from this past experience, the scoping study looked at the development and dissemination of educational and promotional material for different stakeholder groups (e.g. training packs for municipal engineers, support information for PRA activities). Technical, institutional and socio-economic studies may be needed to address specific issues identified in this initial study, especially where the experience of developed countries is not relevant.

Risks and Assumptions

There is a risk that SUDS are not appropriate for low-income countries at the moment. The influence of institutional and legal issues from the experience in the UK show that, although the systems may be appropriate technically, additional work may be required before they can be widely promoted. However, from this small and concise project, it would seem that this alternative approach to urban drainage has the potential to be used on a wider scale.

Collaborators

The project worked in partnership with municipal engineers and planners in Uganda, Brazil and Vietnam. These individuals are seen as important stakeholders in the process of planning, designing and managing urban drainage. NGOs and consultants working on urban improvement projects involving urban drainage will also be invited to take part in the workshop, in order to gain insight into the challenges of working in low-income areas.

Focus of research

The work looked at practical issues, rather than theoretical perspectives. The literature review focused on readily available material, to glean best and current practice rather than the most recent analytical theories. Implementation of drainage was examined primarily from the viewpoint of an engineer/ technician working in small towns of low-income countries.

Target institutions and beneficiaries

Primary target institutions are at the municipal level (local government, NGO or private organisations providing public services), because they have the main responsibility for management of urban drainage. The municipal engineers and planners will benefit from having an alternative method of managing local drainage in a more sustainable fashion. They need the support of professional development organisations, so educational and professional institutions were involved in the project. In the UK study (CIRIA,2000), the water and sewerage undertakers had less of an involvement than local government, planners and highway organisations, although it was initially assumed they had a key role.

Secondary stakeholders were environmental protection agencies and water departments responsible for combating the water degradation. SUDS are being used as a regulatory tool via the planning process in the UK.

The ultimate beneficiaries should be the poor who experience the problems associated with poorly managed urban drainage and the resulting degradation of water resources. The application of the outputs from this work should lead to positive impacts on the sustainable urban livelihoods for the poor.

Poverty issues

Improvements in urban drainage have direct impacts on the poor, as the more affluent members of society have the option to move to less flood prone or polluted areas or flood proof their homes, e.g. through raising the ground level. By improving the environment of poor urban areas, adverse impacts on the livelihoods of the poor can be reduced. The poor bear the brunt of bad drainage, through direct flood damage, pollution of water supplies and the aquatic environment, the breeding of vectors and soil erosion, leading to direct financial costs, loss of income potential, as the home may also be the workplace, and adverse health impacts. These problems can be exacerbated as the poor often live on unsuitable sites (low-lying and flood prone or steep and unstable), have high-density housing (increasing the impermeability of the ground), poor urban planning and control and lack of investment in urban infrastructure. SUDS cannot address all these issues, but have the potential to provide a low-cost, sustainable, integrated solution to urban drainage problems using cheap, locally based systems.

Participation and the poor

The technology options for SUDS mirror the choice between on-site and sewerage in the provision of sanitation. The SUDS drainage technology can be implemented and maintained by the householder. The other key stakeholder is the municipal engineer or planner. From the UK experience, the major barriers were at the municipal level, and so this area formed the initial area of study. As the report has a poverty focus however, representatives of people working with the poor were included (e.g. NGOs working on urban upgrading and slum improvements). The state of knowledge and the resources for this stage of the work did not allow for any in-depth participatory analysis. Previous work by Stephens et al (1994) noted that:

"Flooding was ranked low in comparison to other risks and problems, such as improvements in job opportunities, provision of housing, mosquitoes and smelly back lanes.

A major concern mentioned by the residents related to the predictability of the flood event. Interventions aimed at ameliorating the effects of flooding should try to take account of these needs of the community to understand and adapt their coping strategies.".[1]

[1] Quoted by Kolsky et al in "Low cost sewerage" ed D Mara, 1996

Involving low-income communities in an abstract manner at this stage was not seen as productive as more in-depth, participatory work when the subject has been examined in more depth.

1.3 Dissemination and uptake strategy

The dissemination strategy was developed as part of the project and be related to the demands of the potential users. Any major dissemination will take place in a subsequnet project as such an exercise can only be started once the main issues have been identified, which is the aim of this scoping study.

However, in order to produce demonstration sites for subsequent evaluation, some SUDS will need to be implemented. The scoping study produced information of interest to practising drainage engineers. The results will be distributed at an institutional level within the countries where the work is carried out, as well as via DFID advisors, WELL and the WEDC conference. Targeted, early dissemination includes the project workshops, a low bandwidth website and the production of information and training material suitable for municipal engineers, in a distance learning format.

2. Urban drainage

This chapter briefly introduces some of the principles, practices and problems of urban drainage. It only provides an introduction to some of the disparate issues involved; for a more detailed discussion of the issues see the first parts of the training material prepared under this study.

2.1 The need for surface water drainage

The problems poorly managed runoff causes include:

- small floods damaging roads and buildings, causing disruption to lives and businesses
- pollution from overflowing latrines and sewers, causing faecal pollution and disease
- cross contamination of water supplies
- wet soils leading to ideal conditions for worm infections
- providing habitats for vectors (mosquitoes and snails)
- water pollution from diffuse sources (rubbish, animal faeces, air pollutants)
- erosion of watercourses
- siltation of watercourses
- inconvenience (wet feet in puddles)
- safety (physical danger of being washed away)
- landslides. [Kolsky 1998, WHO 1991]

These issues have adverse impacts on a variety of resources people use, such as:

- human (health)
- natural (water and the aquatic environment)
- financial (disruption to business, low property values)
- social (disruption to communications)
- physical (erosion and structural damage).

2.1.1 Flooding

Runoff occurs naturally and varies in quantity according to the frequency and intensity of rainfall, the impermeability of the land and the condition of the land when it begins to rain (e.g. saturated). Flooding can be divided into two categories;

- flooding arising outside the immediate area
- local flooding.

External flooding is confined to the flood plain of the watercourse. The extent of the flood plain will vary from year to year with the quantity of water coming downstream. Often a regular seasonal pattern will be apparent. Long-term changes to the catchment can alter the size and the frequency of flooding. This type of flooding can be managed by:

- building conventional engineered flood defences;
- preventing the development of the flood plain, allowing the river to flood naturally;
- adapting infrastructure and livelihoods to cope with inundation (e.g. raised pit latrines); and
- managing the catchment upstream to reduce the frequency and severity of flooding.

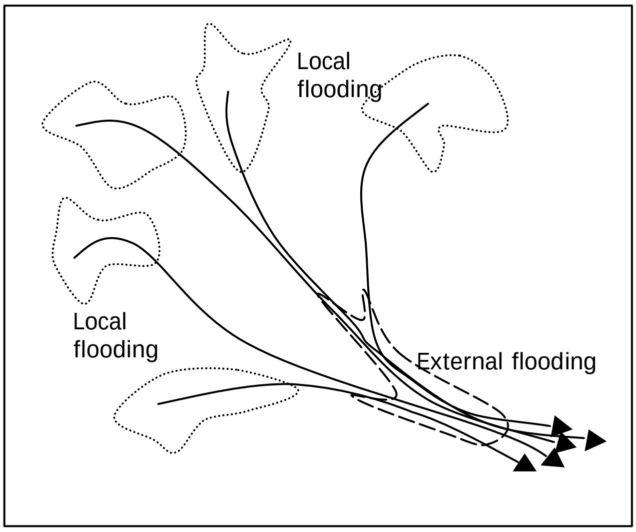


Figure 1 Flooding

Local flooding is not confined to the flood plain. It will vary considerably in terms of location, duration, frequency and intensity. It is made worse by the paving or compaction of ground, reducing the capacity of the soil to absorb moisture and by actions upstream, such as inappropriate drainage provision. The division between external flooding and local flooding is not precise; as one person's local flooding will become somebody else's external flooding further downstream. External flooding will be on a greater scale than local flooding.

2.1.2 Drainage systems

Historically surface drainage and foul wastewater drainage have been collected and disposed of together. This leads to problems of both the large flow volumes involved and the rapidly varying quantities and qualities of the water. By keeping them separate, the "clean" surface water can be disposed of without treatment.

For a fuller discussion of the historical development of urban drainage, see Training Paper no 3, *A short history of urban drainage*

2.2 The problems with conventional systems

2.2.1 Flooding

The focus of conventional drainage design is to remove as much water as quickly as possible. Eventually this will have to discharge to a watercourse. The drainage system increases the flow rate and the volume of flow. The flood peak will arrive sooner in an urbanized catchment and have a shorter but more intense duration. This can lead to flooding and erosion problems downstream of the discharge point.

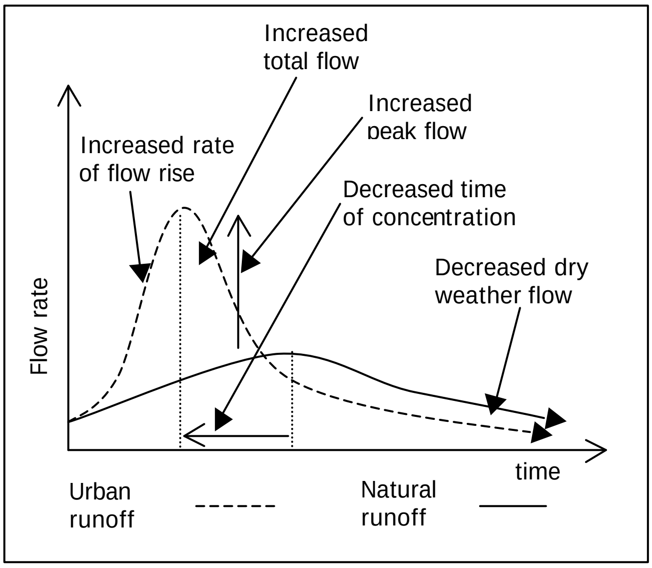
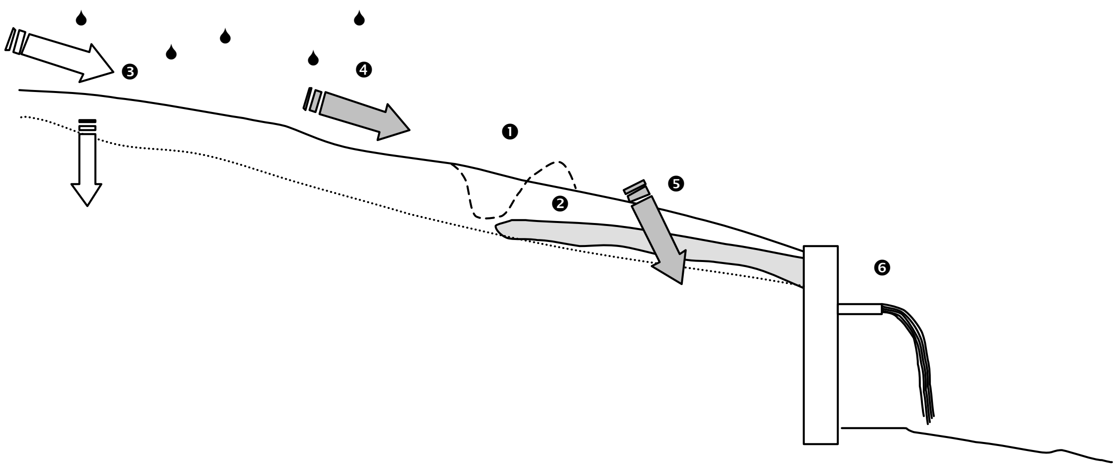


Figure 2 Impact of urbanization on a storm hydrograph

2.2.2 *Water quality*

Conventional approaches to urban drainage concentrate on draining water; the quality, as opposed to the quantity of water, is less of a priority. However, the increased flow rates enable the runoff to carry a sediment load causing erosion at the top of the catchment. This sediment is not just soil, but any solids and liquids deposited on the ground. Thus litter, oil spills, excreta (animal and human) and particulates deposited from air pollution (e.g. from car exhausts) all end up being transported by surface runoff. This will eventually be deposited, leading to siltation and blockages downstream. This leads to a "plug" of concentrated pollutants washing downstream, causing environmental damage and pollution of water resources. Conventional approaches to treating this polluted flow, even if funding was available, are limited technically by the nature of the pollutants and the variation in flows and pollutant loads.

Pollution of protected springs.



Best practice in the construction of protected springs is to dig a ditch upstream of the spring ❶, perhaps with a low bund (ridge), to direct surface water round the spring. A layer of clay is placed above the eye of the spring, to stop surface water infiltrating the soil and reaching the spring ❷. Rain falling upstream percolates into the groundwater ❸, and travels slowly through the ground to the spring. Overland flow will pick up pollutants, including faecal material ❹. If the diversion ditch and clay cap are not there this surface water can infiltrate directly into the spring ❺. The distance to the spring outlet ❻, will be too short to remove the contaminants, leading to a polluted and potentially dangerous water source.

Figure 3 Spring pollution by surface runoff

Despite the accepted relationships between diseases such as cholera and the on-set of rainy seasons, the role of floods, local or large, is often left out of the classic "F" diagram, linking faeces to people.

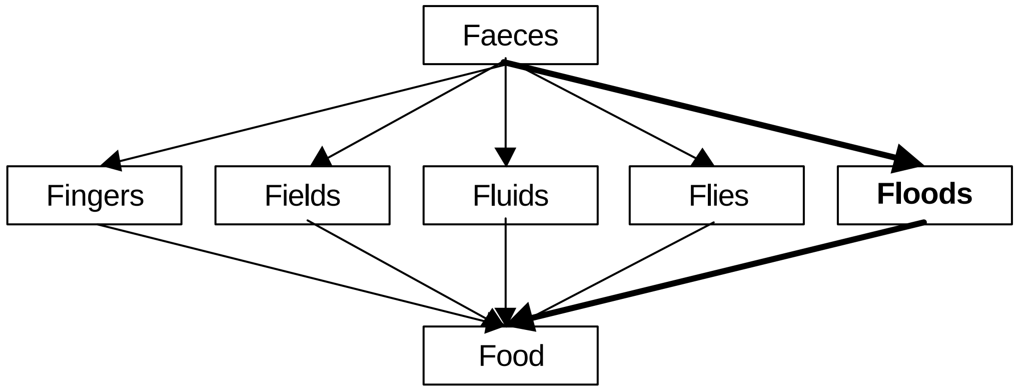


Figure 4 Routes of disease transfer

2.2.3 Water resources

Water is also a value resource. If it is polluted and allowed to flow away, it cannot be used by people (e.g. for water supply) or the environment (e.g. replenishing wetlands). The increase in impervious surfaces reduces the infiltration to the ground and subsequently reduces the replenishment of aquifers. Conventional urban drainage based on removal of water is therefore the opposite of rainwater harvesting approaches. This resource may be used for a variety of uses, from practical domestic and industrial water supplies, to supplying urban rivers and lakes with water and thus supporting the associated environmental, recreational and cultural uses of water bodies.

2.2.4 Management

Besides the technical problems, drainage systems do need resources to design, build and maintain them. Conventional systems are interconnected and complex and require a relatively high level of design expertise. Computer modelling may be able to optimise the design, but require large amounts of detailed topographical and hydrological data. Piped systems are also prone to blockages and need to be surveyed and cleaned to maintain their effectiveness. The use of pipes will be prohibitively expensive for low-income communities, due to the design, capital and maintenance costs. The issues of flooding, road drainage, water quality, environmental impact and the range of competing uses for the water do not fall under the same institutional jurisdiction.

2.2.5 *Expanding cities*

Cities are not static entities. They grow, land uses change and property values rise. This is particularly true for cities in low-income countries. Increased urban growth upstream and downstream of a drainage network requires that network to be extended. Adding to the network at the upstream end of the piped system adds to the volume of water drained by the drainage system and all the downstream pipes are now expected to carry higher flows. The extra water may come from either an increase in catchment size as natural drainage paths are altered, or due to an increase in runoff as existing catchments change from green-field, to semi developed to finally and high proportion of impervious land use. This means that the whole drainage network downstream of the newly built area will have to be upgraded to take account of the increased runoff and pollution ➊. Adding to the top of a drainage system will lead to flooding from the drainage network downstream unless preventive action is taken.

The increasing size of the town or city will also increase the impact on the receiving watercourse. Eventually the impact will be too large for the existing stream or river to cope with and either the water will have to be conveyed further downstream to a larger water body ➋ or the watercourse incorporated into the drainage system.

Lengthening a network at the downstream end will also be needed if urban development takes place below existing drainage outfalls. This will move the flooding and pollution that occurs at the end of the pipe further from the expanding urban area ➌, but each extension will compound the flooding problem as larger and larger pipes and culverts are required

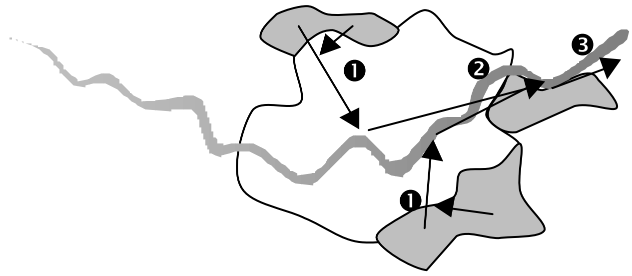


Figure 5 Expanding urban areas

Urban growth

Flooding in Buenos Aires has been identified as not being due to the weather – even with climate change, but inadequacies with the drainage system. A well-defined natural drainage system was culverted and supplemented by a conventional drainage network, but over 50 years the city grew and surface runoff exceeds the system's capacity.

New Civil Engineer, 4/12/2003

2.3 Adaptations for low-income countries

Environmental sanitation in low-income countries tends to focus on excreta disposal, with solid waste management and surface water control being given a lower profile. It has long been recognised that piped sewerage is not an option for the majority of populations in low-income countries, with on-plot pit latrines and septic tanks offering alternatives. This still leaves the issue of disposal of sullage and the management of surface water.

Adaptations can be made to conventional drainage practice to reduce some of the problems. Open channels can be used, to reduce the risk of blockages and make the inspection and the removal of debris easier. Lining the channels can reduce scouring and erosion within the channels. Open channels are easier to build and maintain than piped systems, so local men and women can be involved in the construction process. However, open channels can still become dumping areas for solid waste and the underlying design philosophy is still the rapid disposal of water. How urban drainage fits institutionally is also a challenge that is unresolved, along with issues of cost recovery.

The use of open channels does provide a cheaper method of flood control, but, just as with conventional separate drainage systems, they do not address the problem of water quality, a problem compounded in low-income areas in that surface water drains also provide a disposal route for sullage.

2.4 Alternative drainage methods

For to a variety of reasons, alternative methods of managing urban runoff have been developed in the USA, Australia and Europe. These are variously termed “Best Management Practices” (BMPs), source control, or “Sustainable Urban Drainage Systems” (SUDS). These methods use a series of engineered structures and management practices to control urban runoff in a more sustainable and environmentally responsible manner [Andoh 1994]. Components include:

- the prevention of pollution and the minimisation of impermeable areas
- the use of permeable surfaces for hard paving
- the use of infiltration devices such as soakaways
- the conveyance of excess runoff off the immediate site using very gently sloping unlined channels (swales)
- the local attenuation and treatment of runoff in basins, ponds and wetlands.

The concepts behind this approach are to replicate the natural flow regime so the storm hydrograph resembles the pre-development pattern. Prevention of flow and pollution arising in the first place is favoured over its treatment and subsequent management. Local solutions (source control) is favoured over dealing with the runoff elsewhere.

2.4.1 Benefits

The variety of benefits that SUDS can provide include:

- better management of the quantity of runoff
- groundwater recharge
- wetland recharge
- reduction in flooding
- reduction in erosion
- increased river baseflows
- better management of the quality of runoff
- reduction in pollution of surface and groundwater
- reduction in siltation
- better use of runoff as a resource
- rainwater harvesting
- ecological use

This range of benefits is extensive, with additional issues, such as reduction in irrigation for gardens, improved productivity of aquatic habitats and aesthetic value of water features being important to specific stakeholder groups. The multiple functions can lead to a lack of an institutional “home” for the drainage system. Drainage authorities managing an engineered system may not have the resources, skills or motivation to manage a natural resource. Is managing drainage for rainwater harvesting a drainage issue or water resource issue?

Low-income countries benefits

In addition to the benefits listed above, SUDS have characteristics that may make them suitable for low-income countries. The construction relies to a large part on simple earthmoving (pits for soakaways, basins for ponds, shallow ditches for swales). These can be constructed using labour-intensive methods and do not require any high levels of skill, beyond setting out.

SUDS do not depend on expensive (imported) materials such as pipes, gullies and concrete, so do not rely on extensive supply chains and foreign exchange.

In some areas, SUDS may be able to be constructed solely with contributions of labour and natural materials such as stones.

The focus on preventing problems at source, rather than curing them downstream, makes SUDS design very dependent on the locality. It is best managed at this local level. This ties in with ideas of de-centralisation and subsidiarity, putting the control in the hands of the people best situated to carry out this role. This is reinforced by the principle of polluter pays, as failure of source controls such as soakaways will affect people in the immediate area first.

The focus on source control also puts an emphasis on controlling the drainage in the areas around people's houses. This not only has better impact on malaria control, but will support community-based approaches to implementing SUDS, as the action and results will be local.

2.4.2 Barriers

A series of research projects managed by the UK Construction Industry Research and Information Association (CIRIA) has looked at the potential for using sustainable urban drainage systems and the reasons why they are not widely used. These broke down into three main areas:

- lack of design information
- reluctance to pioneer alternative drainage methods
- institutional issues.

The first issue has been addressed by a series of design manuals from CIRIA and a number of research projects where industry, the environmental regulators and research institutions are collaborating.

The second issue is the subject of dissemination activities from the regulators and CIRIA, using demonstration sites, case studies, videos, booklets and working with the professional engineering institutions to discuss SUDS at seminars and conferences. Overcoming the inherent conservatism of engineers is difficult as SUDS are site specific and do not translate well into standard designs or simple design methods. Each individual design component (basins, soakaways etc.) are well understood by engineers but the different elements need to be combined.

The third issue is proving to be less straightforward to address directly. SUDS are not sewers and so the legal and institutional framework that has developed to manage the *quantity* of water flowing along pipes does not necessarily transfer to issues of environmental impact.

Low-income countries barriers

The same barriers to the wider use of SUDS encountered in the UK occur in developing countries. These are compounded by lack of resources for research, dissemination and promotion. The institutional barriers are reinforced by the apparent low-priority placed on drainage problems. Water supply and sanitation are important issues. They are normally tackled directly, rather than taking a wider view of the problem. Thus polluted water sources are used for drinking after expensive treatment, rather than preventing the pollution. Pit latrines in areas that experience flooding are raised, rather than addressing the control of the runoff. Solid waste in drainage channels requires the drainage channels to be cleared, rather than the solid waste problem addressed first.

The lack of focus and multidisciplinary nature of the drainage systems disperse the motives for applying SUDS. One key institution in the UK has been the planning system. However the planners have little motivation or understanding of drainage problems. This is likely to be compounded in areas where planning controls are weak. Conventional drainage systems are complicated to design [Bhattarai and Neupane, 2000], so increasing the number of stakeholders is going to further complicate the process.

There are also technical issues that are unique to developing countries. The mosquitoes that transmit malaria breed in clean water so urban drainage have more health implications than in industrialised nations. Drainage of clean water will have a bigger impact on malaria reduction than drainage of polluted water. However preventing pollution and building balancing ponds may create ideal habitats for their larvae and so their detention times will need to be designed so the basins dry out before the larvae have time to mature (one week or less).

The whole issue of sullage disposal is another factor that has to be considered. SUDS, whilst incorporating treatment systems, are not necessarily designed for the higher levels of treatment required to cope with sullage. However, in the absence of any other disposal route, the surface water drain will carry sullage, either directly or indirectly. An emerging issue in some locations was the disposal of urine from dry ecological sanitation latrines; in the absence of any other convenient disposal rote, surface water drains are used to dispose of excreta.

The project looked at these barriers to see if there is scope for using SUDS. The people who are most closely involved in any implementation are municipal engineers. The consultation started with these stakeholders, before discussing the issue with other related groups, who may not be so aware of the technical and institutional issues, such as planners, community groups and environmental regulators.

3. Comments on research activities

This chapter provides an overview of the state of drainage and non-drainage literature. A fuller study of the drainage literature is in the literature review. The chapter also provides an overview of the work carried out in the three countries that were part of the study. Full reports of the workshops are available

3.1 Reviewing the literature

The current information on urban drainage for low-income countries is very limited and is mainly restricted to variations on conventional systems. The main work is “Surface water drainage for low-income countries” (WHO/UNEP, 1991), which deals with many issues, with open channels being promoted rather than pipes. This is an improvement on conventional systems from a construction and maintenance point of view, but still leaves the problems of “end of pipe” flooding and pollution.

In “Sustainable urban drainage systems – best practice” (CIRIA, 2001) the benefits of SUDS are set out, along with some of the barriers to implementation. This publication does note the advantages for low-income communities (low capital cost, gradual implementation, labour-based construction), but primarily examines the UK situation. It notes the importance of institutional and socio-economic issues in the development of SUDS. Other works from the US and Australia have demonstrated its use in a range of climatic conditions, but within an industrialised country context.

Institutional and promotional experience can be compared with on-plot sanitation versus sewerage systems

3.1.1 Drainage literature

The literature review set out to look at information that is available at a practitioner level, rather than the latest academic journal papers. It set out to concentrate on the issues and current practice, successes and failures, rather than theories. It concentrated on low-income countries and methods that were applicable to those situations, such as dealing with lack of data rather than information intensive computer models.

The drainage literature is reviewed in the literature review, but some issues can be highlighted. Problems with the existing drainage techniques are not disputed, though solutions may be more debateable. The literature on drainage in low-income countries is extremely limited, and often technical, with hydrological approaches being better documented than hydraulic issues. Some issues are very poorly covered, for example silt management in an urban context. The literature that does exist is not always in the correct format. Many of the people charged with managing drainage on the ground are at technical level or have to cover a wide range of municipal infrastructure services, such as roads and solid waste, so technical information should address their needs.

3.1.2 Non-drainage literature

Although it is not covered in much detail in the literature review, publications that relate to areas allied to urban drainage were also examined. What was most apparent was what was not written. The clearest example of this was the National Environment Report for Uganda, which recognised the problems of water pollution, but did not mention the impact of urban drainage, apart from limited runoff from solid waste tips. This is despite a well-recorded local literature of the impacts of drainage on local water bodies.

Similar lack of integration are apparent in the malaria literature, where the importance of drainage is recognised but the advice for engineers is either too general or in a format that focuses on another stakeholder group. An "engineering textbook" is lacking in this area, despite the wealth of information available in other formats for other audiences. In some of the malaria publications, solutions are proposed that would cause drainage problems elsewhere, so solving one problem would create others downstream.

This lack of co-ordination is widespread (for example documents on road drainage, water resources, emergency infrastructure and ecology all touch on drainage, without addressing problems in either enough detail or addressing the needs and concerns of all stakeholders.).

3.2 Country studies

As the initial (pre-contract) review of literature indicated very limited information on current problems, issues and practices, two (later three) workshops were planned to gain direct practitioner experience of low-income country urban drainage. This was to be coupled in two cases by extensive field visits to look at current situations.

3.2.1 Uganda

The visit to Uganda illustrated the importance of:

- Recognising the coping strategies of the poor,
- The level of capacity and the type of training required.
- Poor design details of conventional drainage aspects (such as screens and channel crossings)

Workshop

The workshop in Uganda was the most participative of the three workshops and included the widest range of stakeholders, although municipal engineers were poorly represented. The capacity and understanding of drainage issues was low compared to the to the other counties in this study. However, the discussion was more free ranging than in other workshops. The current decentralisation has given town engineers more responsibility, but their knowledge of drainage is limited.

Field work

The fieldwork concentrated on a low-income area in the north of Kampala and examined structural responses to the regular flooding that occurs in the area, as well as short visits to various “hot spots” around the city, looking at particular drainage problems and the current increase in maintenance. The main channel is currently being upgraded and this was examined along the whole length of the drain. The screens visited were all not only poorly maintained, but in most cases, impossible to maintain due to their design and location.

A visit to a small town looked at the adverse impact of blocked conventional drainage on the main commercial area. Interviews with the town engineer and chief administrative officer of the council showed both the lack of technical capacity and the skewed funding pattern (no funding for years but an “emergency” generated a “large cheque!”).

3.2.2 Brazil

The visit to Brazil illustrated the importance of:

- co-ordination with arrange of institutions,
- capacity building across sectors and
- cost-recovery that is equitable and sustainable.

Workshop

The workshop consisted of a series of papers from academics and representatives from national and local governments. The Brazilian experience demonstrated that, whilst there is a legal obligation to create municipal master plans, drainage is often not included and action is piecemeal. Conventional approaches often move the problem downstream.

Papers included looking at the links between surface water drainage and health, as this area is often given a lower priority when compared to sewage, water supply and solid waste disposal. An integrated approach was called for as, for example, the problems of operating two separate sewerage systems require close co-ordination between institutional authorities if cross connections are to be prevented. Integration is also required at a larger water resource level, taking a catchment wide focus and moving away from the traditional focus on point source pollution to wider spread diffuse sources. Town planning is a key activity in avoiding and addressing drainage problems.

Policies, political will and administrative boundaries constrain drainage provision, as does long-term access to financial resources. Cost recovery through specific taxation was proposed as a method of funding drainage, though those most in need of drainage provision are often those least able to pay and drainage works are often less viable than other urban infrastructure services. Long-term plans need to be supported by capacity building and technical support for all sectors. Master plans often fail in their implementation or are only implemented in limited, disjointed areas.

The conclusions of the workshop included the need to have a social understanding of urban populations and a supportive institutional arrangement, especially land-use planning. Co-ordination is required between urban drainage managers and

- providers of other urban services,
- town planners,
- water resources managers.

Whilst many technical options are available, questions about selection and local suitability indicated the need for more research and data.

3.2.3 Vietnam

The visit to Vietnam illustrated the importance of:

- Recognising the coping strategies of the middle income residents,
- The need for an integrated approach to urban wastewater management,
- The financial issues required to provide more than limited coverage of urban drainage,
- The range of alternative drainage procedures that can be used.

Workshop

The workshop was focused on municipal engineers, who are the key stakeholders in this area. The format was a formal conference, with papers being presented on a variety of related topics. The combined nature of the surface drainage systems, with high levels of septic tank effluent, meant that the discussion included significant foul sewerage issues. Indeed the paradigm of separate sewerage systems was seen as unobtainable in the short-term or medium term for provincial cities. Incremental approaches and more pragmatic models of wastewater management were contrasted to standard text-book approaches. Whilst many of the papers were technical, the highlight was a paper on runoff formulae that concluded with a quote from a love song that mentions what used to be a beautiful river and is now a concrete lined, black, smelly open sewer.

Field work

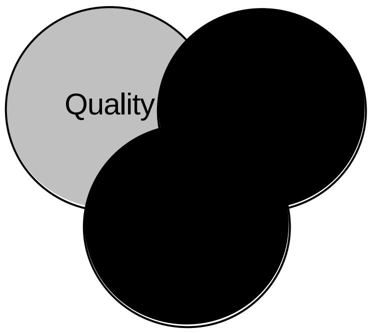
The fieldwork looked at two cities, Hanoi and the coastal port of Haiphong. Both cities suffer from prolonged flooding over several weeks. Interesting issues were the extensive use of urban lakes, the “combined” nature of the drainage system, with high loads of septic tank effluent entering the surface water system and the coping strategies of fairly affluent householders, living in an area that suffers from flooding over a prolonged period, requiring people to both raise the floor level of their houses and even live on the first storey during the larger floods. Hanoi had well maintained drains and plentiful evidence of regular street sweeping.

4. Analysis

This chapter summarizes some of the main issues raised during the research. As a scoping study, the project aimed to identify a range of issues that relate to urban drainage in low-income countries, rather than present solutions. This would require further work.

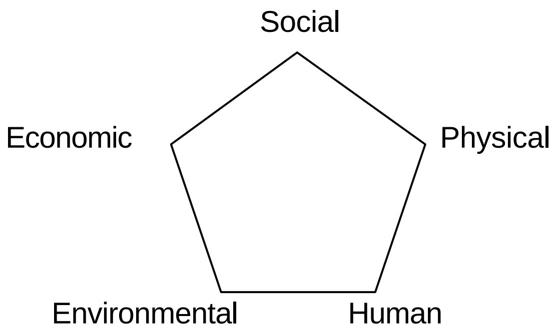
4.1 Research scope

The research stream under the KAR programme that this project is grouped under has a goal of "c*ombating the degradation of water resources".* However the problems associated with urban drainage are multidisciplinary. In the UK, the focus on water quantity (flooding) led to problems of water quality. More recently in Scotland, a tendency to focus on water quality and wildlife led by the environmental regulator played down the importance of flood control, which was the remit of local authorities. The work in the UK therefore adopted a model of balancing quantity, quality and "amenity" (water resources, wildlife, landscape issues).



Balancing the focus

For this research however, the "assets" used in the Sustainable Livelihood Framework have been used, to give a greater prominence to institutional and community issues.



A livelihood approach

This will not play down the importance of degradation of water resources, but put them in a wider context than just a water resources field. An alternative viewpoint is to take an Integrated Water Resource Management context, based on the work of the Global Water Partnership, but focussing geographically on urban areas, rather than a total catchment. In this context, water resource degradation is put into a fuller framework of institutional, social and economic issues, besides the limited technical approach of a water resources model.

For a fuller discussion of the social, economic, physical, human and natural impacts of urban drainage, see Training paper 4 – *The Impacts of Urban Drainage.*

4.2 Issues arising

4.2.1 The use of SUDS

The most significant finding in this scoping study is not that SUDS *may* have the potential for use in low-income countries, but that they are *already* being used successfully and therefore they are a technology that is suitable for use in urban areas of low-income countries. Many of these uses were not formal, but examples of all the drainage features were seen on the field visits.

In direct discussions at the Uganda workshop, the more “engineered” approaches, such as pervious pavements, were seen as requiring more work to examine their applicability and the availability of materials, whilst other techniques could be more readily implemented. Issues of maintenance and ownership were also raised – issues that are also current in the UK.

4.2.2 Coping strategies of poor communities

One area not highlighted in the literature (drainage or urbanisation) is the variety of coping strategies developed by people used to living in areas that flood regularly, many of which could be grouped under a SUDS category rather than conventional gravity drainage. These included changes to the local landscape using bunds and raising ground levels (going vertically “up”) rather than the conventional techniques of pipes and channels (going vertically “down”), due to the relative water levels. In areas that flood regularly, the local communities have learnt to live with the water, rather than seeking to control it entirely. This included a fairly affluent area of Hanoi that is inundated to a considerable depth (100s rather than tens of millimetres) for periods of weeks, yet the area is thriving.

4.2.3 Priorities for institutions

The importance given to urban drainage issues are mixed. The problems of pollution, flooding, impact on the poor and impact on the environment are all clear. The steps taken by the poor to mitigate those impacts locally are apparent. Official recognition of the issue however is fragmented, institutionally, spatially and over time. A field visit to Lugazi (a small town in Southern Uganda) clearly demonstrated these issues. The town council had allocated a large proportion of their funds to solve a flooding problem, but this was a “one-off” expenditure of USh 40,000,000/= (£13,300.00), rather than a regular budget line. The plan was to drain a business area that flooded (causing very significant economic losses) rather than provide drainage further upstream that was causing the runoff problem. The problem was being caused by lack of road drainage from the main road that ran through the town (which would be the responsibility of the national government).

Costs and benefits

At the Ugandan workshop, the issue of direct costs and indirect benefits was raised. The Lugazi example had clear direct benefits, so funds were being provided, but the protection of wetlands provides a “passive” service, i.e. economic costs are realised when the wetland is destroyed and these costs are borne by people who do not necessarily benefit from the development of the wetland.

4.2.4 Institutions

One of the problems met with in trying to assess the importance given to urban drainage was the spread of institutional responsibility, with no one organisation having a central role. In Uganda, the national environmental report only included a passing reference to urban drainage, and then in relation to runoff from solid waste disposal sites. Thus, whilst anecdotally and with reference to specific problems, a response to urban drainage problems is seen as vital, the lack of institutional home and an holistic approach leads to the issue being divided and dispersed. The conflict between institutional responsibilities and the requirement to take an integrated view require co-ordination and a common understanding that may be difficult to achieve. An example of this is the preparation of a drainage Master Plan for Kampala separately (and before) the preparation of a sanitation plan.

What drainage there is, is often road drainage or drainage of house plots. Once the immediate objective has been reached (draining the road or house plot), the runoff becomes an issue for whoever is downstream. As the problems compound downstream, the focus is on the location of the flooding or pollution, rather than examining the cause.

Political will, timescales and understanding are one of the causes of this institutional dilemma.

Learning from the past ...

re: the Nottingham cholera outbreak in 1832
"... Altogether there were 930 attested cases and 330 deaths. It was generally agreed at the time that the lower parts of the town had been the worst affected and that the higher streets, built on porous sandy rock, had been almost immune. It might be supposed that such a calamity would have driven home the obvious inference that the drainage and ventilation of the houses in the lower part of the town required attention; the town fathers, however, contented themselves by acquiring new burial grounds"

J.D. Chambers, quoted in "looking back" -
Environmental Health in Nottingham 1847-1983, by J D McDonald

Land rights

One aspect that appeared several times was the issue of land – land ownership, planning and space requirements. Land ownership is especially important in informal settlements where lack of land title and official recognition limit public investments (private, community, governmental or donor-led). As development (especially informal development) takes place rapidly with little or no planning and control, providing any urban service in advance is unlikely. Whilst providing water supply and electricity can be achieved in an unplanned settlement, road access may be more difficult (due to the need to remove buildings that block routes). Drainage paths are even more constrained than roads in that the water will have to follow the natural drainage paths unless expensive diversion works are employed.

Some drainage techniques (even channels) were seen as taking up too much land. Part of this is due to perceptions (SUDS literature often shows images of expansive wetlands rather than less photogenic soakaways) and also partly due to thinking very locally – a series of small drainage features at the top of a catchment, integrated into the urban landscape, may free up land further downstream that is flooded regularly. The dual nature of many drainage features (such as playing fields that can be used to store flood waters or a detention basin that can also be used for fishing) can alter perceptions of land use.

4.2.5 Design

Very limited material is available on designing drainage and it nearly all relates to the gravity systems developed in industrialised, temperate countries. Issues of sullage, silt, appropriate technology and downstream pollution are not widely covered. The diversity of design criteria (such as protection of downstream water resources) receives less prominence than removing floodwater rapidly. The design of large primary and secondary drains has more coverage than local tertiary drainage. In the Uganda workshop, a general lack of sufficient drains, whatever the design, was noted.

Many of the design approaches assume the concept of separate wastewater flows (with excreta disposed of elsewhere), but this belies the facts of sullage disposal (especially in low-income areas), indiscriminate defecation, general pollution of ground surfaces, erosion and overflowing on-plot sanitation facilities.

Appropriate technology

Engineers do alter standard drainage practice to adopt more appropriate technologies, such as the use of channels rather than pipes, and the use of lower design criteria (such as designing for floods with a recurrence interval of six months rather than two years. Flooding will still occur, but the frequency will have been reduced; this compromise may be acceptable where funds are limited). The design focus however is still moving rather than remedying the problem and does not address issues of pollution.

Training needs

It is apparent that levels of knowledge, understanding and the awareness of the range of issues involved in drainage were low, especially with general municipal engineers. It was also apparent that conventional training courses are less likely to be available to such staff, so a distance-learning and text book/ guidance manuals would be of more use.

Data

Current design methods rely on detailed information on rainfall intensity and duration (i.e. storms that last an hour, rather than an average for a whole day) over several years. Whilst average rainfall data is useful for meteorological and large-scale hydrological information, it is of less use for calculating runoff in small urban catchments. Design methods have to be adapted to cope with less data and under- or over-design is likely.

Malaria

Whilst there is some information on environmental management to control vectors such as mosquitoes, little appears to have been written recently by or for engineers. Personal communication with a researcher[2] on a USAID funded community-based project on mosquito control identified a “lack of interest” on behalf of drainage engineers as being the barrier he was experiencing.

4.2.6 Water resource degradation

Pollution

The impact of urban drainage on water resources is not contested. Whilst data from the England and Wales may not be available, information from Uganda is extensive and well studied. The field trips all provided evidence of faecal contamination (just from the smell!) as well as the presence of litter and other debris. The silt problem, though obvious, was not covered in as much detail in the Ugandan academic literature as the studies were from a public health perspective, looking at faecal and chemical pollution, rather than more physical parameters. Sources of pollution were both diffuse and point sources. In the case of Kampala this pollution has direct impacts on public water supplies, as the storm water discharge from the greater part of the city is upstream of the water supply intake.

[2] Professor Steve Lindsay, Chair in Disease Ecology, Institute of Ecosystems Science, University of Durham, working on a project in Uganda.

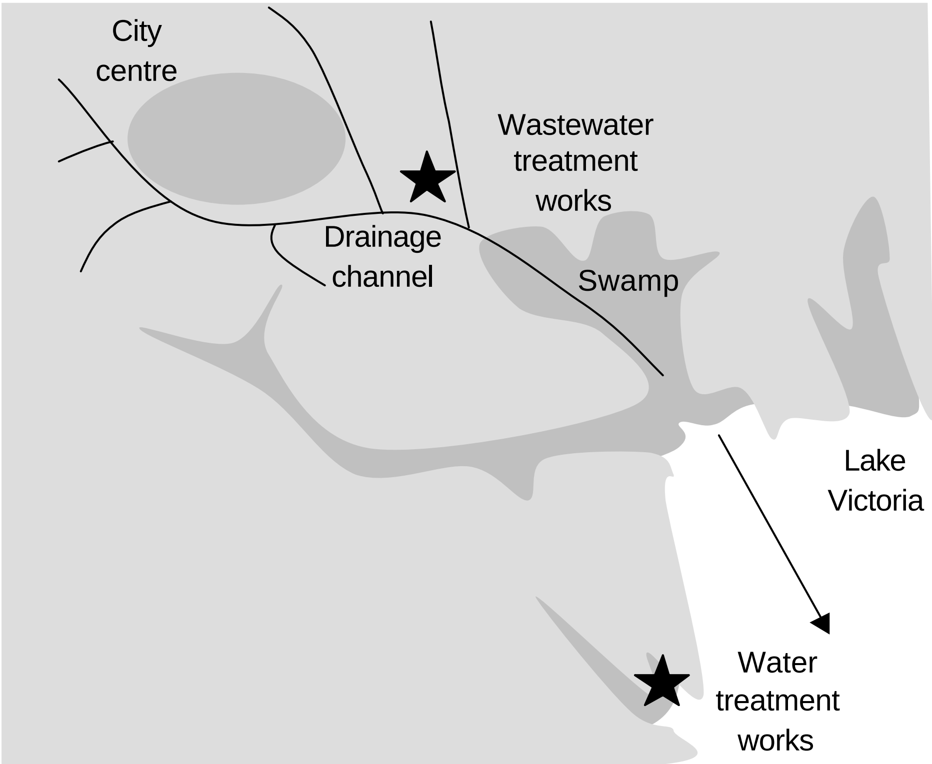


Figure 6 Relative position of stormwater channel and water supply intake

On a smaller scale, work in Uganda on groundwater pollution of urban springs found evidence relating to increased pollution of springs after rainfall, indicating a strong influence of stormwater flows on contamination (as opposed to pollution directly from nearby pit latrines).

This pollution issue was understood, but different organisations are responsible for water quality and urban (road) drainage and these respective bodies had different priorities that were not shared.

Change in flow rates

A parallel concern to the loss of a water resource through contamination is the loss through flow changes, such as increased runoff at the expense of groundwater recharge. None of the areas investigated was particularly water stressed in terms of groundwater resource quantity.

Rainwater harvesting

One water resource issue that does however relate to stormwater drainage is rainwater harvesting. This takes a different viewpoint of rainwater being an asset rather than a waste. Thus a lack of rainwater harvesting facilities is a resource failure and this lack of use of a resource has parallels to the degradation of the resource through pollution and neglect.

4.2.7 Solid waste

The available literature concerning low-income country urban drainage indicates the adverse impact of poor solid waste management. This was not supported during the field visits in both Uganda and Vietnam. Solid waste was present in the drainage channels, but the problems of blockage stemmed from poorly designed screens of drainage channels, that were not, or more often, could not, be maintained. It is a very "visible" problem, but the vast proportion of solid matter in the channels was silt, rather than litter. What litter, especially plastic bags, does blow into the channel (there being little evidence of deliberate dumping), tends to block screens and then cause localised flooding.

Site visits in India (not part of this study), did indicate a larger problem with solid waste, but this was a result of more solid waste in the environment, rather than a specific drainage issue. Recent legislation in Bangladesh has addressed this issue directly, with the use of light plastic bags being banned in Dhaka, due the adverse impact they were having on the city's drainage system and leading to flooding. This approach appears to be working.

Specific research on this issue, from South Africa[3], emphasizes that the solution is one of proper solid waste management, rather than trying to sort out the problem in the drainage system. All the available screens have their limitations and require constant support. The issue therefore moves from being a technical problem of screen to design to a more complex institutional problem, with interagency co-ordination and liaison.

4.2.8 Silt

As mentioned above, the main component of solid matter observed in urban drainage systems is silt. Rapid development results in large numbers of construction sites and trenches for utilities – significant sources of pollution from silt. Coupled with unbound roads, poorly maintained or non-existent silt traps and gullies, this leads to significant quantities of silt in the drainage system.

The majority of maintenance activities observed during both field visits centred on silt removal. Hanoi has an impressive number of (female) street sweepers removing debris from the streets, but the channels were still needed to be de-silted. Reductions in the amount of silt being generated from construction sites, road works and unbound roads is unlikely in the short term (and is still the subject of debate and research in the UK) so improved maintenance techniques will be required. This was illustrated in Kampala, where a dry swale in the centre of a main road was being de-silted with relative ease, whilst a flow-

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[3] *The removal of urban litter from stormwater conduits and streams,* Armitage, Rooseboom, Nel and Towshend. WRC, South Africa (1998)

ing drainage channel was taking considerably more effort, expense and inconvenience to the workers.

4.2.9 Maintenance

Maintenance of drainage was observed on the field visits (although some of this was reactive, responding to flooding rather than proactive and planned). The majority of this work was on silt removal. Better management of the silt in the drainage system should improve the operation of drains. Screens did appear to be very poorly maintained, but the cause was probably partly due to the poor design that meant they could not easily be cleaned.

5. Conclusions and recommendations

There are three issues that are of particular significance. These are:

- Institutional environment and policies
- Co-ordination and design criteria
- Technical concerns.

The recommendations centre on advocacy and dissemination of information.

5.1 Institutional environment and policies

5.1.1 Priorities

Urban drainage has a low priority, only gaining recognition when something goes wrong, such as cholera outbreak or significant flooding of property. Research into why this so would enable the development of targeted advocacy materials to educate and inform the various stakeholder groups involved. Within drainage design and management, the priority needs to shift from solely looking at flooding to encompass a wider range of issues.

Financial arrangements

Whilst the need for urban services to be independent of subsidy is seen as the only sustainable way forward, public funding for public drainage does appear inevitable. This however leads to reactive spending plans, with allocation of funds based around crisis management rather than long-term integrated planning. Policy makers and politicians need to be more aware of the benefits of well-managed urban drainage and the wide range of issues it encompasses.

Designers need to be aware of relating drainage to the “polluters” in order to justify expenditure. By encouraging the reduction in surface runoff through source control techniques, the “public” drainage problem is lessened and the “polluter” takes on a larger share of the costs of constructing and maintaining drainage systems. This can be achieved by offering reduced local taxes to property owners who are not connected to any form of public drain. Methods to raise awareness of the issues need to be developed for the stakeholder groups involved and generate a sustainable income stream for public drainage works.

5.1.2 Millennium development goals

Drainage has an important contribution to make to the millennium development goals – especially the environmental goal

Millennium development goal number 7
Ensure Environmental Sustainability

The environment provides goods and services that sustain human development so we must ensure that development sustains the environment. Better natural resource management increases the income and nutrition of poor people. Improved water and sanitation reduce child mortality, and better drainage reduces malaria. It also reduces the risk of disaster from floods. Managing and protecting the environment thus contribute to reaching the other Millennium Development Goals. Fortunately, good policies and economic growth, which work to improve peoples' lives, can also work to improve the environment.

Target 9 Integrate the principles of sustainable development into country policies and programmes and reverse the losses of environmental resources.

Target 10 Halve by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation.

Target 11 Have achieved by 2020 a significant improvement in the lives of at least 100 million slum dwellers.

http://www.developmentgoals.org/

Implications for donors

Donors play a leading part in the adoption by the world community of development targets on water supply, sanitation, gender, economic development, urban living conditions and water resources. Each of these issues cannot be dealt with in isolation and so integrated approaches are required. Part of an integrated approach should include urban drainage and thus an awareness of the impacts of poor drainage and the range of possible remedies should be fostered, within the international development community and donors (both "water" and "urban services" such as WSP, UNICEF, WSSCC, UNICEF, HABITAT, as well as environmental (IUCN etc.), health (especially in relation to cholera and malaria, such as WHO) and other development partners (International Development Banks, other bilateral donors)). This does not require a specific focus on drainage issues, but requires an acceptance that drainage is a core urban service, with impacts on water supply, sanitation, the economy, the environment, urban planning, health, the burden on women within the home and general living conditions in informal housing areas.

Recommendation

It is not feasible just to call for better drainage provision and policies; what is required is information on *why* policy makers are not interested in drainage and *what* would make politicians give a higher priority to the subject.

The Training Material and Briefing Note produced under this project are designed for technical staff at a municipal level, as this was initially recognised as being a key set of stakeholders, but different audiences require different information in different formats, to relate drainage to their particular concerns.

It is recommended therefore that advocacy and capacity building activities are designed and promoted to inform decision makers of the main issues and, in turn, raise the profile of this subject. These would require dialogue with policy-makers to identify their concerns and drivers. The financial issues and methods of cost recovery are probably at the centre of this debate.

A briefing note for policy makers and planners has been produced as one of the outputs for this project and is included with the training material.

5.2 Co-ordination and design criteria

Many of the problems with conventional technological approaches stem not from the technology per se, but the design criteria used. These are often limited (for example not taking into account water quality or water resources issues). The route to a more rounded approach to design and management is the formation of stakeholder fora or other mechanisms for sharing priorities. Inter department liaison and sharing is essential is a wider range of design criteria are to be adopted, for the wider benefit of society and the environment.

5.2.1 Poverty

The needs of the poor are often neglected, either through the lack of drainage or the provision of inappropriate solutions. Pedestrians, disabled people and other disadvantaged social groups do not have their needs taken into account. This requires a change in the perspectives of what, or rather, who drainage is for.

5.2.2 Planning for drainage

Many of the problems identified are a consequence of people living in the wrong place. Many informal settlements are on marginal land. Town planners need to understand the issues and work to alleviate the problem without resorting to expensive engineering solutions.

Co-ordination is also required with other providers of urban services. Poor solid waste management adversely affects the drainage system, which in turn can impact on sewerage and water supply systems.

5.2.3 Water resource degradation

Existing conventional drainage is undoubtedly causing water resource degradation, both to the quantity and quality of the water resource. Conventional drainage projects need to encompass water quality concerns and aim to improve the water resource, rather than taking only a flood prevention role. However, actions to reduce adverse impacts are limited if standard methods are used, so the adoption of SUDS techniques is essential if water resource degradation is to be reduced.

Recommendation

Design criteria for urban drainage are too limited and do not necessarily relate to stakeholders' needs. The major areas requiring greater co-ordination are
- town planning, especially with respect to low-income areas,
- urban infrastructure provision, and
- water resources management.

It is recommended therefore that advocacy and capacity building activities are designed and promoted to inform key stakeholders of the main issues and, in turn, promote dialogue and co-ordination. The Training Material and Briefing Notes produced under this project are an initial move in this direction, but different audiences require different information in different formats, to relate drainage to their particular concerns.

In order to facilitate the dialogue and to set design standards, the development of interdisciplinary performance indicators is highly recommended.

A briefing note for technical staff and a set of training materials have been produced as one of the outputs for this project.

5.3 Technical concerns.

5.3.1 Design paradigms

In the countries studied, the standard drainage ideal of separate sewer systems was not only not apparent, it was obvious that it will not be achievable outside the centre of capital cites for many years. Either vastly increased funding is required to have any expectation of reaching this standard of provision, or new paradigms of wastewater management need to be explored, such as increased source control, decentralisation of treatment and more pragmatic, incremental approaches to strategic sanitation planning.

Coping strategies

The existence of practical coping strategies used by people living in low-income areas that flood frequently should be recorded, recognised and formalised. These have considerable scope in following the role set by pit latrines in becoming the preferred drainage option in low-income areas.

Data

Design will be more efficient and effective if drainage systems are based on realistic rainfall and other design data. This small-scale (i.e. sub-catchment) level is different from the data collected for large-scale water resources management. Either data collection needs to be expanded considerably or more incremental methods of provision, based on experience rather than forecasting, need to be developed and promoted.

5.3.2 SUDS

It is recognised that SUDS are a suitable alternative to more conventional methods of urban drainage. In some areas they are the preferred drainage technique (for example the use of ponds in Hanoi). Learning from parallels with sanitation developments, a mixture of promotion, education, information provision, research, development of standards and design guidelines are all required to support their use. However, the mostly significant barrier (based on experience of educating technical staff in the UK and in low-income countries) is making alternative techniques “legitimate” and not second- best. There is still an assumption that piped sewerage is the acme of sanitation provision in all cases and that any other option is less desirable. Winning hearts and minds is therefore the key to promoting wider use of SUDS.

Silt control

SUDS have considerable scope for contributing to silt control in urban areas. Silt control needs to be made a key design criterion, alongside water quantity. It is not acceptable to design a drainage system in low-income countries without any consideration of maintenance, and as silt removal appears to be the most significant problem, it should be given due prominence. Conventional drainage systems do not give enough consideration to this area and the concept of a self-cleansing velocity is not applicable to the large quantities of solid material involved.

5.3.3 *Capacity building and the enabling environment*

A general dearth in textbooks, educational material and training courses is apparent, not just for SUDS, but drainage appropriate for low-come countries generally. This needs to be addressed at university level and technical colleges. A parallel capacity building activity is to ensure that the enabling environment is conducive to appropriate drainage techniques – through supportive standards, policies, legislation, institutional arrangements and funding.

Recommendation

It was originally expected that this project would lead onto more technical research and practical implementation. However, there are many advocacy and policy issues that have a higher priority.

Generally there is low priority within the technical community to work on urban drainage. Technical advancements are not being developed, except in a few notable cases. What developments that have been made are not being disseminated in the correct format. For example, simple *engineering* textbooks on designing drains to control malaria are feasible but do not exist.

It is recommended therefore to focus technical interventions on capacity building, initiatives in order to improve the performance of current projects and generally promote a wider understanding of drainage issues within the watsan sector.

A briefing note for technical staff and a set of training materials have been produced as one of the outputs for this project.

A text book (published by IWA) is being written by one of the project partners.