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Urban drainage - the alternative approach

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THE PAPER PRESENTS an alternative drainage philosophy and strategy which mimics nature's way by slowing down (attenuating) the movement of urban runoff. This approach results in cost-effective, affordable and sustainable drainage schemes. The alternative strategy can be described as one of **prevention rather than cure** by effecting controls closer to source rather than the traditional approach which results in the transfer of problems downstream, compounding the problem, resulting in its cumulation and, the need for large scale centralised control.

The alternative strategy is set in context relating to the evolution of current practice and the implications of fragmented institutional responsibilities. Issues relating to socio-economic factors and appropriate development are discussed and the alternative strategy is shown to incorporate tenets of a holistic approach.

The paper concludes by recommending the adoption of the alternative strategy for the provision of urban drainage infrastructure in developing countries. It suggests that this **paradigm shift** should help developing countries to leap frog the developmental stages in their provision of effective urban drainage infrastructure for their rapidly burgeoning urban centres.

Background

The current world population of over five billion people is estimated to increase to over six billion by the end of the millennium. Of the estimated 90 million people currently added to the global population, each year, 94 percent are in developing countries. The poor of the developing countries are moving into urban areas and as a result the urban centres are the fastest growing areas of these countries. The majority of the increased global population will therefore live in the burgeoning urban centres of the developing countries. This will no doubt place unparalleled demand on the already inadequate urban drainage infrastructure in most developing countries.

The resolution of problems associated with infrastructural provision in most developing countries currently follows along the traditions of the developed countries. Often, this is not appropriate for the locality (Sonuga, 1993). A review of urban drainage practice shows that, in the past, the philosophy has been based on conveying peak flows of municipal waste water and storm runoff away from the urban areas as quickly as possible. This has resulted in downstream flooding and heavy pollution of receiving waters.

The problems of urbanisation manifest and currently being dealt with in both developed and developing coun-

tries such as flooding and pollution of ecologically sensitive urban streams, will no doubt grow worse in the developing countries. If the cost estimates of £107 billion (1992 price base) attached to the meeting of the European Council (EC) urban wastewater treatment Directive by the EC member countries (Wright, 1992) is anything to go by, then it is clear that the provision of urban drainage infrastructure along the conventional approach is going to be unaffordable for the developing nations.

This paper presents an alternative drainage philosophy and strategy, based on the philosophy of the single pipe system (Smisson, 1980), which aims to mimic nature's way by slowing the movement of storm water from urban areas, encouraging the infiltration of relatively uncontaminated rainfall runoff to help maintain base flows in rivers and the beneficial re-use of rainwater through distributed storage close to source.

Case studies are presented demonstrating the significant cost savings that can be realised by adopting the alternative approach.

Evolution of conventional urban drainage systems

The urbanisation process has involved the growth of communities with people living closer and the conversion of open ground, that absorbed rainwater, to impermeable pavements and buildings. Associated with this has been the accompanying reduction in areas where the resulting stormwater, following rainfall, could be absorbed into the soil. This resulted in flooding in the vicinity of households and as a result, open channels were constructed to convey run-off from roads and roofs, away from properties to prevent flooding.

The increasing population concentrations associated with the urbanisation process also resulted in increases in waste generation. Household wastewater were connected (disposed off in the nearest open channel) and in turn created problems of smell. As a result, the open channels constructed to alleviate flooding were covered creating combined sewer systems.

Sewage treatment (initially via sewage farms) evolved from the need to alleviate the problem of pollution resulting from discharges from combined sewers into receiving waters close to the centres of population. For example, the Thames River through London in the U.K., was becoming foul smelling between 1862 and 1864. Sewers were therefore built down to the estuary below London to take London's wastewater and discharge it straight into the estuary. A number of years later, however, problems

were again becoming apparent so sewage treatment started in the late 1800s.

A review of the pattern of development of urban drainage described, shows that mankind's response has characteristically been one of finding a cure to an observed problem. Mankind has traditionally operated and still to an extent operates under a feedback law. A control action is sought and implemented only when an undesirable state of affairs is observed.

A publication titled "Urban Drainage The Natural Way" (HRD, 1992) which summarises the proceedings of a two-day conference held in Oxford in the U.K. in 1992 (Conflo '92) considers how "Source Control" a collective term used to describe the management of runoff at or near the point of impact of rainfall and before it reaches the traditional piped drainage and sewer systems of urban areas, might be used to mitigate the impacts on the natural water environment, of storm run-off from urban development. Institutional arrangements are highlighted as not being wholly conducive to the use of the Source Control methodologies for the implementation of engineering solutions to problems associated with urban drainage.

Institutional issues

In most countries, the institutional arrangements pertaining to responsibilities and control of the various stages (facets) of the water cycle have typically been fragmented with, for example, one institution responsible for municipal water supply, wastewater sewerage and treatment; another responsible for land drainage and urban runoff drainage systems; and yet another for the drainage of highways and urban roads. This fragmentation has contributed to unequal attention and unequitable allocation of resources to the various facets of water resources management and has not been conducive to the implementation of an integrated watershed or catchment approach to urban drainage owing to the imposition of artificial boundaries. Cross-connections, wrong connections and combined sewer overflows mean in effect that the traditional descriptions of foul, combined or surface water sewerage systems of urban drainage, which have typically formed the basis for the divisions in institutional responsibilities, are not strictly correct. In the urban environment, the interactions between the various wastewater networks (e.g. combined sewers, highway drainage and land and surface water drainage systems) means in effect that wastewaters derived from sources under the jurisprudence of one institution could in effect ultimately be disposed off into a receiving water through a network in the jurisprudence of another institution.

If the overall interests with regards to mankind's interactions with the water cycle in the urban environment is stated as one of; "the provision of adequate quantities of safe (potable) drinking water supplies, the safe disposal of all urban wastewaters, the maintenance of water re-

sources and the prevention of adverse aquatic environment impacts", then it is suggested that the division of institutional responsibilities be along the lines of "service provider" and "regulator".

The service provider in this context would be an integrated institution with overall responsibility for the abstraction and supply of potable water supplies and the safe collection and disposal of all wastewater sources from the urban environment including stormwater run-off from roofs, road and other impermeable surfaces. Boundaries for such institutions would not be along the lines of administrative regions but rather on receiving water catchment or natural watershed basis.

The regulator would then have the function similar to that of environmental protection boards and agencies (essentially a policing function/role) with regards to the maintenance of water resources.

In most developing countries, solid waste disposal is closely linked with urban wastewater drainage in that open sewers and drainage channels often end up also being receptacles for solid wastes generated in the community (Ajayi, 1993). This leads to blockages, reductions in capacity and an exacerbation of flooding problems. In such situations, it is suggested that the institutional arrangements be along the lines of an "Integrated Environmental Service" provider (incorporating water supply, wastewater and solid waste functions) and a corresponding "Integrated Environmental Control Agency".

It is the author's view that the proposed institutional arrangements will provide an appropriate framework for the equitable allocation of resources to the various environmental service needs and should result in a climate conducive to the implementation of the alternative approach being advocated.

The alternative approach

The alternative drainage concept being advocated utilises the single pipe system philosophy (Smisson, 1980). This approach differs from the conventional combined drainage concept in that no overflows are permitted from the single pipe system. A single sewer network system conveys the highly polluting urban wastewater sources to a treatment facility prior to its discharge as treated wastewater into a receiving water course. Flows in excess of downstream sewer capacities during rainfall are retained adjacent to the intakes to the sewer system, in local transient storage.

Wastewater that has entered the sewer system is prevented from overflowing or flooding a downstream location because the rate of release of water from upstream parts of the catchment is limited, by the use of flow control devices, to the capacity of the downstream sewer. Details of the basis for design of the single pipe system are described elsewhere (Smisson, 1980).

The single pipe system design philosophy recommends the use of *minor* and *major* drainage systems. The minor system consists of a piped drainage network constructed

to serve the area with sufficient capacity to convey base flows and the “more frequent” storm runoff from roads, highways and other paved areas likely to be sources of relatively polluted runoff.

The major system consists of the natural drainage routes and patterns evolved by nature prior to mankind’s interference through development. This is defined by the topography and geomorphology of the area. Overland flow routes for the major system may incorporate roadways, existing streams and their flood plains and, suitably graded lawns, park lands and green belts. Overland routes can be engineered such that large parks and gardens etc. are utilised as flow attenuation or retention/detention basins which encourage evapo-transpiration and percolation.

Sadly, the lack of adequate planning policies and controls coupled with a lack of awareness of the importance of the natural drainage routes has resulted in developments that alter or obstruct the natural drainage paths. There is a need therefore for a increased awareness of the impacts of uncontrolled urban developments and a clear demarcation and inclusion of natural drainage paths in urban development plans. Plans for land use changes should incorporate features to increase the surface storage and reduce the velocity of overland flows. The hydrogeological characteristics of the area should be taken into account such that the maximum potential for percolation into the underlying soil is realised.

A review of the hydrological cycle would suggest that one of the key objectives in environmental water quality protection should be that of preventing the contamination of relatively unpolluted water sources. Rain water tends to be the least contaminated of sources. Collection and storage of rainwater water runoff from roofs, for example, could serve the dual purpose of significant reductions in the volume of runoff into sewer networks and the provision of water which could be used for general purposes such as watering of lawns and gardens.

Flooding from combined sewers in most urban centres is caused by increase in runoff rates and volumes resulting from expansion and growth beyond the core area. The search for conventional solutions of larger relief sewers or detention basin in the areas where the problems are manifest (i.e. the urban centre), are fraught with problems of lack of space and congestion of services. Adopting the alternative philosophy of prevention rather than cure would mean solutions investigated look at ways in which flows into and through the urban centres can be reduced or attenuated before they arrive at the problem areas.

The single-pipe system drainage concept advocated as an alternative to the conventional approach, represents a shift from a *curative* approach to a *preventative* approach. This inevitably results in the conservation of resources and leads to cost beneficial schemes for either the provision of new urban drainage infrastructure or the resolution of problems with existing infrastructure caused by the urbanisation process. The potential benefits result-

ing from adopting such an approach are demonstrated by the case studies presented.

Case studies

Three case studies showing the benefits and significant cost savings that accrue from adopting the alternative philosophy of effecting control closer to source in a distributed fashion are described.

York, Ontario - Toronto, Canada

The borough of York, a suburb of Toronto, Canada, has a combined sewer system and in the past had suffered from severe sewer backup and overflows polluting local Rivers. In 1968, following a consultant’s recommendation, York embarked on a \$50 million program along the traditional structural-intensive solution of sewer separation and storm sewer enlargement. Between 1968 and 1976, York spent an average of \$646,000 per annum (22 percent of its annual budget), on this project (GAO, 1979).

By 1976, the borough council had become quite concerned about the tremendous cost of the project and engaged an engineering firm to find an alternative solution. This firm determined that the conventional approach of relief sewers was far too costly and suggested an alternative approach which involved using flow regulators in catch basins, constructing limited-storage underground tanks, and either disconnecting down spouts (from roofs), or installing restrictors in the down spouts. Under this approach, when sewer system capacity is exceeded, stormwater would be temporarily stored in underground tanks or on the surface for slow release into the system.

York opted for a 10-year storm protection and accepted a final cost of \$987,633. The alternative approach was completed in 1978, and has worked satisfactorily with no reported flooding.

Wadley Road - Waltham Forest, London

The Wadley Road Storm Sewer System serves a steeply sloping catchment area of approximately 20 Ha. Overflows from storm water sewers had inundated Wadley Road every year for as long as residents can remember creating flooding up to about 1 meter deep (Andoh, 1994).

The only solution which seemed possible (adopting the traditional approach) was the construction of a bypass sewer system at an estimated cost of £90,000 to £100,000. Though this solution would cure the flooding problems at Wadley Road, it run the risk of flooding another street further downstream. A review of the problem showed that a viable, and by far more cost effective alternative, solution would be to use Hydro-Brake™ flow controls to slow down flows and mobilise available system storage throughout the catchment area upstream. Nine Hydro-Brake™ flow controls of various suitable sizes were installed at a cost of £24,000 resulting in a reliable economical solution well below the cost of an unsatisfactory traditional alternative.

City of Evanston, Illinois - USA

Evanston, a community with a population of approximately 75,000 is served by a combined sewer system. Sewer overloading leading to frequent backups, occurring up to six times a year, was a major problem facing the city. In 1987, an engineering consultant was engaged to evaluate the problem and develop a cost effective alleviation program for the City's combined sewer problems (Barber et. al., 1994).

The traditional solution of relief sewers/sewer replacement, was estimated to cost \$290 million. In addition, this solution would cause major disruption affecting up to 90% of the City's streets. The high cost of the traditional solution coupled with the potential disruption to local residents caused the city to seek a more affordable solution.

A review of alternatives resulted in the adoption of a plan involving partial sewer separation with above ground storage and overland flow and Inlet restrictors installed in catch basins to limit the inflow to the hydraulic capacity of the existing system. This alternative is estimated to cost \$143 million, approximately 50% of the conventional sewer relief scheme.

Following completion of the first phase of the project, Evanston has been subjected to several storm events which would have created basement backup in the past. A survey of the area's residents revealed that no backups were experienced.

Concluding remarks

It is more now than ever before in the history of mankind becoming evident that ecological systems cannot cope with many of mankind's activities resulting from industrialisation and urbanisation.

Unfortunately, mankind has traditionally operated and still to an extent, operates under a feedback law with a control action being sought and implemented only when an undesirable effect or state of affairs is observed. "Urban drainage practice and control philosophy until recently has, as result, been based on solving localised problems either by transferring excessive flows in drainage systems downstream by upgrading sewer pipes or, relieving localised flooding by constructing local storm overflows" (Andoh, 1994).

Problems of downstream flooding and pollution and the realisation of the interdependence and interaction of the effects of the localised control measures, has focused attention, in more recent times, on the need for an integrated systems approach which looks at urban drainage networks as part of integrated catchment systems incorporating 'flow sources', 'in-sewer' components, 'end of pipe' systems and receiving waters. With an integrated systems approach, the effects of localised control measures on the entire system can be evaluated leading to the evolution of optimal solutions satisfying multi-objective criteria in a holistic manner. When implemented within a framework of sustainable control philosophies, such as the alternative approach being advocated, cost effective

solutions are obtained as demonstrated by the case studies presented.

The main factors which have prevented the widespread adoption of the alternative approach are "Tradition" and "Institutional Issues". Engineers have been trained to think along the lines of the traditional concepts and the Institutional arrangements in most countries are not conducive to the implementation of the alternative approach.

Provision of urban drainage infrastructure along traditional lines is too costly. Developing countries are not going to be able to afford the traditional approach and need to look for cheaper alternative strategies for resolving problems associated with urban wastewater drainage. The alternative approach described provides a framework which should enable staged implementation of effective urban drainage infrastructure.

In order for developing countries to realise the potential of the alternative approach and thereby leap frog the traditional developmental life cycle, there is the need for a *paradigm shift* and a review of Institutional arrangements. Changes in institutional structures to reflect integrated environmental service provision and control and an increased awareness through educational programs and public awareness campaigns should help in the evolution of an environment conducive to the implementation of "Urban Drainage The Natural Way".

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