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Taming of Floods in Trinidad

G.S. Shrivastava*

Every year, many areas in Trinidad are adversely affected by severe flooding in the aftermath of intense rainstorms. As a consequence, there are considerable disruptions in the socio-economic activities, and the annual financial losses in the agricultural, industrial and commercial sectors conservatively run into tens of millions of dollars. In addition, at times, there has also been loss of human lives and structural damage to buildings, roads and bridges. Moreover, the solution to the flooding problems and the public debate surrounding the same, has hitherto centred essentially on the classical hydraulic engineering approach of attempting to control or eliminate floods by constructing embankments and dredging, widening, paving and straightening watercourses. However, this one-dimensional approach to a multi-dimensional problem has been ineffective. Indeed, due to the creation of an illusion of flood security and the absence of land use controls, it has often resulted in increased flood damage. Further, global experience has shown that while controlling floods is impossible, managing them - for reducing hazards to lives and property by the most cost effective measure - is not. An appreciation of this distinction is central to the development of a flood policy framework. It is against such a background that this paper presents a critical review of some of the issues relating to the flooding problem in Trinidad, in the hope that it would be useful in formulating a much needed flood management strategy.

1. Introduction

Flood disasters account, in economic terms, for about a third of all natural disasters in the world (**Berz 2000**). Judging from the magnitude and the recurring nature of the social disruptions and economic losses in Trinidad, this statement seems to be true and is perhaps an understatement for the island. Furthermore, the flooding problems in Trinidad are complex in nature and have geographical, historical and socio-economic roots. To begin with, a careful reflection reveals that the flooding problem in Trinidad has many dimensions. However, the public debate and the attempted solutions hitherto have essentially centred on the classical hydraulic engineering approach of attempting to control or eliminate floods by improving the conveyance capacity of the watercourses and building flood embankments. It is not surprising therefore that this one-dimensional approach to a multi-dimensional problem has not been successful. The one-dimensional approach which is becoming the sanctioned discourse relating to floods in Trinidad, is no doubt a reflection of the general public perception that it is possible to eliminate floods by engineering intervention. There is a time warp in this perception, which goes back to Thomas Tredgold's definition in 1828 of civil engineering as an art of directing the great sources of power in nature for the use and convenience of man (**Watson 1988**).

Simple probabilistic reasoning shows that elimination of floods is impossible (**Chow *et at* 1988**), and may even be undesirable from philosophical and other viewpoints relating to the cycles in nature; such as the cycles of floods and droughts: Times of floods are just as necessary as periods of dryness. Moreover, no part of the world is immune from adverse effects of floods. Even arid and semi-arid areas experience rare but unexpected and devastating floods (**Wheater 1995**). It is recognised, however, that while it is not possible to control or eliminate floods, managing it is possible by accepting a hydro-economic trade-off

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* Dr. Gyan S. Shrivastava is a Senior Lecturer in the Department of Civil Engineering, Faculty of Engineering, UWI, St. Augustine.

between the flood risk and the cost of preventive measures (**Williams 1994**). On one hand, ignorance of this reality is the cause of much local public dissatisfaction and needless debate and is a priority area for public education. On the other hand, recognition of this reality is central to the development of a flood policy framework.

The need for the integration of social and engineering sciences for the management of disasters was recently thoughtfully articulated, using the power of analogies by **Dias & Kkanayake 2002**. With specific reference to flood disasters, it can be said that there is an unquestionable need to link engineering attributes, such as robustness, redundancy and ductility to the corresponding community attributes, such as participation, leadership and resilience for breaking the vicious annual cycle of flood and drought, and the corresponding cycle of institutional action and inaction. Against the foregoing background, this paper which hereafter refers specifically to Trinidad unless stated otherwise, critically examines the nature and causes of the local flooding problem and suggests a management strategy for creating a sustainable solution for the same.

2. Flood Wave Generation

Before proceeding further, it is considered worthwhile to briefly outline the physics of the formation of a flood. In this context, there are a number of possible scenarios of flooding, such as rainstorms, tsunamis, storm surges and dam breaks. However, this paper concentrates mainly on the rainstorm-generated floods, which are defined as rainstorm-generated discharge or flood waves propagating through the stream network in a watershed. Such a flood wave can be considered as the output response of a watershed system to a precipitation input. Further, its genesis lies in the tropical depressions formed at the West Coast of Africa and the annual equatorial oscillation of the inter-tropical convergence zone (ITCZ).

The hydraulic characteristics of a rainstorm generated flood wave are influenced by the following factors. Firstly, the meteorological characteristics of a rainstorm, such as its duration, intensity, speed and direction of propagation, cloud structure and areal extent, determine its precipitation potential. Secondly, the hydrographic response of a watershed to a rainstorm is influenced by its slope, area, land use, geomorphology, antecedent precipitation condition, and the terminal boundary condition, e.g. tide level and sand bars in an estuary. The third factor in shaping the flood wave, and determining its speed of propagation, is human interference. These are impoundment reservoirs - which either traps a flood wave or accelerates its movement in a full reservoir, built environment in flood plains, built encroachment on river banks, inadequate bridge waterways, carelessly placed pipeline crossings, inappropriately-sized culverts, disposal of solid waste and large derelict objects in the watercourses, deforestation, soil erosion, and sedimentation.

At this point, it is pertinent to say a few words about a flood wave, which is generally of an unprecedented magnitude, and which is caused by a dam break (**Chow *et al.* 1988**). It may be noted that the annual probability of a dam failure is 10^{-4} and the probability of failure of a dam in its lifetime is 10^{-2} (**Vischer & Hager 1998**). Further, a dam can fail due to overtopping, landslide, seismic excitation, terrorism and piping failure of its foundation. Thus, there is a finite probability of a dam break generated flood wave, and locally the most likely cause is expected to be failure by overtopping; since the outflow structures for the three dams, namely Hollis, Navet and Arena, are – in all probability – designed for floods less than the probable maximum floods. For example, the Arena dam's spillway has a capacity of 86 m^3s^{-1} (**Phelps 1975**); which approximately translates into a one in five hundred year peak flow (**NEMA 1996**). Unfortunately, virtually little is known about the likely impact of this type of flooding under the local conditions, and this aspect should be considered a priority area for research.

3. The Flooding Problem

As stated earlier, the flooding problem is multi-dimensional. Here, however, only the three main dimensions are identified. The first dimension relates to land use, and there are a number of issues to be addressed here. It is recognised that the pressure of population growth encourages people to settle in exposed areas, which, among other things, leads to a loss of flood plain storage and consequently a rise in flood levels. Moreover, people sometimes do not know the natural features of the areas they settle into, have no idea of what can happen, and are completely taken by surprise by flood events. Further, urbanisation in the upper portion of watersheds increases the volume and peak of runoff, and the rates of soil erosion and sediment transport. For example, it has been shown that the areal extent of urbanisation in the San Juan River Basin increased by approximately 20% during the period 1969 - 1992 (**Atkins 1993**), which can increase the 50 year peak flow by approximately 25% (**McCuen 1998**). Further, judging from the growth in unplanned land use (**Trinidad Guardian 2000 A**), it is not difficult to deduce that either there are institutional weaknesses or legislative weaknesses or perhaps, both. Here, it may be of interest to note that similar institutional and legislative problems exist elsewhere in the Caribbean (**Warren 2002**).

The second dimension relates to the need to define situation specific acceptable levels of flood risk for the design of drainage systems. One issue of relevance here is the vulnerability of petro-chemical and other industries in the low-lying Point Lisas area and elsewhere. It may be noted that the Hydro-Agri Ammonia Plant and the Nestle factory have been severely affected by floods in the recent times (**Shrivastava 1999**; **Trinidad Guardian 2002 B**). In ascertaining an acceptable level of flood risk, it needs to be remembered that excessive attention to some risks leaves others unattended. Then, there is a philosophical question: How safe should we make society? (**Hambly and Hambly 1994**). It is believed, however, that a reasonable level of flood risk can be ascertained by a comparative assessment of other risks, and by hydro-economic analyses (**Chow *et al.* 1988**)

The third dimension relates to the need for research, for providing critical information for decision-making, in a number of areas ranging from meteorology to land use planning. These areas are identified subsequently in this paper. It may be noted, however, that without such information it would not be possible to develop a flood management strategy.

4. Flood Management Strategy

Briefly speaking, a flood management strategy has four main components, such as objectives, scenarios, constraints and measures. A suitable objective is to minimise, for a specific level of flood risk, loss of human life and livestock, damage to property and crops, disruption in transportation systems, and risk to health in the aftermath of floods. Then, there is a need to define the governing scenario. Thereafter, it is necessary to identify the constraints, such as: topography, geology, land use, state of the stream network, estuarine boundary condition, and the institutional and legislative framework. Finally, there is a need to define the measures required for managing the flooding problem in the most cost-effective manner. Once these pre-requisites have been assembled, a flood management strategy may be derived by the application of a decision support system. The details of its methodology may be found elsewhere (IHE 2002). It may be noted, however, that given the multiple objectives, the approach is not to find the optimal strategy, but the least inferior strategy.

The measures can be broadly classified as structural and non-structural. Among the structural measures, the most common set of measures is the engineering design, construction and preventive maintenance of the natural and man-made drainage systems. In this context, it may be noted that dredging, paving, straightening and widening of watercourses have been, and are, the favourite, and the most visible, structural measures for combating the flooding problem (**Trinidad Guardian 2002 C**). Further, such measures, in spite of their undesirable ecological consequences (**Gordon *et al.* 1996**), have the advantages of quick mobilisation, and are politically expedient since their visible mode soothes the public resentment; albeit only temporarily. Also, such measures do not treat the underlying causes of flooding, but only provide symptomatic relief.

Runoff detention basins, which are another set of structural measures, maintain equilibrium between the pre and post runoff peaks, and thereby prevent an increase in flood peaks downstream of a land development. Therefore, construction of such basins should be a mandatory requirement for all existing and new land developments. This action, however, may require legislative and institutional strengthening. Further, such basins should be bio-engineered for deriving additional communal benefits in terms of aesthetics, recreation and water quality enhancement (**Anderson 1998**).

Impoundment reservoirs, which can be considered a major structural measure, should be designed for multiuse option, since its construction requires a large economic investment, and considerable time, normally in the range 10 - 50 years, for planning, engineering design, financing and construction. Further, its construction requires the resolution of many sensitive social and environmental issues, such as the relocation of communities, destruction/disruption of natural habitats and downstream environmental impacts. It follows, therefore, that reservoirs should be designed and operated for multiple use for maximising their benefits to the society. This is possible through the use of operations research-based reservoir operating rules which resolve the conflicting demands among the various uses, such as the opposing water supply and flood management demands placed on a reservoir storage. Unfortunately, however, multiple use has not been the case locally, and reservoirs are kept as full as possible for the singular objective of the security of water supply.

It should be noted that the before-mentioned structural measures, if used in isolation, make flooding less frequent but more sudden and damaging, because of a greater degree of the built environment and illusion of flood security. A comprehensive, and sustainable, solution to the flooding problem therefore also depends on the concurrent application of non-structural measures, some of which are: land use planning, research, solid waste disposal systems, and – recognising the inevitability of flood – disaster preparedness and mitigation.

Among the non-structural measures, land use planning is of foremost importance, and has a critical role to play in reducing the misery of flooding by identifying flood risk areas and regulating built environment in the same. It also involves reforestation and rehabilitation of watersheds, and in some cases removal of people, property and critical facilities from risk defined floodplains, for example a 10-year flood plain, which may be preserved as open spaces. The benefit cost ratio of such activity, based on the experience elsewhere, is likely to be more than one, not including lives saved (**Grimm 1998**). However, there is a need to accurately define a flood plain because such a definition has legal implications. In this regard, there is a need to calibrate hydraulic reasoning with geomorphic assessment (**Thompson & Clayton 2002**).

Research needs, in addition to those related to probable maximum and dam break floods stated earlier, can be briefly stated as follows. First, there is a need to urgently finalise a code of practice for the design of drainage systems, which has been under preparation for sometime (**BOETT 2002**), and which will prescribe, among other things, temporal distribution and return period of design storms, methodology for estimating peak flows which takes into account future urbanisation, and capacity of runoff detention basins and spillways.

Secondly, there is a need to prepare, by rainfall-runoff modelling, Geographic Information System (GIS) based flood risk maps, which would facilitate the institution of a flood risk insurance programme. Before this can happen, however, there is a need for the construction of discharge measurement structures for the accurate measurement of high stream flows. It is to be noted that at present most of the local stream flow records, with the exception of low flows, are grossly inaccurate and virtually useless (**DHV Consultants / Delft Hydraulics / Lee Young & Partners 1999**). Thirdly, there is need to study the impact of climate change on the intensity and frequency of rainstorms.

The issue of the indiscriminate disposal of solid waste, and of large derelict objects, in the watercourses, is well known. This is certainly an area where lack of enforcement of the existing anti-litter law and institutional weaknesses are clearly evident but there is another subtle point, which relates to a fundamental error in the water resources planning in the past. It is the de-linking of communities from rivers; with reference to water supply, recreation and aesthetic beauty. Simply put, communities which receive their water supplies entirely from far away sources, such as Port of Spain receiving water from Hollis Reservoir, cannot be expected – based on the experience elsewhere (**Kane 2001; Newbold 2000**) – to cherish their rivers. The conversion of the Port of Spain's St. Ann's River into the East Dry River, which has essentially become a channel for the hydraulic transport of solid and liquid waste to the Gulf of Paria is a powerful, but sad example. Therefore, there is a need in the future to re-link communities with rivers that meander through them.

Disaster preparedness and mitigation need to be integral to a flood management strategy, and involve, among other things, public education, provision of flood relief shelters, provision of a flood risk insurance programme - for which premiums would be dependent on a community's adoption of effective measures for reducing flood damage, real time flood warning, and interaction with the protective and emergency services. The National Emergency

Management Agency (NEMA) is ideally placed to be the agency responsible for coordinating the aforementioned activities.

Of all the non-structural measures, real time warning is perhaps easiest to implement and the most likely to reduce the extent of damages. Hydrological events, unlike other natural disasters such as earthquakes and volcanic eruptions, build up slowly, and provide opportunities for real time flood forecasting, which refers to the prediction of stage, discharge, time of occurrence and duration of a flood wave at any specific location. It is important to note that two criteria, namely accuracy and timeliness need to be simultaneously satisfied for a forecast to be useful. It may be noted that real time forecasting is entirely possible for the Caroni, Caparo and Cunupia Rivers, and indeed an accurate flood warning can be issued up with a lead-time of up to 24 hours. For the smaller rivers in urban watersheds, such as Diego Martin, however, this is not possible because the watershed lag, defined as the time difference between the centroid of effective rainfall and the peak of the discharge hydrograph at any location, is of the order of half an hour or less; which is too little a reaction time for effective flood warning (**Shrivastava 1989**).

5. Conclusions

In the Greek mythology, hydra is a many-headed snake, which was difficult to obliterate because its heads regrew after being cutoff. The flooding problem can be considered a hydra whose many heads, such as unplanned land use, deforestation etc., can reappear time and again; if sustained efforts and vigilance are not exercised. It should be remembered that floods ultimately affect everyone in a community, and therefore their mitigation require a collective effort. Finally, we ought to give up the vanity of controlling floods, and learn to live with them in harmony.

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