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**Modeling of Flood Water Flow: A Review**

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**Abstract.**
A flood is an overflow of water that submerges or drowns land. In general flooding scenario, water levels rise causing areas neighboring water bodies and some road segments in these areas to be flooded and they said two aspects of flooding interest us first, the water body floods reaches a water level higher than normal causing water to flow to the surrounding areas and second, the flowing water interacts with roads, covering road segments. The primary effects of flooding include loss of life, damage to buildings and other structures roadways, and canals. Damage to roads and transport infrastructure may make it difficult to mobilize aid to those affected or to provide emergency health treatment. One of the methods to reduce the velocity of flood water flow across road is to design obstacle objects as diffuser and places it along beside road shoulder. The velocity of water flow will depends on the diffusion pattern of water. The pattern of diffused water will depends on the design of the obstacle objects. This paper will review the impacts of flooding and modeling to protect road flooding
**Keywords:** flood; water bodies; diffuser; velocity; rain.

## Introduction

Floods can happen on flat or low-lying areas when the ground is saturated and water either cannot run off or cannot run off quickly enough to stop accumulating. This may be followed by a river flood as water moves away from the floodplain into local rivers and streams. Floods can also occur if water falls on an impermeable surface, such as concrete, paving or frozen ground, and cannot rapidly dissipate into the ground. Flooding and flash flooding pose serious infrastructure hazards to human populations in many parts of the world. During a flood, it is critical to identify road segments that are flooded so that rescue and response routes can be determined and rescue personnel and supplies can be distributed promptly.

Floods are the second most common and widespread of all natural disasters [1]. One of the most face flooding is North Carolina faces extreme hazards and consequences from flooding, particularly those floods caused by hurricanes. Since 1989, there have been 14 federally declared disasters in North Carolina. Floods are one of the most common natural hazards, causing significant damage, loss of life, and other negative impacts in the United States and around the world. Two aspects of flooding interest us:

1) The water body floods reaches a water level higher than normal causing water to flow to the surrounding areas and

2) The flowing water interacts with roads, covering road segments. A water body lakes, rivers, and streams become a water body only because a part of the land surface area is lower in elevation than surrounding areas.

In the sense of spatial modeling, lakes can be modeled as polygons. However, as with roads, rivers and streams can be modeled as linear objects using polylines. A river that is quite wide, making it unreasonable to model it as a singular polyline, can be modeled as two polylines running roughly parallel to each other. This representation as polylines is consistent with spatial model of the linear state roadway network.

Flooding can cause damage to the infrastructure and repairing is needed. Repairing damage from Hurricane Floyd alone has cost $3.5 billion, and Floyd destroyed 4,117 uninsured and underinsured homes [2]. The nation's transportation infrastructure plays a critical role in coping with hurricane events by providing rescue routes. To utilize the existing transportation infrastructure system efficiently in rescue, we must identify road segments that are flooded and road segments that are not flooded so that rescue and response routes can be determined and rescue personnel and supplies can be distributed promptly and in a timely manner [3]

Safe roads are the foundation for traffic safety. Studies at home and abroad have shown that a good roadside environment reduces traffic accidents, while poor ones promote accidents. In a studies on traffic accidents and bad weathers in multiple Canadian cities, it showed that rainfall increases the chance of a crash by 75%, and the chance of a personal injury by 45% [4]. Traffic accidents related to bad weather is estimated to be about $ 100 million per year in Canada. The road accidents account for at least 28%~34% or more, even if the accident are caused by the human factor, in many cases they are also subjected to the impact of the roadside environment [5].Climate is an important consideration for the traffic environment. For mountain roads, more attention should be paid on the impact of geological disasters induced by abnormal and severe weather. In China, mountainous areas including the plateau, makes up about 2/3 the country's land area. The natural conditions of plateau's are unique, and can easily lead to serious disasters Correspondingly, roads built on plateaus have high incidence of disaster, a wide influence range, various inducing factors, and great artificial destruction [6]

**Flood Impacts**

There are many impacts from flooding. The Kentucky Transportation Cabinet (KYTC) estimated the June 2011 floods that impacted the state cause 30 million in damage to the state's roadways. Future flooding events will lead to further monetary costs and impair the operational structure integrity of the state's roads. The loss of critical infrastructure produces negative effects over the short-term and long-term. Road segment with several portions of the road under water. Part of the road segment may not be flooded even though it is in the flooded area because the elevation of a road changes along its length so that parts of it may be above flood level. The challenge is to find those portions that are flooded and to determine their depth so that appropriate response actions can be taken [6]

Louisiana Transportation Research Center (LTRC), in response to this concern sent investigative teams into the area shortly after the hurricane floodwaters were pumped down to assess the flooding impact to pavement structures in the area. For this pilot effort, a falling weight deflectometer FWD was used to measure surface deflections. The data collected with the FWD were subsequently used to back-calculate elastic modular of the pavement layers. Another deflection testing device, the Dynaflect, was used to determine the structural number and subgrade resilient modulus of the tested pavements. Coring at different locations was also carried out to verify in situ pavement thickness and the integrity of pavement structure. Details from these in situ tests can be found elsewhere [5]. In general, higher predicted values, including layer modulus of elasticity, subgrade resilient modulus, and SN value are expected for stronger pavement structures that exhibit better performance under trafficking. Hurricane Katrina devastated New Orleans and southeastern Louisiana on August 29, 2005, leaving hundreds of thousands either displaced or homeless. Nearly 4 weeks later, Hurricane Rita made landfall in the southwestern portion of the state, further damaging Louisiana's infrastructure and, once again, bringing destruction to the New Orleans area. While much of the damage to buildings and bridges was obvious and immediately recognized, the detrimental impact of flooding on roadways would not be so easily determined. There are approximately 3,220 km, 2,000 mi of roadway in the Greater New Orleans area which were submerged in floodwaters for up to 5 weeks. Among them, more than 800 km ,500 mi are part of the federal-aid highway system, and the remaining 2,420 km ,1,500 mi are local routes [7].

LTRC's Dynaflect results for LA 46 collected both before and after flooding. The pre-flood test was conducted in August of 2002 and the post-flood test was conducted in October of 2005. The pavement structure, according to the Dynaflect results, had an average SN of 5.1 before flooding, but an average SN of 4.2 after flooding. A similar decreasing trend also occurred for the subgrade modulus. Before flooding occurred, the subgrade had a resilient modulus of 44 MPa 6, but after flooding, the modulus decreased to 33 MPa. Both the pavement structure and subgrade were weakened by the floodwater, indicative of submergence damage. With these preliminary findings as support, the Louisiana Dept. of Transportation and Development to conduct a full scale pavement testing survey for the federally funded urban highway system in the flooded areas of New Orleans. A summary of the research effort associated with analyzing the field testing data collected in this effort follows [7].

Streams are fed by runoff from rainfall and snowmelt moving as overland or subsurface flow. Floods occur when large volumes of runoff flow quickly into streams and rivers. The peak discharge of a flood is influenced by many factors, including the intensity and duration of storms and snowmelt, the topography and geology of stream basins, vegetation, and the hydrologic conditions preceding storm and snowmelt events. Land use and other human activities also influence the peak discharge of floods by modifying how rainfall and snowmelt are stored on and run off the land surface into streams. In undeveloped areas such as forests and grasslands, rainfall and snowmelt collect and are stored on vegetation, in the soil column, or in surface depressions. When this storage capacity is filled, runoff flows slowly through soil as subsurface flow. In contrast, urban areas, where much of the land surface is covered by roads and buildings, have less capacity to store rainfall and snowmelt. Construction of roads and buildings often involves removing vegetation, soil, and depressions from the land surface. The permeable soil is replaced by impermeable surfaces such as roads, roofs, parking lots, and sidewalks that store little water, reduce infiltration of water into the ground, and accelerate runoff to ditches and streams. Even in suburban areas, where lawns and other permeable landscaping may be common, rainfall and snowmelt can saturate thin soils and produce overland flow, which runs off quickly. Dense networks of ditches and culverts in cities reduce the distance that runoff must travel overland or through subsurface flow paths to reach streams and rivers. Once water enters a drainage network, it flows faster than either overland or subsurface flow.

Streamflow in Mercer Creek, an urban stream in western Washington, increases more quickly, reaches a higher peak discharge, and has a larger volume during a one-day storm on February 1, 2000, than streamflow in Newaukum Creek, a nearby rural stream. Streamflow during the following week, however, was greater in Newaukum Creek. With less storage capacity for water in urban basins and more rapid runoff, urban streams rise more quickly during storms and have higher peak discharge rates than do rural streams. In addition, the total volume of water discharged during a flood tends to be larger for urban streams than for rural streams. For example, streamflow in Mercer Creek, an urban stream in western Washington, increases earlier and more rapidly, has a higher peak discharge and volume during the storm on February 1, 2000, and decreases more rapidly than in Newaukum Creek, a nearby rural stream. As with any comparison between streams, the differences in streamflow cannot be attributed solely to land use, but may also reflect differences in geology, topography, basin size and shape, and storm patterns.

The hydrologic effects of urban development often are greatest in small stream basins where, prior to development, much of the precipitation falling on the basin would have become subsurface flow, recharging aquifers or discharging to the stream network further downstream. Moreover, urban development can completely transform the landscape in a small stream basin, unlike in larger river basins where areas with natural vegetation and soil are likely to be retained

**3. Modeling to protect road flooding**

Temporary flood barriers (TFBs) offer a practical and economical solution to prevent the worst effects of flooding on vulnerable roadways. TBFs are physical structure installed along the margins of roadways that prevent water from inundating them during flooding events. They assist in preventing damage to roads, and provide a means of keeping roads open even while flooding is ongoing. The potential exists for TBFs to redirect high waters onto adjacent, unprotected properties, which may cause damage. TFBs are structures installed during periods of flooding to protect roadways and other vulnerable areas from potentially-damaging inundation. TFBs are typically located along one or both sides of a road corridor to preserve infrastructure functionality. Positioning depends on the source of water and the angle at which the water approaches a roadway. TBFs are beneficial in their capacity to suppress hazardous water flows, bolstering the safety of travelers, and ensuring traffic flows are not disrupted which is key during floods that require evacuation. TBFs consequently improve evacuation efficiency while lowering the probability of stranding people in perilous situation where they are exposed to the dangers of rapidly rising flood waters. The main objective of using this is to keep roadways in a safe and operable condition during hazardous flooding events [8].

Three different urban flooding models were applied in Sukhumvit urbanized area in Bangkok. The first model can exchange the surcharged water and surface storage by using virtual reservoir applied with the pipe network model. The second model is the two layers model which is the combination of pipe network and street net work model. The last model is the Digital Elevation Model (DEM) linked with pipe network model. The result of simulation of all models compared with the flood field data showed that the last model provided the best computed result. To examine the extension of application of model A and B capability, it was found that the first model was still can be applied for the light rainfall case. The two-layered model can be applied for the moderate rain and suitable for real time control due to its reasonable performance time. But today it is feasible to model urban flooding with the interaction between the pipe system and surface flooding and this raises new possibilities for managing urban flooding problems [8]. In a general flooding scenario, water levels rise causing areas neighboring water bodies and some road segments in these areas to be flooded. This section describes spatial modeling of water bodies and provides brief descriptions of various flooding scenarios [4, 5].

Due to the increasing demand for habitat protection and ecological connectivity at road crossings, alternatives to traditional culvert designs are being implemented. One alternative is a bottomless arch culvert with a simulated streambed representing the culvert invert. Such culverts are designed to not only mimic the natural streambed, but also to facilitate natural stream processes such as sediment transport, flood routing, and debris conveyance. Such designs can also address the requisite hydraulic conditions of specific aquatic species that must navigate the culvert. In the bottomless culvert test facility, each substrate material was placed upstream, inside, and downstream of the culvert. The elevation of the top of the material was meticulously graded to correspond with the elevation of the top of the steel box/culvert interface (i.e., culvert spring-line). For each substrate material, five entrance configurations were tested featuring three different inlet contraction ratios (0 %, 33 % and 75 %) for both projecting and non-projecting (headwall) entrance conditions. The 0 % contraction configuration was limited to the non-projecting condition. Collected test data included incipient motion velocities, depths of scour, and extent of scour. Each substrate and inlet configuration was tested over a range of headwater depths. Headwater depths were expressed dimensionless as the headwater depth measured relative to the pre-scour invert at the culvert entrance over the pre-scour culvert height, $Hw/D$. The headwater depth was measured in a corner of the headbox adjacent to the culvert entrance, where the velocity was negligible and the headwater depth, $Hw$, represented the total energy head at the culvert entrance [7].

A methodology for simulation of urban flooding urban flooding may be due to various causes. The runoff generally starts as overland flow on the street before entering the underground pipe system through catch pits. Its shows that a street system connected to a pipe system through manholes/catch pits. If the intake capacity of the drainage system is limited, only a fraction of the water can flow into the pipes and a large runoff volume will be transported on the surface during and after a heavy rainfall. This may happen even if the underground pipe system has sufficient capacity [2,3], The water in the pipe system may return to the street system if the capacity of the pipe system is insufficient. In this case the water will flow from the pipe system to the street system, causing surface flooding. The duration of flooding on the street depends on the intake capacity of the catch pits, the drainage capacity of the pipe system, infiltration and evaporation in the catchment area. In the present modeling approach, the urban drainage system consists of two networks, one representing the free surface flow in the streets and one for the pipe network. The drainage system is modeled as two dynamically interconnected networks. The hydrodynamic model is based on an implicit solution of the St Venant equations. The two networks route the rainfall runoff simultaneously in the pipes and on the streets. Manholes (network nodes) function as points of flow exchange between the pipe and the street systems. Water from the street system can enter the pipe system by flowing through catch pits or manholes and vice versa. Its shows the modeling approach for urban flooding. Figure 1 shows shapes and orientation of diffuser [6].

Two models are needed, i.e. a hydrological model, which simulates surface runoff from rainfall and a hydraulic model describing flows in pipes, streets and storage of water on the surface. In urban flooding simulation, the hydrological process is separated conceptually from the hydraulics of the drainage system. The computation of the surface runoff from rainfall can be carried out by a standard surface runoff model, e.g. a time/area, kinematic wave or linear reservoir model. A surface runoff hydrograph is computed for each sub-catchment. Runoff hydrographs from each sub-catchment are then used as input for the hydrodynamic model, simulating flows in the pipe and street systems. The runoff from the catchments is entered in the model either on the streets or directly in the sewers depending on the local layout of the drainage systems. Hence, the initial flooding will be generated due to insufficient capacity of either the pipes themselves or of the inlets to the piped system. As the pipe and inlet capacities can differ significantly, it is important to get this part of the schematization right [4, 5].

At the same time, the increasing cost of providing hard engineered flood defenses and the growing emphasis on sustainable development has resulted in greater attention being given to finding more sustainable, 'softer engineering' solutions. This is reflected in the Government's Flood and Coastal Erosion Risk Management Strategy 'Making Space for Water' [9]. A key pillar of the strategy is to adopt a whole catchment approach and make greater use of rural land use solutions, including the creation of wetlands, wash lands and effective land management techniques. Forests and woodland have long been associated with an ability to slow down run-off and reduce downstream flooding [10]. In fact, deforestation has often been cited as a major contributing factor in the apparent rise in flood events in the developing world.

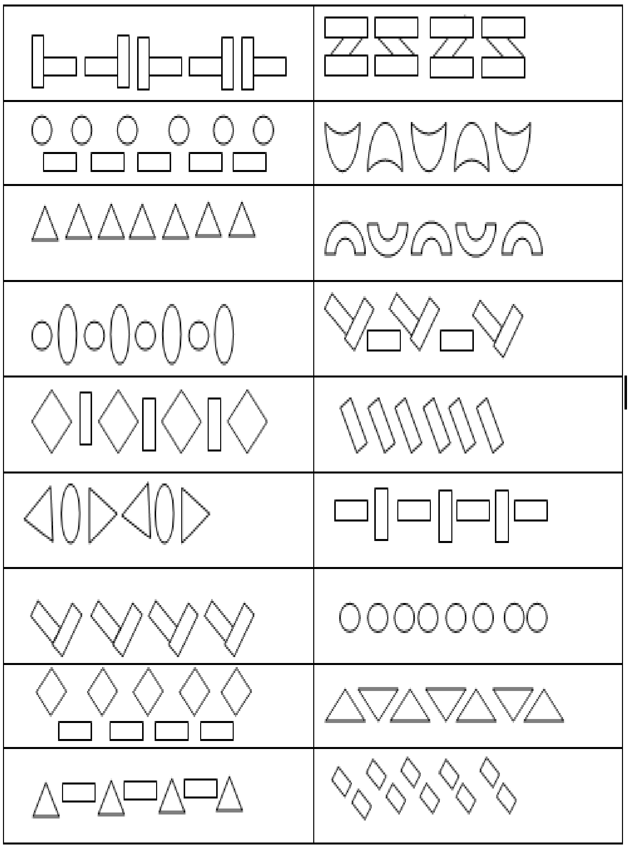

**Figure 1.** Shapes and orientation of diffuser [4]

Re-planting or creating new forests is increasingly viewed as offering a number of opportunities to help reduce flood risk. The potential to assist flood defense however, is highly dependent on the scale of forest cover and its location within the landscape. Other important factors include the type of forest and how it is managed. This paper examines whether woodland expansion in the UK could make a significant contribution to tackling the predicted rise in flood risk, as part of a whole-catchment approach to sustainable flood management.

To mitigate flooding propensity in Bangladesh, both the government and people will have to adopt watershed-scale best management practices (BMPs) – a series of activities designed to: (a) reduce the run-off, (b) increase the carrying capacity of drainage system, and (c) increase land elevations. Proposed BMPs are: floodplain zoning, planned urbanization, restoration of abundant channels, dredging of rivers and streams, increased elevations of roads and village platforms, building of efficient storm sewer systems, establishment of buffer zones along rivers, conservation tillage, controlled runoff near construction sites, adjustment of life-style and crop patterns, good governance, and improvement in flood warning/preparedness systems.

One of the most obvious ways to protect road embankments from erosion due to overtopping during flood events is to raise the elevation of the road profile above the flood water. Unfortunately, in areas prone to flooding, this is not always an easy or inexpensive task due to floodplain law and the need to mitigate backwater effects. The overtopping flows create a hydraulic jump on the downstream road embankment, causing extreme erosion which often creates failure of the driving surface. Repairing the damage from these overtopping events in northwestern Minnesota has caused the Minnesota Department of Transportation (MnDOT) to keep some routes closed for several weeks after the flood waters recede. One 3.22 km segment of Minnesota highway has experienced flood overtopping each of the past 3 years and 4 out of the last 5 years. Damage created by these floods has exceeded 2 million dollars. In addition, cost to businesses and travelers on these frequently flooded routes gets burdensome. This research is aimed at discovering cost-effective, low maintenance techniques to protect these road embankments from overtopping flow. Main Roads of Western Australia uses riprap and vertical concrete walls, FHWA and the USACE have done research using articulated concrete blocks. Since road overtopping flow is essentially flow over a broad crested weir, we can use these relationships to estimate velocities. Once the flow velocities over the broad crested weir are known, appropriate erosion protection can be selected and designed.

Two-dimensional modeling of dam failure flooding has been successfully demonstrated through the use of such models as the CCHE2D-Dambreak model. This modeling approach offers a tremendous improvement over traditional one-dimensional solutions in terms of the high degree of spatial and temporal detail in the model results. Detailed output for water depth, flow velocity, timing of flood arrival and duration of flooding is available from the two-dimensional model such that all aspects of the flood may be thoroughly analyzed. A special case in flood modeling from dam failure involves simulation of the flooding that may result in the event that more than one dam fails and the floodwaters from the multiple dams combine into a single flood event. This may occur when two or more dams are located in tandem along the same river, or it may occur when two or more dams are located on separate tributaries that flow into the same river. Failure of a single dam is a rare event, and multiple simultaneous dam failures are certainly even rarer [10].

However, the ability to model such an event and understand the potential flood conditions that may occur under various scenarios involving the timing of each dam failure and the water levels in each dam is important. The CCHE2D-Dambreak model offers such a capability, and this paper presents an application of that multiple dam failure modeling feature. An example is presented in which two dams located in tandem on the same river fail, and several scenarios are modeled to investigate the combined flood event [8,9].

In the rare event of a dam failure, little can typically be done to mitigate the magnitude of the downstream flood that will occur. The volume of water involved is usually so large that it overwhelms existing flood control or river control structures downstream of the dam. The mere presence of floodwaters will certainly cause water related damage in many areas, and the high velocity of flow that will likely accompany such a flood event may also cause structural or erosion related damage. Detailed knowledge, both spatially and temporally, of where the floodwaters may extend, the depths to which the floodwaters may reach, and the flow velocities associated with the flood can be valuable pieces of information that will enhance preparedness planning for such an event. A model that can accurately predict the flood depths and flow velocities with two-dimensional spatial detail, and can also provide temporal detail of such information, is a vital tool in the analysis of dam breach flooding.

The U.S. Army Engineer Research and Development Center (ERDC) Coastal and Hydraulics Laboratory (CHL) has the mission of conducting research and operational support for the U.S. Army in the area of military hydrology, which encompasses many diverse aspects of hydrology and hydraulic engineering related to how rivers, floods, dams and other water resources issues may impact military planning and operations. Among the most common types of analyses that are conducted in this field are studies of the potential effects of dam breach flooding. For the results of these studies to be of greatest benefit, detailed spatial and temporal evaluation of flood depths, flow velocities, timing of flood arrival, and duration of flooding are required. A model that can provide this information, often under severe time constraints and based on limited input data, is essential. Traditional one dimensional dam breach flood models can provide some of this information, but they generally lack sufficient two-dimensional spatial detail in many critical areas.

There are many approaches for reducing flood hazards in basins under development [4]. Areas identified as flood-prone have been used for parks and playgrounds that can tolerate occasional flooding. Buildings and bridges have been elevated, protected with floodwalls and levees, or designed to withstand temporary inundation. Drainage systems have been expanded to increase their capacity for detaining and conveying high stream flows; for example, by using rooftops and parking lots to store water [7,9]. Techniques that promote infiltration and storage of water in the soil column, such as infiltration trenches, permeable pavements, soil amendments, and reducing impermeable surfaces have also been incorporated into new and existing residential and commercial developments to reduce runoff from these areas. Wet-season runoff from a neighborhood in Seattle, Washington, was reduced by 98 percent by reducing the width of the street and incorporating vegetated swales and native plants in the street right-of-way. In response to frequent flooding along the Napa River in California, the local community integrated many of these approaches into a single plan for flood protection that is expected to reduce flood damage while helping to restore the river ecosystem. The plan involves bridge reconstruction, levee setbacks, a floodwall, moving of vulnerable structures, detention basins, larger storm water conveyances, and a high-flow bypass channel [10].

The U.S. Geological Survey in cooperation with the City of Charlotte and Mecklenburg County, North Carolina, developed a flood information and notification system (FINS) to address the need for prompt notification of flood conditions in urban areas where streams rise and fall rapidly. FINS is based on a large network of streamflow gagging and rainfall stations that broadcast information within minutes of being recorded via radio telemetry. The system automatically notifies the National Weather Service and emergency responders in the region when rainfall and streamflow indicate the likelihood of flooding, giving these agencies additional time to issue warnings and evacuate areas if necessary [10]

**Conclusions**

Floods are one of the most common natural hazards, causing significant damage, loss of life, and other negative impacts. There are many impacts from flooding such cause 30 in damage to the state's roadways. There are some ways that are done by researcher before to slow the velocity of the flood water flow but there are not use the obstacles object to investigate the flow water pattern as to estimate the velocity of the flood water

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