Identifying the Impact of Tidal Level Variation on River Basin Flooding

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Abstract

Different parts of Sri Lanka are regularly subjected to a wide range of natural disasters, of which floods are most common. When severe, flooding can decrease the economic and social development of the country and the Government of Sri Lanka has to spend huge amounts of money each year to address such problems. Floods occur mostly because of heavy rainfall combined with human-induced factors in the catchment areas. In this project, tidal level variation is considered as a factor for floods in the river basins. The tidal level changes periodically due to the gravitational attraction from the sun and the moon and the centrifugal force of the earth's rotation. This project studied the relationship between changes in tide and river water level in the mouth of the Kelani River. Tidal data was collected from the Colombo Harbor, and water level data and river flow data was obtained from the Nagalagam Street gauge and Hanwella gauge. It was found that there is a direct relationship between tidal level and flood level in the river mouth area. Therefore, it is proposed that tidal level variations be considered in order to make accurate flood predictions in the river mouth areas.

Introduction

Flood is defined as a body of water that rises and overflows into land settlements that are not normally under water (Kulathilaka 2007). It is known that with the population increases since national independence, land areas have become scarce and as a result, low-income families have occupied the flood plains of rivers, which have been demarcated as reservations. Putting up structures and using land without considering flood risks has often invited flood situations (NDRSC 2008).

Due to the heavy rain resulting from the South-West Monsoon, some districts of the Western, Southern and Sabaragamuwa Provinces of Sri Lanka experience frequent flood situations. The most affected districts are Colombo, Gampaha, Kalutara, Rathnapura, Kegalle, Galle and Matara. Riverine floods develop slowly when there is rainfall for a continuous period or may come in the form of flash floods caused by excessive and intense rainfall over a short duration (Kulathilaka 2007). This usually happens when a tropical cyclone or a depression strikes. The flood effect can be in the form of a local impact in the neighborhood or community or it can affect a very large area.

Floods cause huge damage to physical infrastructure, disrupt economic and social activities, and cause loss of life, and human suffering. In 2007, some 438,880 people were affected by floods and 20 deaths were reported by district authorities due to floods in Sri Lanka (Table 1; NDRSC 2008).

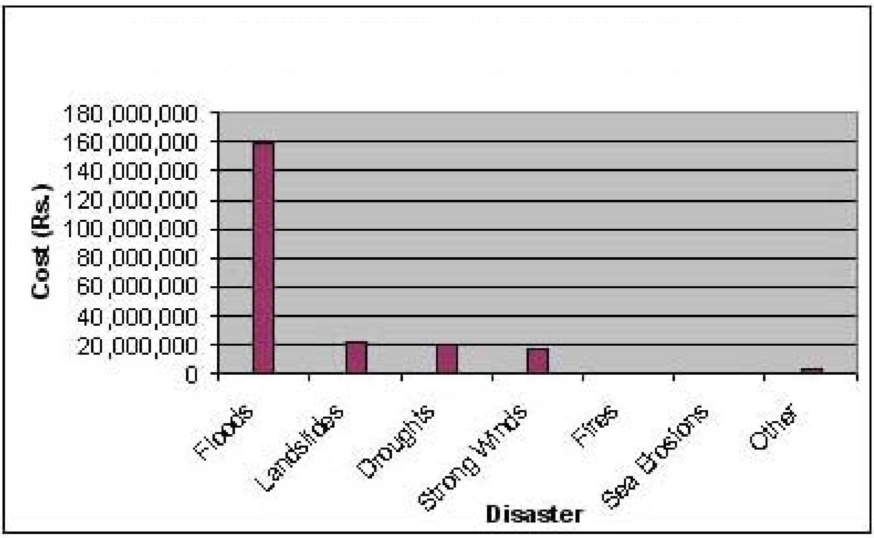
Table 1. Disasters compared in terms of the events of 2007.

Event	Number of affected people	Deaths	Injured	Houses damaged	
				Fully	Partially
Flood	438,880	20	17	2,568	7,237
Land Slide	15,199	14	11	437	1,371
Drought	57,435	-	-	-	-
Strong Wind	4,914	3	51		1,532
Fire	1,193	4	24	282	6
Lightning	9	7	2	-	-
Total	517,630	48	105	3,287	10,146

Source: NDRSC, 2008

According to these figures, floods are the biggest natural disaster related problem in Sri Lanka and the Government of Sri Lanka spent Rs.160 million on relief, rehabilitation and reconstruction programs in 2007 for flood affected districts (Figure 1).

Figure 1. Costs of relief, rehabilitation and reconstruction of Sri Lanka in 2007.



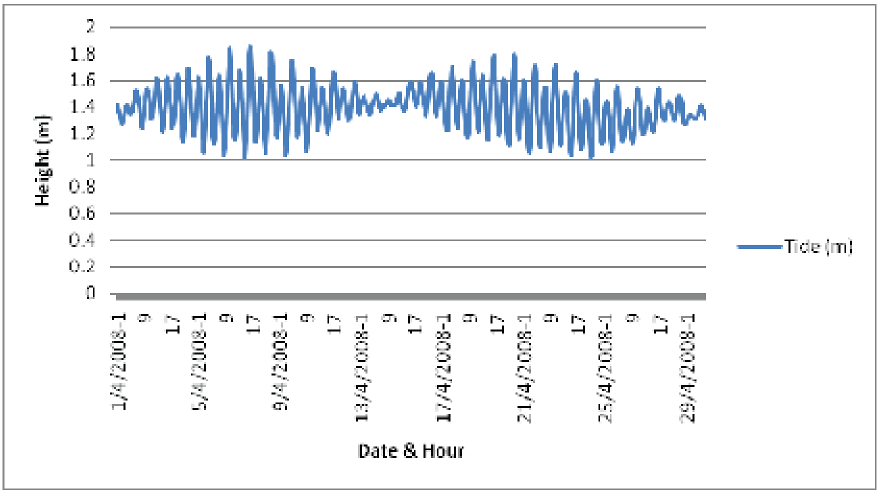
Source: NDRSC 2008

Tides

The surface of all ocean waters rise and fall periodically as a result of the gravitational attraction of the moon and the sun on the earth and the centrifugal force of the earth's rotation (Abbott and Ingham 1992). Far out at sea, tidal changes go unnoticed, but along the shores and beaches, the tides govern many of our water-related activities, both commercial and recreational but are also recognized as a hazard by ship navigators (NOAA 2009).

With the relative movements of the moon and the sun with respect to the earth's location, the tidal level varies. At the same time, the tidal level of a particular locality is affected by the bathymetry of the sea floor, resonance of the basin, friction of the bottom, currents, freshwater inflow and seasonal variations (UTM 2007). Therefore, tides must be observed in the relevant location for accurate applications. Figure 2 shows the tidal variations in the Colombo Harbor in the month of April 2008.

Figure 2. Tidal height changes in April 2008 at the Colombo Harbor tide gauge.



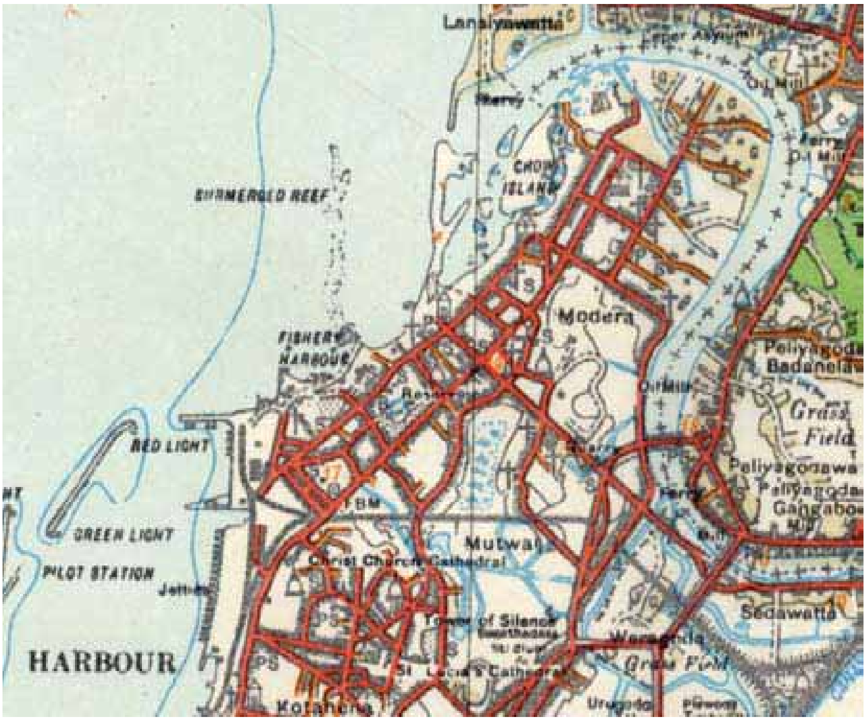
Aim

River flooding is a natural phenomena based on many different factors. This project expected to identify a relationship between tide level changes and river basin flooding near river-mouth areas. It raises the question as to how river flood risk will change under the influence of tidal level variations.

Methodology

Both sides of the Kelani River from Hanwella towards the sea are identified as flood-prone areas. Therefore, this area was selected for the study and data on the river water level and the tidal level at the river mouth were needed. Since there was no tide gauge located at the mouth of the Kelani River, the tide data was obtained from the Colombo Harbor tide gauge, which is situated close to the site (Figure 3). It is maintained by the National Aquatic Resources Research and Development Agency (NARA) and the data was obtained with the help of the National Hydrographic Office (NHO).

Figure 3. Tide gauge and the river water level gauge locations (1 inch sheet - Colombo).



Excessive rain into the upper catchment brings lots of water into the river and increases the river flow. This is the main cause for river flooding. This can be detected with the rising of the water level gauge at the river. For this study, two water level gauges in the Kelani River were used; one at Nagalagam Street and the other one at Hanwella. They are maintained by the Irrigation Department of Sri Lanka. The Nagalagam Street gauge is situated closer to the river mouth (Figure 3) and was compared with the tidal data to identify a pattern. The Hanwella gauge is situated quite far from the river mouth and is used as a measure of river flow and indicator of flooding.

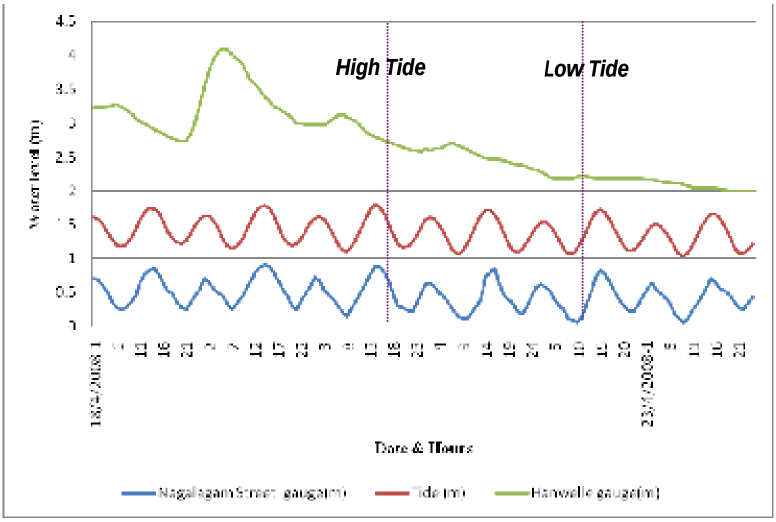
In this study, both tidal and water level data were obtained on an hourly basis on each day from April to June 2008 and analyzed for a pattern to identify a relationship between them. During this period, several flood occasions were reported at the site. From the data obtained, a graphical analysis was carried out for the following cases:

- The water level pattern of the river-mouth with the tidal pattern during the non-flood periods (with low river flow).
- The water level pattern of the river-mouth with the tidal pattern during the flood periods (with high river flow).

Results and Analysis

The water level of the Nagalagam Street gauge changed directly with the Colombo Harbor tide gauge (Figure 4). When there was high tide, the water level at Nagalagam Street was also high; when it was low tide, the water level was also low. In the mean time, the Hanwella gauge shows minimum correlation with the tide gauge (during low water levels and non-flood) because it is situated away from the river-mouth towards the upstream. It gives information about how the water flows in the up-stream-river during the period.

Figure 4. Variation of the tide and river water level during a non-flood period.



From 01:00 hours on 19/07/2008 to 02:00 hours on 21/07/2008, and 11:00 hours on 23/07/2008 to 14:00 hours on 24/07/2008, the water level of the Hanwella gauge rose, and these two periods were identified as flood periods in the Kelani River (Figure 5). During the same period, the water level of Nagalagam Street also increased, but this increment is not as obvious as in the Hanwella gauge. Here, the water level of Nagalagam Street has not behaved in a manner that corresponds with the tides as clearly as during the non-flood periods as shown above. Therefore, the graphs for these durations are magnified and analyzed as follows (Figure 6).

Figure 5. Variation of the tide and river water level during the flood period.

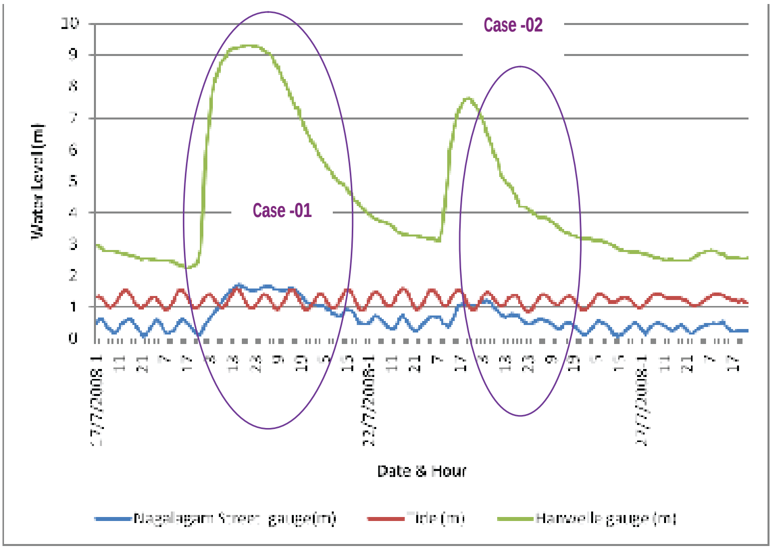
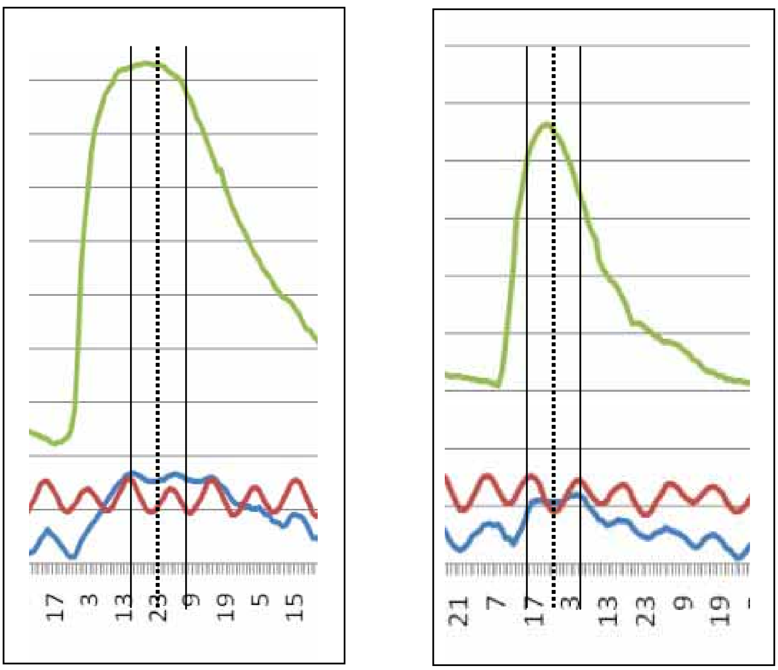


Figure 6. Comparison of the river water level and the tidal level during the flood period.



(a) Case-01 (19-20/07/2008) (b) Case-2 (23-24/07/2008)

At about 13:00 hours (19/07/2008) the tide gauge read a high tide (Figure 6a). At the same time the river water level at Hanwella was getting close to a high level. With this situation, the Nagalagam Street gauge had the highest reading. When it reached 22:00 hours the river water level at Hanwella was at its peak but the Nagalagam Street gauge read a lower water level than at 13:00 hours because the tide level was lower than that at 13:00 hours (low tide). Again the Nagalagam Street gauge reading rose at about 05:00 h the next day, even though the Hanwella gauge was less than at 22:00 h, because it was another high tide time.

The same pattern can be observed in the second case (Figure 6b). At 17:00 hours on 23/07/2008 and 05:00 hours on 24/07/2008, Nagalagam Street gauge read a high water reading because at the same time the tide gauge was giving a high tide and the Hanwella gauge read a high reading. Even though the Hanwella gauge gave the highest reading at 23:00 hours on 22/07/2008, the Nagalagam Street gauge reading was lower than that of 17:00 hours and 05:00 hours, since it was low tide.

Conclusion

The water level of the river-mouth is directly correlated with the tidal variation of the sea. The collective result of the river flow and the tidal level will determine the water level of the lower river areas. When there is high water flow and a high tide, the water level of the river-mouth area is increasing. If the river flow is in a flood risk situation, then the high tide will cause the water level of the river-mouth to increase and it will increase flood risk. With the start of the low tide, the flood risk will decrease. Therefore, when predicting floods in lower river basins, one has to consider the tidal factor, especially in areas where there is a large tidal variation.

Recommendation

The tide gauge that was being used for this work was not situated at the river mouth, therefore, in future studies it is recommended to have a tide gauge at the river mouth.

In this study, we could not collect the river flow data at the river mouth area (Nagalagam Street) along with the water level data, therefore, we used the Hanwella gauge water level data to get an idea about the river flow, but for more accurate work, one has to use the river flow data along with the water level data at the same place.

Usually at river mouths, sand bars are formed due to the tidal currents and other water movements. These will block the natural flow of the fresh water of the river to the sea. Therefore, it is recommended to carryout a bathymetric profile survey at the river-mouth to verify any sand movements during the time.

Acknowledgements

We must express our sincere thanks to Ms. P. P. G. Dais, Deputy Director-Hydrology of the Irrigation Department of Sri Lanka and her staff for providing the water level data and to Mr. R. K. A. Ariyrathne, Surveyor of the National Hydrographic Office NARA for providing the tidal data to carryout this work. Without their valuable contribution, this project could not have been a success.

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