Overland Flow Modelling in Hong Kong

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Introduction

This paper discusses the use of new modelling techniques applied to the Tsuen Wan, Kwai Chung and Tsing Yi areas of Hong Kong. In particular, it details how overland flow modelling has been used to develop a more realistic representation of flooding which has in turn been related to actual flooding locations. The paper also discusses how different flood alleviation options have been evaluated in terms of cost and benefit.

Background

The Drainage Services Department (DSD) of the Hong Kong Government commissioned Montgomery Watson (MW) to investigate the Tsuen Wan, Kwai Chung and Tsing Yi areas of Hong Kong in order to produce a Drainage Master Plan. This study, which ran from 1996 to 1998, utilised five HydroWorks models to complete a detailed flooding analysis and develop a range of flood alleviation options.

This traditional analysis produced three options to alleviate flooding ranging in cost from 58 to 100 million pounds sterling. In view of the scale of these alleviation schemes, the Hong Kong Government requested further evidence to demonstrate that the proposed options represented value for money. In addition, the flooding predictions from the model could not be adequately related to actual reported flooding due to the limitations of the flooding representation in the models. Large volumes of flooding were being predicted at many manhole locations which did not correspond to reported events.

A new approach was required to rationalise both the analysis and the proposed alleviation schemes to achieve an optimised and fully justified solution.

The New Approach

One of the difficulties with the analysis was the use of five overlapping models. These were required due to the limitations of HydroWorks only allowing a maximum of 5,000 nodes and meant that results had to be collated from several different sets of model runs.

The release of InfoWorks removed the limitation for the maximum number of nodes thus making it possible to combine the models into a single file.

Although this made the logistics of flood analysis more straightforward, it made no difference to the predictions of flooding. With the extreme storm events being considered, vast volumes of flooding were being predicted at certain locations with flooding depths being much larger than actual levels reported.

It was therefore agreed that an overland flow model would be developed to include the probable flow paths above ground. This was completed by Montgomery Watson using GIS database techniques and was based on the predictions of flooding from the traditional analysis. Flood routes were determined from background mapping and relative ground levels in the main areas of flooding. Where possible, actual channels were included in the model utilising real road widths. Assumptions were however made for kerb heights and roughness. Also, due to the size of model, no attempt was made to include gully restrictions to re-entry of flow. A standard naming convention was used for the overland flow links to distinguish them from other pipes and open channels.

The final combined model comprised approximately 8,900 nodes, 9,150 real pipes and channels and 4,550 overland flow links. Analysis was then carried out for one in 10, 20, 50, 100 and 200 year return period storm events.

Flood Extent Analysis

The results of the combined model were analyzed again using GIS database techniques. The depth of flooding and the velocities of flow in the overland flow links were extracted to produce plans using the actual road widths.

These levels and velocities were used to complete site surveys to relate the predictions of flooding to report flooding and also to determine the extent of flood damage.

The model predictions correlated well with reported flooding and although for extreme events such as 200 year return periods the flooding depths were still very large in some areas, the predictions for all events gave much more realistic predictions. The inclusion of the overland flow links showed that in many areas, the above ground flows would be entirely contained within the kerb channels and thus would cause no actual flooding or damage to properties.

A further benefit of the overland flow model was that the model proved more stable with vastly reduced incidences of volume generation.

Options

Three main options were developed comprising a tunnel, three storage tanks and more limited urban improvements such as widening existing culverts and upsizing pipes. The ‘Do Nothing’ option was investigated as a datum from which to index the capital schemes being evaluated and was itself considered as an option.

Cost Benefit Analysis

A detailed cost benefit analysis was carried out for the three options and the ‘Do Nothing’ option. Using the flood extent plans, a series of site visits were undertaken to actually relate the flooding predictions to the number of properties affected and the degree of damage likely to occur for each option.

The costs of damage arising from flooding over a range of return periods were estimated for all options and a loss probability relationship established. This meant that the average annual benefit of protecting the study area from flooding could be determined.

The risk of loss of life and injury due to large flood depths and velocities was also evaluated and commented upon. However, no attempt was made to evaluate the cost of this to the Government of Hong Kong. This and other intangible costs such as loss of emergency services, police protection and medical care were listed as intangible losses which should be considered outside a pure cost benefit analysis. The United Nations report 'Manual and Guidelines for Comprehensive Flood Loss Prevention and Management' was used as a guide for this evaluation.

The capital costs of the three alleviation schemes were developed in some detail to give an estimate of the likely costs of construction. This also included a degree of risk estimation and consideration was also made regarding the viability of construction.

The costs were then compared to the benefits of each flood alleviation scheme for scheme design lives of 100 and 200 years. This showed that the tunnel option gave the best cost benefit ratio as well as being the most practical and feasible option from a construction point of view.

This detailed analysis, combining the results of the overland flow model with the costs of flooding damage, allowed an optimisation of the alleviation options. For example, the diameter of the tunnel option was significantly reduced over the options from the previous study. This was possible by permitting low levels of flooding which could be shown to be contained within the road channels. This sort of analysis was only possible by considering the consequences of overland flow. Cost savings in the region of 30 % resulted from this new approach to flooding analysis.

Conclusion

In conclusion, the benefits of including overland flow links in models have been demonstrated. Although it should be understood that the model is still an approximation, a more realistic prediction of flooding has been achieved which bears a much stronger relation to reported events. This improved representation has allowed a more detailed cost analysis to be carried out than was previously possible and has generated capital cost savings.

References

1. WaPug User Note 37 Richard Allit
2. Urban Flood Protection Benefits a Project appraisal guide. Dennis J Parker, Colin H Green and Paul M. Thompson, Gower Technical Press, 1987
3. Manual and Guidelines for Comprehensive Flood Loss Prevention and Management, United Nations Development Programme 1991

DISCUSSION

Question **George Heywood** **Tynemarch**
It is good to see overland flood flow being considered did you take into account the camber of the road and allow above kerb flow? Also did you look at re-engineering the roads in the solution?

Answer
We did consider the effects of above kerb height flow , but the constraints of the budget precluded detailed investigation. Our predictions of flood depth are probably on the high side, conservative. Camber was not allowed for.
Road re-engineering was not considered because of constraints of the locations.

Question **Jim Grandison** **Insight Surveys**
As flow capacity and flooding is related to tide levels, were these considered.

Answer
Yes various assumptions were made on tide levels. It was agreed that a single level average tide level was used , i.e. not time varying. So the overland flow did not take into account the variation in tide during an event. High tide level was below road level.

Question **Jon Farrer** **Bullen Consultants Ltd**
You carried out a 200 year storm analysis , what happens on lesser storms say 30 year design, you will always localised problems in your 200 year solution.

Answer
It is true that the local problems will exist but these would be solved after the overall tunnel solution had been implemented. The overall scheme was the main one under investigation.

Question **Brian Reed** **CIRIA**
Were any studies done to look at how the catchwaters effect the situation, as they intercept storm flows of the upland areas.

Answer
The catchwaters were investigated and included in the model but there were problems with them as a design assessment issue.
1. The catchwaters are generally designed to take a 1 in 5 year flow. We were dealing with the 1 in 200 year event, so they had a minor effect.
2. The flow in the catchwater is controlled by gates. These gates are closed when reservoirs are full. As the gates are managed by a different Government Department it is not possible to say what state of closure they would be in on any given event.
3. Hong Kong is prone to land slips in major storm events, the land slips often damage or block the catchwaters.