AN INNOVATIVE APPROACH TO FLOOD HAZARD MAPPING IN HAMILTON CITY

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ABSTRACT

Hamilton City Council (HCC) recently embarked on a Three Waters Modelling program to better understand the potential risks and hazards relating to the water, wastewater and stormwater networks. In terms of stormwater, this has meant developing an understanding of flooding potential across the whole city, and identifying areas of potential high risk hazards to enforce development and planning constraints and red flag areas.

In order to achieve a cost effective solution across the whole city an innovative approach was developed by AECOM and Hamilton City Council. The approach that has been adopted included a rapid flood hazard model covering the city. The outputs from this model were then used to quantify the number of affected properties in each sub-catchment. Performing a cost benefit analysis between the model build cost and the potentially affected properties identified areas of benefit for detailed modeling.

This paper describes the model's conceptualisation and development. It explains the methodology used to deliver the project on time and budget while achieving the required outputs. It also discusses the limitations of certain aspects of the results and the potential advancements that could be made for marginal additional cost. Finally, it examines the lessons learnt and how they can be applied to future projects.

KEYWORDS

Hydrological and Hydraulic Modelling, Two Dimensional Model, Flood Hazard Mapping

PRESENTER PROFILE

Shaun Jones – Shaun has 10 years of diverse engineering experience in the Auckland region including environmental, geotechnical and civil engineering. His career to date has involved design and construction management of stormwater management systems, hydrological assessments and stormwater modelling.

1 INTRODUCTION AND BACKGROUND

In 2010 Hamilton City Council (HCC) embarked on a program to develop computer models to represent the behaviour and performance of its wastewater, water supply and stormwater networks. The project is known as the HCC Three Waters Modelling Program and excludes the specific modelling of the water supply and wastewater treatment plants.

The Three Waters Modelling Program was awarded to the AECOM team which consisted of AECOM, AWT, DHI and Watershed. The contract commenced in September 2010 and was split into three phases being:

Phase 1

- Develop calibrated trunk water supply and wastewater models from field monitoring, flow gauges and asset data. The models will be used to understand any existing and future system performance issues at a high level.
- Undertake Flood Hazard Mapping (FHM) scoping based on a rapid flood assessment (RFA) approach. The level of detailed modelling was determined from these results and was for the future fully developed 100 year rainfall event with climate change.
- Support any Catchment Management Planning work and stormwater flow gauging as necessary.

Phase 2

- Develop a calibrated all pipe water supply model from additional field test data. The model will be used to understand any existing and future system performance issues in more detail.
- Develop five calibrated wastewater network models based on short and long term flow gauge data.
- Support any Catchment Management Planning work and flow gauging as necessary.

Phase 3

- Provide support to HCC regarding any ongoing model queries and updates.

1.1 STORMWATER FLOOD HAZARD MAPPING OBJECTIVES

The client's objectives in developing a FHM for the City included:

- Meeting the requirements of the Regional Policy Statement where the 100 yr hazard was required to be identified and managed
- Development of hazard maps for use in the District Plan and LIM's
- Ability to set building restrictions in areas identified as prone to flooding
- Understand secondary overland flow paths
- Support Catchment Management Planning – a requirement of the Clients Comprehensive Stormwater Discharge Consent with Waikato Regional Council

1.1.1 STORMWATER DELIVERABLES

The stormwater deliverables are as follows:

- development of hazard classifications that meet the requirements of RPS and the City
- a set of hazard maps for use in the District Plan
- GIS layers showing depth and velocity to enable floor levels and secondary overland flow paths to be defined and managed
- FHM Report

2 MODEL CONCEPTUALISATION AND DEVELOPMENT

In order to achieve the objective of identifying potential flood hazards across the City, an innovative approach was required. During the development of the original proposal, AECOM held workshops to develop an appropriate methodology that would achieve the objectives.

A project specific methodology was developed to understand the extent and likely impact of extreme event flooding within the City. This methodology is discussed below:

Step 1: City Wide FHM

The City Wide FHM was undertaken to provide a high level understanding of the potential flooding hazards across the City. The City Wide FHM approach provides a conservative estimate of flooding as it assumes that all of the pipes and catchpits are fully blocked and that any rain that falls on the land becomes runoff (i.e. no losses).

The model included a digital terrain map covering the whole City. The model software utilises a grid system to simulate the ground surface, in this stage the grid size was 5m square.

No piped reticulation was modelled in the City Wide FHM; however, culverts larger than 900mm diameter were incorporated. During the model build a total of 41 culverts were surveyed.

The rainfall hydrology used was 100 year ARI (Average Recurrence Interval) plus climate change incorporating the requirements of HCC's Development Manual and Regional Policy Statement. The hyetograph was a nested storm to ensure the critical duration for each catchment was considered. The 100 year plus climate change rainfall was applied to the Digital Terrain Model (DTM) for the 6, 12 and 24 hr duration storms.

The result files for all three storm durations were processed in accordance with the 2D hazard classification methodology discussed in Section 3.2. The results were provided as a raster output for inclusion in the Hamilton City Councils District Plan Hazard Maps and GIS system.

The modelled flood predictions were discussed with HCC Operations staff and there was agreement that the results generally reflected reality.

These City Wide FHM results were used to understand the potential hazards and define the scope for Step 2 – Detailed Flood Hazard Mapping.

Step 2: Detailed Flood Hazard Mapping (Detailed FHM)

The City Wide FHM results were used to establish the number of buildings within the flood plain. Eight sub catchments were identified with the number of affected buildings ranging from 35 to 1060. A cost benefit analysis of the cost to build the models vs. the benefit in terms of affected buildings was carried out. This analysis identified which of these areas were to be included in the detailed FHM. Key attributes of the detailed models are as follows:

- Hydrological analysis was undertaken using the Model B kinematic wave approach. This provides a robust assessment of rainfall losses and runoff.
- The primary drainage network was incorporated into the model
- Inletting into the primary network was calculated on the number of catchpits in the sub-catchment multiplied by 25 l / s
- 2m square terrain grid

As the time of concentration for most of the catchments was less than 2 hours, a 6 hour storm was selected. The 6 hour duration was the shortest design storm considered and contains all critical durations within it. The 100 year with climate change 6 hour duration storm was then applied to each of the detailed model areas. The results from these models have been processed for hazards in accordance with section 3 and converted to vector files as required by HCC.

Step 3: Development of a 2 m Grid City Wide FHM with Culverts

In order to validate the results from Step 1 a refined model similar to the City Wide FHM was developed. This involved using a 2m grid (as opposed to 5m grid) and included all the culverts (as opposed to only those with diameters greater than 900mm). The approach assumes there are no pipes or catchpits and that all surfaces are impervious.

This step showed that using the 5m course grid identified the same flood hazards as the 2m grid.

Step 4: GIS deliverables

The results from Steps 1 to 4 have been compiled into one GIS deliverable in vector format. The file shows the peak hazard in accordance with Section 3. In addition, a shapefile with each cell represented as a vector has been produced.

This file contains maximum depth, maximum velocity and maximum depth x velocity. Each cell also contains details of the origin to identify whether it is located within the detailed model area or not.

2.1 KEY FINDINGS

The outputs from the four steps above have varying levels of confidence. This is primarily due to the amount of detail in each model. In this regard, the following should be noted:

City Wide FHM

The 5m grid City Wide FHM results have the least confidence and generally provide the upper extreme of the flood potential for areas. In some cases there is a potential that the downstream impacts have been reduced due to the primary drainage system not being incorporated.

The following can be observed from these results:

- Overland flow paths were identified
- Indicates whether the larger culverts can convey the 100yr flows
- That the majority of flooding areas are constrained to gully systems and low lying areas with no natural drainage

City Wide FMH with Culverts

The 2m grid City Wide FHM results are the next in level of confidence and slightly better than the 5m City Wide FHM results. This is due to all culverts being included in the models thus allowing for flow to be passed forward. With the culverts in the model the most upstream impacts should be reduced. Without the primary pipe system (pipes and catchpits) allowed for in the model and 100% rainfall runoff the flooding will still be conservative.

In addition to the 5m City Wide FHM the following can be observed from these results:

- With the smaller culverts included any flooding in the upper catchment can be understood

Detailed FMH

The detailed FHM modelling provides the highest level of confidence in the model outputs. This is due to catchments being loaded to the pipe system thus utilising that capacity, losses to ground being taken into account and all culverts in place.

The following can be observed from these results:

- With the inclusion of the primary drainage system the extent of flooding areas are more accurately defined
- Flood levels can be used for planning purposes (as opposed to simply identifying where flooding is expected to occur)

The detailed model results have been merged with the initial City Wide FHM project to provide Flood Hazard Maps suitable for inclusion in the District Plan and GIS layers, albeit with differing levels of confidence in the accuracy of the hazards.

3 HAZARD CLASSIFICATION

3.1 BACKGROUND

Surface flooding, as well as overland flow with unsafe depths and/or velocities were identified and agreed with Hamilton City as shown in Table 1 and Figure 1 below. The

FHM program identifies areas with the potential to cause damage according to chosen criteria. These criteria considered the following aspects:

- Flooding of private or public property or buildings
- Overland flow occurring to such a depth and/or velocity as to pose a possible safety hazard to vehicles and pedestrians.

2D Hazard Classification Methodology

High risk flood zones mean that land is subject to flooding during the 100 year ARI event; and during such an event:

- the depth of flood waters exceeds 1 metre;
- the speed of flood waters exceeds 2 metres/second; or
- the flood depth multiplied by the flood speed exceeds 1.

The outputs from the model can to be used for the following applications:

- Flood Hazard Mapping
- Hamilton City GIS layer for internal and public information, although the confidence in the outputs needs to be taken into account
- Land Information Memorandums (LIM's)

It is therefore necessary to ensure that outputs sufficiently fulfil the requirements of all applications while maintaining consistency in presentation and extractable information.

3.2 HAZARD CLASSIFICATION METHODOLOGY

To determine the hazard classification as described in Table 1 below, the velocity and depth for each grid is used at each time step during the simulation to determine the hazard classification at the given time step. The depth/ velocity criteria for each hazard classification are shown in Figure 1 below. The hazard is classified with one of the following values:

Table 1: Hazard Classification Category

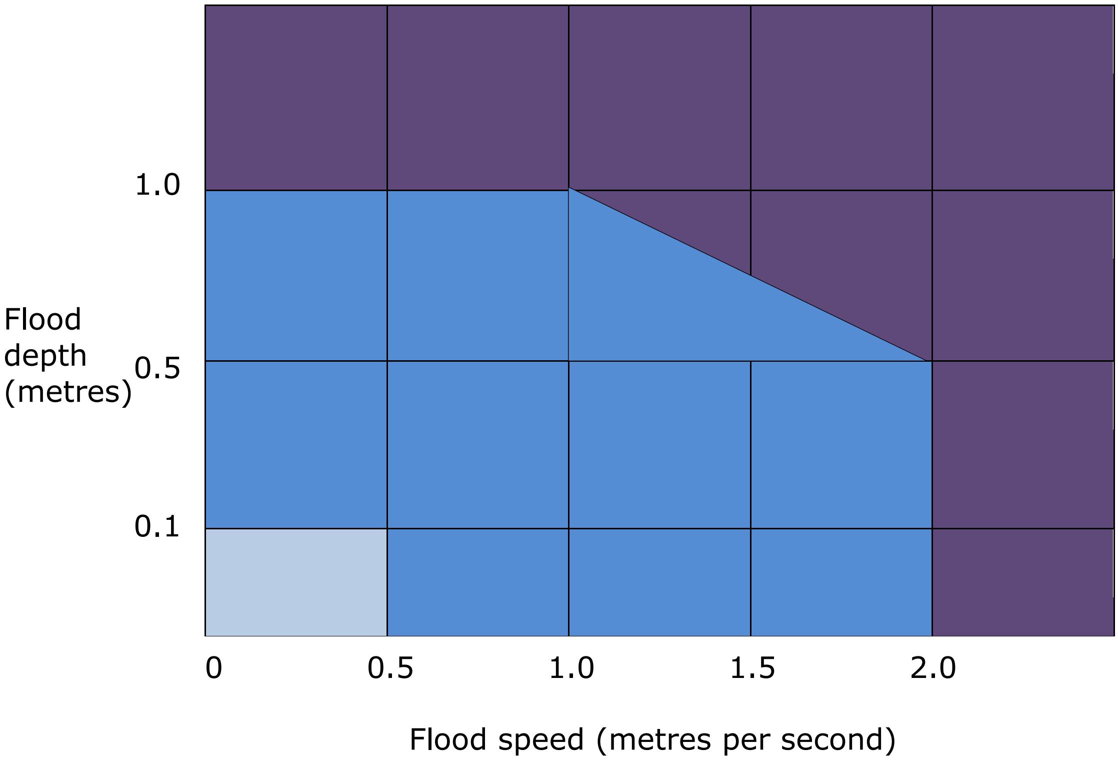
Hazard Classification	Description
3	High Risk Zone
2	Medium Hazard
1	Low Hazard
0	No Hazard

The maximum value during the simulation for each grid cell is extracted from the result file and used to determine the hazard classification. This method evaluates the hazard classification at each time step and determines the maximum / worst case hazard. These classifications are then used for the raster output showing the colour scheme for each grid cell based on the model results.

Hazard classification raster outputs for depth and velocity were also developed. For these outputs the velocity and depth for each time step were used to determine the hazard classification (refer to Figure 1 below). The worst case hazard was extracted from the results to define the final hazard classification.

For the depth only output, the maximum depth for each time step was extracted to generate the vector output.

Figure 1: Depth – Velocity Criteria for Hazard Classification



The hazard classification is used to produce digital GIS raster shape files which clearly highlighted flood and overland flow hazards.

4 OPPORTUNITIES FOR IMPROVED OUTPUTS

The FHM completed to date is the first step for HCC to develop a detailed understanding of the flood hazard risk which in turn will be used to develop capital and renewal works programmes, set design criteria, influence building practices etc. Further advancements can be made for marginal costs. These advancements are outlined below.

4.1 FLOOD DAMAGE ANALYSIS

Flood damage analysis is a hydro-economic assessment to understand the financial impact of flooding. This analysis could be carried out with varying levels of accuracy depending on the technique used to obtain floor levels.

This approach provides the understanding of the risk exposure should a significant storm event occur and enables prioritisation of capital spend on a city Wide and catchment basis.

In order to undertake this analysis additional model runs would be required and floor level surveying carried out. The models and results from this study are key to this analysis.

4.2 FLOODED FLOOR COUNT

Once the habitable floors and levels within the flood zones are understood, a flooded floor count could be carried out. This is a relatively simple analysis and provides an understanding of the magnitude of the flooding problem within the city or catchment by catchment.

4.3 INFRASTRUCTURE REQUIREMENTS

Capacity issues within the network can be identified by running the level of service events through the model i.e. the design standard for infrastructure design in residential areas is 2yr ARI, therefore by running the 2yr ARI event through the model the network constraints can be identified. This work can be used by Hamilton City to define infrastructure upgrade programmes where flooding issues are also identified.

4.4 FUTURE DEVELOPMENT SCENARIO

The FHM information can be used to assist developers in determining the effect that the development will have on the catchment including flooding, retention and detention analysis.

4.5 STORMWATER QUALITY

The models can be used in conjunction with ECOLAB to understand the effect of contamination of the receiving environment. This analysis can be carried out for various scenarios including different future land use scenarios with different levels of treatment.

In addition, the analysis of stormwater quality could be considered in terms of Hamilton Citys contribution to the overall water quality of the Waikato River.

4.6 EROSION PREDICTION

Large areas of Hamilton are drained via gully systems that discharge into the Waikato River. Increased flows due to urbanisation can cause long term erosion issues. The detailed models can be used to understand extreme event velocities within these gully systems.

5 LESSONS LEARNT

5.1 CLARIFY THE CONFIDENCE LEVEL AT THE OUTSET

All stormwater modelling has inherent inaccuracies. These inaccuracies are compounded when certain assumptions are made. Properly conveying this is critical to ensuring the outputs are correctly interpreted and used.

5.2 CULVERT SETUP

The City Wide FHM used Mike11 to represent the culvert setup. This required significant amounts of setup time to stabilise the model. Using the structure setup in Mike21 is less time consuming and does not have the same stability issues. The limitation of this methodology is when trying to deal with outlet controlled culverts as Mike21 structures do not represent these flow regimes correctly.

5.3 LIDAR IS NOT INFALLIBLE

LiDAR is only as accurate as the equipment used to obtain the data and post processing of the data. Significant inaccuracies can occur where ground surface is covered by vegetation.

5.4 CLIENT INFORAMTION

Asset information held by the client may not be appropriate for modelling purposes.

6 CONCLUSIONS

Overall this project has provided HCC with an understanding of the City Wide flood issues and enabled Council to meet their responsibilities under the Regional Policy Statement. The risk of flooding can now be mitigated in new areas by restricting development in areas at risk. The outputs from the detailed modeling will allow Council to embark on flood damage analysis, plan for capital infrastructure and support catchment management planning.

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