Leichhardt Flood Study – Why Not Just do it All at Once?

R.THOMSON\textsuperscript{1}, D.PATON\textsuperscript{2} and B. KILAPARTY\textsuperscript{1}

\textsuperscript{1} Cardno Lawson Treloar
\textsuperscript{2} Leichhardt Council

ABSTRACT

Leichhardt Local Government Area (LGA) incorporates a number of historical inner west Sydney suburbs including Leichhardt, Balmain and Rozelle. With a total area of approximately 10 square kilometres, and a population of approximately 51,000, it has one of the highest densities in NSW. It includes three major catchments, as well as numerous smaller flow paths. As it is one of the oldest areas of Sydney, the stormwater infrastructure is also very aged and generally under designed and formalised overland flow paths, in most cases, are non-existent.

Leichhardt Council commissioned the flood study to define not only the mainstream flooding, but also the overland flooding across the entire LGA. Whilst the mainstream flooding extents were not examined in detail beyond the Leichhardt boundaries, an intensive and complex modelling approach was still required to examine the many small confined flow paths throughout the LGA.

A series of detailed 2D hydraulic models were established for the Leichhardt LGA. Due to the detail required, the models utilised a 1 metre grid (more than 10 million grid cells) and incorporated all the pits and pipes in the LGA (approximately 3,500 pits). The Direct Rainfall method, where rainfall is applied directly to the 2D grid, was also adopted.

This paper reviews the process of establishing this model and the calibration process. It provides an overview of:

- Pit and Pipe data collection, utilising a unique cost saving approach.
- Collection of historical observations, including resident survey of 20,000 owners & occupiers.
- The calibration and verification process, including the historical flood events and comparison with alternative modelling techniques. This includes the verification of the Direct Rainfall approach.
INTRODUCTION

Leichhardt LGA lies in Sydney's inner west and includes the suburbs of Annandale, Leichhardt, Lilyfield, Rozelle, Birchgrove, and Balmain. The LGA covers an area of approximately 10 square kilometres. The study area is roughly bounded by Parramatta Road to the south, the Harbour to the north, Johnstons Creek and the City of Sydney to the east and Hawthorne Canal to the west.

Leichhardt Council commissioned the Leichhardt LGA wide flood study to define not only the mainstream flooding across the entire LGA, but also the overland flooding issues. One of the challenges in modelling of the flowpaths in Leichhardt is the small confined flowpaths prevalent in the study area.

SURVEY DATA ACQUISITION

Leichhardt Council already held LIDAR data across the entire LGA. Additional ground survey was also undertaken to define the channels within the study area.

Council also wanted all of their pits and pipes included in the flood model. To do this, an extensive pit and pipe survey was undertaken across the entire LGA. Approximately 3,500 pits were surveyed, including details on inlets, internal dimensions, depths to invert and other key details.

In undertaking the survey, a unique approach was adopted to minimise the overall cost of this exercise. The pits were positioned electronically in the field using GIS and aerial photography. The surface levels were then determined utilising the un-thinned LIDAR data. This reduced the overall cost of the survey by negating the need for traditional survey techniques to determine horizontal and vertical location.

COMMUNITY CONSULTATION

A questionnaire was sent out to selected community members to provide feedback on flood experience within the Leichhardt LGA. Community members that were selected were those within a 20 metre buffer from main stormwater pipes or potential overland flow paths within the LGA. Potential overland flowpaths were identified utilising coarse 2D modelling with a PMF event applied using Direct Rainfall.

The questionnaires were sent in December 2007 to approximately 22,000 households (including owners and occupiers). The questionnaire featured 8 questions, which were directed at gaining understanding of community awareness of flooding as well as historical flood information against which the hydraulic model could be calibrated. In addition to the mail out, residents were also able to submit an on-line questionnaire.

A total of 902 responses were received, representing a return rate of 4%, which is relatively low (although it is noted that the mail out included owners and occupiers). Only a few responses were received via the on-line system, suggesting a preference for the mail out.
Approximately 50% of the respondents lived in the area for less than 10 years, and 30% of the respondents lived in the area for less than 5 years. While there was a high level of flood awareness amongst the respondents (67%), most of the knowledge of flooding was for more recent flood events. An estimate of the flood experienced suggests that approximately 95% of the respondents would have been present for at least some floods in 2000 to 2006, while only 50% of residents would have been present for any flooding in the 1990s. This generally led to a skew of observations of flooding between 2000 to 2006, rather than in the 1990s when more significant flood events were experienced in Leichhardt.

**MODEL SETUP**

A detailed 1D/2D hydraulic model (SOBEK) was established for the study area. The 1D component of the model included all of the pits and pipes (approximately 3,500) as well as some of the stormwater channels and key structures such as culverts.

Due to the dense urbanisation of the area, there are many small confined flowpaths, often characterised by narrow laneways or small gaps between terrace houses. In order to define the overland flowpaths within the study area, a detailed 2D terrain model was required. A 1 metre grid cell size was adopted for the study, which is equivalent to more than 10 million grid cells across the entire LGA. As this exceeded current computer capacity, the LGA was broken into 10 individual models, which represented groups of sub-catchments.

**Hydrology**

The Direct Rainfall ('rainfall on the grid') approach was adopted for the study. In this approach, rainfall is applied directly to the 2D terrain rather than using traditional hydrological models.

There are a number of advantages of the modelling approach, particularly given the Leichhardt LGA. In flat areas, catchment outlets are not always obvious. Furthermore, additional cross catchment flows may occur in larger events. The rainfall on the grid approach overcomes these issues, as the model will automatically divert flood waters along different flowpaths during high flow events.

When there are a large number of pits and pipes, such as in the Leichhardt LGA, it can be difficult to determine the catchment that applies to a particular pit using traditional hydrological modelling. With rainfall on the grid, flows are automatically routed to the pit. This can provide a significant saving in time, as well as reduce potential errors in the application of flow.

Some of the catchments within the study area extended beyond the LGA. Where this was the case, the hydrology was undertaken utilising the traditional hydrological modelling package XP-RAFTS.

**Model Roughness**
A detailed 2D model roughness grid was established for the entire study area. A constant roughness approach was adopted, rather than depth varying. It is noted that some recent studies (e.g. [1]) have adopted a depth varying roughness for Direct Rainfall models. It is therefore important to verify this methodology with an alternative technique. This is discussed below in the model verification.

**Buildings & Fences**
A number of approaches have been tested recently on the modelling of buildings within floodplains. A discussion of some of these techniques can be found in [2]. For this study, all buildings within the LGA were modelled as raised elements within the 2D domain of the model. This approach effectively creates blockages to the flowpaths through properties. Fences within the study area were generally modelled as high roughness elements.

**MODEL CALIBRATION**

Three historical events (January 1991, February 1993 and April 1998) were identified for the model calibration, based on responses from the community consultation together with historical records of flooding held by Sydney Water. These historical rainfall events range from approximately a 5 year ARI through to a 50 year ARI rainfall event, depending on the critical duration. These storm events represented the largest events on record which also had a sufficient number of flooding observations. For example, while a number of residents experienced flooding in 2007, this event was relatively minor for Leichhardt.

A comparison of the model with the historical observations identified that the model was capable of reproducing the historical flood levels generally within +/- 0.1 metres, or better.

**MODEL VERIFICATION**

While the Direct Rainfall technique entered into mainstream commercial 2D modelling over the last 10 years, it has increased in popularity in recent years. As it is still relatively new to the industry, it would generally be recommended to verify the approach in comparison to a more traditional approach to hydrology. The verification of the Direct Rainfall method was undertaken by comparing the results with the traditional hydrological model XP-RAFTS. It is not always expected that the two models will match (in fact, two separate traditional hydrological models with similar parameters can result in significantly different answers (refer to [3]). However, where there are differences some interpretation of the results can be made, and the model can be checked as to why this is the case.

In this situation, the verification also provides a comparison of the Direct Rainfall method with the alternative approach (i.e. traditional hydrological modeling). Therefore, should both models provide comparable results then it can be inferred that the Direct Rainfall model is at least as good as the alternative approach that could have been adopted. The key things considered included the peak flow, the volume of runoff, timing of the peak flow and the shape of the hydrograph.
The comparison was undertaken on three relatively small sub-catchments (Figure 1 and Table 1), as larger catchments are more likely to contain significant hydraulic controls, such as culverts. These controls would impact on the results as these were not included in the XP-RAFTS hydrological model. In addition, the primary aim of this comparison is to ensure that the timing and peak flows from the hydraulic model are reasonable, with the focus on the runoff areas rather than the mainstream flooding areas.

![Figure 1. Sub-catchment Areas](image)

<table>
<thead>
<tr>
<th>Sub-Catchment</th>
<th>Storm</th>
<th>XP-RAFTS Peak Flow (m$^3$/s)</th>
<th>XP-RAFTS Volume (m$^3$)</th>
<th>SOBEK Peak Flow (m$^3$/s)</th>
<th>SOBEK Volume (m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>February 1993</td>
<td>7.2</td>
<td>4540</td>
<td>6.6</td>
<td>3650</td>
</tr>
<tr>
<td>O</td>
<td>February 1993</td>
<td>7.8</td>
<td>4030</td>
<td>7.5</td>
<td>3770</td>
</tr>
<tr>
<td>A</td>
<td>100yr 90mins</td>
<td>3.2</td>
<td>6350</td>
<td>3.1</td>
<td>5430</td>
</tr>
</tbody>
</table>

The comparisons were undertaken both for the historical flood event of February 1993 as well as the 100 year ARI design event. The comparisons are shown in Table 1 and two of the hydrographs are shown in Figures 2 & 3. The peak flows from the SOBEK model were determined from both the pipe flow and overland flow component.

The comparison shows a good agreement between the peak flows from the XP-RAFTS model and the SOBEK model. The overall volume of runoff is higher in the XP-RAFTS model than in the SOBEK model. This is a function of the storages which are available in the detailed SOBEK model (particularly within the properties, at road depressions etc). By comparison, there is no storage available in the XP-RAFTS model other than indirectly through the rainfall losses.

The timing of the peaks, as shown in Figure 2 & 3, was also similar in both the XP-RAFTS model and the SOBEK model. It is noted that the hydrograph from the XP-RAFTS model shows twin peaks. A split catchment approach was adopted, with the initial peak resulting from the impervious areas. It is expected that the SOBEK model is providing a better representation in this case, as the runoff from impervious areas is generally directed through properties, rather than through designated flow paths.
CONCLUSION

The flood modelling undertaken for the Leichhardt LGA has utilised a unique approach. It has incorporated the Direct Rainfall method, incorporated all the pits and pipes, and utilised a fine grid cell size to define both the mainstream flooding areas and the overland flow areas.

A comparison of the results of the modelling with historical storm events demonstrate that the model is capable of reproducing the peak water levels observed. The Direct Rainfall method was also verified against an alternative (XP-RAFTS) hydrological model. This comparison suggests that the Direct Rainfall model, including the method for modelling buildings and roughness within the 2D model, is a suitable approach for this particular study area.

Overall, the methodology adopted for the study demonstrates the ability to undertake a detailed analysis of both mainstream flooding and overland flow. What would normally have been done as a series of detailed studies, has been condensed into a singular study which has allowed Leichhardt Council to understand the full extent of their flooding problems.

REFERENCES

