Modelling the Hydrology of a Complex Partly Urbanised Catchment

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Summary Modelling the hydrology and hydraulics of flood flows in a complex partly urbanised catchment has always presented some unique problems, associated in the main with flow diversions and transitions. Two recently released models (WBNM and HEC-RAS) provide much improved capabilities in these difficult areas. This paper reviews these two models and provides some observations on their benefits in a recent study of a 'complex partly urbanised coastal catchment at Thirroul near Wollongong'.

1. INTRODUCTION

The catchment of Hewitts Creek is located to the south of Sydney, in the northern suburbs of the City of Wollongong. This 470 ha catchment extends from a high sheer faced escarpment at about RL 500 m AHD down to the beach over a distance of about 4 km. Since the mid nineteenth century the more easterly (lower lying) land has been a residential area for workers in the nearby coal mines. Increasing urbanisation has generated many flooding problems for these more developed older areas. A locality plan of the area is reproduced in Figure 1 and catchment layout plan in Figure 2.

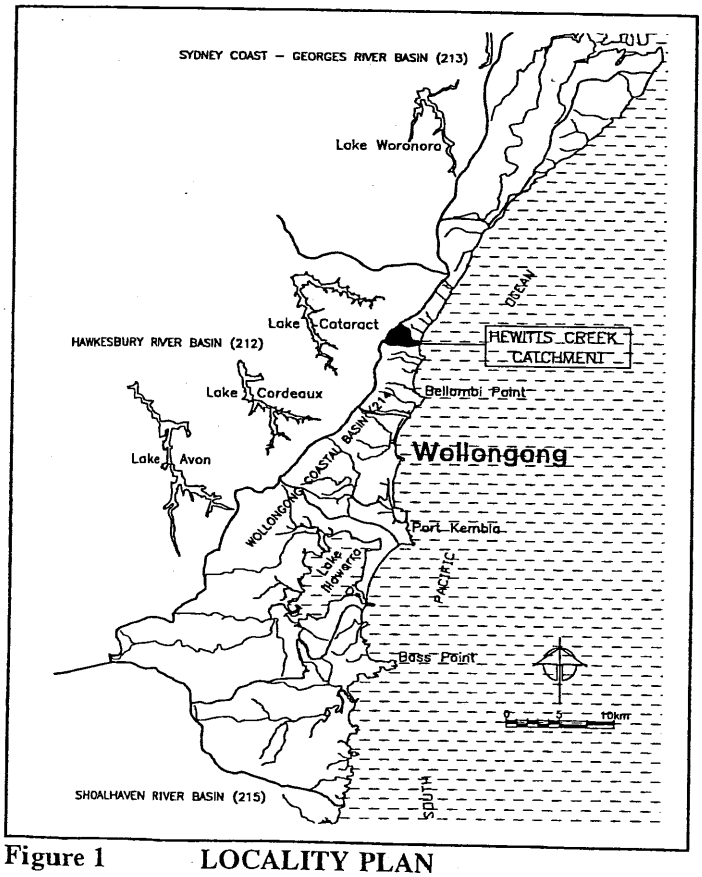

Figure 1 LOCALITY PLAN

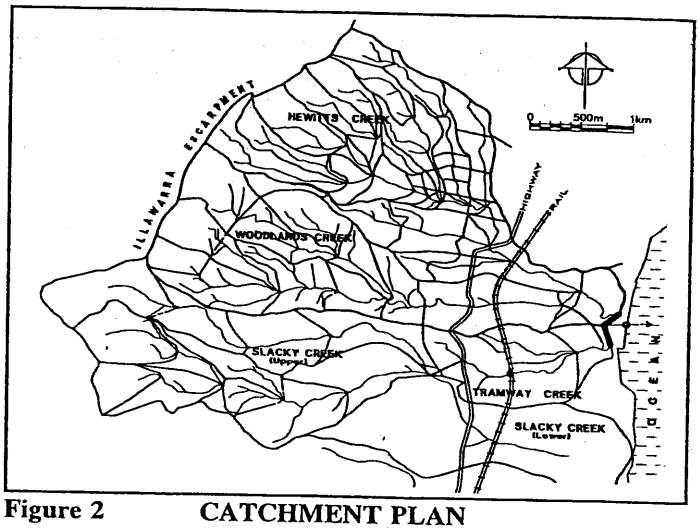

Figure 2 CATCHMENT PLAN

This study was undertaken to quantify the level of flooding in the catchment and to identify key factors influencing flooding in the catchment.

2. WBNM HYDROLOGIC MODEL

The Watershed Bounded Network Model(WBNM), developed in 1979 by Boyd et al.(1), was rewritten and significantly extended in 1995 by Boyd et al. (2). This new model (WBNM-V2) now includes many features of relevance to both urban and rural catchments with routing on pervious and impervious areas computed separately. Generation of AR&R design rainfall, including the 200yr, 500yr ARI and PMP events, together with rainfall gauge weightings makes rapid design mode evaluation possible. WBNM-V2 offers five rainfall loss models and three watercourse routing models. Given culvert and weir details, WBNM-V2 is able to generate a rating or basin discharge relationship, making review of flood levels possible at selected nodes. High flow diversions, which often occur in urban catchments, are now easily modelled. All data input and results of a run may be displayed graphically to facilitate application of the model.

The 650 ha study area was subdivided into 83 subareas, reflecting the geometry of the stream system and nodes at

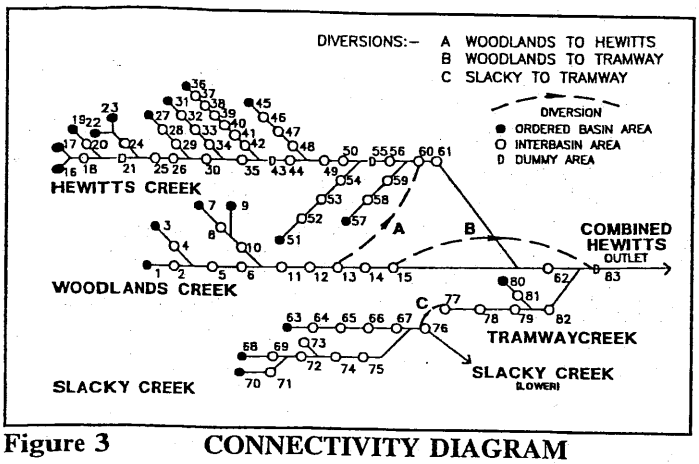

Figure 3 CONNECTIVITY DIAGRAM

which discharges or flood levels were desired (refer Figure 3). Using the inbuilt rainfall data from AR&R'87 and Bulletin 51, a range of design rainfall ARI's and durations was readily modelled, with WBNM-V2 automatically selecting the critical storm duration. The ability to model high flow diversions proved to be invaluable. An iterative approach, using both WBNM-V2 and HEC-RAS, was used to establish the commencing flowrate and percentage diverted at each diversion. One such diversion occurs at a culvert structure on Slacky Creek (an adjoining catchment) where high flows are diverted into Tramway Creek. Of the other two diversions, one occurs at the culvert through the Illawarra Rail embankment, diverting flow from Woodlands to Hewitts Creek and the third occurs when Woodlands Creek overtops, to the east of the rail line, diverting flow to Tramway Creek.

Agreement between WBNM-V2 and several other models previously applied to this catchment was very good, except where the older models could not adequately represent diverted flows.

3. HEC-RAS HYDRAULIC MODEL

Hydraulic modelling of the Hewitts Creek stream network was undertaken using HEC-RAS, a program recently developed by the US Army Hydrologic Engineering Centre(3) with the aim of superseding the widely used HEC2 program. HEC-RAS(V1) is at present a steady state model but will ultimately include unsteady flow and sediment transport capabilities. Data input is via a 'windows' based graphical user interface, enabling easy visualisation of the stream network, channel geometry and model output . HEC-RAS is capable of transparently modelling transitions between supercritical and subcritical flow, without the necessity of laborious model restructuring required in the original HEC2 model.

Whilst lack of flow data prevented direct validation of stream flowrates predicted by the WBNM model, flood height data was available for two historical events, at a number of locations, enabling calibration of the combined WBNM/HEC-RAS models by adjustment of stream roughnesses. Difficulties in calibration were experienced in the vicinity of several culverts, possibly the result of partial debris blockages during the historic events, and in the sandy ocean outlet reach of Hewitts Creek where flood levels are highly dependent on both scour and tidal conditions. Having calibrated the hydraulic model using historic data, design flood profiles for

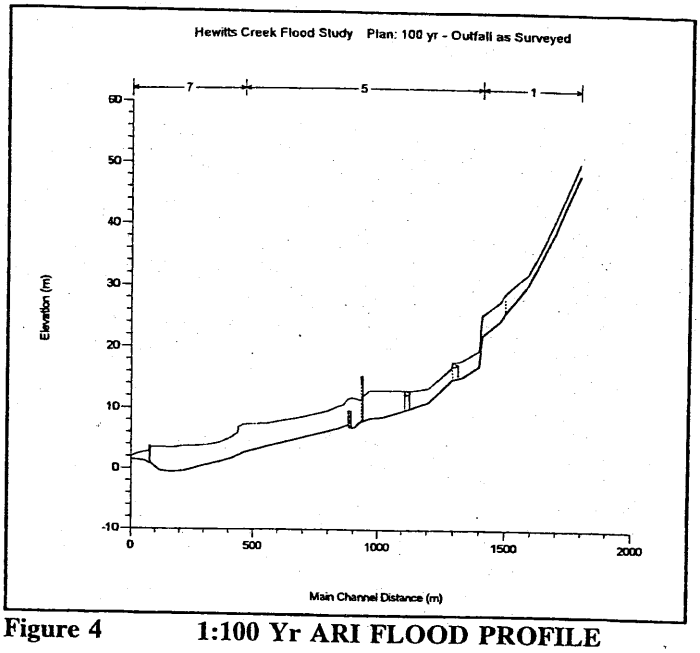

Figure 4 1:100 Yr ARI FLOOD PROFILE

the 20, 50 and 100 year ARI events and the Probable Maximum Flood were prepared for Hewitts Creek and its tributaries. In recognition of the inherent uncertainty in predicted flood levels, a range of sensitivity analysis was undertaken to determine the impact on flood level of factors such as uncertainty in flowrates and stream roughnesses, culvert blockages, ocean levels and beach scour.

4. OBSERVATIONS & CONCLUSIONS

It is the author's conclusion that both WBNM-V2 and HEC-RAS offer significant improvements over their predecessors, particularly when modelling flooding in a complex partly urbanised catchment, where flow diversions and supercritical to subcritical flow transitions are prevalent.

Both models are significantly easier to establish, edit and run than their predecessors and both models include much improved graphic capabilities. Application of these two models to this relatively complex partly urbanised catchment has provided an excellent insight into the catchments behaviour.

5. REFERENCES

1. BOYD, M., PILGRIM, D., AND CORDERY, I. "A Watershed Bounded Network Model for Flood Estimation-Computer Programs and User Guide" 1979 University of NSW Water Research Laboratory Report No. 154

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3. US ARMY CORPS OF ENGINEERS, "HEC-RAS River Analysis System" User Manual - Version 1. July 1995, Hydrologic Engineering Center, Davis California