4. FLOOD BEHAVIOUR SUMMARY

4.1 EXISTING FLOOD BEHAVIOUR

4.1.1 Double Bay Catchment Flood Study

The *Double Bay Catchment Flood Study* was prepared as the first phase of investigations for this project (Bewsher Consulting, 2008). The flood study provides an assessment of flood behaviour under existing catchment conditions. Flood levels, flood velocities and the extent of flood inundation have been determined for floods with different probabilities of occurrence. This helps to determine the magnitude of the flood problem within the catchment, and to identify the main problem areas. It also provides the necessary flood models to examine the effectiveness of undertaking various floodplain management measures within the catchment, which is further examined in this report.

The flood model is comprised of a *hydrologic* model (DRAINS) and a *hydraulic* model (TUFLOW Build 2006-06-BF).

The *hydrologic* model determines the runoff resulting from a particular rainfall event. The primary outputs from the model are hydrographs at various locations along the waterways to describe the quantity, rate and timing of stream flow that results from rainfall events. The model covers the entire catchment.

The *hydraulic* model consists of a linked two-dimensional/one-dimensional (2D/1D) model using a 2 metre grid. The hydraulic model simulates the movement of floodwaters through the waterway reaches, storage elements and hydraulic structures. The model calculates flood levels and flow patterns and also models the complex effects of backwater, roughness, overtopping of embankments, waterway confluences, bridge constructions and other hydraulic structures across the study area.

Ideally a flood model is calibrated to a historical event, but insufficient information about historical rainfalls and flood levels was available.

Design floods are hypothetical floods used for floodplain management studies. Design floods with the following Average Recurrence Intervals were modelled: 1 year, 2 year, 5 year, 10 year, 20 year, 100 year and the probable maximum flood (PMF) (see the glossary for definitions). Design floods are modelled by applying design rainfall totals which are derived from *Australian Rainfall and Runoff* (2000). The 25 minute and 2 hour duration storms were chosen as best defining the critical durations for the study area for all events up to the 100 year ARI event, while the 15 minute and 90 minute duration storms were selected for the PMF. The design floods were modelled with an initial harbour level of 1.0m AHD, recognising that the higher Sydney Harbour design water levels are associated with longer duration storms in the Tasman Sea.

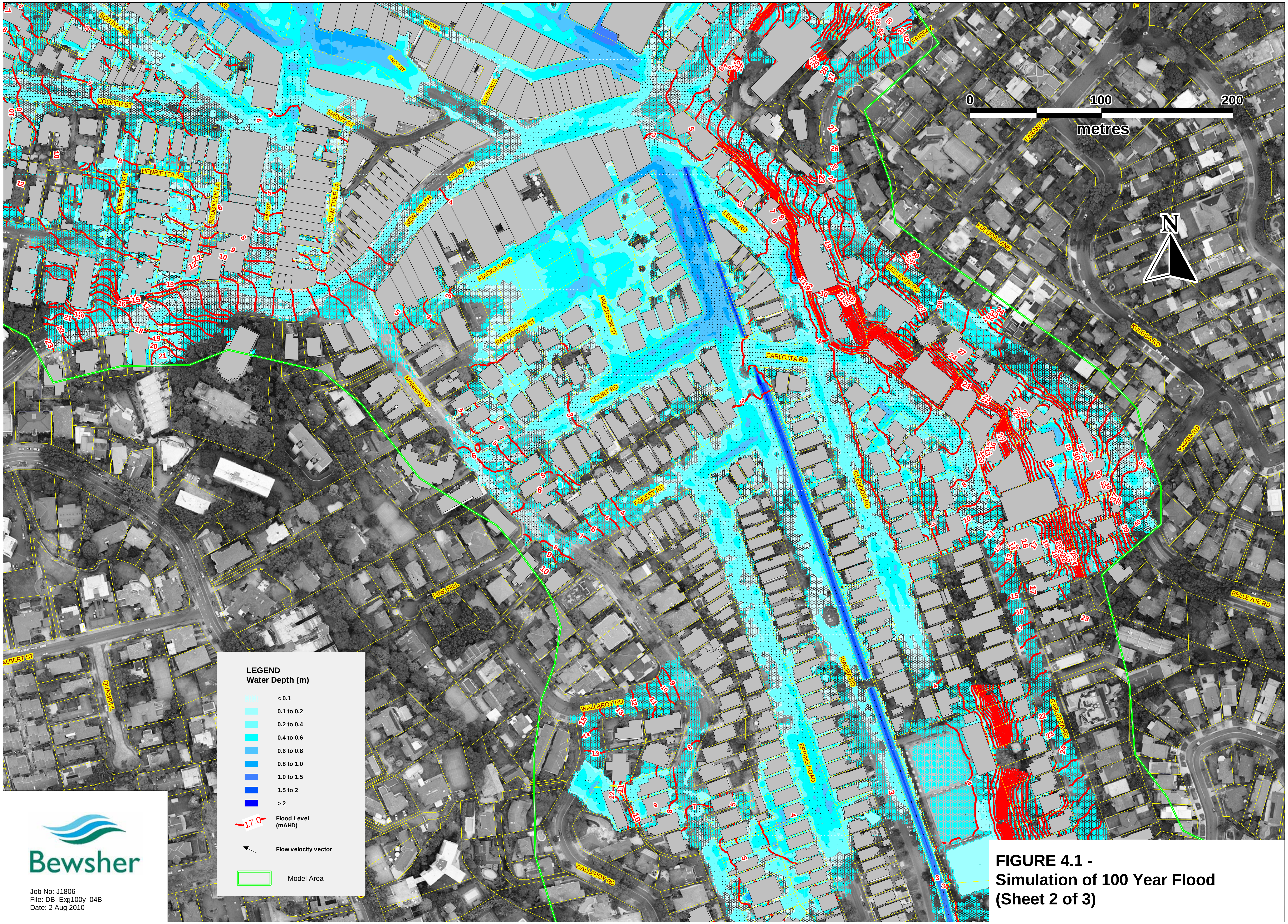
4.1.2 Revised Flood Modelling

As part of this FRMS&P, the potential impacts of conduit blockage and climate change have been assessed (see following sections). For these purposes it was determined that there would be benefit in updating the hydraulic modelling by adopting the latest TUFLOW version (Build 2009-07-AF-iSP). The adoption of the latest software led to some localised changes in the calculation of overland flow flood regimes. The revised 100 year flood maps (which reflect a maximum envelope of blocked and unblocked simulations) are provided in **Figure 4.1**. A complete electronic set of all design flood event files has been provided to Council.

Bewsher

Job No: J1806
File: DB_Exg100y_04A
Date: 2 Aug 2010

FIGURE 4.1 -
Simulation of 100 Year Flood
(Sheet 1 of 3)



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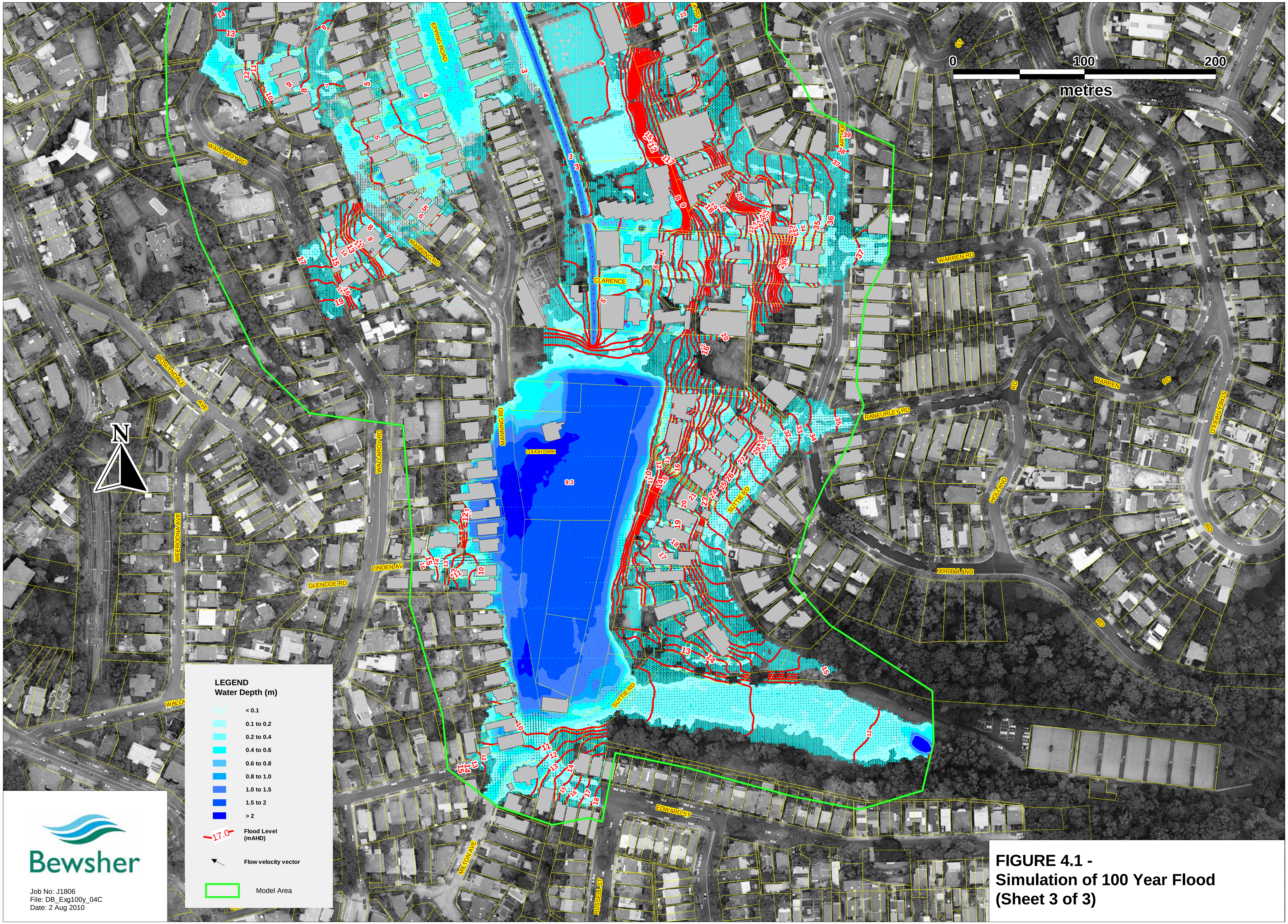
File: DB_Exg100y_04B
Date: 2 Aug 2010

FIGURE 4.1 -
Simulation of 100 Year Flood
(Sheet 2 of 3)



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Job No: J1806
File: DB_Exg100y_04C
Date: 2 Aug 2010

FIGURE 4.1 -
Simulation of 100 Year Flood
(Sheet 3 of 3)

4.1.3 Culvert Blockage

The Flood Study model simulations assumed 50% blockage of sag pits and 20% blockage for on-grade pits, but did not allow for blockage of conduits. The Floodplain Management Committee requested that the impact of culvert blockage be assessed as part of this FRMS&P.

Objects able to block waterway structures come in all sorts of shapes and sizes. Objects implicated in the significant blockage of culverts observed during flooding in Wollongong (1998) and Newcastle (2007) include boulders, vegetation, fencing, outdoors furniture, garbage bins and motor vehicles. In most urban catchments, allowance for blockage needs to be made as it is highly likely that waterborne debris will reduce the effective waterway area at culvert openings. The propensity for blockage increases as the severity of a flood increases. This can increase flood levels and potentially divert floodwaters into adjacent areas.

For the Double Bay catchment, Council decided to model the 100 year ARI flood including 50% blockage at the four major culverts illustrated in **Figure 4.2**. The comparison between blocked and unblocked model runs is shown in **Figure 4.3**. As expected, flood levels increase adjacent to the partially blocked pipes, by a maximum of about 0.35m on Kiaora Road near culverts “c” and “d” (from **Figure 4.2**). The flood is also more extensive in that area.

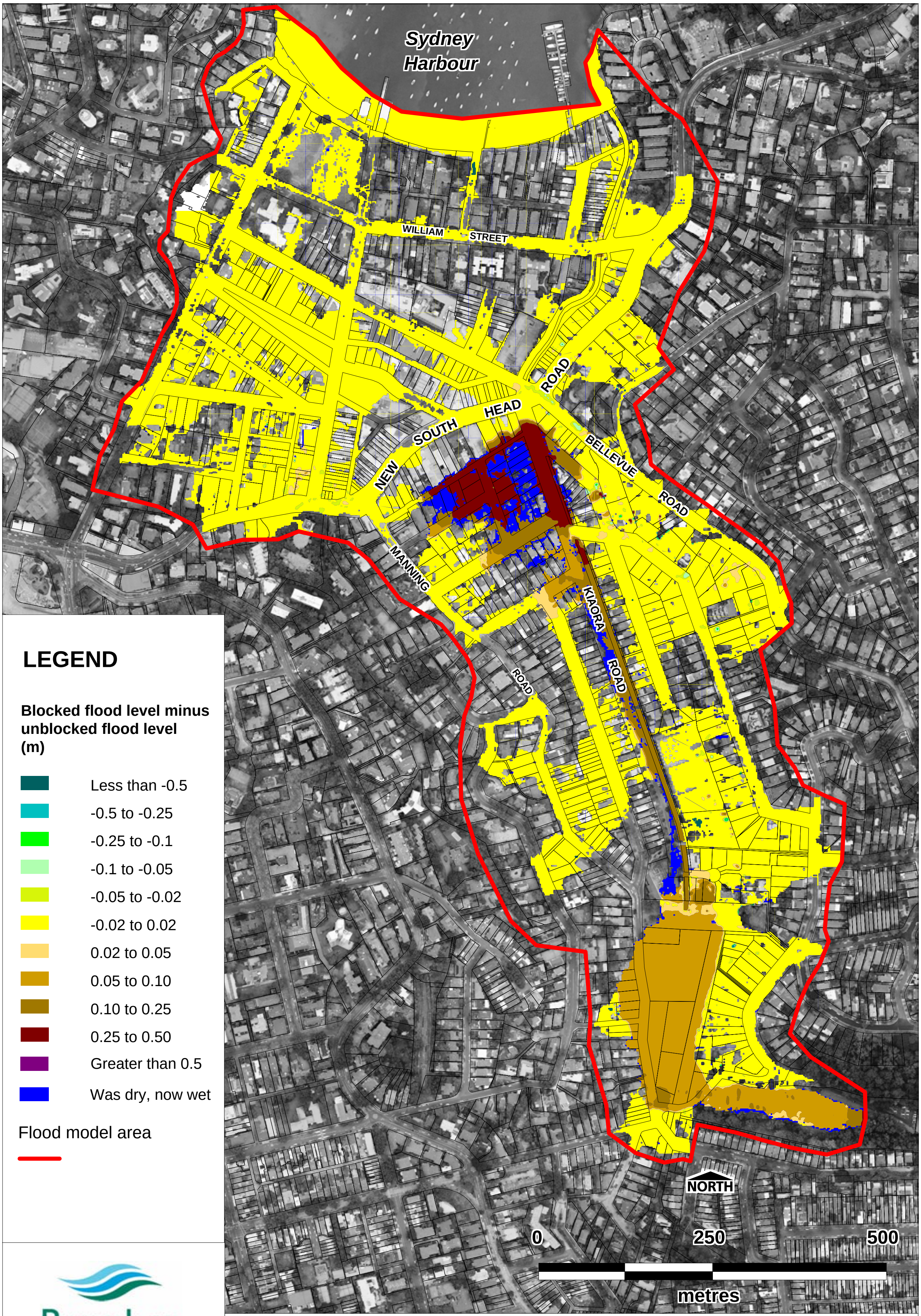
a. Culvert entrance at Cooper Park (looking downstream)

b. "2nd amplification" culvert entrance near Carlotta Road (looking downstream)

c. "Bifurcation" culvert entrance adjacent to Kiaora Road (on right, looking upstream)

d. Culvert entrance adjacent to Kiaora/Leura Roads (looking downstream)

FIGURE 4.2 – Culverts 50% Blocked for Blocked Model Run



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File: J1806_Blockage.WOR
Date: 2 Sep 2010

FIGURE 4.3 - Main Conduits Blocked Versus Unblocked, 100 Year ARI Flood

4.2 CLIMATE CHANGE FLOOD RISK

There is increasing evidence that the temperature of the earth's atmosphere and oceans has increased over the last century, and that the accumulation of greenhouse gases in the earth's environment will accelerate this process in future years. Australian average temperatures are projected to rise by 0.6 to 1.5°C by 2030 and by between 2.2°C to 5.0°C by 2070, should global greenhouse gas emissions continue to grow at rates consistent with past trends (CSIRO/BOM, 2010).

Climate change can potentially affect flood behaviour in the study area through increased sea levels and increased severity of flood producing storms.

From 1870 to 2007, the global average sea level rose by 20cm, with an increased rate from 1993 to 2009 (CSIRO/BOM, 2010). Sea levels are expected to continue rising throughout the 21st century and there is no scientific evidence to suggest that sea levels will stop rising beyond 2100. In October 2009, the NSW Government released the *NSW Sea Level Rise Policy Statement* (DECCW, 2009), which lists sea level rise (SLR) planning benchmarks of increases above 1990 mean sea levels of 40cm by 2050 and 90cm by 2100.

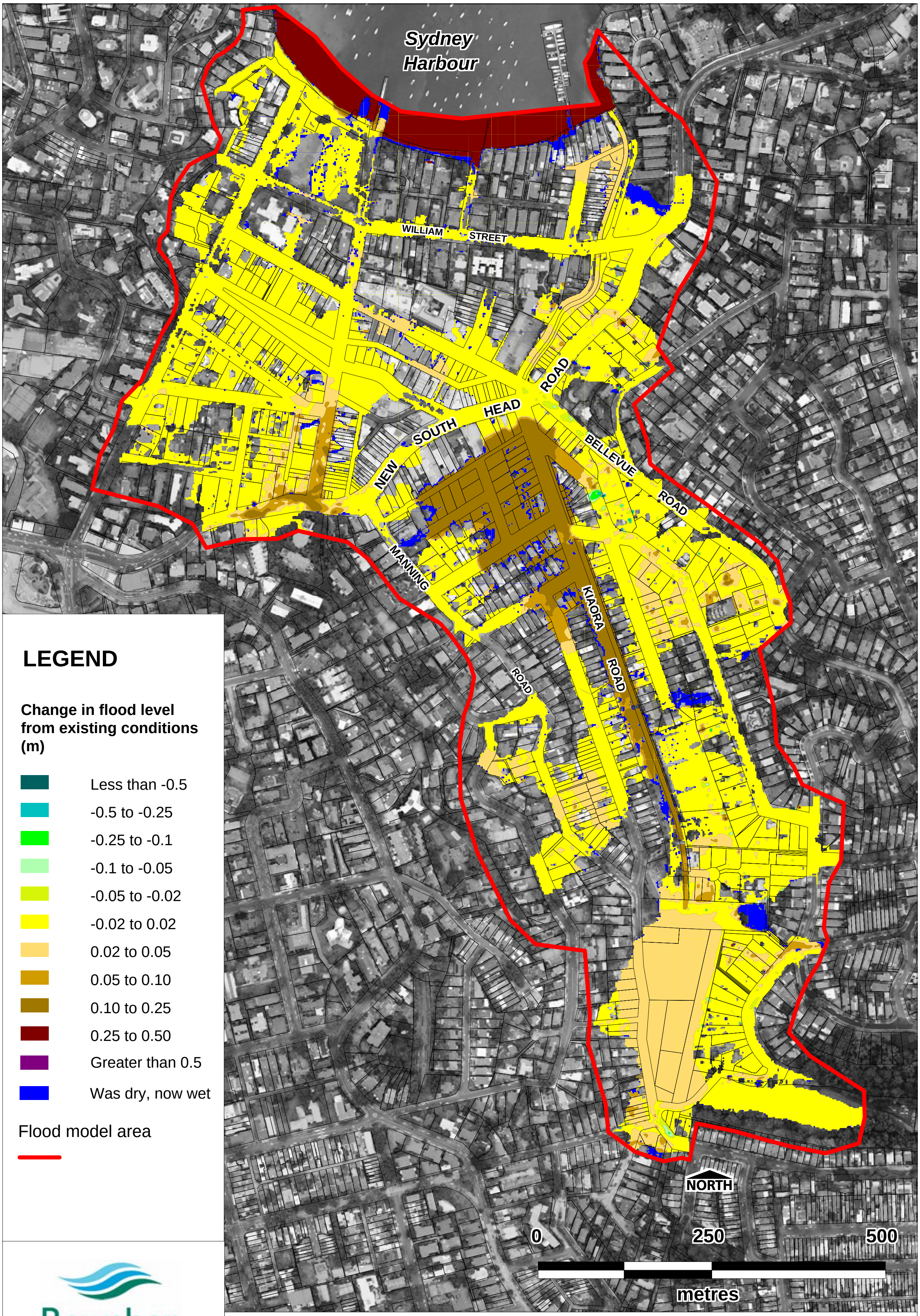
The impact of climate change on rainfall is a topic of greater uncertainty. The *Practical Consideration of Climate Change* Floodplain Risk Management Guideline (DECC, 2007) reports that extreme rainfall (40 year 1 day rainfall total) could increase by 10% for Sydney Metropolitan catchments by 2070.

Accordingly, two 100 year ARI climate change model runs were conducted following this approach:

	2050 Climate Change scenario	**2100 Climate Change scenario**
Tailwater level	0.4m higher than base case	0.9m higher than base case
Rainfall intensity	5% increase	10% increase
Storm durations used for enveloping model results	25 minutes; 2 hours	25 minutes; 2 hours
100 Year ARI harbour level used for enveloping mapping	1.85m AHD (0.4m higher than base case)	2.35m AHD (0.9m higher than base case)

Figure 4.4 compares the 100 year ARI climate change flood results using the 2050 SLR planning benchmark and a 5% increase in rainfall intensity to the 100 year ARI existing case. The largest increase over existing levels is about 12cm just upslope of New South Head Road.

Figure 4.5 compares the 100 year ARI climate change flood results using the 2100 SLR planning benchmark and 10% increase in rainfall intensity to the 100 year ARI existing case. Unsurprisingly, flood levels increase in many areas. Levels influenced by the Lough Playing Fields de facto detention basin increase by about 6cm, whilst the most sensitive area is around the block bounded by Kiaora Road, New South Head Road, Anderson Street and Court Road, where levels increase by about 0.3m. The latter is attributed to the ground there being lower than the level of New South Head Road (see **Figure 4.6**). Flood levels are increased by about 0.3-0.4m in Marine Parade near the Harbour.



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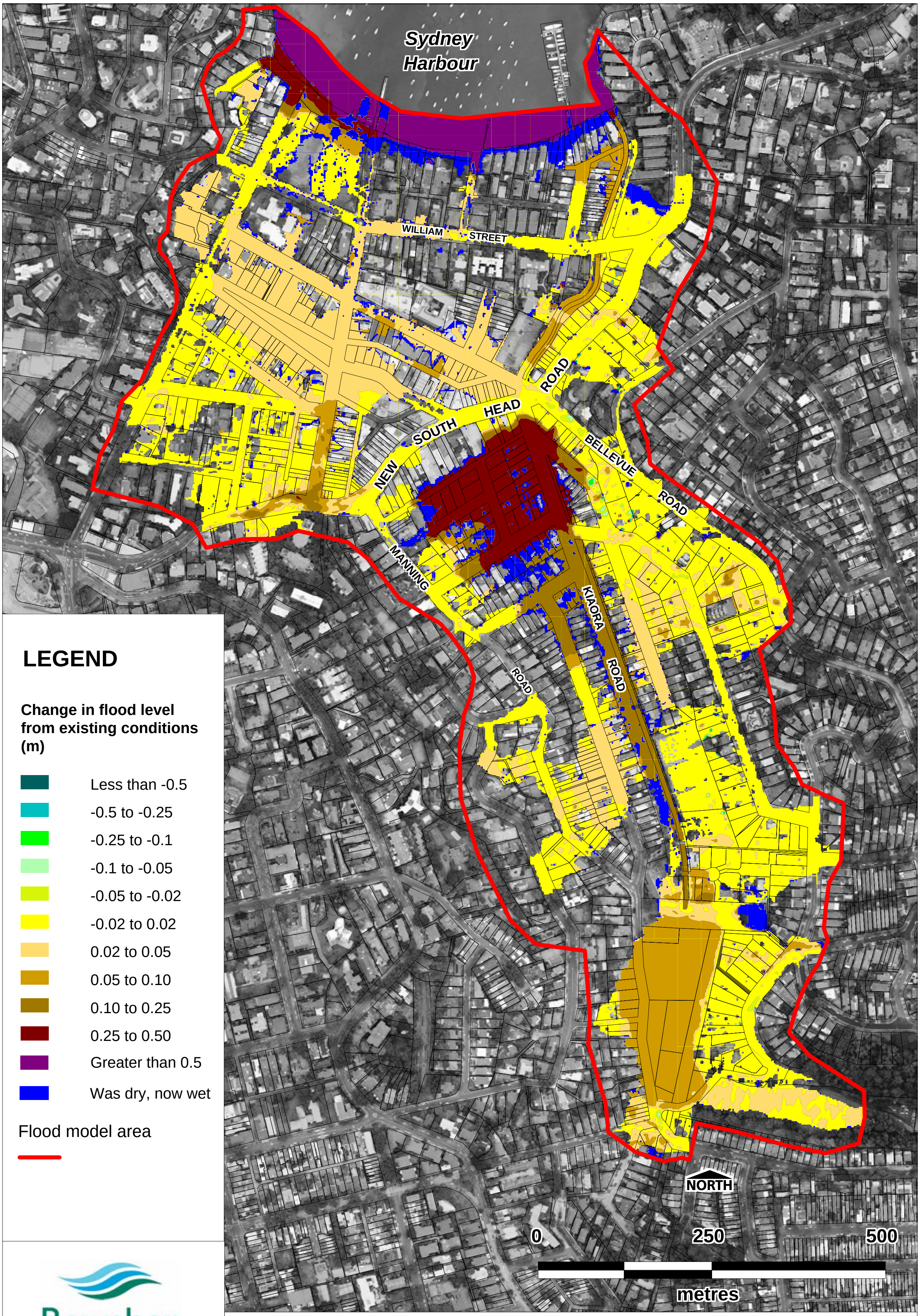
File: J1806_Climate2050.WOR
Date: 2 Sep 2010

FIGURE 4.4 - Change in Existing 100 Year Flood Levels due to Climate Change in 2050



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Date: 2 Sep 2010

FIGURE 4.5 - Change in Existing 100 Year Flood Levels due to Climate Change in 2100

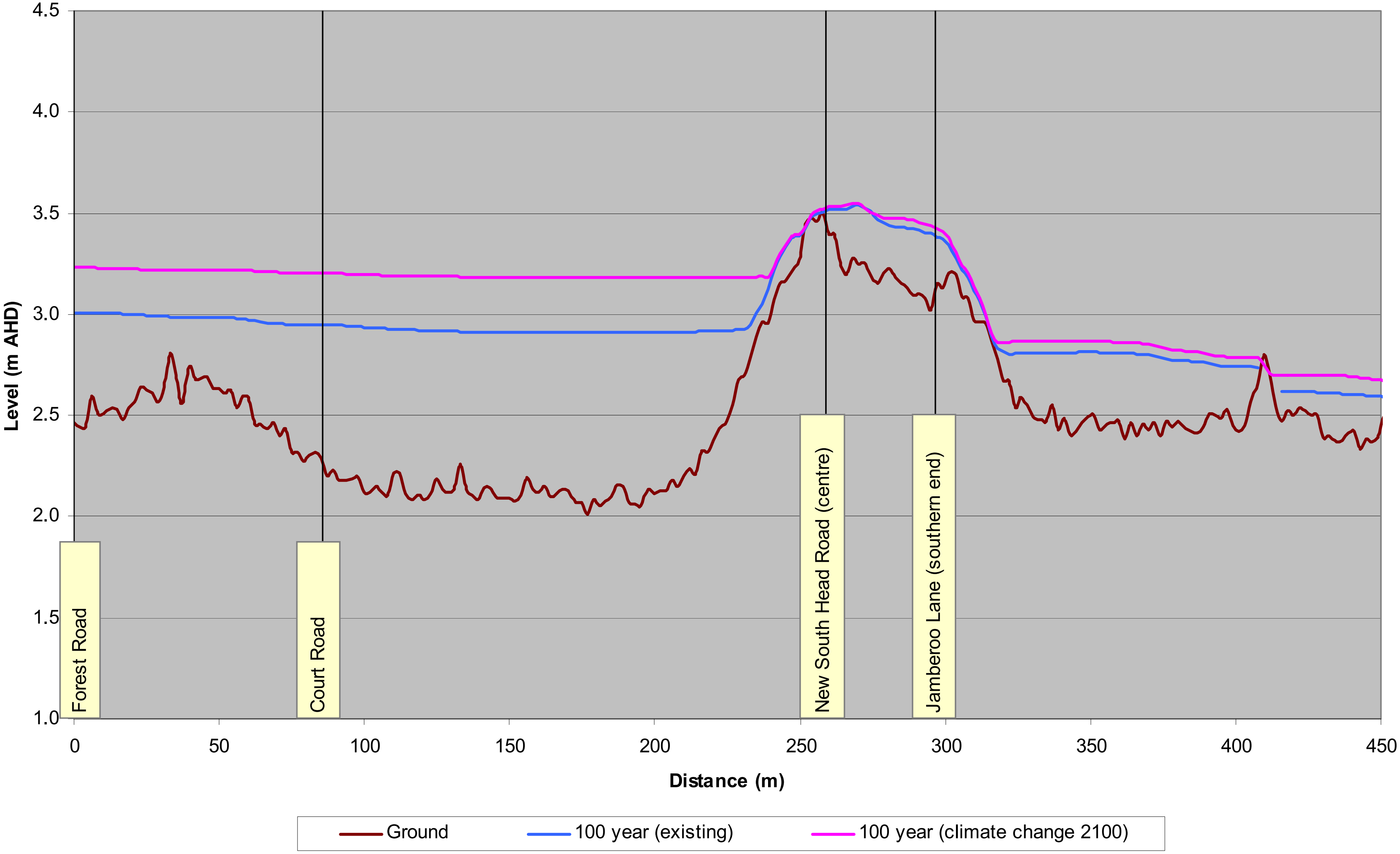

FIGURE 4.6 – Flood Profile along Kiaora Road and Jamberoo Lane through New South Head Road

4.3 FLOOD RISK MAPPING

4.3.1 Introduction

Floodplain management is all about managing the risk of flooding across the floodplain. In doing so, it should be recognised that different parts of the floodplain are subject to different degrees of flood risk. It is important not to confuse "flood risk" with "flood hazard" or "provisional flood hazard". The terms "hazard" and "provisional hazard" are defined in the *Floodplain Development Manual* (NSW Government, 2005) and relate to the magnitude of a *specific* flood. For example, a site may experience high hazard conditions in a 100 year ARI flood and low hazard conditions in a 5 year ARI flood. On the other hand, flood risks (as used to define land use planning precincts) do not relate to a single flood, but rather to all floods.

4.3.2 Flood Risk Precincts

Flood risk precincts consider the probabilities and consequences of flooding over the full spectrum of flood frequencies that might occur at a site. When expressed in mathematical notation:

$$\textit{Flood Risk} = \int_{\substack{\textit{all}\\\textit{floods}}} \textit{Probability} * \textit{Consequence}$$

where *probability* is the chance of a flood occurring, and *consequence* is the property damage and personal danger resulting from the site's flood characteristics. Note that in carrying out this assessment, the existing land uses and any private warning/evacuation plans at the site are ignored, and typical residential land uses and the normal public warning/evacuation plans are assumed.

Many Councils have categorised floodplains into flood risk precincts (typically low, medium and high) and more recently some have also defined an overland flow precinct for land where inundation is shallow and distant from watercourses and major trunk drainage systems – conditions which do not meet the criteria used in the *Floodplain Development Manual* to demarcate "flooding". Separating "drainage" and "overland flow" from "flooding" may assist addressing the perceived impact of flood notations on property values. Categorising flooding and inundation risks allows different development controls to be applied in different parts of the floodplain, recognising both the type of development proposed and the flood risk where the development is to be located.

At the time of writing (Sep 2010), Council is considering proposals to revise the flood risk management provisions in its development planning controls. Hence, neither flood risk precincts nor an overland flow precinct have been mapped at this stage. If Council determines to adopt a scheme similar to those utilised for many other LGAs, this mapping will need to be completed.