SUTHERLAND SHIRE COUNCIL

REVISED OYSTER CREEK FLOOD STUDY

FINAL REPORT

SEPTEMBER 2010

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Project Revised Oyster Creek Flood Study	**Project Number** 110040
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REVISED OYSTER CREEK FLOOD STUDY

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FOREWORD

The NSW State Government's Flood Policy provides a framework to ensure the sustainable use of floodplain environments. The Policy is specifically structured to provide solutions to existing flooding problems in rural and urban areas. In addition, the Policy provides a means of ensuring that any new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the Policy, the management of flood liable land remains the responsibility of local government. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities.

The Policy provides for technical and financial support by the Government through four sequential stages:

1. Flood Study
- Determine the nature and extent of the flood problem.

2. Floodplain Risk Management
- Evaluates management options for the floodplain in respect of both existing and proposed development.

3. Floodplain Risk Management Plan
- Involves formal adoption by Council of a plan of management for the floodplain.

4. Implementation of the Plan
- Construction of flood mitigation works to protect existing development, use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

The following Revised Oyster Creek Flood Study constitutes a revision of the first stage of the management process for Oyster Creek and its catchment area. WMAwater (formerly Webb, McKeown & Associates) were commissioned by Sutherland Shire Council to prepare this study in order to account for creek works undertaken in 2008 to 2009. This report documents the work undertaken and presents outcomes that define flood behavior for existing catchment conditions after the implementation of channel works as proposed in the Oyster Creek Floodplain Risk Management Plan of June 2005.

EXECUTIVE SUMMARY

This Revised Oyster Creek Flood Study was completed in September 2010 to update the design flood data to reflect the management works undertaken by Sutherland Shire Council as recommended in the Oyster Creek Floodplain Risk Management Plan of June 2005. The works undertaken that may affect flood levels are:

- Installation of a debris structure beneath the Box Road footbridge; and
- Channel widening and clearing in the reach immediately upstream of the Box Road footbridge to upstream of the Bates Drive road crossing.

Detailed survey was provided to indicate the extent of the works.

The hydraulic effect of the channel widening and clearing is to reduce design flood levels within the area of the works. The works in the reach to approximately 100m upstream of Bates Drive have little impact, as the Bates Drive culverts with an assumed 100% blockage (as determined in the June 2005 Flood Study) act as a significant restriction to flow. Further upstream to the Box Road footbridge, the works produce a greater reduction in flood level as the effect of the Box Road hydraulic restriction is much reduced and the scale of the works represents a greater proportion of the waterway cross sectional area than further downstream.

Installation of the debris structure beneath the Box Road footbridge provides a benefit and a dis-benefit. The benefit is that it will reduce the likelihood of blockage of the culverts under Bates Drive, for this reason for design it is now assumed that these culverts will only be 50% blocked (thus significantly reducing flood levels at Bates Drive and upstream). The dis-benefit is that the structure itself will act as a hydraulic restriction (with or without collected debris) and the Manning's "n" friction factor has been increased beneath the footbridge. However this dis-benefit is compensated for by an increased waterway beneath the footbridge.

Overall the works under as part of the Oyster Creek Floodplain Risk Management Plan of June 2005 have reduced the 1% AEP flood levels by up to 0.5m, resulting in lower Flood Planning Levels in parts and reduced flood damages in the future.

Updated design flood information was provided in digital form to Sutherland Shire Council on completion of this study.

1. INTRODUCTION

Oyster Creek has a 3.5 km^2 catchment which drains to Oyster Bay and the Georges River (Figure 1). The catchment area is predominantly occupied by urban development including both residential and commercial/light industrial development. There are no large areas of open space except for sporting fields and creek lines.

In October 2005, Sutherland Shire Council adopted the Oyster Creek Floodplain Risk Management Study and Plan (References 1 and 2) prepared by WMAwater (formerly Webb, McKeown & Associates). The Plan prioritized a range of floodplain management measures ranging from physical works to planning controls and community education.

In 2008/2009, Council implemented the following priority flood mitigation works at Oyster Creek:

- Construction of a debris deflector at the Box Road footbridge;
- Stream clearing immediately downstream of the footbridge;
- Creek widening and bank stabilisation between the Box Road footbridge and Bates Drive; and
- Installation of a flood marker in Carvers Road Reserve.

The implemented measures such as creek widening and clearing will have resulted in a reduction in flood levels within the reach from Box Road to Bates Drive. Hence, the results and findings of the original Oyster Creek Flood Study (Reference 3) need to be revised and the flood model updated to determine the revised extents of flooding in Oyster Creek. Among the key elements addressed and outlined in this report are:

- Revised inundation extents for the 10%, 5%, 2%, 1%, 0.2% AEP events and the PMF;
- Revised list of flood affected properties for the aforementioned events;
- Characterisation of *High*, *Medium* and *Low* Flood Risk Zones as per current NSW Flood Prone Land Policy and identification of affected properties;
- Preparation of Hazard Maps for flood events; and
- Recommendations for amendments to the *Sutherland Shire DCP 2006*.

2. BACKGROUND

2.1. Study Area

The study area for this Revised Oyster Creek Flood Study was taken as the reach of floodplain extending from approximately 170 m upstream of the Box Road footbridge down to Oyster Bay, a distance of some 1900 m (Figure 1). Previously it was found that downstream of Bates Drive there are no buildings inundated in the 1% AEP event and further upstream from Box Road the development is largely outside the floodplain area.

Bates Drive was constructed on a raised embankment with six 3 m by 1.8 m box culverts underneath. The invert of the culverts is at 0.7 mAHD and thus it acts as a weir to restrict tidal flow upstream. For this reason the upstream reach is only semi-tidal and predominantly freshwater. In 2008/2009, creek widening and bank stabilisation were undertaken by Council in the reach between Box Road and Bates. Debris collector “devices” were also installed at the outlet of the main stormwater pipes discharging upstream of Bates Drive and a wooden debris deflector was installed below the Box Road footbridge to reduce the likelihood of blockage reaching the Bates Drive culverts.

The eastern overbank area upstream of Bates Drive was filled in the early 1960's and some 20 houses constructed. All have experienced inundation of their yards at some time during the 1970's. Several homes have more recently been rebuilt with floors above the previously determined 1% AEP flood level. The only known record of flooding is provided in Reference 4 and is summarised in Table 1.

Table 1: Flood History from M G Carleton’s Report (Reference 4)

Event	No. of Buildings Inundated above Floor	House No’s * Inundated in Buderim Avenue	Approximate Peak Level at Bates Drive (mAHD)	Number of Recorded Flood Levels
?? 1969	approx. 8	unsure	3.0	nil
?? 1970	unknown	??	??	nil
26 March 1974	6	5,7,17,27,31,33	2.8	8
11 March 1975	10	5,7,15,17,23,25, 27,31,33,39	3.0	11
4 March 1977	nil	-	2.4	8

Note: * Some buildings may have been rebuilt since 1977.

In March 1975 Bates Drive was overtopped but since 1977 there are no records of houses or yards being inundated.

2.2. Available Data

As part of this study, the following sources of information have been reviewed in addition to those from the previous Oyster Creek Flood Study (Reference 3):

- Field inspections;

- Survey data including detailed contour survey and cross-sections along Oyster Creek, Sutherland Shire Council (Figure 2);
- ALS data of Oyster Creek and its surrounds from the confluence with Georges River to upstream of Box Road, Sutherland Shire Council;
- Debris deflector design, GHD, June 2008; and
- Aerial photography from www.nearmap.com.

Detailed site inspections have been undertaken by WMAwater on several occasions in the past to develop and refine our understanding of the catchment and conditions within the study area.

2.3. Photographs

The following are photographs depicting conditions prior to implementation (2003/04) of the mitigation measures (left picture) and those depicting existing conditions (2010) with the mitigation measures in place, as outlined in Section 1 (right picture):

Photograph 1: Bates Drive bridge and culverts (left = 2003/2004, right = 2010)

Photograph 2: View upstream of Bates Drive (left = 2003/2004, right = 2010)

Photograph 3: View across Oyster Creek to Buderim Avenue (left = 2003/2004, right = 2010)

Photograph 4: View towards Box Road footbridge (left = 2003/2004, right = 2010)

Photograph 5: Box Road footbridge (left = 2003/2004, right = 2010)

Photograph 6: View downstream of Box Road footbridge (left = 2003/2004, right = 2010)

Photograph 7: View of drainage outlet downstream of Box Road footbridge (left = 2003/2004, right = 2010)

3. APPROACH ADOPTED

The approach adopted herein was the same as that of the previous Flood Study (Reference 3). The hydrologic data were obtained from the established WBNM model and served as input to the hydraulic model (MIKE-11) of Oyster Creek. With the limited amount of rainfall and flood data available and given the lack of any stream gauging, the model calibration process focussed on ensuring the design flood levels are compatible with the expected frequency of the known historical events. The calibrated MIKE-11 model was then used to quantify the design flood behaviour for a range of design storm events up to and including the Probable Maximum Flood (PMF).

The MIKE-11 model layout of Oyster Creek extends from 170 m upstream of Box Road down to the confluence with Oyster Creek (Figure 3). To account for the constructed works revised model cross-sections were derived from the detailed survey information (Figure 2) provided by Council. Bates Drive was defined implicitly in the model as a composite control structure with capacity for both culvert through flow in combination with road overtopping. At Box Road the footbridge and the recently installed debris deflector were simulated by adjusting the in-channel roughness to make allowance for any localised hydraulic impacts, particularly when the deck becomes overtopped.

4. DESIGN FLOOD RESULTS

4.1. Overview

A rainfall/runoff routing approach using the WBNM model was adopted to derive estimates of design inflow hydrographs. These estimates then defined boundary conditions to produce corresponding design flood levels using the MIKE-11 hydraulic model. From the previous Oyster Creek Flood Study (Reference 3), the 2 hour duration storm was found to be critical. This particular duration was adopted for all other design event frequencies. In a similar manner, the 45 minute storm duration was found to be the critical duration for the PMF event.

In addition to runoff from the catchment, the reach of Oyster Creek downstream of Bates Drive can also be influenced by backwater effects resulting from Georges River flooding. As noted previously, these two distinct flooding mechanisms may or may not result from the same storm. The Oyster Creek catchment is much smaller in size (3.5 km^2) compared to the Georges River catchment (960 km^2). Hence, for a given flood event, it is more likely that the Georges River level would peak after the corresponding flood peak occurs in Oyster Creek. It is acknowledged however that this may not necessarily be the case. Consideration must therefore be given to account for the joint probability of coincident flooding from both runoff from the Oyster Creek catchment and backwater effects from the Georges River.

A full joint probability analysis is beyond the scope of the present study. Traditionally, it is common practice to estimate design flood levels in these situations using a ‘peak envelope’ approach that adopts the highest of the predicted levels from the two mechanisms. For each design event on Oyster Creek, the relevant design flows were used in conjunction with a static water level in the Georges River. The current design flood levels for the Georges River are provided in Table 2.

Table 2: Design Flood Levels – Georges River

Event	Level (mAHD)
PMF	2.9
0.2% AEP	1.8*
1% AEP	1.7
2% AEP	1.6*
5% AEP	1.5
10% AEP	1.4*

Note: * estimated for the purposes of this study.

Nevertheless, it was noted in Reference 3 that for a significant flood event in Oyster Creek, the impacts of assumed tailwater conditions in the Georges River would be confined to the lower reaches of Oyster Creek.

4.2. Blockage Assessment

Given the combination of urban development and natural bushland within the catchment, the potential blockage of culverts and stream crossings by debris can increase the flood levels experienced along Oyster Creek. The role of blockages in exacerbating flood impacts during the August 1998 storm in North Wollongong highlights the importance of considering the implications for blockages in design flood assessment.

Based on numerous site inspections, and discussions with Council officers and local residents, the issue of potential culvert blockage is particularly relevant for Oyster Creek. Anecdotal evidence in Reference 4 indicates that two of the Bates Drive culverts were partially blocked in the 1974 event.

Evidence from the August 1998 North Wollongong storm indicates that there is the potential for culvert openings of less than 6 m width to be blocked during a runoff event. For Oyster Creek this observation would imply that all of the Bates Drive openings and the Box Road opening could be either partially or fully blocked.

For the previous Oyster Creek Flood Study (Reference 3) it was assumed that there was 100% blockage at both the Bates Drive and Box Road culverts. However, construction of a debris structure beneath the Box Road footbridge will reduce the likelihood of blockage of the Bates Drive culverts and widening and lining of the channel beneath the Box Road footbridge will reduce the likelihood of blockage compared to previously. Although construction of the debris structure will itself increase the hydraulic conveyance at Box Road.

The incidence of blockage will vary from flood to flood and may depend on the individual circumstances of each event (season of year, associated or not with high winds, was the debris structure "clear" prior to the event? etc.). There is no technically rigorous approach for accurately quantifying the benefits (in reducing blockage downstream) and dis-benefits (increase the hydraulic conveyance at Box Road due to blockage and the structure itself) of construction of a debris structure beneath the Box Road footbridge. For this Revised Oyster Creek Flood Study the following were adopted for design flood estimation:

- *A reduction in the assumed level of blockage of the Bates Drive culverts from 100% to 50% to account for the likely reduction in debris entering from upstream of the Box Road footbridge. However trees, vehicles and fencing can still enter Oyster Creek from the catchment between Box Road and Bates Drive and for this reason some blockage must be assumed at the Bates Drive culverts for design; and*
- *A Manning's "n" value of 0.08 was assumed at the Box Road footbridge to reflect the reduction in conveyance due to the debris structure itself and the likelihood of blockage by the debris it will prevent passing downstream.*

To quantify the impacts of potential blockages on design flood behaviour, two additional blockage scenarios (Table 3) were simulated using the MIKE-11 model.

Table 3: Blockage Modelling Scenarios

Scenario	Description
Base Case	Bates Drive culverts 50% blocked and Manning's "n" value of 0.08 at the Box Road footbridge
Scenario 1	As base case but No blockage at the Bates Drive culverts
Scenario 2	Bates Drive culverts and Box Road opening 100% blocked

The results of the above sensitivity analyses are provided in Table 4.

Table 4: Comparison of Peak Flood Levels Due to Blockage– 1% AEP

Location	Blockage Scenario		
	Base Case: 50% blockage (m AHD)	1: No Blockage	2: 100% Blockage
		Values represent the relative change in level (metres) compared to the base case	
Bates Drive	3.33	-0.29	0.30
100 m upstream of Bates Dr	3.39	-0.25	0.28
200 m upstream of Bates Dr	3.44	-0.22	0.27
300 m upstream of Bates Dr	3.53	-0.18	0.24
400 m upstream of Bates Dr	3.66	-0.13	0.21
Box Road	5.12	-0.06	0.14
50 m upstream of Box Rd	5.43	-0.01	0.02

As expected, the results indicate that the inclusion of 100% blockage at the Bates Drive culverts has a significant impact on flood levels upstream and vice versa. The impact of blockage at the Box Road opening is much less significant. The results from the base case were adopted for the establishment of design flood levels.

4.3. Design Events

For the design runs, the Manning's "n" values provided in Table 5 and Table 6 were adopted for pre-works and post-works conditions respectively.

Table 5: Adopted Manning's "n" Values in MIKE-11 Model for Pre-Works Conditions

Chainage (m)	Left Overbank	Channel	Right Overbank
0 – 1080	0.10	0.04	0.10
1095 – 1290	0.10	0.04	0.20
1315 – 1335	0.06	0.04	0.20
1360 – 1560	0.04	0.04	0.20
1575 – 1605	0.06	0.05	0.20
1620 – 1767	0.06	0.06	0.20
1783 – 1915	0.10	0.10	0.10

Table 6: Adopted Manning's "n" Values in MIKE-11 Model for Post-Works Conditions

Chainage (m)	Left Overbank	Channel	Right Overbank
0 – 1080	0.10	0.04	0.10
1095 – 1290	0.10	0.04	0.20
1315 – 1335	0.04	0.04	0.20
1360 – 1560	0.04	0.04	0.20
1575 – 1605	0.05	0.04	0.20
1620 – 1767	0.04	0.04	0.15
1783 – 1915	0.10	0.10	0.10

Peak height profiles for the 10%, 5%, 2%, 1%, 0.2% AEP events and the PMF are provided on Figures 4 and 5. A listing of the design flood results (peak flood levels and flows) at each model cross-section for the adopted design scenario is provided in Appendix B.

Design flood contours for the 1% AEP event are provided on Figure 6 and the revised inundation extents are provided on Figure 7 for all design events, the revised hydraulic and hazard categorisation for the 1% AEP event on Figure 8 and the revised Flood Risk Precincts on Figure 9.

5. CONCLUSIONS

The Oyster Creek Flood Study of June 2005 has been revised to include the following works undertaken by Sutherland Shire Council in 2008/2009 as recommended in the Oyster Creek Floodplain Risk Management Study/Plan of June 2005:

- Construction of a debris deflector at the Box Road footbridge;
- Stream clearing immediately downstream of the footbridge;
- Creek widening and bank stabilisation between the Box Road footbridge and Bates Drive; and
- Installation of a flood marker in Carvers Road Reserve.

The results of this study can be used to update the flood planning information adopted for development control purposes within the Oyster Creek floodplain.

There was insufficient change in the design flood levels and extents to warrant amendments to the *Sutherland Shire DCP 2006.*

6. REFERENCES

1. Sutherland Shire Council

   Oyster Creek Floodplain Risk Management Study
   Webb, McKeown & Associates Pty Ltd, June 2005

2. Sutherland Shire Council

   Oyster Creek Floodplain Risk Management Plan
   Webb, McKeown & Associates Pty Ltd, June 2005

3. Sutherland Shire Council

   Oyster Creek Flood Study
   Webb, McKeown & Associates Pty Ltd, June 2005

4. M G Carleton

   Oyster Creek Flood Investigations
   Project Report, November 1977

5. NSW Government

   Floodplain Development Manual

   April 2005

Figures

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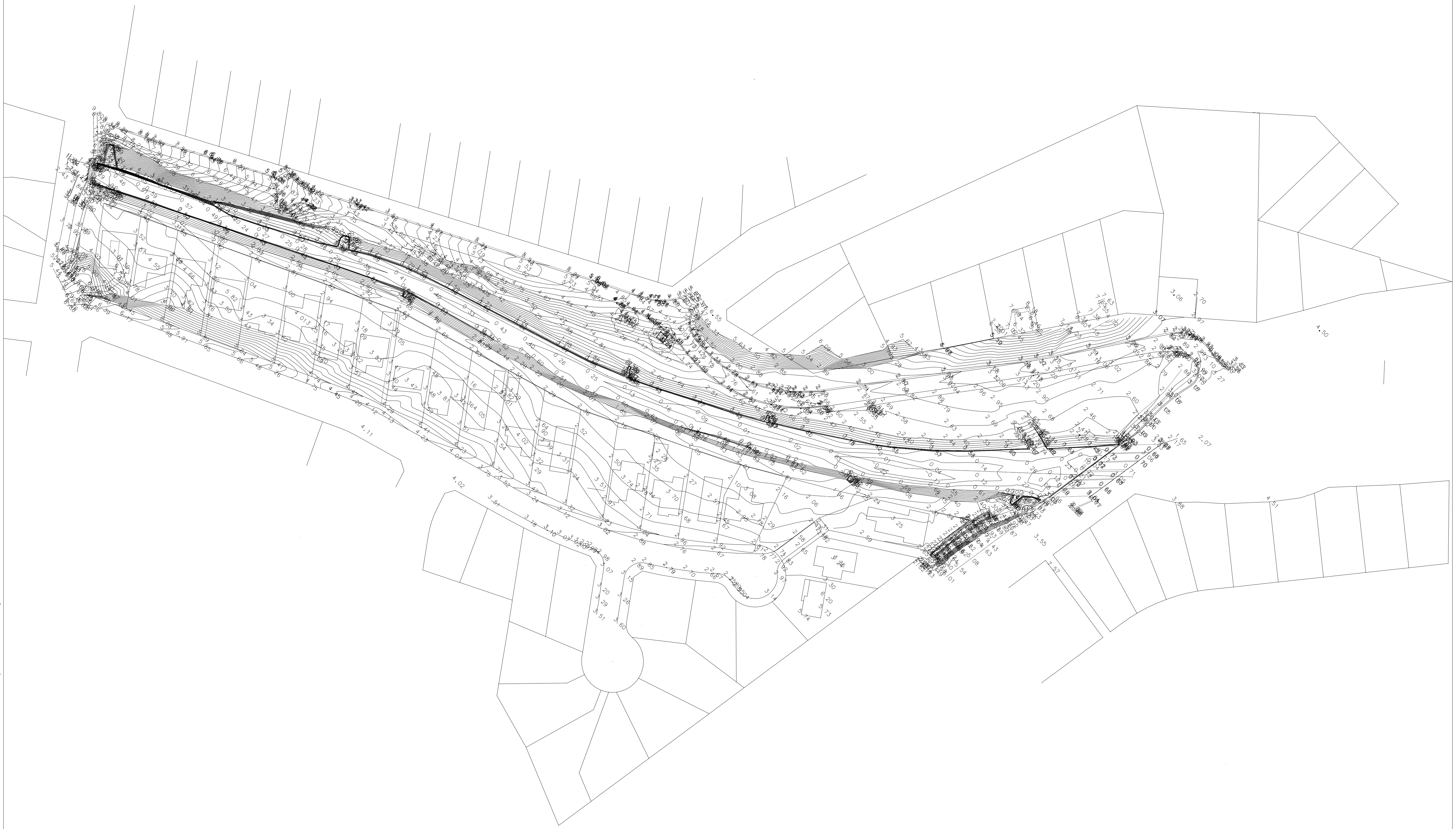
FIGURE 2

SURVEY DATA



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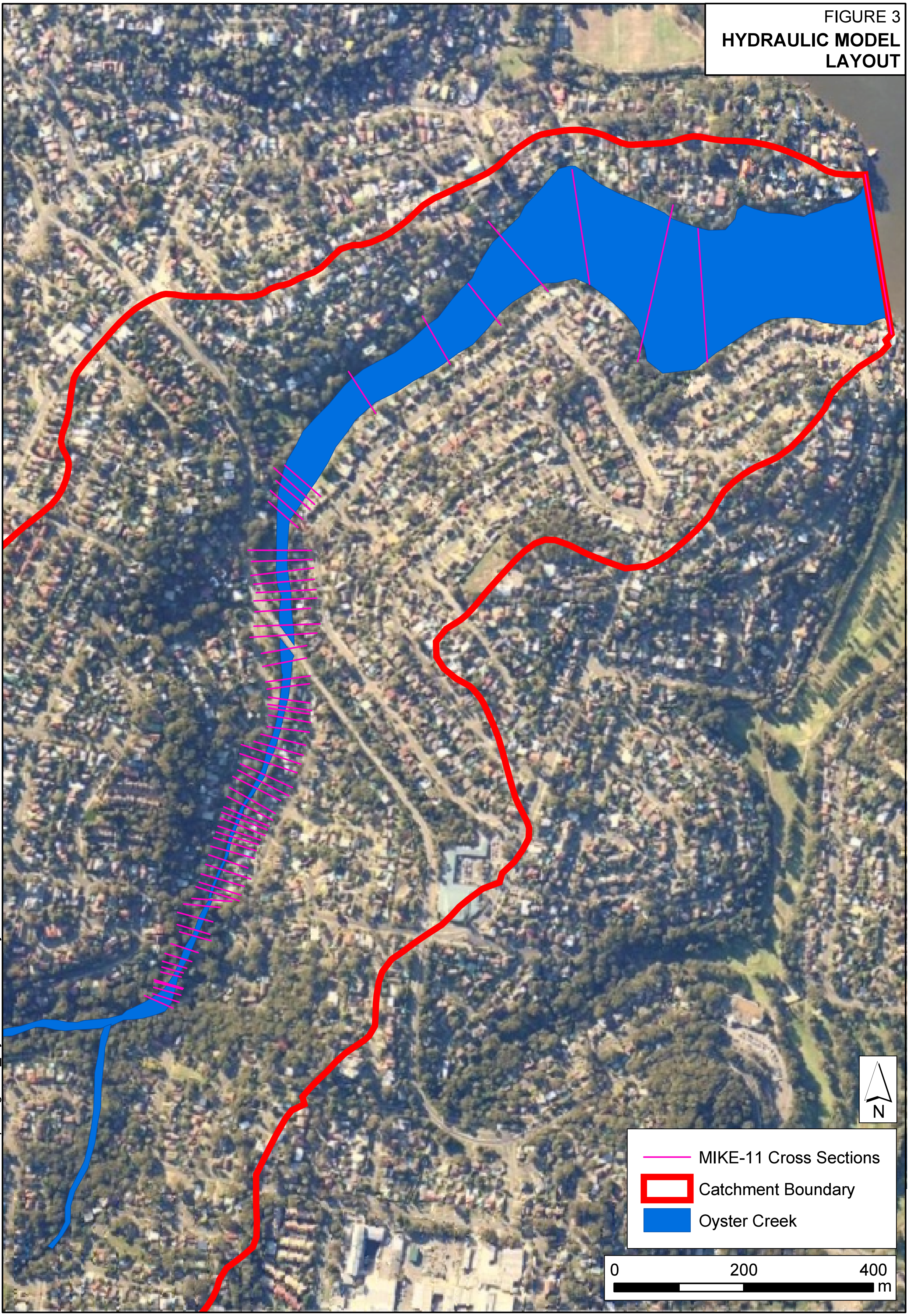

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FIGURE 4
PEAK HEIGHT PROFILES
COMPARISON AGAINST HISTORICAL
FLOOD DATA

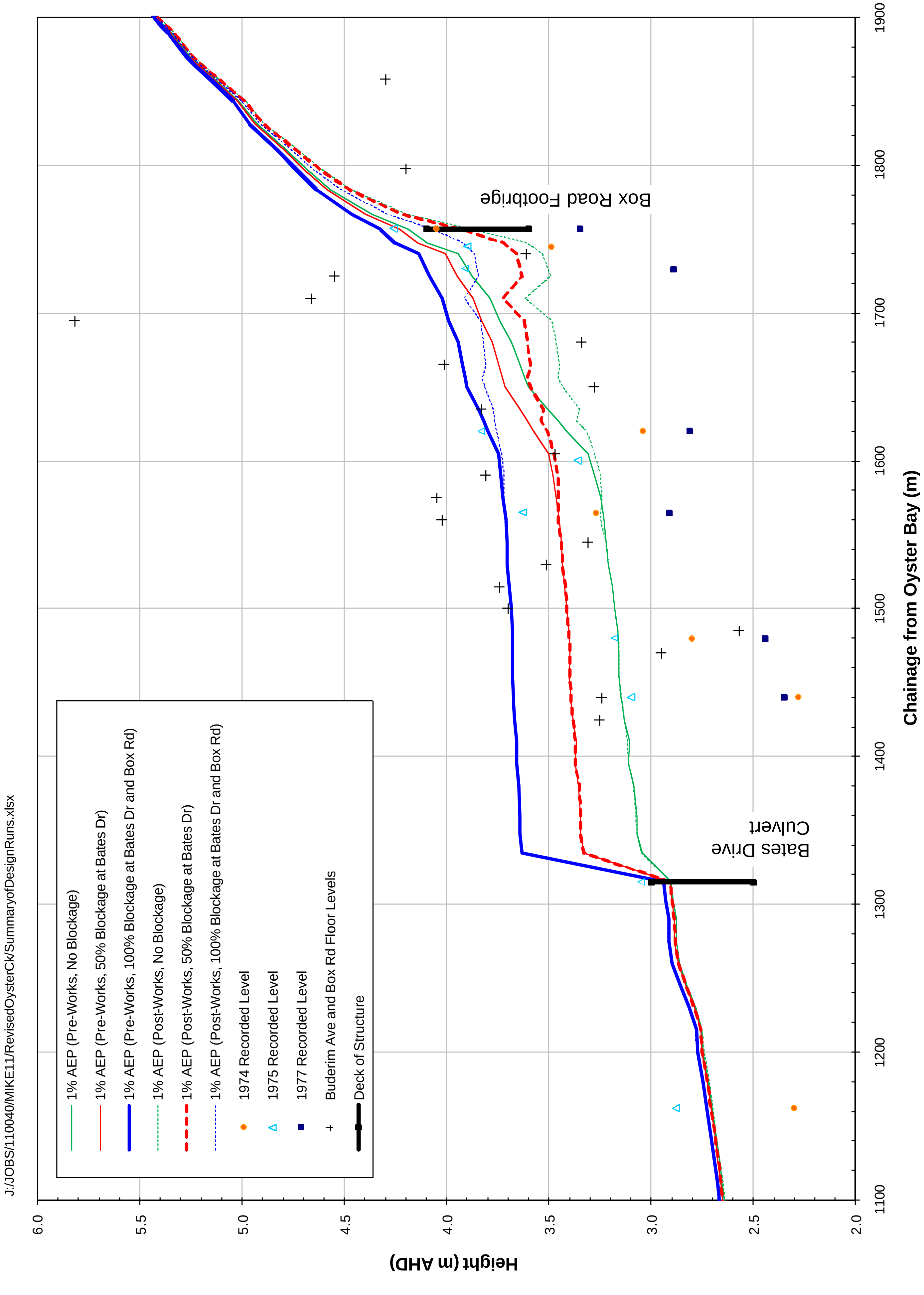

FIGURE 5
PEAK HEIGHT PROFILES
COMPARISON OF PRE- AND POST-WORKS
DESIGN FLOODS

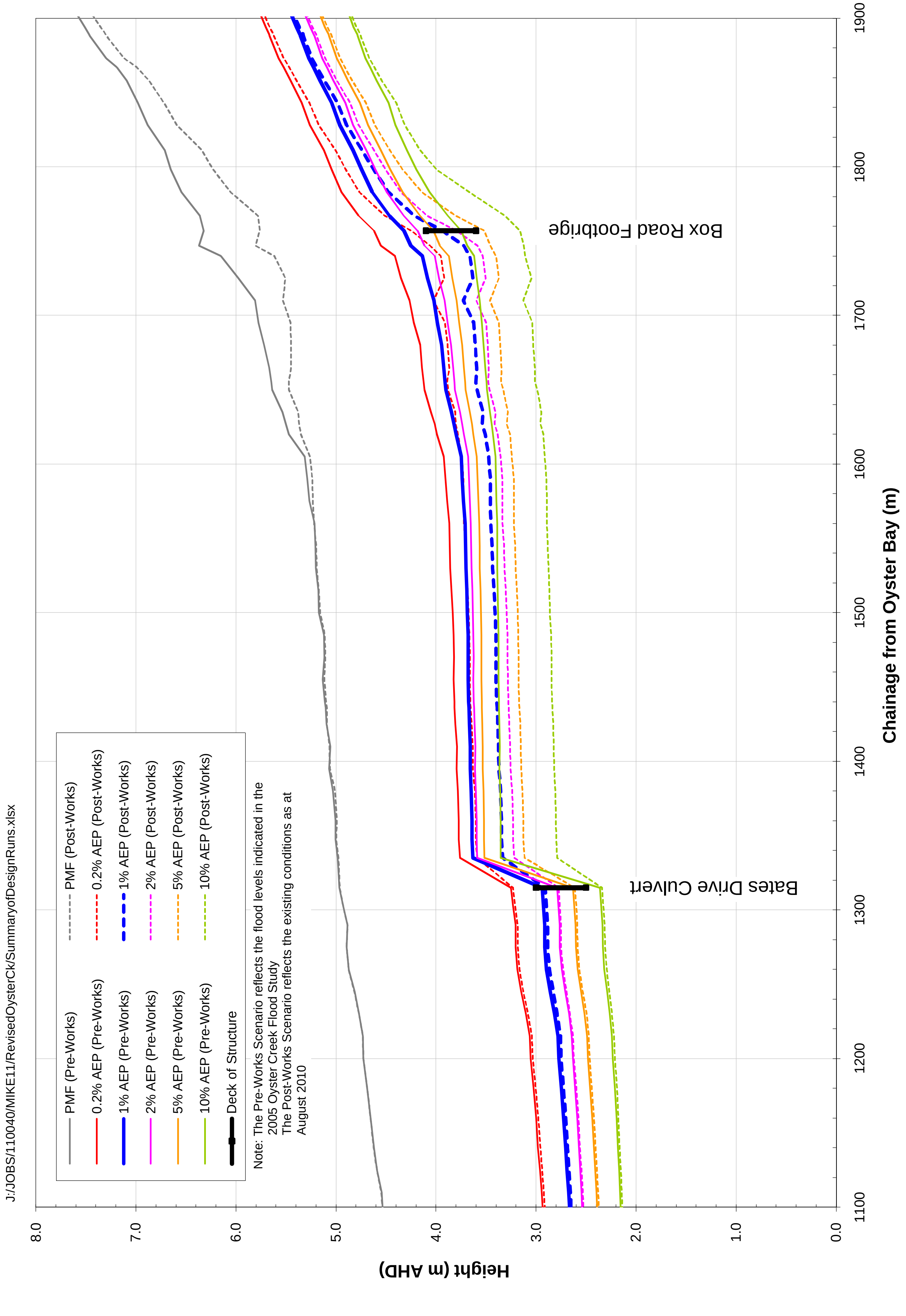

FIGURE 6
DESIGN FLOOD CONTOURS
1% AEP FLOOD WITH 50% BLOCKAGE
AUGUST 2010

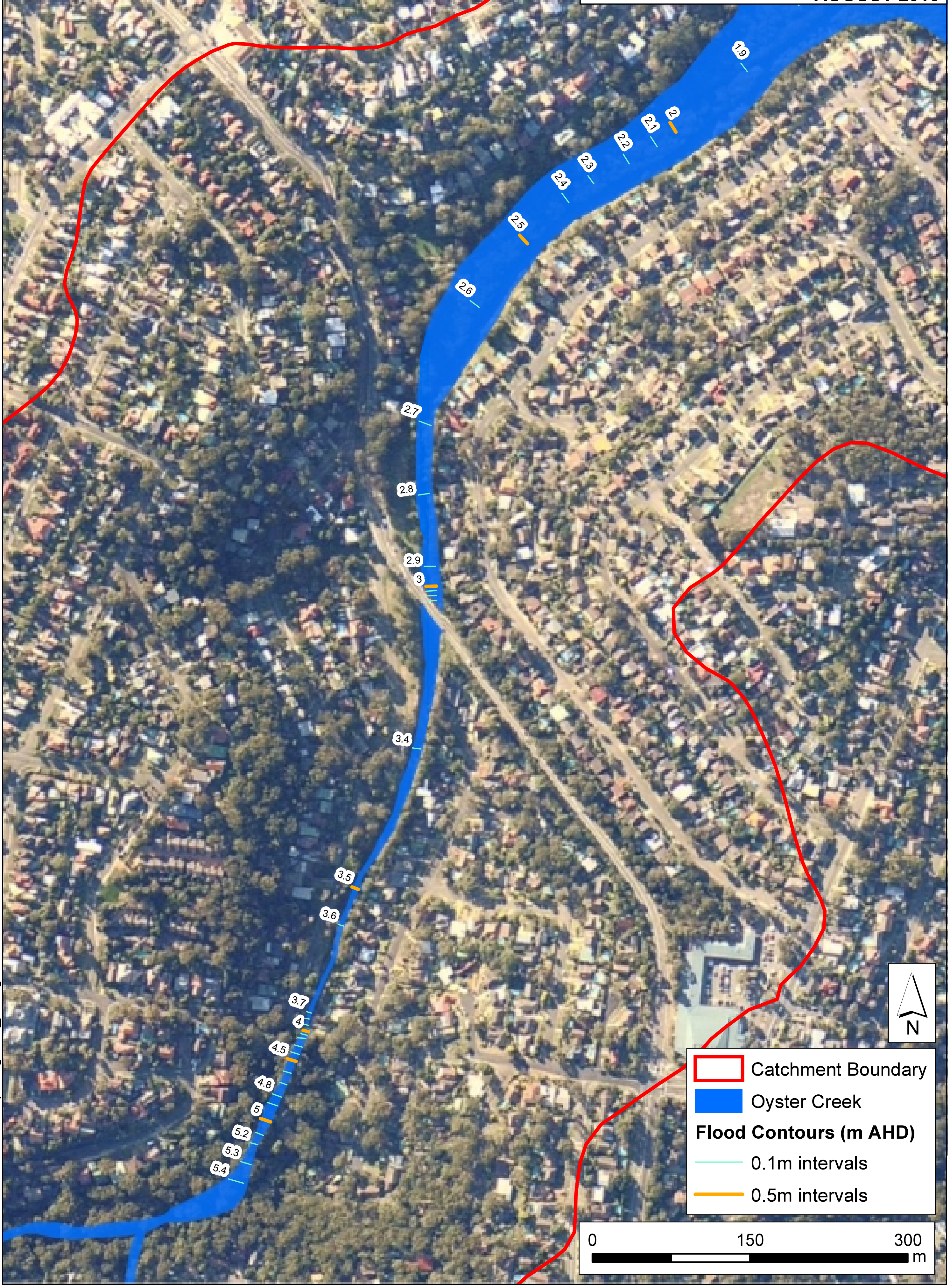

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FIGURE 7

INUNDATION EXTENTS FOR ALL DESIGN EVENTS

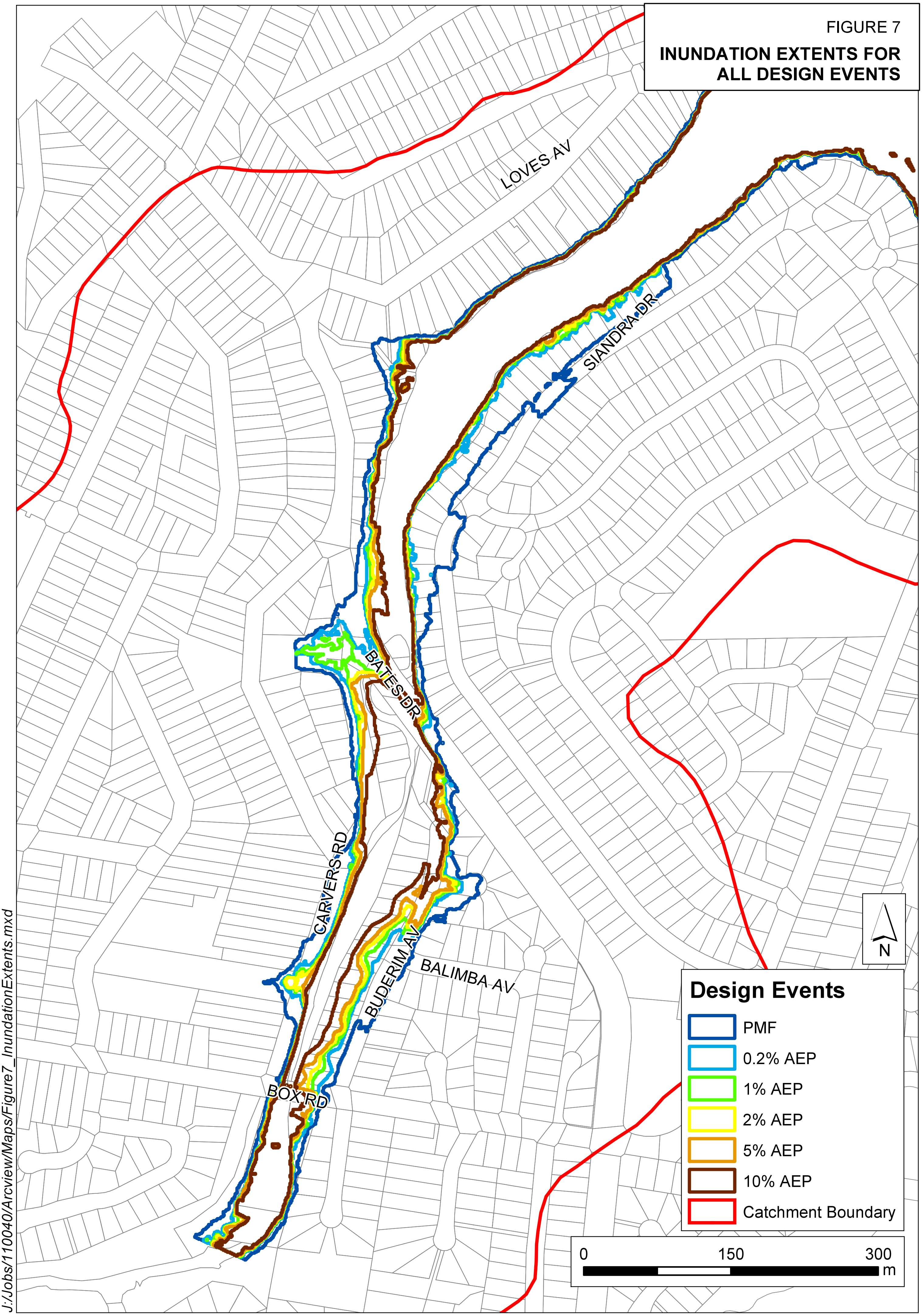
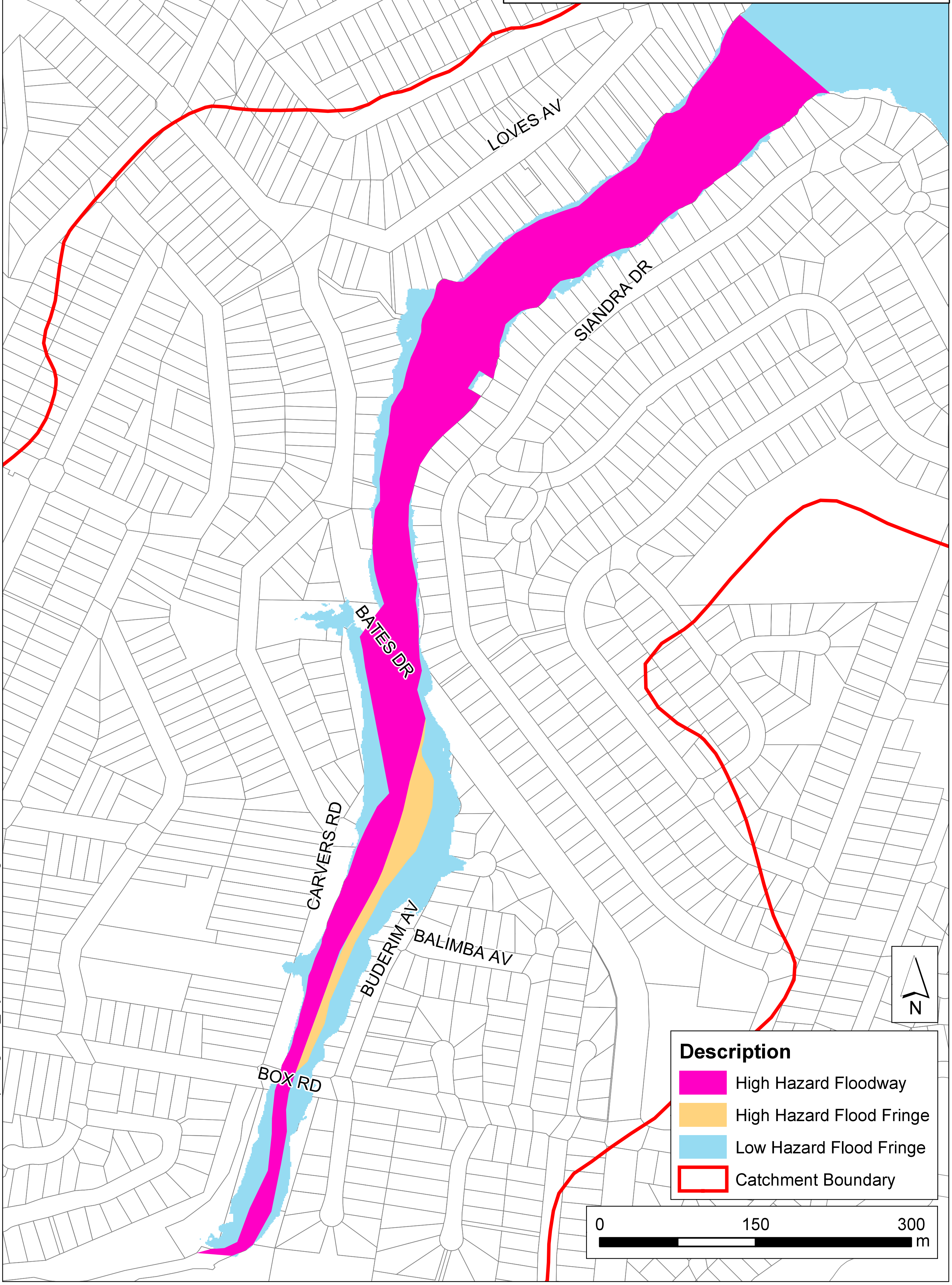


FIGURE 8

HYDRAULIC AND HAZARD CATEGORISATION
1% AEP FLOOD WITH 50% BLOCKAGE



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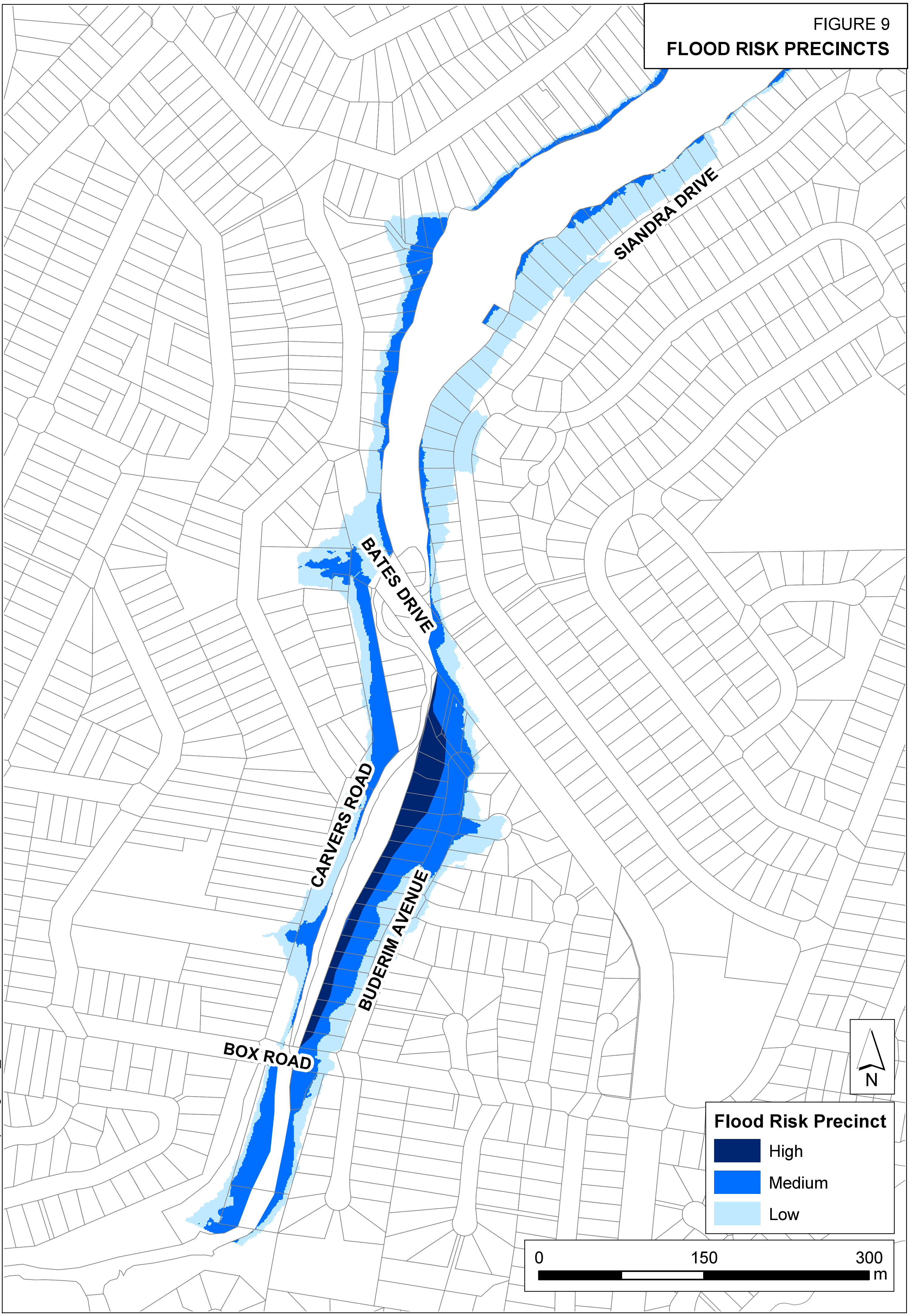

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Appendix A

APPENDIX A: GLOSSARY

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power.

	redevelopment: refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).
flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the

impacts of flooding.

floodplain — Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.

floodplain risk management options — The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.

floodplain risk management plan — A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.

flood plan (local) — A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.

flood planning area — The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the “flood liable land” concept in the 1986 Manual.

Flood Planning Levels (FPLs) — FPL’s are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the “standard flood event” in the 1986 manual.

flood proofing — A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.

flood prone land — Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.

flood readiness — Flood readiness is an ability to react within the effective warning time.

flood risk — Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below.

existing flood risk: the risk a community is exposed to as a result of its location on the floodplain.
future flood risk: the risk a community may be exposed to as a result of new development on the floodplain.
continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.

flood storage areas — Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.

floodway areas Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.

freeboard Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.

habitable room **in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom.
in an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.

hazard A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.

hydraulics Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.

hydrograph A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.

hydrology Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.

local overland flooding Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.

local drainage Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.

mainstream flooding Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.

major drainage Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves:

- the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or
- water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or
- major overland flow paths through developed areas outside of defined drainage reserves; and/or
- the potential to affect a number of buildings along the major flow path.

mathematical/computer models The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.

The merit approach weighs social, economic, ecological and cultural impacts of

merit approach land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains.

The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.

minor, moderate and major flooding Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood:

minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded.
moderate flooding: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.
major flooding: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

modification measures Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.

peak discharge The maximum discharge occurring during a flood event.

Probable Maximum Flood (PMF) The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.

Probable Maximum Precipitation (PMP) The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.

probability A statistical measure of the expected chance of flooding (see AEP).

risk Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.

runoff The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.

stage Equivalent to "water level". Both are measured with reference to a specified datum.

stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.

Appendix B

Post-Works: 50% Blockage

MIKE11	PMF Event		0.2% AEP Event		1% AEP Event		2% AEP Event		5% AEP Event		10% AEP Event	
Chainage (m)	Flood Peak (mAHD)	Peak Discharge (m^3/s)	Flood Peak (mAHD)	Peak Discharge (m^3/s)	Flood Peak (mAHD)	Peak Discharge (m^3/s)	Flood Peak (mAHD)	Peak Discharge (m^3/s)	Flood Peak (mAHD)	Peak Discharge (m^3/s)	Flood Peak (mAHD)	Peak Discharge (m^3/s)
0	2.90	329	1.80	108	1.70	82	1.60	73	1.50	61	1.40	45
780	3.27	306	2.16	101	2.00	76	1.90	67	1.79	56	1.63	42
800	3.44	306	2.25	101	2.08	76	1.98	67	1.85	56	1.69	42
820	3.58	306	2.33	101	2.14	76	2.04	67	1.91	56	1.74	42
840	3.70	306	2.40	101	2.21	76	2.10	67	1.97	56	1.79	42
860	3.81	306	2.47	101	2.26	76	2.15	67	2.02	56	1.84	42
880	3.91	305	2.53	101	2.31	76	2.20	67	2.07	56	1.88	42
900	4.00	305	2.58	101	2.36	76	2.25	67	2.11	56	1.92	42
920	4.10	299	2.64	98	2.42	74	2.30	65	2.16	55	1.96	41
940	4.17	298	2.69	98	2.46	74	2.34	65	2.20	55	1.99	41
960	4.24	298	2.73	98	2.49	74	2.38	65	2.23	55	2.02	41
980	4.30	298	2.77	98	2.52	74	2.41	65	2.26	55	2.04	41
1000	4.35	298	2.80	98	2.55	74	2.43	65	2.28	55	2.06	41
1020	4.40	298	2.83	99	2.58	74	2.46	65	2.31	55	2.08	41
1040	4.45	297	2.86	99	2.60	74	2.48	65	2.33	55	2.10	41
1060	4.49	297	2.88	99	2.62	74	2.50	65	2.35	56	2.12	41
1080	4.53	297	2.91	99	2.64	74	2.52	65	2.37	56	2.13	41
1095	4.53	297	2.91	99	2.65	74	2.52	65	2.37	56	2.14	41
1110	4.55	290	2.92	96	2.66	72	2.53	64	2.38	54	2.14	40
1125	4.59	290	2.94	96	2.67	72	2.55	64	2.39	54	2.15	40
1140	4.62	290	2.96	96	2.69	72	2.56	64	2.40	54	2.16	40
1160	4.66	290	2.98	96	2.70	73	2.58	64	2.42	54	2.18	40
1180	4.69	289	3.00	96	2.73	73	2.60	64	2.44	54	2.19	40
1200	4.73	289	3.03	96	2.75	73	2.62	64	2.46	54	2.21	40
1215	4.73	289	3.04	96	2.76	73	2.63	64	2.47	54	2.22	40
1230	4.77	290	3.08	96	2.79	73	2.66	64	2.50	54	2.24	40
1245	4.82	290	3.13	96	2.83	73	2.70	65	2.53	54	2.27	40
1260	4.87	283	3.17	94	2.87	71	2.73	63	2.57	53	2.30	39
1275	4.89	283	3.18	94	2.88	71	2.75	63	2.58	53	2.31	39
1290	4.88	282	3.18	94	2.89	71	2.75	63	2.59	53	2.32	39
1302.5	4.93	282	3.21	95	2.90	71	2.76	63	2.60	53	2.33	39
1315	4.96	283	3.23	95	2.91	71	2.77	63	2.61	53	2.34	39
1335	4.98	283	3.59	95	3.33	71	3.22	63	3.12	53	2.79	39
1347.5	5.00	283	3.60	95	3.35	71	3.23	63	3.13	53	2.80	39
1360	4.99	283	3.60	95	3.35	71	3.23	63	3.13	53	2.80	39
1380	5.01	284	3.61	95	3.35	72	3.24	63	3.13	54	2.81	39
1395	5.06	272	3.63	92	3.37	69	3.26	61	3.15	52	2.82	38
1410	5.06	272	3.63	92	3.37	69	3.26	61	3.15	52	2.82	38
1425	5.09	272	3.65	92	3.38	69	3.27	61	3.16	52	2.83	38
1436	5.09	272	3.65	92	3.39	69	3.27	61	3.17	52	2.84	38
1440	5.10	273	3.66	92	3.39	69	3.28	61	3.17	52	2.84	38
1455	5.12	273	3.66	92	3.40	69	3.28	61	3.17	52	2.85	38
1470	5.11	273	3.66	92	3.40	69	3.28	61	3.18	52	2.85	38
1485	5.11	273	3.67	92	3.40	69	3.29	61	3.18	52	2.85	38
1500	5.16	274	3.67	92	3.41	69	3.29	61	3.18	52	2.86	38
1515	5.17	270	3.69	91	3.42	69	3.30	60	3.19	51	2.87	38
1530	5.19	270	3.70	91	3.44	69	3.32	60	3.20	51	2.88	38
1545	5.20	270	3.71	91	3.44	69	3.32	60	3.21	52	2.88	38
1560	5.22	270	3.72	91	3.45	69	3.34	60	3.22	52	2.89	38
1575	5.23	271	3.73	91	3.46	69	3.34	60	3.22	52	2.89	38
1590	5.24	271	3.73	91	3.46	69	3.34	61	3.22	52	2.90	38
1605	5.26	271	3.74	91	3.47	69	3.36	61	3.24	52	2.91	38
1620	5.35	271	3.78	91	3.51	70	3.38	61	3.26	52	2.93	38
1627	5.37	271	3.80	91	3.54	70	3.42	61	3.29	52	2.96	38
1635	5.38	271	3.81	91	3.53	70	3.41	61	3.28	52	2.95	38
1650	5.47	257	3.88	87	3.59	66	3.46	58	3.33	49	2.99	36
1655	5.47	257	3.89	87	3.60	66	3.48	58	3.35	49	3.01	36
1665	5.45	257	3.87	87	3.59	67	3.47	58	3.35	49	3.01	36
1680	5.45	257	3.88	87	3.61	67	3.48	58	3.36	49	3.03	36
1695	5.46	257	3.91	87	3.62	67	3.50	58	3.37	50	3.04	37
1710	5.53	258	4.03	87	3.73	67	3.60	58	3.46	50	3.13	37
1725	5.51	258	3.92	87	3.63	67	3.50	59	3.37	50	3.05	37
1740	5.62	258	3.95	87	3.66	67	3.53	59	3.40	50	3.11	37
1747	5.80	258	4.06	87	3.72	67	3.59	59	3.46	50	3.12	37
1757	5.76	258	4.25	87	3.93	67	3.79	59	3.52	50	3.16	37
1767	5.78	258	4.51	87	4.22	67	4.09	59	3.80	50	3.31	37
1783	6.05	258	4.77	87	4.48	67	4.35	59	4.14	50	3.67	37
1798	6.23	250	4.90	84	4.63	65	4.51	57	4.33	49	4.00	35
1811	6.34	250	5.01	84	4.74	65	4.62	57	4.46	49	4.16	35
1828	6.59	250	5.17	84	4.90	65	4.77	57	4.61	49	4.31	35
1843	6.72	250	5.27	84	4.99	65	4.86	57	4.70	49	4.40	36
1858	6.87	250	5.40	84	5.12	65	4.99	57	4.84	49	4.54	36
1867	6.99	250	5.47	84	5.19	65	5.06	57	4.91	49	4.62	36
1873	7.12	250	5.52	84	5.24	65	5.11	57	4.96	49	4.67	36
1888	7.30	251	5.62	84	5.33	65	5.19	57	5.04	49	4.75	36
1889	7.30	251	5.62	84	5.33	65	5.20	57	5.05	49	4.76	36
1894	7.35	251	5.66	84	5.37	65	5.24	57	5.09	49	4.80	36
1903	7.44	251	5.72	84	5.43	65	5.29	57	5.14	49	4.85	36
1915	7.50	251	5.76	84	5.47	65	5.34	57	5.19	49	4.90	36