Frenchs Creek
Floodplain Risk Management Study

Final Report

Flooding from Frenchs Creek at Elm Avenue and Calool Crescent

Warringah Council

Final Report
December 2010

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1 FOREWORD

The State Government's Flood Prone Land Policy provides for the development of sustainable strategies for managing the occupation and use of floodplains from a risk management hierarchy perspective. The policy has the primary objective '*to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible.*'

Under the adopted policy, management of flood prone land falls to the responsibility of Local Government. State Government, through the Department of Environment, Climate Change and Water (DECCW), subsidises support works to reduce potential flood damage and personal danger in existing developed areas. DECCW also provides specialist technical support to assist Councils to ensure that the management of flood prone land is consistent with flood risk, with a view to ensuring that development does not cause an increase in potential liability.

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

- Flood Study – Determines the nature and extent of the flood problem.
- Floodplain Management Study – Evaluates management options for the floodplain with respect to both existing and future development.
- Floodplain Management Plan – Involves development of preferred options and formal adoption by Council of a plan of management for the floodplain.
- Implementation of the Plan – Implementation of property modification measures (e.g. modifications to existing development and planning and development controls); response modification measures (e.g. flood warning and evacuation planning); and flood modification measures (e.g. construction of flood mitigation works).

The Frenchs Creek Floodplain Management Study encompasses stage two of this management process. This study has been prepared by DHI Water & Environment Pty Ltd for Warringah Council to identify and evaluate management options for the floodplain under both present and future catchment conditions.

2 EXECUTIVE SUMMARY

The Frenchs Creek Floodplain Risk Management Study covers the catchment area draining to Middle Harbour via Frenchs Creek and Corridor Creek. The catchment that is the subject of this study is the area bounded by Forest Way to the east, Garigal National Park to the west, Wyatt Avenue to the north, and Blackbutts Road to the south. While the total catchment area of Frenchs Creek is some 550 hectares, the area addressed by this flood study covers the 210 hectare portion of the catchment shown in Figure 1.

Overland flooding of the Frenchs Creek catchment has historically resulted in inundation of private and commercial property and has affected road and property access. Overland flooding has been reported to have been caused by a range of mechanisms including the accumulation of overland flows in the upper catchment, overland flows exceeding the inlet capacity of the pit and pipe drainage system, surcharging of the pit and pipe stormwater system, flows exceeding the capacity of open channels in the catchment and blockage of the stormwater system inlets.

A Flood Study of the Frenchs Creek catchment (reference /2/) was undertaken prior to this study, to determine the existing flood behaviour of flood prone areas for a range of flood risk levels from the 20% Annual Exceedance Probability (AEP) event through to the Probable Maximum Flood (PMF).

Flood behaviour was determined for flood prone areas using mathematical modelling tools developed specifically for the study. Catchment runoff and overland flows were calculated using the MIKE Storm (reference /4/) modelling software. MIKE Storm is a hybrid model that combines the features of a fully dynamic pipe network model, including the stormwater pit and pipe network and a two dimensional, physically based hydrological catchment model for surface flow modelling into a system modified specifically for urban storm water applications. This model was calibrated to two historical storm events: April 1998 and March 2003. The calibrated model was also validated against regional design flow rate estimates.

The flood model predictions indicate that in many areas of the catchment the capacities of existing flow channels, major piped stormwater drainage conduits and road culverts are exceeded, resulting in overland flooding for a range of simulated flood risk levels. As a result of the overland flooding, a number of properties are affected by flooding above floor level. The following table provides a summary of the potential numbers of properties affected by flooding during design storm events.

Number of Properties Affected by Flooding

Flood Event	Nº Properties Flooded	Nº Properties Flooded Above Floor Level
FPL	460	378
PMF	424	318
1% AEP	342	120
2% AEP	304	101
5% AEP	264	76
20% AEP	213	63

The developed flood modelling tools and reported flood behaviour for existing catchment conditions have now been used as the basis for the Frenchs Creek Floodplain Risk Management Study.

A wide range of floodplain risk management options were assessed as part of this study. The range of options covers property modifications, response modifications and flood behaviour modifications. Where appropriate, the hydraulic model developed for the Flood Study was used to assess the hydraulic impact of any proposed flood behaviour risk management option (e.g. structural mitigation works) on flood behaviour. Potential options were evaluated based on a range of social, environmental, financial and technical criteria, as well as an overall appropriateness to the catchment. The evaluated options have been summarised and ranked in Table 23.

In the next stage of the project, the findings of this study should be reviewed and the preferred mix of options carefully combined as part of a consolidated Floodplain Risk Management Plan for the catchment. In developing the Floodplain Risk Management Plan, it is likely that weightings will be applied to the ranking matrix by Council. The weightings may be applied to account for factors such as the wider community benefit, costs effectiveness, etc. Planning controls are considered an essential component of continuing floodplain risk management.

3 GLOSSARY OF TERMS

This glossary is based on the glossary of terms published in the New South Wales Government Floodplain Management Manual (reference /1/).

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 of discharge 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 peak flood discharge of 500m^3/s or larger occurring in any one year (see average recurrence interval).
Australian height datum (AHD)	A common national plane of level corresponding approximately 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.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
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 particular location.
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).
Flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local heavy rainfall. Often defined as flooding which peaks within 6 hours of the causative rain.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, lake or dam and/or 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 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 now covers the whole of the floodplain not just that part below the flood planning level as indicated in the 1986 Floodplain Development Manual (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 of the NSW Government Floodplain Management Manual 2001. Usually includes both written and diagrammatic 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 of the 1986 Floodplain Development Manual.
Flood planning levels (FPLs)	Are the combinations of flood levels and freeboards selected for the planning purposes, as determined in floodplain risk management studies and incorporated in floodplain risk management plans. The concept of flood planning levels supersedes the "standard flood event" of the 1986 Floodplain Development Manual.
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 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 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 flood 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 risk is simply the existence of 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 the 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 flow, or significant increase in flood levels.
Freeboard	A factor of safety typically used in relation to the setting of floor levels, levee crest levels etc. It is usually expressed as the difference in height between the adopted flood planning level and the flood used to determine the flood planning level. Freeboard provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the floodplain, such as wave action, localised hydraulic behaviour and impacts that are specific event related, such as levee and embankment settlement and other effects such as “greenhouse” and climate change. Freeboard is included in the flood planning level.
Geographical information systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
Hazard	A source of potential harm or a situation with a potential to cause loss. In relation to the NSW Floodplain Management Manual 2005 the hazard is flooding which has the potential to cause damage to the community.
Hydraulics	The 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 that shows how the discharge or stage/flood level at any particular location changes with time during a flood.

Hydrology

The 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.

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 the discretion in determining whether urban drainage problems are associated with major or local drainage. For the purposes of the NSW Floodplain Management 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 the system capacity is exceeded; and/or
- Water depths generally in excess of 0.3m (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 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.

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 flood.

Moderate flooding: low-lying areas are inundated requiring the removal of stock and or the 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.

Net present value (NPV)	Net Present Value is a means of deciding on the financial viability of an investment. NPV is defined as the difference between the initial cost outlay and the present value of expected cash inflows. A positive NPV value is acceptable whereas an NPV of zero yields the internal rate of return. A negative value for NPV suggest that investment is not worthy of the money that is invested.
Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood (PMF)	The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation. 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 the PMF should be addressed in a floodplain risk management study.
Probable maximum precipitation (PMP)	The greatest depth of precipitation for a given duration meteorologically possible over a given size of 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 the estimation of the probable maximum flood.
Probability	A statistical measure of the expected chance of flooding. (See annual exceedance probability).
Runoff	The amount of rainfall that actually ends up as stream flow, 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.
Topography	A surface which defines the ground level of a chosen area.
Water surface profile	A graph showing the flood stage at any given location along a water course at a particular time

* This glossary has been developed in consultation with the NSW Floodplain Development Manual, 2005 (reference /1/).

4 INTRODUCTION

Warringah Council is committed to developing a sustainable Floodplain Risk Management Plan for the Frenchs Creek Catchment (Figure 1) consistent with the NSW Government's Flood Prone land policy and in accordance with the procedures outlined in the NSW Floodplain Development Manual, 2005 (reference /1/).

Overland flooding of the Frenchs Creek catchment has historically resulted in inundation of private and commercial property and has affected road and property access. Past overland flooding has been caused by a range of mechanisms including the accumulation of overland flows in the upper catchment, overland flows exceeding the inlet capacity of the pit and pipe drainage system, surcharging of the pit and pipe stormwater system, flows exceeding the capacity of open channels in the catchment and blockage of the stormwater system inlets.

Warringah Council commissioned the Frenchs Creek Flood Study (reference /2/) in order to determine the flood behaviour for a range of flood risk levels for present and future catchment conditions. Overland flood behaviour is described in this report in terms of the nature and extent of floodplain inundation.

The Frenchs Creek Floodplain Risk Management Study uses the information in the Flood Study to identify, analyse and compare various risk management options in the context of effects on flooding, social, economic and ecological factors. It provides the basis for robust decision making in the preparation of the subsequent Floodplain Risk Management Plan.

5 CATCHMENT DESCRIPTION

The Frenchs Creek Study area comprises approximately 210 hectares in the Upper Middle Harbour catchment. The catchment covers parts of the urban residential areas of Belrose and Frenchs Forest in the Warringah Council local government area. The study area comprises the areas of Belrose and Frenchs Forest draining to Frenchs Creek and Corridor Creek. This catchment area is roughly bounded by Forest Way to the east, Garigal National Park to the west, Wyatt Avenue to the north, and Blackbutts Road to the south. An overview of the study area is provided in Figure 1.

The Frenchs Creek catchment is a moderately steep, urbanised catchment. It is characterised by predominantly low-medium density urban development. Most of the catchment is serviced by formalised kerb and gutter connecting to a sub-surface piped stormwater system. In the lower parts of the study area, the sub-surface piped system drains to the open channels of Frenchs Creek and Corridor Creek. Many reaches of these two channels have been altered from their natural state by concrete or block lining. The open channels run through narrow drainage easements which are restricted by the close proximity of residential properties whose boundary fences restrict flows in some instances.

Frenchs Creek Arm Sub-Catchment

In the north of the study area, the Frenchs Creek arm originates in the vicinity of Wyatt Avenue. The natural swales and gullies that would once have collected rainfall in this area have been replaced by a piped stormwater system. The system is presently an enclosed system until it reaches Pringle Avenue, in the geographical centre of the catchment. The piped system upstream of Pringle Avenue generally follows the natural creek line, down Neridah Avenue, through Curragundi Avenue, through Lyndale Place (the former Dairy Farmers Site), St Anne's Close, Knightsbridge Avenue and the back of properties in Pringle Avenue until the Pringle Avenue intersection with Hews Parade where the open channel begins. In storm conditions the overland flows are likely to have a tendency to follow the original creek line, causing road and property flooding.

Corridor Creek Tributary Sub-Catchment

Corridor Creek runs through the former Belrose – St Ives road corridor. The creek channel has been moved from its assumed natural alignment where it ran down what is now Kapunda Place. During storm flow conditions, overland flows are likely to follow this original creek line, causing flooding to properties in Kapunda Place.

Lower Catchment

Corridor Creek merges with Frenchs Creek in the reserve area to the east of Kew Close. From here Frenchs Creek flows to Elm Avenue, where it passes through the Elm Avenue culvert and along the northern side of Calool Crescent. This area has experienced flooding problems in the past and has been the focus of a number of former studies.

Haigh Avenue Tributary Sub-Catchment

A third watercourse, known as the Haigh Avenue tributary, joins Frenchs Creek from the south, just downstream of Calool Crescent immediately upstream of the study boundary.

6 STUDY APPROACH

The overriding objective of this Floodplain Risk Management Study is to develop and assess an appropriate set of measures that may be combined to effectively manage the range of flood risks identified for the Frenchs Creek floodplain. A range of tasks have been undertaken to meet this objective including the following.

a) Compilation of all relevant and available flood related data for the study area by searching relevant data sources, including the Frenchs Creek Flood Study Report and all available previous reports.

b) Assessment of the impact of flooding in the Frenchs Creek catchment, including social, economic and environmental impacts associated with flooding.

c) Identification of a broad range of potential risk management options for the Frenchs Creek catchment, including property modification, response modification and flood modification options.

d) Evaluation of risk management options, using a range of subjective and objective criteria including cost/benefit analysis and the modelling tools developed during the Flood Study, where appropriate.

e) Recommendation of most appropriate risk management options for the Frenchs Creek catchment.

7 COMMUNITY CONSULTATION

Community and stakeholder consultation is an important and integral part of the floodplain management process for the Frenchs Creek catchment. Initial consultation for the Frenchs Creek Study involved announcing the Flood Study to the wider community via Council's regular column in Saturday's Manly Daily. A press release appeared in the column in November 2004.

Accompanying the press release in November 2004, Council distributed a newsletter and questionnaire by letterbox drop to residents identified as living in areas known to be and predicted to be subject to flooding. The purpose of the newsletter and questionnaire was to inform the community of the Study and also to access community knowledge of historical overland flooding in the study area. The questionnaire sought advice as to whether residents have experienced overland flooding, the nature and depths of flows and the timing of such flows. It also provided an opportunity for the residents to express their support for various types of flood management measures across a range of available alternatives.

Approximately 1350 copies of the community newsletter and flood questionnaire were circulated through the community. A total of 186 replies were returned via the reply-paid envelope.

Community members identified as potentially having more detailed information on past flood events were contacted by DHI for follow up interviews. A total of 84 property owners were interviewed either by phone or face to face for their recollections and views on flooding in the catchment. Many photographs and video footage of recent flooding in the catchment were provided by the community for reference.

The Belrose Open Space Corridor Association (BOSCA) is a key community group in the catchment. BOSCA was approached initially by letter in September 2004. Meetings were held on site with BOSCA representatives on two occasions in October 2004. Discussions were based on BOSCA's first-hand knowledge of historical flooding and BOSCA's views on potential flood management measures.

As well as the local community, the NSW Department of Environment, Climate Change and Water (DECCW) (incorporating the former NSW Department of Natural Resources, which itself was previously the Department of Infrastructure, Planning and Natural Resources), NSW Roads and Traffic Authority and the local representatives of the State Emergency Service were contacted to inform them of the study and request flooding information.

A Working Group was established to act as a continuing forum for community concerns to be expressed and to provide a method of providing input into the Floodplain Risk Management Study (FRMS) and commenting on the Draft FRMS Report. The Working Group comprised thirteen members of the local community, including residents and representatives from DECCW, the NSW Department of Planning, the local SES and BOSCA.

Information collected from the community questionnaires, and resident and stakeholder interviews is presented as Appendix A of the Flood Study report, along with a copy of the Manly Daily Press Release, Community Newsletter and Questionnaire.

An Open Day was held at Glenrose Shopping Centre on the 10th December 2005. The open day was advertised in the Manly Daily newspaper one week prior, a community newsletter advising of the open day was sent to all residents who resided within the 1% AEP flood extent or who had taken the time to reply to the questionnaire at the commencement of the Flood Study.

The overall community response to the Open Day was positive with approximately 30 community members visiting the stand. A number of residents confirmed that the flood mechanisms and overland flow paths as described in detail in the Flood Study report do indeed match very closely with their recollections of past flood events.

During discussions with residents a number of concerns were raised regarding flooding in the Frenchs Creek Catchment. These concerns included:

- The proposed development of the former Belrose – St Ives road corridor and the potential impact of this development on overland flooding in the area;
- The Recent upgrade of Forest Way, with the perception that it has worsened flooding; and
- Stream bank stability and the potential effect of bank failure on flood behaviour.

Members of the community also suggested a number of potential flood mitigation options at the Open Day, the two Public Exhibitions and via the Working Group. These options are included below and are addressed further in Section 12 of this report.

- Upgrade the culverts at Elm Avenue to contain flows within creek channel.
- Divert flow from Glen Street to the easement east of Glenrose Shopping Centre and upgrade drainage in easement to carry 1 in 100 year event.
- Redirect drainage from Forest Way to the east towards Oxford Falls.
- On-site detention/rainwater tanks for residents which can be utilised for garden and/or grey water usage, particularly at Lyndale Place on the former dairy site.
- Construct a stormwater retention basin in Munnumba Reserve.
- Regular scheduled maintenance of catchment infrastructure, such as street sweeping, check for culvert/drain blockages, etc.
- Reduce the number of deciduous trees which block certain pits and then cause flooding. Replace the trees with natives.
- Provide detention pits in Wingara Reserve.

Community Consultation will continue throughout the Floodplain Risk Management Study process. This study is to be publicly exhibited, with the exhibition announced in

the Mayoral Column in the Manly Daily. A community newsletter will be sent to all residents of the Frenchs Creek floodplain to alert them of the study exhibition. The press releases will also announce an upcoming open day as another opportunity for residents to comment and provide feedback on the assessed flood risk management measures proposed to reduce the impact of flooding on the community and infrastructure.

8 FLOODING IN THE CATCHMENT

8.1 Flood Study Review

The Frenchs Creek Floodplain Risk Management Study uses information presented in the Frenchs Creek Flood Study undertaken by DHI as a key reference. The Flood Study Report was completed in June 2006 and was adopted by Council in May 2010. The Flood Study report documents the collection of data, development of the hydrological and hydraulic model, calibration of the model to historical flooding events and sensitivity analysis, along with the results from the simulations of design storm events.

Previous studies in the catchment, undertaken by Webb McKeown in 2001 and 2003 (references /14/ and /16/), analysed the annual recurrence interval (ARI) of the historical storm events for which there were recorded data. A summary of their analyses is provided in Table 1.

Table 1 Summary of Estimated Historical Flood Event ARI.

Date	Rainfall Gauging Station	Storm Duration	Estimated ARI	
			Rainfall Intensity	Flood Levels
October 1987	Warriewood	1 hour	1 in 50	-
February 1990	Warriewood	Not provided	1 in 5	-
December 1990	Belrose – Bowling Club	Not provided	1 in 5	-
2 April 1992	Belrose – Bowling Club	30 minute, 1 hour and 2 hour	1 in 50	1 in 20
10 April 1998	Warriewood	30 minutes	1 in 20	-
10 April 1998	Warriewood	1 hour	1 in 10	-
10 April 1998	Belrose – Bowling Club	30 minute, 1 hour and 2 hour	1 in 50	1 in 20
10 April 1998	Belrose – Glen St	1 hour	1 in 20	-
		2 hour	< 1 in 50	-
8 August 1998	Not provided	Not provided	1 in 5	-
10 March 2003	Belrose – Glen St	1 hour	1 in 27	-

Note: All data has been taken from previous studies undertaken by Webb McKeown Associates (references /14/ and /16/).

Experience with flooding in urbanised flash flood type catchments in Wollongong in August 1998 and Newcastle in 2007 has demonstrated that 100% blockage of stormwater drainage systems due to trapped debris can occur during major flood events. As part of the most recent Frenchs Creek Flood Study (2010) sensitivity analysis was undertaken to determine the impact of 100% blockage on flood levels. Full blockage of

the pipe systems was generally found to result in higher flood levels in the open channel sections of Frenchs Creek, although some areas were found to have a resulting reduction in flood levels. For a discussion of the impacts of blockage, please refer to the Flood Study Report (reference /2/). As a precautionary planning measure Council has adopted flood levels that are based on 100% blockage within their stormwater drainage system. Nevertheless, it is understood that Council is continuing to attempt to reduce the amount of blockages at stormwater pit inlets and drainage culverts through debris mitigation measures and its maintenance program. Whilst the peak flood data with blockage were presented on the figures in the flood study report, only results without blockage were presented in tables within the body of the report. To ensure continuity between the Flood Study report and this Floodplain Risk Management Study, the tables and figures in this report contain data for the 1% AEP flood event and the PMF without blockages in the piped stormwater drainage systems, unless noted otherwise

The flood model predictions indicate that in many areas of the catchment the capacities of existing flow channels and stormwater infrastructure are exceeded, resulting in overland flooding for a range of simulated flood events. Table 2 provides a summary of the peak water surface levels and velocities for the design flood events for the unblocked scenario. The representative locations are provided in Figure 2. The water surface levels for the PMF and 1% AEP design storm events are provided in Figures 3 and 4.

One impact of a rainfall event is that surface runoff can mobilise debris from the catchment and carry it into the stormwater system, which consists of either piped or open channel networks. The entries to the open channel network are usually pits at the edges of roads, or grated pits in channel beds. Figure 5 shows typical examples of blockage to piped stormwater entries within the Frenchs Creek catchment.

When debris is mobilised within the open channel system, it is carried downstream by the flow and can become lodged in culverts and bridges. In culverts, large debris such as boulders, trees, branches or shopping trolleys usually cause a blockage at the entrance to the culvert, or in extreme cases, may cause blockage in the culvert itself. These large obstructions then act to trap smaller debris, effectively blocking the flow. At bridges, floating debris may become trapped by the bridge piers or by the bridge deck. As debris causes a blockage in the system, it may then cause streamflow to bypass the culverts and bridges and flood the roads and adjacent properties. If the blockage is severe, debris may then be collected on handrails and cause further flooding and damage. If the blockage is not too severe, it is often washed downstream when the peak of the storm has passed, leaving little evidence of the cause of the unexpected flood levels. Figure 6 shows typical examples of the impact of blockage at culverts and bridges.

Table 2 Summary of Peak Water Surface Levels and Velocities – Design Flood Events

Location		Ground Level (mAHD)	Water Surface Level (mAHD)					Velocity (m/s)				
			PMF	1% AEP	2% AEP	5% AEP	20% AEP	PMF	1% AEP	2% AEP	5% AEP	20% AEP
1	Calool Crescent	119.92	122.72	121.89	121.78	121.72	121.64	4.60	4.20	4.24	2.83	4.39
2	Calool Crescent	122.35	123.61	123.00	122.88	122.82	122.72	4.52	3.11	3.07	3.08	2.99
3	Winani Close	128.53	128.84	128.64	128.63	128.63	128.61	1.27	0.98	0.97	1.16	0.89
4	Trentbridge Road	125.26	128.12	127.34	127.12	127.07	126.92	3.98	2.41	2.36	0.95	2.23
5	Pringle Avenue	132.18	134.53	133.74	133.64	133.56	133.49	6.72	4.55	4.46	4.01	4.47
6	Pringle Avenue	142.44	143.55	143.03	142.90	142.82	142.75	2.74	1.83	1.67	1.34	1.15
7	Knightsbridge Avenue	146.37	148.15	147.54	147.36	147.21	147.12	2.28	1.24	1.08	0.80	0.59
8	St Annes Close	148.87	149.88	149.55	149.39	149.25	149.16	1.54	1.29	1.06	0.71	0.40
9	Lyndale Place	154.62	155.13	154.87	154.78	154.71	154.71	0.98	0.61	0.55	0.39	0.34
10	Curragundi Avenue	164.37	164.73	164.67	164.64	164.63	164.53	1.90	1.49	1.70	1.17	0.30
11	Burrswood Close	156.89	157.14	157.07	157.04	157.01	157.01	1.84	1.01	0.65	0.60	0.34
12	Haigh Avenue	128.00	129.45	129.09	128.96	128.88	128.82	9.09	8.92	8.64	6.09	7.95
13	Lowanna Street	147.98	148.31	148.07	148.00	148.02	147.98	1.49	1.35	1.32	0.94	0.64
14	Glen Street	157.95	158.27	158.19	158.15	158.10	158.11	1.95	1.52	1.35	1.00	0.94
15	Pringle Avenue	132.07	133.53	133.37	133.36	133.35	133.34	3.05	2.81	2.76	2.63	2.73
16	Kapunda Place	137.52	138.50	138.39	138.34	138.25	138.14	1.63	1.53	1.49	1.46	1.18
17	Kapunda Place	146.87	147.16	147.15	147.14	147.11	147.11	2.22	2.13	2.13	1.92	1.91
18	Willow Tree Crescent	165.52	166.19	166.09	166.08	166.01	165.99	1.77	1.98	1.97	1.85	1.69
19	Ralston Avenue	155.98	156.33	156.23	156.17	156.14	156.13	2.59	2.22	2.06	1.76	1.57
20	Lynette Place	140.44	142.03	141.37	141.20	141.11	141.02	1.16	0.70	0.63	0.51	0.39
21	Pringle Avenue	137.10	137.58	137.30	137.25	137.22	137.19	4.26	3.21	3.01	2.26	2.33
22	Willow Tree Crescent	153.93	154.18	154.13	154.11	154.07	154.05	2.33	2.11	2.06	1.46	1.77
23	Creek Confluence	129.20	130.53	129.94	129.81	129.72	129.66	5.17	3.60	3.48	2.87	3.33
24	Elm Avenue	124.80	125.74	125.33	125.22	125.18	125.12	2.46	1.07	0.84	0.75	0.58
25	Coora Avenue	142.97	143.28	143.15	143.11	143.07	143.07	2.19	1.71	1.61	1.23	1.24
26	Wingara Avenue	131.37	131.73	131.65	131.62	131.57	131.59	2.55	1.94	1.79	1.56	1.34

8.2 Flood Behaviour

The Frenchs Creek catchment is characterised by several principal overland flow paths. The following descriptions give more detail on flooding in specific areas of the catchment. The descriptions hold for all design events modelled, with only slight variation in the depth and width of flow over the range of the design storm events.

8.2.1 Upper Frenchs Creek Catchment (Above Pringle Avenue)

Overland flooding in the upper Frenchs Creek catchment is generally characterised by sheet overland flows accumulating in depressions and flowing down slopes to the kerb and gutter system. Once in the kerb and gutter drainage, the flows generally follow the road grade to pit inlets to the stormwater system. Flows entering the piped stormwater system are conveyed to the catchment outlet at a faster rate than flows that are forced to pass overland. There are no formalised open channels in the catchment upstream of Pringle Avenue.

In many areas, flows in the kerb and gutter system overwhelm the system's capacity and flow overland. The upper part of the Frenchs Creek sub-catchment has a series of streets that run across the natural slope of the catchment and flows tend to accumulate on the road surface at sag points in the road profile. Flows that are not able to enter the stormwater system flow over the top of kerb and in most cases, onwards through private property. Many times the initial point of kerb overtopping is at a driveway meaning that the overflow is often initially directed towards a property's garage. Overland flows that enter private property in many cases accumulate in or against buildings and other flow obstructions before flowing around the obstruction.

The first point of noteworthy overland flow accumulation is at Curragundi Avenue. Flows accumulate at this point from the street flows from Charleroi Road and Neridah Avenue. The piped stormwater system at Curragundi Avenue has also been known to surcharge in this location. Model analysis of the flow behaviour in this area confirmed that the sub-surface stormwater system is prone to surcharging at this location under storm conditions. Flows that cannot be conveyed by the sub-surface stormwater system flow overland through private properties to Ralston Avenue. Flows arriving at Ralston Avenue cross at the low point to the open space on the opposite side of the road.

The sub-surface stormwater system running from north of Ralston Road is joined at Ralston Road by an augmented trunk drain originating at Forest Way. These two stormwater lines have a capacity larger than the pipe capacity further down slope. As a result excess flows pass overland here towards Lyndale Close through an open space between properties designated for storm water overflows. Two large basins have been constructed below ground in the open space, but the capacity of the basins is significantly smaller than the runoff volumes arriving at this location for the events modelled and has been shown to have an insignificant attenuating effect on the flow hydrograph at even the 20% AEP event. Flows that pass overland through the open space are met head-on by the rear fence of numbers 3 and 4 St Annes Close. Flows pass overland through these properties above the residential floor level. Moving further downstream, the flows accumulate in the cul-de-sac of St Annes close before moving on overland to Knightsbridge Avenue. At Knightsbridge Avenue, flows pond in the sag point of the road surface to depths exceeding 1m before flowing overland through private properties. The overland flow path then generally follows the property

boundaries at the rear of properties in Pringle Avenue before emerging to cross Pringle Avenue near the intersection of Hews Parade. Flows ponding on Hews Parade then flow from the road into the open channel downstream of Pringle Avenue where the overland flows re-join the stormwater runoff entering the channel from the sub-surface drainage system.

Along the length of the main flow path described above, flows accumulate from other more minor overland flow paths. In particular, a significant flow contribution is made from a flow path originating above Burrswood Close. Flows from upstream of Burrswood Close flow overland through properties to Stratham Place before following the street surface to Pringle Avenue, where they join the main flow path.

8.2.2 Corridor Creek Catchment

The Corridor Creek sub-catchment runs through land once gazetted for an arterial road link from Dee Why to St Ives. This sub-catchment begins on the eastern side of Forest Way and collects runoff from the road surface which then runs overland through the vacant land into a channel covered by heavy vegetation. This channel flows in a predominantly north west direction close to and parallel to the rear boundary of properties in Kapunda Place. The channel is man made in this section and has less than 20% AEP event capacity. Flows in excess of the channel capacity flow overland through the properties in Kapunda Place onto the road surface, which is the natural low point in this part of the catchment. Flows coming overland join the accumulated flows from west of Kapunda Place and flow down the street into the cul-de-sac. Flows that cannot enter the pits in Kapunda Place flow overland through properties at the end of the street to Pringle Avenue. Downstream of Pringle Avenue, flows travel in the natural channel and its adjacent overbank areas through the corridor land to the rear of Winani Close. At Winani Close flows continue in the channel to the confluence with Frenchs Creek. Alternatively, when the channel capacity here is exceeded, the excess flow passes onto Winani Close and follows the street surface to Elm Avenue and Calool Crescent where it flows on the Frenchs Creek Floodplain.

8.2.3 Lower Frenchs Creek Catchment (Below Pringle Avenue)

Downstream of Pringle Avenue, Frenchs Creek is characterised by open channel flow. The channel path cascades over and, in some places, has carved through an igneous rock base. The channel walls are typically steep sided and have been stabilised with rock, concrete or brickwork walls in some sections. Below Elm Avenue the channel is concrete lined to the Calool Crescent culverts.

In larger flood events such as the calibration events of April 1998, March 2003 and the modelled design events, the open channel sections between Pringle Avenue and the confluence with Corridor Creek are exceeded, resulting in properties flooding on either side of the creek channel. Downstream of the Corridor Creek confluence, Frenchs Creek has two parallel flow paths. The first follows the creek channel while the second short-circuits the channel confluence and flows parallel to the main channel down Winani Close to Elm Avenue.

Flows which follow the main channel progress towards the culvert under Elm Avenue. The theoretical capacity of this culvert has been reduced by two factors. First, capacity is hampered by the skew angle of the culvert to the predominant flow direction and secondly, the culvert inlet area is reduced by a sewer manhole crossing on the upstream

side of the culverts. Under flood conditions, these two factors contribute to flows backing up behind the culvert before overtopping Elm Avenue road surface. Flows that overtop the road pass over Elm Avenue road surface, with some of the flow re-entering the creek channel downstream of the culvert, but noticeably more flow is conveyed by the sloping road surface onto Calool Crescent. Flows on Calool Crescent combine with those from Winani Close. The resulting overland flow path runs parallel to the channel down Calool Crescent before re-entering the channel at the Calool Crescent culverts. Floodwaters on Calool Crescent flow down the street at a level higher than the flows in the creek channel.

8.2.4 Haigh Avenue Tributary

The Haigh Avenue tributary originates at Lionel Watts Park. Flows from the park pass onto Glen Street and onwards to Lowanna Street. Flows that cannot enter the sub-surface storm water system in the Lowanna Street cul-de-sac pass through private property to the open space behind Glenrose Shopping Centre. Overland flows accumulating in the open space flow in a swale down the natural slope to Haigh Avenue, where they flow onto the road surface and then into the open channel to rejoin the piped storm water flow at this location.

8.3 Access Road Flooding

Due to the fast flood response time in the catchment (refer to Section 8.4 for further discussion), residents should be made aware that there is potential for the access routes in the Frenchs Creek catchment to become flooded in some locations where the creek crosses the road network. This may happen very quickly because the time to the peak of the flood is approximately 2 hours for the 1% AEP flood event at the downstream end of the catchment and may be as little as 30 minutes in the upstream end of the catchment. This is a very fast flood response to a rainfall event. There are five locations flooding of the access road may occur:

- Knightsbridge Avenue
- Pringle Avenue north (Frenchs Creek crossing)
- Elm Avenue
- Calool Crescent
- Pringle Avenue south (Corridor Creek crossing)

These five locations have previously been identified as potential locations at which to place flood depth indications and are shown on Figure 20.

Table 3 Peak Flood Depths and Velocities at Potential Access Road Flood Locations.

Location	Ground Level (m)	No Blockage of Pits and Pipes				100% Blockage of Pits and Pipes			
		PMP		1% AEP		PMP		1% AEP	
		Water Depth (m)	Velocity [1] (m/s)	Water Depth (m)	Velocity [1] (m/s)	Water Depth (m)	Velocity [1] (m/s)	Water Depth (m)	Velocity [1] (m/s)
Knightsbridge Avenue	146.42	1.75	1.32 (4.99)	1.16	0.74 (4.37)	1.41	1.30 (4.44)	1.00	0.93 (4.01)
Pringle Avenue North	137.62	0.55	3.59 (7.27)	0.35	2.24 (4.52)	0.53	3.34 (6.33)	0.31	2.29 (4.13)
Elm Avenue [2]	124.19	1.18	6.17	0.75	3.52	1.72	6.12	1.44	3.41
Calool Crescent	121.92	0.16	1.32 (1.65)	0.09	0.21 (1.69)	1.32	7.54 (2.04)	0.87	4.52 (0.98)
Pringle Avenue South	134.50	1.48	1.89 (8.15)	1.21	1.13 (7.82)	1.51	3.04 (5.53)	1.49	1.96 (4.65)

Notes: *1 The maximum velocity does not always occur at the location of maximum depth, so where this happens the maximum 1% AEP velocity for the unblocked case was located and all velocities at this location are recorded in parentheses in the table.*

2. At Elm Avenue, the maximum velocity occurs at the same location as the maximum water depth and so no velocities in parentheses have been provided.

To indicate the potential hazards due to floodwaters at the five creek crossing locations, a summary of the maximum depths of floodwater at the creek crossing has been provided in Table 3. The depths for the PMF and 1% AEP flood events for the scenarios with no blockage and 100% blockage in the pits and pipes have been included. Also shown in the table are the velocities that occur at the maximum depth location. It should be noted that the maximum velocity does not always occur at the location of maximum depth and this was found to be so in four out of the five cases presented in Table 3. Accordingly, the maximum 1% AEP velocity for the unblocked case was located and all velocities at this location are recorded in parentheses in the table. As can be seen, in all but a few cases, the maximum velocity is much greater in locations away from the point of maximum depth, with a maximum difference of 6.7m/s where Corridor Creek crosses Pringle Avenue.

8.4 Flood Hazard

Flood Hazard Categorisation has been undertaken for the 1% AEP and PMF events. Provisional flood hazard categories were assessed and mapped as part of the Flood Study according to guidelines prescribed in the NSW Floodplain Development Manual (reference /1/). *Low* and *High* Hazard categories were assigned by assessing the flow velocity and depth at each model grid cell over the course of the model simulation and classifying the peak combination of velocity and depth using criteria described in Appendix L of the NSW Floodplain Management Manual (reference /1/). Plans mapping the flood hazard are presented in Figures 7, 8 and 9.

The flood hazard ratings developed in the Flood Study are considered "provisional" because they have not considered a range of other factors that may influence the flood hazard to the community and property. The provisional hazard should be considered in conjunction with the following factors in order to determine the true hazard.

- Size of flood.
- Effective warning time.
- Flood readiness.
- Rate of rise of floodwaters.
- Depth and velocity of floodwaters.
- Duration of flooding.
- Evacuation problems.
- Effective flood access.
- Type of development.

Flood hazard ratings can be raised or lowered after consideration of these factors.

The consequences of a flood can sometimes be reduced if residents in the floodplain are given adequate warning time to make appropriate preparations to their property and/or

initiate evacuation. In the case of Frenchs Creek, the small, steep nature of the catchment means that there is little or no lead time for an effective flood warning.

The small catchment size lends itself to fast catchment response caused by intense storms of durations between one and three hours. Flood waters will typically rise and recede quickly, typically in less than one to two hours. While most of the main flow paths described in Section 8.2 typically pass overland through residential property, the flow paths are quite localised and confined. The confined nature of the overland flooding to steep, residual 'gullies' means that flow paths are of a similar width over a wide range of floods from the 20% AEP flood up to the PMF. The similar flood extent over the wide range of floods investigated is a reflection of the location of the Frenchs Creek catchment close to the major catchment divide. In most parts of the catchment, flood affected residents have easy access to flood free land in close proximity. In locations in Knightsbridge Avenue and Pringle Avenue North of Hews Parade, there is potential for individual houses to be isolated by high hazard floodwaters. In these locations, there are elevated floor levels above the PMF level that would allow for a safe haven for residents to wait out the flooding for a few hours.

While there is provisionally high hazard flooding through a number of residential properties, the brick veneer and/or double brick construction of the majority of residences is not expected to be in danger of structural damage due to the floodwaters. Historically, structural flood damage has been limited to the undermining of retaining walls and swimming pools and pushing through/over fences. Typically, residential buildings are not exposed to undermining from overland flood flows. Residential buildings adjacent to the upstream side of the open channel in the Elm Avenue are in close proximity to the channel, but bank protection works here have recently been upgraded to limit bank erosion.

The population of the Frenchs Creek catchment is generally already reasonably flood aware. There have been several significant storm events in recent years that have resulted in flooding of properties and infrastructure. During the community consultation process the community was generally aware that there was a problem and was keen for something to be done to reduce the risk of flooding. However, the limited warning times mean that there is limited scope to reduce flood hazard ratings or flood damage estimates on the basis of flood awareness.

On the basis of this review, there is limited basis to adjust the provisional hazard ratings determined in the flood study.

A floodplain hydraulic classification for the 1% AEP flood and PMF, as per the guidelines in the NSW Floodplain Development Manual, is provided in Figures 10 and 11.

8.5 Climate Change

Scientists and governments at an international level have accepted that the enhanced greenhouse effect is likely to result in climate change. Climate change may have a number of possible adverse effects on flooding behaviour, such as an increase in sea level and altered weather patterns. The Frenchs Creek catchment is well away from the coast and significantly elevated above sea level and so would not be affected by any

increase in sea level. Altered weather patterns may intensify storms and also result in an increase in the frequency and severity of flooding and droughts.

Current indicators are that climate change could result in a 10-20% increase in rainfall in the Frenchs Creek region, although no definitive values are available at this stage. Given that the flood levels for the PMF are not much higher than those for the 1% AEP event in the Frenchs Creek catchment, a small increase in rainfall would not be likely to have any significant impact on the predicted 1% AEP flood levels. Any impact from climate change is expected to result in flood levels for the 1% AEP event which are lower than those for the currently assessed PMF. Accordingly, it was considered that modelling climate change impacts was not warranted at this stage and that any potential impact from climate change on planned development within the Frenchs Creek catchment could be considered on its merits at the time of design, when more detailed climate impacts data may be available.

9 FLOOD DAMAGE ASSESSMENT

9.1 Flood Damage Categories

The methods in which flood damages are measured and estimated are outlined in Appendix M of the Floodplain Development Manual (reference /1/). The Manual describes the basic flood damage categories commonly used in technical studies, which are summarised in Table 4 below.

Table 4 Types of Flood Damage (reference /1/)

CATEGORY LEVEL 1	CATEGORY LEVEL 2	CATEGORY LEVEL 3
Tangible Damages Financial	**Direct Damages** Actual Contact with flood water	**Contents** Includes building contents, cleaning and repair or replacement of goods.
		Structural Includes damage to cupboards, walls, doors and repair or replacement of structural items.
		External Includes contents of sheds, urban infrastructure and vehicles.
	Indirect Damages Disruption caused by the flood	**Clean-up** Includes removal of food debris and removal of discarded items.
		Financial Includes loss of wages, loss of sales, loss of production and alternative accommodation.
		Opportunity Includes unavailable services such as school closures, telephone facilities and reduced levels of services from public authorities.
Intangible Damages Social and Environmental	**Direct Damages** Drowning Loss of Memorabilia	
	Indirect Damages Inconvenience Worry	

Intangible damages are difficult to quantify in financial terms, but represent a real loss for flood victims. These damages can be termed social impacts.

Tangible damages have a measureable financial cost associated with them and are associated with the damage and losses caused both by the flood and the subsequent clean up operations and recovery period. These costs can be regarded as economic impacts.

Direct damages are caused directly by the floodwaters. Indirect damages are the additional financial losses caused by the flood. These two categories can be further subdivided into a third level of different types of damages, as shown in Table 4.

9.2 Social, Economic and Environmental Impacts

9.2.1 Social Impacts

Land Use

The predominant land use in the Frenchs Creek catchment is residential. There is some commercial use, including the Glenrose Shopping Centre to the south west of the catchment and the Ralston Avenue shops and Belrose Service Centre to the north. There is no industrial land use in the catchment.

There are a number of parks and reserves in the catchment, most notably Lionel Watts Park and the Frenchs Forest Showground to the south of the catchment along with Wyatt Reserve to the north and Hews Reserve adjacent to the former Belrose – St Ives road corridor. Belrose Bowling Club is located in the east of the catchment, adjacent to Forest Way.

In addition, there is a road corridor, approximately 75m wide from the soccer ground at Forest Way, running northwest between the properties in Forest Glen Crescent and Kapunda Place and Willow Tree Crescent and Hews Reserve before crossing Pringle Avenue, from where it runs west, south of Winani Close and Calool Crescent and then beyond the study boundary. This area is heavily vegetated and may be developed at some time in the future, subject to development approval.

There are two primary schools located within the catchment, both with playing fields. Belrose Public School is located in the north west of the catchment on Ralston Avenue. Wakehurst Public School located in the south east of the catchment on Glen Street.

There are no known vulnerable communities within the catchment who may have special needs with regard to flood education or evacuation.

Catchment Demographic

Demographic information for the Frenchs Creek catchment areas was available from the 2001 Census. While the catchment overlapped a number of Collector Districts, the demographic profile was reasonably consistent across the various districts.

The age distribution suggests a relatively young catchment, with 69% of the population under 45 years of age. Some 8% of the population is 4 years and under, while 7% is 65 years or older. The age distribution within the Frenchs Creek catchment is provided in Figure 12.

Properties Affected by Flooding

A property survey was undertaken as part of the Frenchs Creek Flood Study Review. This survey included an estimation of floor levels for each property within or adjacent to the 1% AEP flood extent. Ground levels were available from the digital elevation model (DEM) of the catchment. A total of 502 properties were included in the property survey, out of approximately 1650 properties within the study area.

Comparison of the floor levels, DEM and the water surface levels generated during the design storm modelling indicates that there are a number of properties affected by flooding, including the 20% AEP flood. By the 1% AEP event, approximately 20% of properties in the Frenchs Creek catchment are affected by flooding, with 7% experiencing above floor flooding.

Table 5 details the number of properties in the Frenchs Creek catchment that are potentially affected by flooding.

Table 5 Properties Affected by Flooding

Flood Event	Nº Properties Flooded	Nº Properties Flooded Above Floor Level
PMF	424	318
1% AEP	342	120
2% AEP	304	101
5% AEP	264	76
20% AEP	213	63

Properties affected by the PMF and the 1% AEP flood event are presented in Figures 13 and 14 respectively. As can be seen in the figures, Belrose Service Centre, at the south west corner of the junction of Pringle Avenue and Ralston Avenue, is subject to flooding in both the PMF and 1% AEP flood events. The commercial properties at Ralston Avenue shops and Glenrose Shopping Centre are not affected by flooding, but there is a drainage path across the car parking area at Glenrose Shopping Centre, as can be seen in Figures 7 and 8.

Social Impact of Flooding

The social impacts of flooding can be both physical and psychological. Physical problems experienced before, during and after a flooding event may include back problems and other physical injuries related to evacuation and post-flood clean up, viral infections, respiratory infections related to mould and damp along with stress and stress-related conditions. Any pre-existing conditions may be exacerbated by the experience of flooding.

A flood is a traumatic experience. Psychological problems resulting from experiencing a flood may include emotional trauma, anxiety, irritability and depression.

The loss of personal items such as photo albums and other irreplaceable memorabilia can lead to a strong sense of personal loss. The need to replace and/or repair flood damaged possessions may lead to stress associated with financial strain.

Residents who have experienced a flood may become anxious during subsequent rainfall events, to the extent that they are afraid to leave the house for fear of returning to a flooded mess. Children are particularly susceptible to post-flooding anxiety and may suffer nightmares for some time after experiencing a flooding event.

The very short lead time (often less than 2 hours) to the peak flood levels in a storm in the Frenchs Creek catchment may lead to higher levels of risk to residents, who may be unaware of the rate of rise of the floodwaters. This may cause residents to remain in

their homes longer than they should, or delaying evacuation and being caught by rising floodwaters on the streets. As discussed in Section 10.7, the flood behaviour in the catchment makes flood warning procedures or evacuation prior to peak flooding generally unfeasible.

9.2.2 Economic Impacts

Probability of Experiencing a Flood Event

When using statistical means to determine the size of a design event, it is possible to analyse this information to determine the probability of experiencing a given flood in a particular period of time. The Floodplain Development Manual (reference /1/) presents this information in the form of a table, which has been copied into Table 6 below for ease of reference.

Table 6 Probabilities of Experiencing a Given Size Flood Once or More in a Lifetime (Floodplain Development Manual, reference /1/).

Size of Flood (Chance of occurrence in any year) ARI / (AEP)	Probability of Experiencing the Given Flood in a Period of 70 Years	
	At least once (%)	At least twice (%)
1 in 10 (10%)	99.9	99.3
1 in 20 (5%)	97.0	86.4
1 in 50 (2%)	75.3	40.8
1 in 100 (1%)	50.3	15.6
1 in 200 (0.5%)	29.5	4.9

Note: The probabilities are predicted by statistical theory for random events.

Method of Estimating Flood Damage Costs

In determining the financial costs of tangible flood damage, guidance was taken from Appendix M of the Floodplain Development Manual (reference /1/). The results of flood damage surveys are collated and used to estimate the cost of flooding in a specific study area. The flood damage is then presented as a stage-damage curve for different property types. The curves represent the cost of flooding for increasing depths of flooding in a property. For this study, the flood damages were assessed using site specific flood damage curves and the results from hydraulic modelling undertaken during the Frenchs Creek Flood Study (see Figures 15, 16 and 17).

Once the flood damage curves have been created, it is necessary to determine the number and types of properties that are flooded, which in this study was undertaken using aerial photography. Once the properties have been identified and classified, the cost of flood damage can be determined for a flood event by using the flood damage curves.

The average annual damage (AAD) is a statistical method of measuring the cost of flood damage in any year. AAD is calculated by summing the total damage caused by all floods over as long a period as possible, divided by the number of years in the time period. It is assumed that development has not changed over the time period. Once calculated, AAD can be used as a method of comparing the economic benefits of different mitigation methods. It should be noted that AAD only takes into account the physical economic benefits of a mitigation measure and does not account for intangible

benefits, so it may not accurately measure the true cost of flooding or the benefits of a mitigation measure.

From a study of a range of floods in the area, the cost of damage caused by floods of different AEP's can be plotted and values obtained, such as those shown in Table 8.

It was not possible to obtain commercial flood damage data for gas (or service) stations to determine possible flood damage costs for Belrose Service Centre. As an alternative, the following advice on potential flood damage was obtained from the Department of Environment, Climate Change and Water.

- Underground tanks should be water-tight and secure from flotation so as not to sustain any significant flood damage.
- Structural damage to the building/pumps could be small depending on the orientation and the type of construction.
- Stock/contents damage to 1m - 2m deep flooding might be between $20,000 and $50,000.
- Some allowance should be made for some damage to cars, say $20,000.
- Clean up costs of around $2,000.

Flood Damage Curves

Flood damages curves for the economic assessment were determined using Floodplain Risk Management Guideline No 4: Residential Flood Damages (reference /3/). Nine different flood damages curves were utilised for the assessment of flood damages in the Frenchs Creek catchment. These curves were based on a combination of three property types and three property sizes.

Three property types were incorporated:

- single storey slab on ground or low set;
- single storey high set; and
- two storey houses.

House sizes were estimated from the aerial photography. There was a wide variety of house sizes within the catchment, ranging from 100 m^2 to 510 m^2 with a mean house size of 215 m^2. Due to the size of this range, it was considered appropriate to apply varying flood damage curves to the various house sizes, as the flood damages are based in part on the size of the property.

A bell curve approach was used to divide the properties into the classifications Small, Medium and Large. The standard deviation was determined as 55 m2. All properties within one standard deviation on the mean property size were classified as Medium. All houses smaller than this range were classified as Small, while all houses larger were classified as Large. Details of the property classifications are given in Table 7 below.

The flood damages curves used are provided in Figures 15, 16 and 17.

Table 7 House Size Classification of Determination of Flood Damage Curves

House Size Classification	House Size Range m^2	Average House Size m^2	Nº Properties
Small	H < 160	140	61
Medium	160 < H < 270	210	368
Large	H>270	310	72

Flood Damages

The costs associated with flood damages were calculated based on the water surface levels generated for the design flood modelling available from the Flood Study and the flood damage curves discussed above. Flood Damages for the Frenchs Creek catchment are provided in Table 8 below. The values in Table 8 include damages associated with yard flooding and have been calculated using flood levels with no blockage of pipes and pits. All costs are provided in 2009 dollars, based on a 5% annual increase in costs since 2005. Based on this analysis, a 1% AEP event would be expected to generate approximately $9.2million of direct damage to predominantly residential assets.

Table 8 Existing Flood Damages

Flood Event	Flood Damages $ (2005 costs)	Flood Damages $ (2009 costs)
PMF	$ 15,496,800	$18,836,400
1% AEP	$ 7,564,600	$9,194,800
2% AEP	$ 6,432,900	$7,819,200
5% AEP	$ 5,145,900	$6,254,900
20% AEP	$ 4,227,200	$5,138,200
AAD	$ 1,059,100	$1,287,300
NPV20 7%	$ 11,219,900	$13,637,800
NPV20 4%	$ 14,393,200	$17,495,000
NPV20 10%	$ 9,016,500	$10,959,600

The Annual Average Damage (AAD) has been estimated at $1.29 million. Flood damages have been valued in real terms over 20 years. A discount rate of 7% has been used to estimate the net present value (NPV) over the 20 year period, along with a sensitivity analysis using 4% and 10%.

9.2.3 *Environmental Impacts*

The open channel sections of Frenchs Creek are predominantly a natural rock-based channel abutted closely on either side by private properties. Upstream of Pringle Avenue, the channels and gullies contributing to the main lower channel have been piped. The riparian zone of the open channel is characterised by a mix of native and exotic vegetation.

Corridor Creek runs through the former Belrose – St Ives road corridor. Upstream of Pringle Avenue the creek channel has been moved from its assumed natural alignment

where it ran down what is now Kapunda Place. The riparian zone is characterised by a mix of native and exotic vegetation.

Corridor Creek merges with Frenchs Creek in the reserve area to the east of Kew Close. From here Frenchs Creek flows to Elm Avenue, where it passes through the Elm Avenue culvert and along the northern side of Calool Crescent. At the confluence of the two creeks the channel is a modified natural rock based channel, becoming more regular towards the Elm Avenue culvert.

Downstream of the Elm Avenue culvert the creek runs through a large concrete-lined channel adjacent to Calool Crescent before passing through another set of culverts. The concrete channel continues for several hundred metres downstream of the culverts before passing over a waterfall and entering Garigal National Park. The concrete lined section of the creek is fully urbanised and has little environmental value.

The Warringah Council Creek Management Study (reference /15/) classified Frenchs Creek as having low to moderate ecological value with moderate to high development and stormwater discharges. Water quality in the Creek during low flows periods was assessed during the Creek Management Study. Nitrogen and Phosphorus levels were found to exceed the ANZECC default trigger levels. No sampling was undertaken during wet weather flows however it is expected that pollutant loads would increase substantially under wet weather conditions.

The Warringah Local Environmental Plan (2000) indicates that there are no problems with acid sulphate soils in the Frenchs Creek catchment area.

Any development in the Belrose Corridor needs to be carefully considered to manage the flood risk and environmental impacts. In preparing any development options, reference should be made to Section 9.7 of the Frenchs Creek Flood Study Report (reference /2/). The Frenchs Creek Flood Study Report reviewed Webb McKeown's hydrological assessment of the 2002 concept development layout, which included mitigation measures for controlling rainfall runoff volumes from the proposed development. The Frenchs Creek Flood Study indicated that there were potential flooding issues with the 2002 concept development layout, particularly in the following locations.

- Eastern end of Belrose Corridor near Forest Way
- Kapunda Place
- Winani Place

10 EXISTING FLOODPLAIN RISK MANAGEMENT PRACTICES

10.1 Existing Planning Controls

Council has a number of policies and guidelines relating to development on flood affected land. The two most important documents are the Draft Warringah Local Environmental Plan (LEP) 2009 and the Draft Development Control Plan (DCP) 2009, which were on Public Exhibition until December 2009. In addition, the Belrose Road Corridor Development Control Plan and the Waterways and Riparian Lands Policy should be referred to when planning development in the Frenchs Creek catchment.

The purpose of the Draft Warringah LEP 2009 is to make local environmental planning provisions for land in Warringah in accordance with the relevant standard environmental planning instrument under Section 33A of the Environment Planning and Assessment Act (1979).

Section 6.15 of the Draft LEP requires development consent for any development on land shown as "flood planning land" on the Flood Planning Area Map and on land subject to the discharge of a 1:100 ARI (average recurrent interval) flood event.

Development consent must not be granted on this land unless the consent authority is satisfied that the development will not:

a) adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties; or

b) significantly alter flow distributions and velocities to the detriment of other properties or the environment of the floodplain; or

c) affect the safe occupation or evacuation of the land; or

d) significantly detrimentally affect the floodplain environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability or river banks or watercourses; or

e) be likely to result in unsustainable social and economic costs to the community as a consequence of flooding; or

f) if located in a floodway:

   i) be compatible with the flow conveyance function of the floodway, or

   ii) cause or increase a flood hazard in the floodway.

Section E11 of the Draft Warringah Development Control Plan 2009 outlines objectives and requirements for Flood Prone Land as identified on the DCP Map, which categorises it as High, Medium or Low Flood Risk. These flood risk planning precincts are based on the hazard classifications and hydraulic categories as defined in the NSW Floodplain Development Manual, 2005 (reference /1/).

The objectives of the Draft DCP are to:

- ensure the development is compatible with the flow regime of the waterway;
- ensure that existing development is not adversley affected through increased flood damage and/or flood hazard as a result of new development;
- provide for the safety of people and property;
- provide a mechanism to control development on flood prone land; and
- to ensure a sustainable and holistic catchment wide approach is taken to development on flood prone land.

The Matrix Table provided in the Draft DCP lists the requirements relevant to the various types of proposed development.

10.2 Protection of Waterways and Riparian Lands Policy

Warringah Council's Protection of Waterways and Riparian Land Policy (reference /22/) aims to provide clear direction for the management, development and protection of waterways and riparian lands in Warringah. Waterways include watercourses, wetlands and water bodies. Riparian land includes riparian zones, riparian buffers and wetland buffers. This policy complements the Warringah Creek Management Study (reference /15/) which was completed in 2004 and investigated stream conditions in terms of ecological value, hydrological capacity and recreational/social values. It also reflects the objectives and guidelines of the Water Management Act (2000) (reference /23/) which is the principal legislation related to riparian and waterway management, and follows the Department of Environment, Climate Change and Water (DECCW) "Guidelines for controlled activities: Riparian corridors" (2008) (reference /24/).

It is based on the following principles.

a) Natural ecological processes of waterways and riparian land shall be maintained and enhanced to the greatest extent possible by:
   - causing no net loss to biodiversity;
   - supporting natural flow regimes;
   - minimising bank erosion and promoting naturalistic bank protection works when stabilisation is necessary (i.e. soft engineering outcomes);
   - preventing alteration of watercourses (includes piping, channelling, relocation or removal);
   - improving plant communities through natural area restoration; and
   - maintaining natural floodplains where appropriate.

b) Bushfire asset protection zones shall be maintained outside of riparian lands.

c) Piped or channelised watercourses shall be reinstated to more natural forms where possible.

d) Cultural heritage shall be preserved and opportunities created for appropriate public access and recreation in publicly owned land.

10.3 Water Sensitive Urban Design and On-Site Stormwater Detention

Council's Water Sensitive Urban Design (WSUD) Policy seeks to ensure that development is carefully designed, constructed and maintained so as to minimise impacts on the natural water cycle. It encourages sustainable water management, such as the use of rainwater within buildings and onsite detention. The main advantages are improved receiving water quality, reduced quantity of storm flows and reduced demand on the reticulated water supply.

Council's On-site Stormwater Detention (OSD) Rainwater Re-use Policy allows rainwater re-use to offset the volume of storage required by Council's "Onsite Stormwater Detention Technical Specification" without compromising the OSD system's contribution to stormwater management.

As part of the State Environment Planning Policy (SEPP) Building and Sustainability Index (BASIX), on-site detention (OSD) is required for all new houses where the total impervious area exceeds a designated percentage. BASIX ensures each new single dwelling, or alteration/addition to a single dwelling, reduces water consumption by 40% compared with an average home, and allows the volume of rainwater re-use to be credited against the calculated OSD storage volume.

Rainwater re-use can be used for most non-potable applications, such as garden use, laundry and toilet flushing. To achieve full credit against determined OSD volume, rainwater re-use must be used for toilet flushing as a minimum. A combined tank, incorporating OSD and rainwater re-use water in one tank is permitted. A combined tank must ensure that surface water is not used for laundry purposes. Tanks may be located above or below ground. The design must ensure that at least 50% of the site is routed through the OSD system.

10.4 Building Over or Adjacent to Drainage Systems and Easements

Council's Building Over or Adjacent to Drainage Systems and Easements Policy limits construction adjacent to or within drainage easements. Fences are to be not to be built over Council's drainage system as they impede the overland flow path, unless it can be demonstrated that there are sufficient openings to cater for the overland flow and also prevent the potential for debris blockages.

Council's piped or underground drainage system is to have sufficient capacity for a 5% AEP event. If the existing drainage system is not designed for the 5% AEP event then the drainage system will need to be upgraded by the applicant/developer.

An overland flow path through the property is to be provided for all storms in excess of the 5% AEP event, up to and including the 1% AEP event. The width of any drainage easement is generally set at the width of the drainage infrastructure plus 1m on either side, with a minimum width of 3.0 m. Where an overland flow path sufficient to cater for the 1% AEP event cannot be provided through the property, the piped or underground drainage system is to be upgraded.

10.5 Stormwater Drainage Policy

The purpose of Council's Stormwater Drainage Policy is to protect life and property during major floods, reduce inconvenience during minor floods, protect the quality of receiving waters and lift public awareness. It outlines guidelines for implementing the policy.

10.6 Stormwater Drainage from Low Level Properties

Council's Policy on Stormwater Drainage from Low Level Properties applies to all types of developments and land uses where these properties fall naturally away from the street. Its purpose is to manage overland flow, nuisance flooding and groundwater related damage caused by low level properties to adjacent downstream properties during storm events. The policy outlines the requirements for stormwater disposal and provides guidance for property owners when submitting a development application.

10.7 Flood Emergency Management

Flood emergency management is detailed in the Manly Warringah and Pittwater Local Disaster Plan (DISPLAN), which is issued under the authority of the State Emergency and Rescue Management Act (1989). The plan is consistent with similar plans prepared for areas across NSW and covers preparedness measures, conduct of response operations, and co-ordination of immediate recovery measures.

Flooding in Frenchs Creek is typically caused by short, intense storm cells with durations of 1 to 3 hours. The short lead times associated with this type of 'flash' flooding make flood warning procedures or evacuation prior to peak flooding generally unfeasible.

Whilst there is no formalised flood warning system, the Bureau of Meteorology provides a surrogate warning system by issuing a 'severe weather warning' or a 'severe thunderstorm warning'. The Bureau's website shows oncoming storms and rainfall recorded at numerous rainfall gauges in real time. The value of this as a flood warning system still relies on the timely actions by residents themselves.

11 FLOOD PLANNING LEVEL

11.1 Introduction

The Flood Planning Level (FPL) is a planning tool used to manage the risk of flooding in a catchment. The FPL is based on a combination of an adopted flood event, either historical or a design risk level, along with an appropriate freeboard.

The FPL is used for two main purposes:

- development control measures to aid in the management of future flood risk; and
- design levels for mitigation works to manage the existing flood risk.

11.2 Selection of Flood Planning Levels

The selection of a FPL for an area involves balancing the social, economic and environmental considerations against the consequences of flooding. It is important to get this balance right. If the FPL is set too low, new developments may be exposed to flooding relatively frequently. If the FPL is set it too high, some areas may be subject to excessive controls and development limitations.

Although it represents the most extreme flooding event likely, it is generally neither feasible nor practical to safeguard against the PMF event. Therefore a continuing risk of flooding in the catchment will remain. For this reason, the selection of a flood event upon which the FPL is based is a balance between:

- the social, economic and environmental cost of flooding, including the damage to property, infrastructure and the catchment, inconvenience to residents and the potential danger to life and limb; and
- the social, economical and environmental cost of restricting land use in flood prone areas.

Once the appropriate flood event has been selected it is necessary to determine the freeboard to be applied. The purpose of the freeboard is to reduce the risk associated with the selection of the flood event. It effectively provides a factor of safety, taking account of any uncertainties in the flood levels due to poor or limited data, localised changes to the catchment or flood behaviour, wave formation or climate change.

Council's Warringah Local Environmental Plan (LEP) 2000 adopts, by default, a FPL standard of 1% AEP plus 0.5m freeboard. Analysis of the flooding behaviour in the Frenchs Creek catchment has determined that there is not a significant variation in the flooding extent or flooding behaviour from the 20% AEP event through to the 1% AEP and the PMF (see Section 8). Given the relatively small variation in flood levels over the full range of flood events, it is neither feasible, nor socially, environmentally or economically worthwhile to select a higher or lower FPL from the general 1% AEP plus 0.5m standard normally adopted for residential development (as indicated in the 2005 Floodplain Development Manual, reference/1/).

The Department of Planning released a Planning Circular (PS 07-003) in January 2007 (reference /25/) regarding development controls for residential development in low risk areas, i.e. those areas outside the 1% AEP flood extent, but within the PMF extent. These guidelines state that "unless there are exceptional circumstances Councils should not impose flood related development controls on residential development on land above the flood planning level (low risk areas)". Exceptional circumstances are to be used to show a different FPL is needed for residential development based on previous flood history, hazards and local flood behaviour.

Frenchs Creek catchment experiences flash flooding, with rapid rates of rise of floodwaters and little flood warning time due to its small area and steep nature. With a flash flood environment there may be a need for 'shelter-in-place' to enable residents to survive a flood event in their home. For this to occur, homes would need to structurally withstand flood events up to the PMF level. Accordingly, the Frenchs Creek Floodplain Risk Management Plan should investigate the need for Council to apply for exceptional circumstances in order to gain approval to use development controls above the 1% AEP flood level within the Frenchs Creek catchment (and other similar catchments within the Warringah local government area), having regard to any advice from SES on the matter.

All Councils in NSW are required to prepare a new comprehensive local environmental plan in accordance with the Standard Instrument (Local Environmental Plans) Order 2006. In response, Council decided to translate the existing provisions of Warringah LEP 2000 into the new standard format and to prepare an associated Development Control Plan (DCP). Both documents were exhibited from 12 October to 30 December 2009 and submissions were received up to 31 March 2010 (references /20/ and /21/).

The LEP provisions state that development should be in accordance with the Floodplain Development Manual, 2005, and ensures development is compatible with the flood hazards. The DCP states prescriptive controls to ensure the objectives can be met. The DCP controls were developed taking into account flooding issues throughout Warringah local government area, including the typical flood behaviour of Frenchs Creek catchment.

12 FLOODPLAIN RISK MANAGEMENT OPTIONS

12.1 Introduction

There are three broad categories of floodplain risk management options that can be considered to reduce the impact of flooding in the catchment.

- Property Modification Measures such as planning and development controls and voluntary purchase of flood prone properties.
- Response Modification Measures such as flood forecasting, warning and evacuation planning.
- Flood Modification Measures which can include retarding basins, improvements to channel capacity, levee banks, etc.

A total of 28 options for flood risk management were determined based on the results from the modelling undertaken during the Flood Study, along with knowledge of the study area, information provided in previous studies and the community consultation process. A summary of these flood management options is provided in Table 9 below.

The locations of specific options are provided on the plan in Figure 18 and in photographs in Figure 19.

In all cases of floodplain risk, residents should be aware of the contents of Warringah Council's 'Floodsafe' brochure (Appendix A).

Table 9 Floodplain Risk Management Options for Frenchs Creek

Option No.	Floodplain Risk Management Options	Section
	Property Modification Options	**12.2**
1	Planning and development controls	12.2.1
2	Voluntary purchase of flood-prone properties	12.2.2
3	Voluntary house-raising of flood-prone properties	12.2.3
4	Flood-proofing of flood-prone properties	12.2.4
	Response Modification Options	**12.3**
5	Flood forecasting, warning and evacuation planning	12.3.1
6	Public awareness / education programme	12.3.2
7	Flood depth indicators at culverts	12.3.3
8	Obtain further flood information, immediately after next event	12.3.4
	Flood Modification Options	**12.4**
9	Upgrade of stormwater pipes from Curragundi Avenue to Pringle Avenue	12.4.1
10	Redirect drainage from Forest Way east towards Oxford Falls	12.4.2
11	Retarding basin at Belrose Primary School	12.4.3

Option No.	Floodplain Risk Management Options	Section
12	Retarding basin in Munnumba Reserve	12.4.4
13	Retarding basin in Hews Reserve	12.4.5
14	Widening of Corridor Creek channel upstream of south Pringle Avenue culverts	12.4.6
15	Levee at rear of properties in Kapunda Place	12.4.7
16	Upgrade of stormwater pipes from Kapunda Place to Pringle Avenue culverts	12.4.8
17	Upgrade of south Pringle Avenue culverts	12.4.9
18	Widening of creek channel between Pringle Avenue and Elm Avenue culvert	12.4.10
19	Levee to protect properties in Winani Close	12.4.11
20	Retarding basin downstream of south Pringle Avenue culverts	12.4.12
21	Upgrade of Elm Avenue culvert	12.4.13
22	Removal of kerb and gutter and re-cambering of Calool Crescent to redirect flows back into channel	12.4.14
23	Upgrade of Calool Crescent culverts	12.4.15
24	Retarding basin in Lionel Watts Park	12.4.16
25	Divert flow from Glen Street to the drainage easement east of Glenrose Shopping Centre and upgrade drainage in easement	12.4.17
26	Regular scheduled maintenance of catchment infrastructure, including street sweeping, check blockages etc	12.4.18
27	Vegetation control along creek to improve flow and minimise blockage of culverts	12.4.19
28	On-site detention and rainwater tanks	12.4.20

12.2 Property Modification Options

12.2.1 Planning and Development Controls (Option 1)

Land use and development controls are the most effective way of ensuring the appropriate management of future flood risk. In Warringah, land use and development controls are implemented through the Local Environment Plan and Development Control Plan, as described in Section 10.1.

These documents comprise the basis for restricting inappropriate development in areas with a high hazard and/or with the potential to have significant detrimental impact on flood behaviour elsewhere and for reducing potential flood damage by placing controls on development in flood affected areas.

Development controls vary depending on the category of development (e.g. residential, commercial/industrial, vulnerable, critical infrastructure, etc) and whether it is located in a High, Medium or Low Risk planning precinct. Controls are specified according to factors such as floor levels, building components, structural soundness, impact of development on flood behaviour, evacuation, management and design and car storage. For example, a residential development in a Medium Risk planning precinct would be

required, amongst other things, to have floor levels equal to or greater than the Flood Planning Level. Another example might be that for properties affected by the PMF, but not by the 1% AEP flood event, Council might consider a strategy involving vertical flood evacuation, where residents isolated by floodwaters could retreat upstairs to a second storey to avoid getting wet. Such a strategy can be appropriate where the duration of flooding is very short.

12.2.2 Voluntary Purchase of Flood-Prone Properties (Option 2)

Voluntary purchase involves the purchase of flood affected properties by Council, allowing them to be rezoned to a more appropriate land use. Properties are purchased at market price and only when offered voluntarily by residents.

Voluntary purchase is most effective when all of the properties in an affected area are made available for purchase. If only a small number of affected properties are available the scheme is less effective. Cost is also an issue and must be balanced with the prevention in damages and any alternative mitigation options.

There are 25 properties located within the High Hazard envelope during the 1% AEP storm event that also experience above floor flooding during the 20% AEP storm event. The benefit associated with the removal of these properties from the floodplain is the associated prevention in damages. The Net Present Value of the economic benefits at 7% discount over 20 years is $2,486,000.

The current mean house price in Belrose over the over 12 months to December 2009 is $816,000 (based on sales reported to Australian Property Monitors). Based on this value and the number of properties which are currently flood affected, the cost of a voluntary purchase scheme in present worth dollars is estimated at $20,400,000.

This gives a benefit cost ratio of 0.12 and is therefore not an appropriate option in this case based on economic criteria alone.

It may still be appropriate for Council to consider purchase of several isolated properties which are severely flood affected by nature of the property type. These are low-lying properties (slab on ground) that sit within the overland flow path and have been flooded above floor several times in recent years. Once purchased it would be possible for these properties to be redeveloped in a fashion more compatible with the flood behaviour in this area.

12.2.3 Voluntary House-Raising of Flood-Prone Properties (Option 3)

Voluntary house-raising involves jacking a house up to the flood planning level, construction of new foundations, and the reconnection of services. It is most appropriate for weatherboard or timber houses built on piers. It is generally not practical to raise brick houses or those built on concrete slabs.

Voluntary house-raising is considered inappropriate for this catchment as the majority of dwellings in the flood plain are brick homes built on concrete slabs and as such are not suitable for house-raising.

12.2.4 Flood-proofing of Flood-Prone Properties (Option 4)

It is possible to flood-proof a property which is prone to flooding. There are various systems available, most of which involve the placement of a flood gate at building access points and covers for weep holes and vents. The flood gates are portable, involve limited modification to the property and are relatively quick to deploy.

Flood-proofing systems do however rely on sufficient warning time being available to install the gates before flooding occurs. For the Frenchs Creek catchment, the warning time is limited (estimated to be less than one hour). This effectively means that someone must be at home or nearby at the time of the storm event in order to install the flood-proofing system. While they could be installed before residents go on holiday, people may be reluctant to do this as it would effectively advertise their absence and thereby increase risk of burglary. Storm events that occur during the night may also be a problem as residents may not wake in time to install the flood-proofing system.

There are 25 properties located within the High Hazard envelope during the 1% AEP storm event that also experience above floor flooding during the 20% AEP storm event. The estimated cost of flood-proofing an average brick property with front door, rear door, sliding patio doors and four air events is approximately $8,800. Based on the above, the cost of flood-proofing these properties is estimated at $219,000.

The economic benefit associated with flood-proofing is the reduction in flood damages. The Net Present Value of the economic benefits at 7% discount over 20 years is $1,439,000. A reduction factor of 75% was applied to this to take account of residents not being available to install the flood-proofing system. This resulted in a reduction in damages of $360,000 to $1,079,000.

This gives a benefit cost ratio for flood-proofing measures of 1.64. On the basis of economic considerations only, the option of providing flood-proofing measures to flood prone properties is worth further consideration. The legal and liability implications to Council of recommending and funding flood proofing of this type would need to be thoroughly investigated before a policy was adopted.

12.3 Response Modification Options

12.3.1 Flood Forecasting, Warning and Evacuation Planning (Option 5)

Due to the nature of flooding in the Frenchs Creek Catchment, there is little time to alert residents of potential flooding before it occurs. During the critical 2 hour duration storm event, the rainfall intensity peaks at 30 minutes and flooding levels peak around 45 minutes. This gives an indicative warning time in the order of one hour from the start of a predicted storm event, or less than half an hour warning from the rainfall intensity peak. Such a small warning time does not allow for any significant evacuation before commencement of flooding.

Generally, flood events are preceded by some kind of forecast for rain, which may provide a bit more warning time. In densely populated cities such as Sydney, if the Bureau of Meteorology believes that a thunderstorm might result in flash flooding, it will also issue a “severe thunderstorm warning”. Using information from the Bureau of Meteorology’s network of weather watch radars, these warnings are issued via the radio and the internet, in text and graphical formats.

In addition, an automated Flash Flood Warning System (FFSW) can be implemented with a network of rainfall gauges providing real-time notification and warnings of potential flooding. Such a system allows residents to access the most current local information from the internet (perhaps through a link on Council's website), even before a potentially flood-producing storm commences. A FFWS could never be regarded as a complete flood management solution, however when a flash flood can sometimes reach life threatening conditions in a very short time, even a small improvement in warning time could prove to be beneficial.

12.3.2 Public Awareness / Education Programme (Option 6)

There are many benefits to a community that is flood aware. Awareness of flooding and an appreciation of the existing flood hazards can promote appropriate land use and development in flood affected areas. It also encourages residents to be mindful of actions that can minimise or exacerbate flooding, such as reducing the paved areas on their properties or ensuring that stormwater inlets are free from blockages.

The population of the Frenchs Creek catchment is generally already quite flood aware. There have been several significant storm events in recent years that have resulted in flooding of properties and infrastructure. During the community consultation process the community was generally aware that there was a problem and was keen for something to be done to reduce the risk of flooding.

There are a number of approaches that could be used to raise public awareness of flooding in the Frenchs Creek catchment, several of which are noted below.

- Provide flood depth indicators at locations prone to inundation (discussed in Section 12.3.3 below).
- Teach children in local schools about flooding and the dangers associated with urban flooding.
- Provide a booklet on overland flooding to all households in the catchment, similar to those distributed to raise awareness of bush fire risk. The booklet should detail the flooding risks in the catchment, what measures residents can take to minimise the flood risk, what actions can increase the risk and what to do during a flooding event to reduce the damage.
- Provide displays at Councils offices and in local libraries using information from the above booklet.
- Include flood information on Section 149 certificates.
- Include flood information in the Council newsletter issued with quarterly rates notices.

The cost involved with the measures discussed above is in the order of $12,000. While it is difficult to quantify the economic benefit of a flood aware community, the potential reduction in flood levels and reduced risk to property and life from flooding make it a worthwhile exercise.

12.3.3 Flood Depth Indicators at Road Crossings and Culverts (Option 7)

Flood depth indicators at locations prone to flooding are a useful and inexpensive way to raise flood awareness in the catchment, along with providing information of actual flood depths during storm events. It would also be appropriate to include the water levels of previous floods to reinforce the potential for flooding in that area.

We would recommend the installation of flood depth indicators at five locations, shown in Figure 20 and listed below.

- Knightsbridge Avenue
- North Pringle Avenue culverts (Frenchs Creek)
- South Pringle Avenue culverts (Corridor Creek)
- Elm Avenue culvert
- Calool Crescent culverts

The Knightsbridge Avenue location was selected based on the potential for flooding, the depth of inundation and the fact that a car was swept away in floodwater at this location during the March 2003 storm event. As this street is a quiet residential street, rather than a more heavily trafficked thoroughfare and there is no easily identifiable flow path (e.g. a creek channel) at this location, close consultation with the local residents of the street is recommended before installation of a flood depth indicator.

The other four locations are all associated with culverts on open channels which are designed to pass a specific flow capacity. This capacity may be exceeded during a significant storm event, leading to inundation of the road. Culverts also have the potential to become blocked, resulting in flooding during smaller storm events.

The cost of providing and installing flood depth indicators at the five locations specified is estimated at $2,400. While the intangible nature of the benefits of this option excludes a benefit cost analysis, flood depth indicators are inexpensive and help to raise public awareness of flooding in the catchment and should help to prevent dangerous incidents with both pedestrians and motorists, such as the one that occurred in Knightsbridge Avenue during the March 2003 storm event.

12.3.4 Obtain Further Flood Information after Storm Events (Option 8)

It is important to obtain further flood information after each significant storm event to ensure that Council's records are up to date and to keep track of changes to catchment and to flood behaviour. Problems that may arise during storm events, such as material washing downstream and blocking drains, can be dealt with promptly to prevent repeat occurrences. Council's presence in the catchment after storm events reassures residents that the problem is being taken seriously.

12.4 Flood Modification Options

12.4.1 Upgrade of Stormwater Pipes from Curragundi Avenue to Pringle Avenue (Option 9)

Significant capacity issues with the piped storm water system exist between Curragundi Avenue to the north of the catchment and the north Pringle Avenue Culverts, where Frenchs Creek becomes an open channel. This results in overland flooding of properties in St Annes Close, Knightsbridge Avenue, Lynette Close and Pringle Avenue.

The pipe network in this area follows the assumed original creek line, and is located predominantly within private property. Amplification or duplication of stormwater pipes would involve significant excavation and disruption to residents.

The hydrologic and hydraulic model was used to examine this option. Stormwater pipes down the length of this reach were duplicated in the model to improve flow capacity and reduce surcharging. In addition, a number of sealed junction pits were converted to grated inlets to collect flows at strategic locations and further reduce overland flows through properties.

The model assessment shows that duplication of the pipes from Curragundi Avenue to the Pringle Avenue culverts would result in a reduction in surface water levels along this reach, but there would be a significant increase in flood levels downstream of the pipe upgrade. This increase in flood levels downstream of the upgraded pipe network occurs because of the increased volume of stormwater entering the open channel network from the upgraded pipe system. The impact on water surface levels is detailed in Table 10 below. Figure 21 details the proposed route of the new pipe network along with the revised 1% AEP water surface level with the option in place.

If this option is taken forward in the Floodplain Risk Management Plan, refinement of the pipe sizing should be undertaken in the design of the scheme.

The cost of duplicating the stormwater pipes from Curragundi Avenue to Pringle Avenue culverts is estimated to be $1,704,000. This is based on the cost of additional pipes, construction of new manholes, the excavation required and limited restoration of the site (no landscaping).

This cost does not include the cost of acquiring an easement along the pipe route from Curragundi Avenue to the Pringle Avenue culverts. A total easement length of 725m is required. Based on the Council's Policy on drainage easements, the total area of easement required is 4,225m^2 with a maximum width of 6m between Knightsbridge Place and Pringle Avenue.

Land values in the Frenchs Creek catchment are high, with the median property price in 2009 at $816,000 with an average lot size of 725m^2. Based on these values, an assumed land value of approximately $608,000 per property and a factor of 50% to allow for the residents' continued title of the land, we have assumed the cost of acquiring the required drainage easement to be $1,771,600.

Table 10 Impact of Pipe Upgrades from Curragundi Avenue to Pringle Avenue on Water Surface Levels

Location		Ground Level (mAHD)	1% AEP Water Surface Level mAHD		Difference (m)
			Current	Pipe Upgrades-Curragundi Ave to Pringle Ave	
1	Calool Crescent	119.92	121.89	122.12	0.23
2	Calool Crescent	122.35	123.00	123.15	0.15
3	Winani Close	128.53	128.64	128.64	0.00
4	Trentbridge Road	125.26	127.34	127.47	0.13
5	Pringle Avenue	132.18	133.73	133.87	0.14
6	Pringle Avenue	142.44	143.03	142.62	-0.41
7	Knightsbridge Avenue	146.37	147.54	146.75	-0.79
8	St Annes Close	148.87	149.55	149.15	-0.40
9	Lyndale Place	154.62	154.87	154.77	-0.10
10	Curragundi Avenue	164.37	164.67	164.61	-0.06
19	Ralston Avenue	155.98	156.23	156.17	-0.06
20	Lynette Place	140.44	141.37	140.72	-0.66
21	Pringle Avenue	137.10	137.30	137.20	-0.10
23	Creek Confluence	129.20	129.94	130.02	0.08
24	Elm Avenue	124.80	125.74	125.85	0.11

There are also a total of 18 swimming pools which lie along or adjacent to the proposed drainage easement. Of these, approximately 10 pools lie within 4m of the proposed pipe route. It is likely that a number of these pools will be affected by the pipe upgrade works and may require significant repair or even replacement. An allowance of $25,000 has been made for repair or replacement of these swimming pools, totalling $250,000.

This gives an adjusted total cost for this option of $3,725,600.

To spread the impact of the costs for Council, this option could be implemented in three stages. If three stages are implemented, they should be constructed from the downstream end of the pipe network to the upstream end.

At a number of locations along the length of the proposed pipe route there is limited distance between houses to accommodate the proposed drainage easement. In some cases between Knightsbridge Avenue and Pringle Avenue, the inter-house distance is as low as 4-5m, whereas the drainage easement required for these works is 6m. This problem limits the technical feasibility of this option.

The economic benefit of this option is the resulting reduction in flood damages. The Net Present Value of the economic benefits at 7% discount over 20 years is estimated at $2,215,100.

The benefit cost ratio for the duplication of the pipe network from Curragundi Avenue to the Pringle Avenue culverts is 0.59. With a benefit cost ratio less than one, this is not a good mitigation option based on economic criteria alone. The technical feasibility issues may reduce the suitability of this option further.

12.4.2 Redirect Drainage East from Forest Way towards Oxford Falls (Option 10)

The issue of changes to the drainage works along Forest Way following this road being upgraded was raised by a number of residents during the community consultation process. There was concern that catchment areas that formerly drained towards Oxford Falls were re-directed to the Frenchs Creek catchment as a result of the upgrade. The upgrade of Forest Way has been associated with a perceived increase in the number of flood events in the Frenchs Creek catchment in the St Annes Close / Knightsbridge Avenue area.

Details of the drainage layout for Forest Way prior to the upgrade were unavailable from the RTA despite numerous requests. It is difficult to determine whether flooding has increased in the Frenchs Creek catchment due to the works on Forest Way. Additional development within the catchment which has occurred in the upper catchment may have also contributed to increases in overland flows. Weather patterns have varied considerably in past decades and climate change may also be a factor in the apparent increase in flood inducing storm events over recent years.

Runoff from three sub-areas of the catchment converges at Ralston Avenue, just upstream of Lyndale Place, before flowing south down the catchment. These flows are from areas to the north (Neridah Avenue, Curragundi Avenue and Charleroi Road), the west (Ralston Avenue and Cotentin Road) and the east (Forest Way). The available models of the catchment were used to investigate the effect of redirecting the flows from Forest Way away from the Frenchs Creek catchment.

Analysis of the model results available from the Flood Study for the 1% AEP storm event show that the combined overland and piped flow from the section of Forest Way between Hews Parade and just north of Ralston Avenue peaks at $0.8m^3/s$. By comparison, the combined overland and piped flow at Ralston Avenue from the northern and western parts of the catchment peaks at approximately $13.1m^3/s$. Therefore the runoff flow from Forest Way represents only 6% of the flow from the catchment converging to this area. The model was then used to test a diversion of the runoff from Forest Way away from the Frenchs Creek catchment. The model results showed no appreciable difference in water levels at St Annes Close or Knightsbridge Avenue due to the diversion.

It is important to note that the redirected runoff from Forest Way must go somewhere. The impact of additional storm water flows on the Oxford Falls catchment area has not been addressed in this study. This impact would need to be quantified in order to determine the full costs associated with this option and to perform a benefit cost ratio. It is also important to consider that other development within the catchment and possible changing weather patterns would also contribute to the frequency and severity of flooding in this area. Irrespective of this, the negligible improvement in flooding shown by the model testing of this option would not warrant further investigation of this option.

12.4.3 Retarding Basin at Belrose Primary School (Option 11)

Belrose Primary School is located to the north of the catchment, near the junction of Ralston Avenue and Pringle Avenue. The school has a large playing field which has been identified as a potential site for a retarding basin because it would generally not be used during poor weather. This playing field has an area of 7,300m^2. The sloping nature of the site would require significant excavation and hence a significant water depth (i.e. greater than 1m) to retain enough flood volume to be effective on a catchment scale. The risk of standing water to depths of 1m and greater on a school site presents an unacceptable drowning risk to a primary school community where many pupils would not be expected to be able to swim. For this reason a retarding basin located within Belrose Primary School has not been investigated further.

12.4.4 Retarding Basin in Munnumba Reserve (Option 12)

Munnumba Reserve is located on Munnumba Road, near the junction with Knightsbridge Avenue. It is also linked to Pembroke Place via a footpath at the far end of the reserve. The reserve covers an area of approximately 3500 m^2 with a length of 100m and slope of 8.1%.

The reserve does not presently have a significant overland flow path near it. The nearest existing overland flow path is located approximately 60m away from the reserve passing through the rear of the properties 45 and 43 Knightsbridge Avenue. Flow diverted from this existing overland flow path to the reserve would need to pass through the rear of properties at 41 and 43 Knightsbridge Avenue. It would also need to be raised by at least 4m, which is the difference between the flow path ground levels and the lowest point in the reserve. Significant excavation works would be required to provide significant storage in the reserve, due to the steep slope. For these reasons, a retarding basin located within Munnumba Reserve is not considered technically feasible and has not been investigated further.

12.4.5 Retarding Basin in Hews Reserve (Option 13)

Hews Reserve is located in the centre of the catchment on Hews Parade and is adjacent to the former Belrose - St Ives road corridor. The reserve covers an area of approximately 20,800 m^2. It contains a playing field and car park.

The reserve is not located near any significant existing overland flow paths. Whilst the reserve is adjacent to the former road corridor, which has a significant Creek channel passing through it, it is significantly upstream from the creek and so not suitable for off-line storage of flows from this area. For these reasons, a retarding basin located within Hews Reserve is considered technically unfeasible and therefore has not been investigated further.

12.4.6 Widening of Corridor Creek Upstream of South Pringle Avenue Culverts (Option 14)

Corridor Creek runs through the former Belrose - St Ives road corridor, along the rear of properties in Kapunda Place. The creek is an engineered channel, partially rock-lined with a riparian zone comprising a mix of native and exotic vegetation.

The presumed natural flow path in this area is down the centre of Kapunda Place. Any flows that breach the present creek bank alignment flow down the natural slope through the rear of properties on the northern side of Kapunda Place to the road reserve. Flows

that reach the road reserve then pass down the road and west through properties at the cul-de-sac end of Kapunda Place towards Pringle Avenue. Constraining flows within the Corridor Creek channel alignment would result in reduced flooding in Kapunda Place.

This proposed option involves the widening of the existing creek channel to increase the flow capacity. The option was tested in the Flood Study model by adjusting the model to reflect the increase channel capacity. The model was then simulated for the 1% AEP flood event using this configuration and compared to the existing model results to estimate the change in flood behaviour (flood levels, flow distributions, etc) in this area and further downstream.

Increasing the capacity of the creek channel and keeping the flows in the channel resulted in significant reduction to flooding in properties in Kapunda Place for the 1% AEP event.

The existing creek channel is approximately 5m wide and 1m deep. In order to retain all flows in the channel during the 1% AEP storm event it was necessary to enlarge the creek channel to approximately 6m wide and 2m deep.

The model results indicated that widening Corridor Creek resulted in significant reduction in flooding to properties in Kapunda Place. The difference in water surface level for the 1% AEP storm event is provided in Table 11. Figure 22 shows the new water surface level for the 1% AEP storm event along with the location of the reach of the upgraded channel.

Table 11 Impact of widening Corridor Creek on Water Surface Levels

Location		Ground Level (mAHD)	1% AEP Water Surface Level mAHD		Difference (m)
			Current	Corridor Creek Widened	
1	Calool Crescent	119.92	121.89	121.83	-0.06
2	Calool Crescent	122.35	123.00	122.94	-0.06
3	Winani Close	128.53	128.64	128.60	-0.04
4	Trentbridge Road	125.26	127.34	127.25	-0.09
15	Pringle Avenue	132.07	133.41	133.32	-0.09
16	Kapunda Place	137.52	138.39	137.87	-0.52
17	Kapunda Place	146.87	147.15	146.88	-0.27
23	Creek Confluence	129.20	129.94	129.89	-0.05
24	Elm Avenue	124.80	125.74	125.69	-0.05

Increasing the width of Corridor Creek upstream of Pringle Avenue is estimated to cost $173,200. The economic benefit of this option is the resulting reduction in flood damages. The Net Present Value of the economic benefits at 7% discount over 20 years is estimated at $1,240,000. This gives a benefit cost ratio of 7.16. With a benefit cost ratio greater than one, widening Corridor Creek upstream of Pringle Avenue is a good mitigation option based on economic criteria alone and should be given further consideration.

12.4.7 Levee at Rear of Properties in Kapunda Place (Option 15)

Corridor Creek runs through the former Belrose - St Ives road corridor, along the rear of properties in Kapunda Place. The creek is a modified natural channel, partially rock-lined with a riparian zone comprising a mix of native and exotic vegetation.

The natural flow path in this area is down the centre of Kapunda Place and all flows that breach the creek banks flow down through the rear of properties on the northern side of Kapunda Place to the road, where they then flow down the road and west through properties at the end of Kapunda Place towards Pringle Avenue. Keeping flows within the Corridor Creek channel would result in reduced flooding in Kapunda Place.

This option involves the construction of a levee along the rear of properties on the northern side of Kapunda Place. A levee bank/flood wall was added to the flood study model at this location and the model was run to estimate the change in flood levels in this area and downstream.

The model results indicated that the construction of a levee alongside Corridor Creek resulted in significant reduction in properties affected by flooding in Kapunda Place. The difference in water surface level for the 1% AEP storm event is provided in Table 12 below. Figure 23 shows the new water surface level for the 1% AEP storm event along with the location of the levee. The water surface levels behind the levee ranged from 149.90m behind 18 Everton Road, 144.67m behind 16 Kapunda Place, 141.67m behind 28 Kapunda Place and 135.96m at 106 Pringle Avenue. If this option is taken to full design, further modelling should be undertaken to confirm required crest levels for the chosen levee design.

Table 12 Impact of Levee along Corridor Creek on Water Surface Levels

Location		Ground Level (mAHD)	1% AEP Water Surface Level mAHD		Difference (m)
			Current	Corridor Creek Levee	
1	Calool Crescent	119.92	121.89	121.83	-0.06
2	Calool Crescent	122.35	123.00	122.94	-0.06
3	Winani Close	128.53	128.64	128.60	-0.04
4	Trentbridge Road	125.26	127.34	127.25	-0.09
15	Pringle Avenue	132.07	133.41	133.32	-0.09
16	Kapunda Place	137.52	138.39	137.88	-0.51
17	Kapunda Place	146.87	147.15	146.88	-0.27
23	Creek Confluence	129.20	129.94	129.89	-0.05
24	Elm Avenue	124.80	125.74	125.69	-0.05

The cost of constructing a levee at the rear of properties in Kapunda Place is estimated at $147,000.

The economic benefit of this option is the resulting reduction in flood damages. The Net Present Value of the economic benefits at 7% discount over 20 years is estimated at $1,201,000. This gives a benefit cost ratio of 8.17. With a benefit cost ratio greater than one, the construction of a levee along Corridor Creek at the rear of properties on

Kapunda Place is a good mitigation option based on economic criteria alone and should be given further consideration.

The corridor land is presently being considered for re-development. It is suggested that the redevelopment of the corridor include careful consideration of a suitable design aimed at reducing the impact of Corridor Creek floodwaters on existing residential property in Kapunda Place.

12.4.8 Upgrade of Stormwater Pipes- Kapunda Place to Pringle Avenue Culverts (Option 16)

The stormwater pipes that run down the length of Kapunda Place are currently under-capacity, resulting in surcharging and overland flow down the road and through properties located at the end of the cul-de-sac.

As the majority of flooding problems in Kapunda Place are due to flows overtopping the banks of Corridor Creek at the rear of properties, the upgrade of stormwater pipes at this location would only be of additional benefit when considered in combination with the flood modification measures to improve the capacity of the creek channel (options 14 and 15). The levee along the rear of properties in Kapunda Place was selected as it was the most favourable option once the cost benefit analysis had been completed.

The flood study model was used to investigate the impact of duplicating the pipes from the end of the cul-de-sac in Kapunda Place through to Pringle Avenue. Two new inlet pits were added to the network to collect flows at strategic locations and further reduce overland flows through properties at the end of Kapunda Place and adjacent to the creek channel on Pringle Avenue.

The results of the modelling indicate that this option reduced overland flow depths along Kapunda Place and through the properties at the end of the cul-de-sac on this street. The difference in water surface level for the 1% AEP storm event is provided in Table 13. Figure 24 shows the new water surface level for the 1% AEP storm event along with the location of the new pipe work.

Table 13 Impact of Pipe Duplication along Kapunda Place on Water Surface Levels

Location		Ground Level (mAHD)	1% AEP Water Surface Level mAHD		Difference (m)
			With Corridor Creek Levee	Plus New Pipe Upgrades	
1	Calool Crescent	119.92	121.83	121.99	+0.16
2	Calool Crescent	122.35	122.94	123.06	+0.12
3	Winani Close	128.53	128.60	128.69	+0.09
4	Trentbridge Road	125.26	127.25	127.35	+0.10
15	Pringle Avenue	132.07	133.32	133.58	+0.26
16	Kapunda Place	137.52	137.88	137.58	-0.30
17	Kapunda Place	146.87	146.88	146.88	0.00
23	Creek Confluence	129.20	129.89	129.94	+0.05
24	Elm Avenue	124.80	125.69	125.77	+0.08

Water surface levels in Kapunda Place are reduced, but increasing the capacity of the stormwater pipe system results in an increase in water surface levels downstream.

The cost of duplicating the stormwater pipes from Kapunda Place cul-de-sac to Pringle Avenue is estimated at $65,400. This cost includes the new pipes, excavation and placement of these pipes and the construction of new manholes.

This cost does not include the cost of acquiring land to widen the existing drainage easement between Kapunda Place and Pringle Avenue. A total easement length of 100m is required. Based on the Council's Policy on drainage easements, the total area of easement required is 510m^2 with a maximum width of 5.1m between Knightsbridge Place and Pringle Avenue.

Land values in the Frenchs Creek catchment are high, with the median property price in 2009 at $816,000 with an average lot size of 725m^2. Based on these values, an assumed land value of approximately $608,000 per property and a factor of 50% to allow for the residents' continued use of the land, we have assumed the cost of acquiring the required drainage easement may be up to $213,800.

This gives an adjusted total cost for this option of $279,200.

The economic benefit of this option is the resulting reduction in flood damages. Once the benefits achieved from the levee were subtracted, the Net Present Value of the economic benefits at 7% discount over 20 years is estimated at $52,600.

This gives a benefit cost ratio of 0.19. Based on this ratio and the adverse effect of including the pipes on areas further downstream, the pipe upgrade along Kapunda Place is not a good mitigation option based on economic and flood impact criteria alone.

12.4.9 Upgrade of South Pringle Avenue Culvert (Option 17)

The south Pringle Avenue culvert allows Corridor Creek to pass under Pringle Avenue. The existing culvert is a single 1.05m diameter pipe. This pipe is under capacity resulting in flows overtopping Pringle Avenue at this location.

The upgrade of the south Pringle Avenue culvert has been sized based on the improvements to the creek capacity discussed above. This was to ensure that the culvert had sufficient capacity to pass all flows from the former road corridor.

The flood study model was used to investigate the impact of upgrading the south Pringle Avenue culvert. The model results indicated the principal benefit was a reduction in water levels across Pringle Avenue, which occurred when the culvert capacity was exceeded. Figure 25 provides the location of the culvert along with the new 1% AEP storm event water surface levels. There was no discernible reduction in property flooding or flood damages, however as it is desirable form the point of view of reducing disruption to traffic on this main road during storm conditions, it is recommended that this upgrade be carried out as part of works to improve the capacity of Corridor Creek upstream of the culverts.

The upgrade of the south Pringle Avenue culvert includes replacing the existing headwalls at each end of the culvert, replacing the existing 1.05m diameter pipe with a box culvert 2.4m wide and 1.0m high and reparation of the road surface above. The estimated cost of this scheme is $45,600.

12.4.10 Widening of Frenchs Creek and Corridor Creek between Pringle Avenue and Elm Avenue Culvert (Option 18)

The creek channel between Pringle Avenue and Elm Avenue is predominantly a natural, rock lined channel. It is closely abutted on either side by private properties. Widening the creek channel or otherwise improving the channel capacity would decrease overland flooding in this area however it would involve significant excavation. Excavation access would also be difficult down the narrow existing creek channel. Widening the creek channel would have a significant environmental impact. The current policy within DECCW and Council is to maintain natural creek channels wherever possible.

The flood study model was used to investigate the impact of widening the creek channel from the confluence of Corridor Creek to upstream of the Elm Avenue culvert. The change in water surface level associated with the creek widening in given in Table 14 below, while Figure 26 indicates the section of the creek to be widened along with the new 1% AEP storm event water surface level. The model results indicate no difference in the water level at the confluence of Corridor and Frenchs Creeks. At location 4, between the confluence and the Elm Avenue culvert, there is a reduction in water depth associated with the widening of the creek, however, by the time the flow reaches the Elm Avenue culvert the reduction in water level is minimal, due to the flow restrictions (backwater) at the culvert. There is no difference to the water levels downstream of this location.

Should the creek be widened it would also be necessary to improve the hydraulic capacity of the Elm Avenue culvert.

Table 14 Impact of widening Frenchs Creek and Corridor Creek on Water Surface Levels

Location		Ground Level (mAHD)	1% AEP Water Surface Level mAHD		Difference (m)
			Current	Frenchs Creek & Corridor Creek Widening	
1	Calool Crescent	119.92	121.89	121.89	0.00
2	Calool Crescent	122.35	123.00	123.00	0.00
4	Trentbridge Road	125.26	127.34	127.08	-0.25
23	Creek Confluence	129.20	129.94	129.94	0.00
24	Elm Avenue	124.80	125.74	125.73	-0.01

The widening of the creek between Pringle Avenue and the Elm Avenue culvert involves the excavation of a significant volume of sandstone. The estimated cost of this scheme is $243,000.

The economic benefit of this option is the resulting reduction in flood damages. The Net Present Value of the economic benefits at 7% discount over 20 years is estimated at $126,300.

This gives a benefit cost ratio of 0.52. Based on this ratio for the economic assessment, the technical difficulty of the excavation and the potential environmental impacts, the widening of Frenchs Creek may not be a suitable mitigation option.

12.4.11 Levee to Protect Properties in Winani Close (Option 19)

The results of the hydraulic modelling for the flood study suggested that some properties on Winani Close might be inundated by extreme flood events. The resident of 4 Winani Close commented on the Flood Study Report to the effect that none of the properties have been flooded above floor level in any storm event since 1991, when they took up residence. The discrepancy may be due to the 3m grid size in the hydraulic model.

As a result of the comments from residents, the suggestion of providing a levee to protect these properties has not been developed further.

12.4.12 Retarding Basin Downstream of South Pringle Avenue Culverts (Option 20)

Downstream of the south Pringle Avenue culverts, Corridor Creek flows through the former Belrose - St Ives road corridor before merging with Frenchs Creek. This section of the corridor, between Pringle Avenue and Elm Avenue, is approximately 16,000 m^2.

The possibility of locating an off-line retarding basin in this location was examined, using the flood study model of the catchment. It was determined that in order to reduce the water surface level of flows overtopping Elm Avenue in a 1% AEP event to a depth of less than 0.2 m, a retarding basin located in this section of the corridor would need to have a volume of at least 13,000m^3. Based on an appropriate full basin water depth of 1.0 m, the basin would need to occupy the majority of land available in this section of the corridor. A basin of this size would severely restrict the plot yield in the proposed corridor re-development making it difficult to justify economically. The basin would also have significant environmental impacts. On this basis, the option of constructing a large retarding basin in the former road corridor downstream of the south Pringle Avenue culverts has not been examined further.

12.4.13 Upgrade of Elm Avenue Culvert (Option 21)

At present the 3.5m wide by 1.7m high culvert at Elm Avenue is skewed in alignment to the incident direction of flow down the creek. There is also a Sydney Water sewer manhole just upstream of the culvert which has some effect on the capacity of the culvert and has been anecdotally reported to force water out of the channel with a ramp-like action during high flows in the creek channel. The combination of these two factors results in flow backing up behind the culvert before overtopping the Elm Avenue road surface.

The upgrade of Elm Avenue culvert is restricted by a number of factors:

- 400mm sewer line running adjacent to the creek channel with manhole within the channel just upstream of the culverts;

- 150mm sewer line running along Elm Avenue, above the culvert;
- several electrical cables running underneath the culvert; and
- property boundaries on each side of creek channel.

The flood study model was used to investigate the impact on flood levels of realigning the culverts and increasing their capacity within the site constraints. The proposed upgrade includes the addition of a second 2.6m wide and 1.5m high culvert to the north of the existing one. Changes to the water surface level for the 1% AEP storm event with the revised culverts in place are provided in Table 15. Details of this upgrade and the water surface level for the 1% AEP storm event are provided in Figure 27.

Although the improved capacity in the culvert reduces the flow across the road at Elm Avenue, it does not have a significant effect on the depth of flow across the road. The depth of water over the road reduced by 0.13m from 0.94m to 0.81m. Improvements to the capacity of the Elm Avenue culvert would be maximized if performed in conjunction with the widening of the creek channel upstream of the culverts.

Table 15 Impact of Elm Avenue culvert Upgrade on Water Surface Levels

Location		Ground Level (mAHD)	1% AEP Water Depth and Velocity			Change in depth (m)
			Current Depth (m)	Current Velocity (m/s)	Upgrade of Elm Avenue culvert Depth (m)	
1	Calool Crescent	119.92	1.97	4.20	1.97	0.00
2	Calool Crescent	122.35	0.65	3.11	0.65	0.00
4	Trentbridge Road	125.26	2.08	2.41	2.08	0.00
23	Creek Confluence	129.20	0.74	3.60	0.74	0.00
24	Elm Avenue	124.80	0.94	1.07	0.81	-0.13

The cost of upgrading the culvert at Elm Avenue is estimated at $70,500. This cost includes the addition of a second box culvert to the north of the existing culvert, and all repairs to the road and other related infrastructure. It does not however include the cost of relocating the Sydney Water sewer manhole currently located within the creek channel upstream of the culverts.

The economic benefit of this option is the resulting reduction in flood damages. The Net Present Value of the economic benefits at 7% discount over 20 years is estimated at $29,900.

This gives a benefit cost ratio of 0.42. This ratio of less than one indicates that the upgrade of the culvert at Elm Avenue is not a good mitigation when considering economic criteria alone.

The benefit cost ratio does not consider the risk to life. Of most concern is the risk of someone being swept off their feet and being carried downstream by the floodwaters crossing Elm Avenue. If it is decided that Council should pursue this option, a risk

analysis should be undertaken to determine the risk to life with the current arrangement and the change in risk with the culvert upgrade.

12.4.14 Remove Kerb and Gutter and Re-camber Calool Crescent (Option 22)

At present, flow which overtops the Elm Avenue culvert tends to stay on the road surface, flowing down Calool Crescent before rejoining the creek as it passes through the Calool Crescent culverts. Video footage and photographic evidence for the March 2003 flood shows that there is additional capacity in the creek channel on the downstream side of the Elm Avenue culvert due to the floodwaters staying on the road surface and flowing down Calool Crescent. Floodwaters stay on the road surface because they are constrained by the road grade and the road kerb and guttering on the northern side of the street.

This option involves the removal of the kerb and guttering on the northern side of Calool Crescent, where it is adjacent to the creek. The road would also be re-cambered to direct flows on the road back into the creek channel.

The flood study model was used to investigate this option. The model was adjusted to remove the kerb and guttering from the northern side of Calool Crescent and the camber of the road realigned to allow all water on the road to flow back towards the creek channel. The reduction in water surface level for the 1% AEP storm event is given in Table 16. The results of the modelling indicated that water surface levels were reduced in the upper parts of Calool Crescent, however, flows were still affected by the capacity of the Calool Crescent culverts, which caused flows to back up and eventually overtop the road surface. If this option is pursued, consideration should be given to implementing it in conjunction with the upgrade of the Calool Crescent culverts, discussed in Section 12.4.15.

Table 16 Impact of regrade of Calool Crescent on Water Surface Levels

Location		Ground Level (mAHD)	1% AEP Water Surface Level mAHD		Difference (m)
			Current	Calool Crescent Regrade	
1	Calool Crescent	119.92	121.89	121.89	0.00
2	Calool Crescent	122.35	123.00	122.88	-0.12

The cost of removing the kerb and guttering along Calool Crescent and re-cambering the road surface is estimated at $46,200.

The economic benefit of this option is the resulting reduction in flood damages. The Net Present Value of the economic benefits at 7% discount over 20 years is estimated at $30,400.

This gives a benefit cost ratio of 0.66. With a benefit cost ratio less than one, the removal of the kerb and gutter and re-cambering of Calool Crescent is not a good mitigation option based on economic criteria alone.

12.4.15 Upgrade of Calool Crescent Culverts (Option 23)

Frenchs Creek currently passes under Calool Crescent via three box culverts: two 2.15m wide by 1.83m high and one 3.95m by 1.35m. It is proposed to replace these three culverts with a bridge, improving the flow capacity and reducing the likelihood of blockages by removing the culverts and increasing the flow space underneath the bridge. The flood study model was used to investigate the impact this option. The location of this culvert upgrade is provided in Figure 28.

The upgrade of the Calool Crescent culverts resulted in a reduction in flow volume and depth across the road at Calool Crescent. The reduction in water surface level for the 1% AEP storm event is given in Table 17 below. Location B is in Frenchs Creek channel at a point approximately 3m upstream of the Calool Crescent culverts. Figure 28 gives details of the new bridge along with new water surface levels for the 1% AEP storm event. Although the improved capacity in the bridge reduces the flow across the road at Calool Crescent, it does not have a significant effect on the depth of flow across the road.

Table 17 Impact of Calool Crescent culvert upgrade on Water Surface Levels

Location		Ground Level (mAHD)	1% AEP Water Surface Level mAHD		
			Current	Calool Crescent Culvert Upgrade	Difference
1	Calool Crescent	119.92	121.89	121.89	0.00
2	Calool Crescent	122.35	123.00	123.00	0.00
B	Calool Crescent	120.83	122.67	122.58	-0.09

The removal of the existing culverts and construction of a bridge at Calool Crescent has been estimated to cost $153,300.

The economic benefit of this option is the resulting reduction in flood damages. The Net Present Value of the economic benefits at 7% discount over 20 years is estimated at $38,900.

This gives a benefit cost ratio of 0.25. With a benefit cost ratio much lower than one, the upgrade of the Calool Crescent culverts is not a good mitigation option based on economic criteria alone.

12.4.16 Retarding Basin in Lionel Watts Park (Option 24)

Lionel Watts Park covers an area of approximately 52,500m^2 and incorporates two playing fields along with netball and basketball courts and cricket nets. There is an area approximately 6,300m^2 to the north-west of the park which has been identified as a potential location for a retarding basin. Based on a full basin depth of 1m, this would provide approximately 6,300m^3 available storage volume.

This option was tested in the Flood Study model. The model was augmented to provide a low levee along the northern length of the park, as well as the adjacent Frenchs Forest Showground. A dish drain was then placed alongside this levee, to allow runoff from both the park and showground to flow west, along the boundary with Glen Street, thereby diverting all runoff from the park and showground to the basin. It is proposed

that such a basin would then drain to the stormwater network in Glen Street once sufficient capacity was available.

The results of the modelling indicate that the retarding basin fills completely before the peak runoff from the park and showground occurs. There is therefore minimal impact on peak water levels downstream of the basin, and so the option of placing a retarding basin in Lionel Watts Park has not been examined further.

12.4.17 Diversion and Upgrade of Drainage Easement East of Glenrose Shopping Centre (Option 25)

The drainage easement to the east of Glenrose Shopping Centre was discussed during the community consultation process. This easement currently carries a 1.2m diameter pipe from Glen Street to the rear of the shopping centre. Meanwhile, runoff from the Frenchs Forest Showground flows into and across Glen Street. The direction of flow is perpendicular to the kerb and guttering in Glen Street, and during significant rainfall events the volume and momentum of flow causes the runoff to overtop the kerb and guttering, and follow the natural flow path through properties in Glen Street to Lowanna Street and Coora Avenue before joining the overland flows through the reserve to Haigh Avenue.

The flood study model was used to evaluate the option of improving the drainage down Glen Street to divert the overland flow into the stormwater pipe system to the drainage easement. It was found that improving the inlet and pipe capacities down Glen Street had little impact on water levels downstream because it did not solve the problem causing the flow to take that path in the first place - namely the direction and volume of runoff from the showground. For this reason this option has not been examined further.

12.4.18 Scheduled Inspection and Maintenance of Catchment Stormwater Infrastructure (Option 26)

It is important that Council continues to maintain the catchment stormwater infrastructure to ensure it performs as designed during storm events. Regular scheduled inspections of the catchment alert Council to potential problems before they occur. Council's presence in the catchment on a regular basis also helps to assure residents that drainage in the catchment is something Council takes seriously.

Regular scheduled inspections of the catchment infrastructure currently cost Council approximately $2400 per year. It is difficult to quantify the cost of maintenance as it is performed on an as-required basis, but maintenance is already being performed and so is not considered to be an additional cost. It is worth noting that regular inspection may catch minor problems before they become major ones requiring significant and expensive repair.

The Frenchs Creek catchment is characterised by leafy tree-lined streets. Many of these trees are deciduous and shed all their leaves during the autumn months. The accumulation of leaves in the kerb and guttering can cause blockages to kerb inlets and exacerbate overland flooding. Blocked stormwater pits were observed during field inspections and commented on by residents during the community consultation process. Regular street-sweeping to remove leaves from the kerb and guttering, particularly during the autumn months, would help prevent inlet blockages and ensure that inlet capacity is not compromised.

Council currently performs street sweeping of the Frenchs Creek catchment approximately 3 to 4 times per year. The current cost of these works is approximately $2500 per year. Residents should also be encouraged to take ownership of their environment and ensure that the inlets near their properties remain leaf-free.

A longer-term alternative to regular street sweeping is the gradual replacement of the exotic deciduous trees that currently line the streets of the catchment with evergreen species that are native to this location. The cost of tree replacement is estimated at approximately $1200 per tree.

12.4.19 Vegetation Control Within the Creek Channels (Option 27)

Excessive vegetation can reduce the hydraulic capacity of creek channels and affect flood levels. On the other hand vegetation enhances the environmental and aesthetic qualities of the channel and is important for bank stability. It is important to achieve a balance between the environmental, aesthetic and hydraulic objectives.

At the time of the flood study the vegetation along the creek channel was reasonably clear, and so this is reflected in the calibrated model used to assess the hydraulic performance of the system. To simulate a heavily vegetated channel the model was run with creek bed roughness increased by 50%. Conversely a vegetation free channel was simulated by reducing the creek bed roughness by 50%. The impact of allowing vegetation to build up within the channel and then clearing this away is shown in the changes to water levels, as presented in Table 18 below.

Table 18 Effect of Vegetation Control within the Creek Channels on Water Surface Levels

Location		1% AEP Water Surface Level mAHD				
		Current (Roughness = R)	Vegetated (R + 50%)		Cleaned (R - 50%)	
		Level (mAHD)	Level (mAHD)	diff (m)	Level (mAHD)	diff (m)
1	Calool Crescent	121.89	121.99	0.10	121.86	-0.03
2	Calool Crescent	123	123.11	0.11	122.91	-0.09
3	Winani Close	128.64	128.64	0.00	128.62	-0.02
4	Trentbridge Road	127.34	127.45	0.11	127.26	-0.08
5	Pringle Avenue	133.73	133.84	0.11	133.72	-0.01
12	Haigh Avenue	129.09	129.09	0.00	129.09	0.00
15	Pringle Avenue	133.41	133.45	0.04	133.26	-0.15
23	Creek Confluence	129.94	129.98	0.04	129.86	-0.08
24	Elm Avenue	125.74	125.76	0.02	125.73	-0.01

Results suggest that the channel is not particularly sensitive to changes in roughness associated with creek vegetation. Another benefit of controlling the build up of vegetation in the creek channel is the reduced likelihood of blockages, particularly of the Elm Avenue culvert. The impact of pit and culvert blockage was discussed as part

of the sensitivity analysis performed during the Frenchs Creek Flood Study. Results for the 1% AEP storm event indicated that a total blockage of Elm Avenue culvert could result in a 0.65m increase in water levels at that location, while a partial blockage could see water levels rise by 0.25m.

It is recommended that Council assesses the vegetation within the creeks as part of the regular scheduled inspection of the catchment drainage infrastructure, as discussed above. The community should also be encouraged to monitor the creek and report on any vegetation problems. This provides additional eyes and encourages the community to take ownership of the creek.

The cost of vegetation control along the Frenchs and Corridor Creek channels is estimated at $6100 per year.

There are additional environmental benefits to appropriate vegetation control, particularly if it involves the removal of exotic species and allows the controlled re-establishment of native vegetation.

12.4.20 On-Site Detention and Rainwater Tanks (Option 28)

The issue of rainwater tanks and individual on-site detention was raised by residents during the community consultation process.

On-site detention (OSD) involves holding stormwater runoff in a custom built tank and allowing a continuous controlled discharge of water to the existing infrastructure. It is not designed to hold stormwater indefinitely for later re-use.

Rainwater tanks are designed to collect and store runoff for later re-use in non-potable applications, such as garden irrigation, clothes washing or toilet flushing. While they provide valuable sources of water which can be used in place of potable sources, their value in reducing stormwater runoff is linked to the rate at which the water is used i.e. if the tank is full of water before a storm event, there is no storage capacity. In keeping with Council Policy, to achieve a full credit against the OSD volume, the rainwater re-use must, at least, be used for toilet flushing to ensure continual draw down of the rainwater and maximise the available storage volume.

Systems designed to work as both rainwater tanks and on-site detention tanks are available, with rainwater re-use at the bottom and OSD at the top. An orifice plate is located between the two sections, to allow a controlled discharge from the OSD section of the tank to the stormwater system. Once the tank has emptied to the level of the orifice plate, the remaining volume is available for re-use.

The On-Site Stormwater Detention Handbook (reference /18/) contains a study by the Upper Parramatta River Catchment Trust into the appropriate volumes of on-site detention. It was determined that the volume of storage required to reduce the runoff from a developed site to the pre-development runoff level for the 1% AEP storm event was 455m^3/ha. The average lot size in the Frenchs Creek Catchment is approximately 725m^2. This gives the approximate volume of on-site detention that would be required for each property in the Frenchs Creek catchment as 33m^3.

Council currently has a policy regarding on-site stormwater detention and rainwater re-use for single residential dwellings within the catchment. As part of the SEPP Building and Sustainability Index (BASIX), on-site detention (OSD) is required for all new single dwelling developments where the total impervious area exceeds a designated percentage. BASIX ensures each new single dwelling, or alteration/addition to a single dwelling, reduces water consumption by 40% compared with an average home, and allows the volume of rainwater re-use to be credited against the calculated OSD storage volume.

12.5 Summary of Economic Analysis of Various Options

In order to assess the economic feasibility of the options, a benefit cost analysis approach has been used. In general, an option will not be carried out if the benefits do not outweigh the costs, i.e. the benefit cost ratio is less than 1. It is often the case however that due to the intangible benefits to the community, which are difficult to quantify, an option which "fails" the benefit cost analysis might still be worthwhile based on social grounds. It is also the case that some options are not wholly appropriate for this type of evaluation.

A summary of the results of the economic analysis are presented in Table 19.

Table 19 Economic Analysis of Floodplain Risk Management Options for Frenchs Creek

Option		Benefit $x1000	Cost $x1000	B/C Ratio	Comments
1	Planning and development controls	Not applicable	Council Costs	N/A	Essential part of Floodplain Risk Management Plan and will reduce damages over time.
2	Voluntary purchase of flood-prone properties	2,485.7	20,400.0	0.12	Voluntary purchase of 25 properties in high hazard zone which also experience over-floor flooding during 20% AEP event. Based on 2005 average house price in Belrose of $772,000.
3	Voluntary house-raising of flood-prone properties	Not assessed	At home-owners cost	-	Properties primarily brick on slab, not suitable for house-raising measures.
4	Flood-proofing of flood-prone properties	360.0	219.0	1.64	Flood-proofing of 25 properties in high hazard zone which also experience over-floor flooding during 20% AEP event. Based on flood-proofing estimate of $7,200 per house.
5	Flood forecasting, warning and evacuation planning	0	Not assessed	0	Insufficient warning time to implement effective forecasting, warning and evacuation plan.
6	Public awareness / education programme	Intangible (0)	12.2	0	Relatively inexpensive way to improve flood awareness in the catchment. Should result in reduced damages over time.
7	Flood depth indicators at culverts	Intangible (0)	2.4	0	Relatively inexpensive way to improve flood awareness in the catchment. Should result in reduced damages

Option		Benefit $x1000	Cost $x1000	B/C Ratio	Comments
					over time.
8	Obtain further flood information, immediately after next event	Intangible (0)	Council Costs	0	Relatively inexpensive way to improve flood awareness in the catchment. Should result in reduced damages over time.
9	Upgrade of pipes from Curragundi Ave to Pringle Ave	2,215.1	3,725.6	0.59	Cost based on construction costs plus estimates relating to acquisition of easements, etc.
Option		**Benefit $x1000**	**Cost $x1000**	**B/C Ratio**	**Comments**
10	Redirect drainage Forest Way towards Oxford Falls	Not assessed	Not assessed	-	Runoff from Forest Way represents minimal contribution to flows from the north of the catchment. Diverting runoff toward Oxford Falls resulted in negligible reduction in water levels downstream.
11	Retarding basin at Belrose Primary School	Not assessed	Not assessed	-	Retarding basin in Belrose Primary School not costed due to location of flow path and difference in elevation and hazard to primary school children. Likely to be expensive.
12	Retarding basin in Munnumba Reserve	Not assessed	Not assessed	-	Retarding basin in Munnumba Reserve not costed due to location of flow path and difference in elevation.
13	Retarding basin in Hews Reserve	Not assessed	Not assessed	-	Retarding basin in Hews Reserve not costed due to location of flow path and difference in elevation.
14	Widening of Corridor Creek upstream of South Pringle Avenue culverts	1,240.0	147.0 (+45.6)	7.16 (5.67)	B/C analysis carried out without (and with) upgrade to south Pringle Avenue culverts.
15	Levee along Corridor Creek at rear of properties in Kapunda Place	1,201.0	147.0 (+45.6)	8.17 (6.23)	B/C analysis carried out without (and with) upgrade to south Pringle Avenue culverts.
16	Upgrade of stormwater pipes from Kapunda Place to Pringle Ave	52.6	279.2	0.19	Kapunda Pl pipe upgrade only considered along with upgrade to Corridor Ck, however this is not included in B/C Analysis. Cost based on construction costs plus estimates relating to acquisition of easement.
17	Upgrade of south Pringle Ave culverts	0	45.6	0	Reduces inundation of Pringle Avenue however no discernable reduction in property flooding or flood damages.
18	Widening of Frenchs Creek between Pringle Ave and Elm Ave culverts	126.3	243.1	0.52	Significant environmental concerns, currently natural channel, unlikely DECCW would allow channel works.
19	Levee to protect properties in Winani	0	Not assessed	0	Not required due to brick wall around No 4 Winani Close.

Option		Benefit $x1000	Cost $x1000	B/C Ratio	Comments
	Close				
20	Retarding basin d/s of south Pringle Ave culverts	Not assessed	Not assessed	N/A	Size of basin exceeds available land in the former road corridor.
21	Upgrade of Elm Avenue culvert	29.9	70.5	0.42	Increased capacity through culvert did not markedly reduce water levels across road surface. Cost does not include relocation of stormwater sewer manhole or other services, which are likely to increase costs considerably.
22	Remove kerb and gutter and re-camber Calool Cr	30.4	46.2	0.66	Reduced water levels in road reserve, but limited reduction in flood damages.
23	Upgrade of Calool Cr culverts	38.9	153.3	0.25	Increased capacity through culvert did not markedly reduce water levels across road surface.
24	Retarding basin in Lionel Watts Park	Not assessed	Not assessed	-	Retarding basin in Hews Reserve not assessed due to volume of storage required to be effective.
25	Divert flow from Glen St to the drainage easement east of Glenrose Shopping Centre	Not assessed	Not assessed	-	Not costed due to direction and volume of flow, diversion not successful in reducing water levels downstream.
26	Regular scheduled inspection and maintenance of catchment infrastructure	Unable to estimate	4.9 per year	-	Will ensure infrastructure is operating as required, should result in reduced need for major maintenance and reduced damages over time.
27	Vegetation control within creek channels	Unable to estimate	6.1 per year	-	Recommended to ensure channel capacity maintained and to prevent blockages of culverts. Environmental benefit in removing exotic species.
28	On-site detention and rainwater tanks	Unable to estimate	Not assessed, uptake dependent on home-owner agreement	-	Currently only required for new developments and renovations to prevent increase in runoff volumes to existing constructed and natural drainage systems and/or when the additional impervious area is more than 35% of the total site area or more than 50m^2. Likely to be very expensive to retrofit to existing properties due to size of storage required. Large amount of disruption to existing homeowners.

13 COMPARISON OF OPTIONS

The final outcome of the Floodplain Risk Management process, as detailed in the Foreword to this report, is a balanced and sustainable plan to manage flood risk in the Frenchs Creek catchment into the future. The NSW Floodplain Development Manual requires that the plan balances the merits of social, economic, cultural and environmental considerations which are relevant and supported by the community.

Option assessment needs to take into account a broad range of issues which will then guide the selection and prioritisation of management options. The assessment categories should be inclusive of the issues relevant to Council and the community. Each option and the finally adopted management plan will inevitably involve a level of compromise which involves balancing often conflicting objectives.

The NSW Floodplain Development Manual recommends a subjective matrix based approach to ranking various options. The chief advantage of this approach is that it allows each ranking category to be considered from a common basis. While this approach is unlikely to provide a clear indication of what should be included and what should be left out of a Management Plan, it will provide a basis for discussion that will guide Council's decision making process.

13.1 Description of Ranking Categories

The development of the ranking categories was discussed with the Working Group and Council, based on the requirements of the NSW Floodplain Development Manual. There are five broad areas into which the ranking categories fall, as outlined below.

- Flood mitigation impact: includes impact on flood levels and engineering feasibility
- Environmental impact
- Social impact: includes community impact and acceptance
- Economic; includes economic impact and feasibility
- Planning: includes compliance with Council Policies and Plans

Using the preferences outlined in the discussions with the Working Group and Council, a number of ranking categories were selected that reflected the issues and impacts in the Frenchs Creek catchment. Each mitigation option was assessed against the ranking criteria, which are described in more detail in Sections 13.1.1 to 13.1.5 below. Section 13.2 describes the scoring system applied to each of the ranking categories.

13.1.1 Flood Mitigation Impacts

Flood Levels

The hydraulic impact of a particular mitigation option on the flood behaviour in the catchment is considered in this category in terms of changes in flood level. Flood behaviour includes both the positive and negative impacts of a particular option and they are considered together to determine the overall impact. A positive impact will

reduce the flood levels at some location in the catchment, whilst a negative impact will increase flood levels. Any particular mitigation option may have both negative and positive impacts and so a cumulative score will be applied to each option.

This is a qualitative assessment, based on the results of the hydraulic modelling. As noted in Section 12, some options were not modelled and in these cases an engineering judgement as to their likely hydraulic impact will be made.

Engineering Feasibility

This category describes the technical feasibility of implementing the mitigation option. For example, in some options this may mean the availability of space for construction, in other cases it may mean a technically difficult option. This category does not take into account the cost of implementation or the social and environmental impacts, which are assessed elsewhere in other categories. This is a qualitative assessment of the constructability of an option and is based on engineering judgement.

13.1.2 Environmental Impact

The environmental impacts consider the potential to enhance the environment through implementation of the mitigation option. The assessment includes consideration of the impact on the environment of any construction, clearance or maintenance activities. The requirements of Warringah Council Creek Management Study (reference /15/) have been taken into consideration in this assessment.

This is a qualitative assessment because separate detailed environmental studies have not been undertaken for the catchment. In the absence of knowledge about the flora and fauna in specific locations, the actual impact of construction works cannot be accurately assessed.

13.1.3 Social and Community Impacts

Social Impacts

Social impacts include a variety of qualitative measures, such as: disruption due to flooding of residential property; loss of property; inability to access services such as electricity, gas, telephone, etc.; disruption of road access; post-flooding trauma, etc. This assessment is subjective, partly because it depends on individual responses to the impacts and partly because many of the impacts are intangible.

Safety

The change in the risk to people's safety due to the implementation of a mitigation option is a subjective assessment. An individual's behaviour in a stressful situation, such as a flood event, is not always logical and greater risks than normal are sometimes taken, for example by passing through floodwaters to gain access to property. In assessing this parameter, it has been assumed that an individual's judgement is not impaired by the mitigation measures, for example, in the provision of flood depth markers at culvert locations, people are not tempted to drive or walk through the floodwaters where there may be hazards such as hidden debris, missing manhole covers or high velocities. For some options, good safety in design will be essential to further reduce the level of risk to personal safety.

Community Criteria and Working Group Comments

Input from the community has been welcomed at all stages of this study. Members of the community and the Working Group have been encouraged to take part in the flood

study and the flood risk management study by completing questionnaires, taking part in resident surveys and responding to requests for feedback on the mitigation options. This process includes the public response to the two previous Public Exhibitions of the Flood Study and the Public Exhibition of the Floodplain Risk Management Report, which will be undertaken in August 2010. The community ranking in the final version of this report will include the response from the Working Group and the wider community to the mitigation options. The final analysis and method of scoring of the community criteria will be dependent on the response from the community to the Public Exhibition of this report and will be decided when the community responses have been received.

The floodplain risk management options described in Section 12 were presented to the Working Group for consideration and the flood risk management options were discussed in detail at a Working Group Meeting held on 18 November 2009. The Working Group declined to compare the options at that stage of the study, but a summary of the comments from the meeting is presented in Table 20.

Table 20 Working Group comments on the Flood Risk management Options

Option		Working Group Comments and Recommendations
9	Upgrade of pipes from Curragundi Ave to Pringle Ave	The rectification work should go ahead, but this upgrade could be broken up into sections so that the work can be carried out over a number of years and be costed accordingly.
10	Redirect drainage Forest Way towards Oxford Falls	The drainage should be redirected back towards Oxford Falls, because 6% is a very significant flow. Undertaking this option in conjunction with upgrading the stormwater pipes from Curragundi Avenue to Pringle Avenue (Option 9) should be considered.
11	Retarding basin at Belrose Primary School	This option should be undertaken subject to the School's approval. Some design should be undertaken to check the feasibility of the option. The following comment was sent to Council after the meeting by a member of the Working Group: The school oval below mid screen is potentially ideally located to be a large flood detention device in major events. This option was dismissed on the basis of risk/danger to the primary school aged children, but is worth more thought. Considering the number of school hours in a year (1920 school hours out of 8760 in a year), there is a 20% chance that a 1% AEP flood event will occur during school hours. So, the risk that the large event occur at all and then at school hours in minimal. Should it occur during school hours then teachers would be able to ensure that no one is in that area of the school grounds. The basin could be designed so restricted size piping could handle the 'low flow' so that only major flood events that need to be detained to relieve the downstream system are stored on the school grounds. Water depth could be managed to a maximum of say 1m. Bunding would double as spectator viewing mounds.
12	Retarding basin in Munnumba Reserve	This option is impractical.
13	Retarding basin in Hews Reserve	This option is impractical.
14	Widening of Corridor Creek upstream of South Pringle Avenue culverts	The Working Group agreed with the FRMS Report's recommendation. This option was considered to be better than a levee. The Working Group commented that the option of locating two more retarding basins within the road corridor should be investigated. One basin should be placed just upstream of Pringle Avenue and the other south of Hews Reserve to catch water from Willow Tree Crescent.
15	Levee along Corridor Creek at rear of properties in Kapunda Place	Recommended and agreed with the FRMS's recommendation.
16	Upgrade of stormwater pipes from Kapunda Place to Pringle Ave	The Working Group commented that it would be interesting to know how much water the levee took away.
17	Upgrade of south Pringle Ave culverts	Road overflows cause significant danger to traffic and this situation is far more serious than speculated. It is imperative that the work be done. Agreed with recommendation from the FRMS that the work be carried out in conjunction with improvements to the capacity of Corridor Creek.

Option		Working Group Comments and Recommendations
18	Widening of Frenchs Creek between Pringle Ave and Elm Ave culverts	The option of a Corridor Creek diversion to bypass the confluence with Frenchs Creek was seen as the best option, with a retarding basin in the road corridor downstream of Pringle Ave and to the south of 4 Winani Close. The creek bank at the rear of the properties in Trentbridge Road in the vicinity of the confluence should be increased in height.
19	Levee to protect properties in Winani Close	This was not considered a good solution. To the knowledge of one Winani Close resident, the properties have not flooded in the almost 20 years that he has lived there.
20	Retarding basin downstream of south Pringle Ave culverts	This basin should be sited in the location as described in the Working Group's Option 18 recommendation.
21	Upgrade of Elm Avenue culvert	Safety of traffic and pedestrians is a big problem at this location and the culvert needs to be fixed.
22	Remove kerb and gutter and re-camber Calool Cr	The Working Group disagreed with the recommendation in the FRMS Report and said that this option should be undertaken, but in combination with upgrading the Calool Crescent culverts (Option 23).
23	Upgrade of Calool Cr culverts	The culverts should be upgraded in conjunction with the removal of kerbs and gutters and re-cambering of Calool Crescent (Option 22).
24	Retarding basin in Lionel Watts Park	No comment.
25	Divert flow from Glen St to the drainage easement east of Glenrose Shopping Centre	The Working Group had no knowledge of complaints about flooding in this area and thought flooding was not as big an issue here as in other areas.
26	Regular scheduled inspection and maintenance of catchment infrastructure	The Working Group agreed that maintenance was very important. They recommended that the Council budget for inspection and maintenance should be doubled.
27	Vegetation control within creek channels	There is a need to address branches overhanging Frenchs Creek because when they fall into the creek they can block the culverts.
28	On-site detention and rainwater tanks	No comment.

13.1.4 Economic Impacts

Economic Cost of Implementation

This should be a quantitative assessment based on the cost of implementation of the mitigation option, but where they were not taken forward for full investigation, the mitigation options were not costed. As a result, broad bands have been applied so that where the option has not been assessed on economic grounds a judgement of the likely costs can be made to provide a score in the ranking matrix. For those items that have been assessed in the report, costs are available in Section 12.

Reduction in Potential Property Damage

This is a qualitative judgement based on the estimated change in average annual cost of damage to properties with each mitigation option. Not all options were assessed

economically, as noted in Section 12 subsections, so in these cases a judgement has been made.

13.1.5 Planning

Compatibility with Current Council Policies and Plans

The criterion has been assessed considering the compliance with current Council Policies and Plans, as described in Sections 10, 11 and 12.2.1 of this report.

13.2 Ranking of Options

13.2.1 Scoring System

In the ranking of the mitigation options, each option is given a rating according to how well it meets the considerations within the category. The rating is scored on a points basis within the category, where:

+2	option has a significant positive impact
+1	option is positive
0	neutral rating
-1	option has a negative impact
-2	option has a significant negative impact

Not all of the mitigation options were quantitatively assessed in all the ranking categories. As a result, the rankings have to be qualitative rather quantitative to ensure that all the options can be included in the ranking matrix. Where this occurs, the method for assessment is described in the relevant sub-section in Section 13.1.

The scoring currently used in for the Community Criteria has been taken from the original community consultation questionnaire undertaken as part of the Flood Study. Out of a total of 186 returned community questionnaires, not all respondents indicated their level of support for the floodplain management measures listed. A summary of the mitigation options and the number of responses and average scores is provided in Table 21 below. At the early stage of the flood study not all mitigation options had been identified. Where there was no option for the community to score, a value of zero has currently been entered in the assessment matrix (Table 23) so that all options are fully scored. These values will be subject to change when the public response to the Floodplain Risk Management Study has been received after the Public Exhibition in 2010. More details of the results of the Community Questionnaire may be found in Appendix A of the Frenchs Creek Flood Study Report.

Table 22 presents a summary of the scoring system applied to each of the ranking categories in this study. As mentioned previously, these ranking categories were chosen because they were of importance in the catchment and to both the community and Council.

Table 23 presents an assessment matrix for the mitigation options described in Section 12. This assessment may be used by Council as the basis for prioritising options for the Floodplain Risk Management Plan. Section 13.2.2 presents a more detailed discussion of the scores in the assessment matrix.

Table 21 A summary of the level of support from the community to the floodplain management measures.

Floodplain Management Measure		Average Score *	Community Ranking	Number of Responses	FRMS Score
Measures that modify the way a flood behaves					
a	Constructing detention basins	3.6	14	149	1
b	Constructing bypass channels	3.8	12	146	1
c	Enlarging bridges and culverts	3.9	9	147	1
d	Creek widening and/dredging	3.8	12	158	1
e	Cleaning creeks of debris	4.7	1	167	2
f	Removing creek and floodplain obstructions	4.4	2	152	1
g	Construction of permanent levees	3.3	15	143	0
h	Filling low-lying land	2.7	18	141	0
Measures that modify property					
i	Voluntary purchase	3.2	16	132	0
J	Voluntary house-raising	3.1	17	131	0
k	'Flood-proofing' measures in a property	3.9	9	141	1
l	Controls on new development (e.g. floor levels, extent of filling, site detention, impervious areas)	4.4	2	151	1
Measures that modify people's response to flooding					
m	Improving flood warning systems	4.2	4	151	1
n	Improving formal evacuation procedures	4.0	7	139	1
o	Promoting community flood awareness	4.2	4	135	1
	- Installing flood markers (e.g. on telegraph poles)	3.9	9	135	1
	- Providing a flood notification certificate to owners	4.0	7	136	1
p	Promoting community flood readiness	4.1	6	140	1

Note: *An average score of 5 was 'Strongly Support' and 1 was 'Strongly Against'

Table 22 Summary of Scoring System Applied to the Ranking of the Floodplain Risk Management Options

Ranking Category	**Score**				
	-2	**-1**	**0**	**1**	**2**
Overall Hydraulic Impact	Significant increase in flood levels	Slight increase in flood levels	No change in flood level	Slight reduction in flood levels	Significant reduction in flood levels
Engineering Feasibility	Very difficult to implement	Some difficulties in implementation	Feasible, engineering input required	Feasible, limited engineering input required	Very easy to implement, minimal engineering input
Environmental impacts	Permanent or significant damage to the environment	Short term damage or some permanent damage to the environment	No impact	Some improvement to the environment	Significant improvement to the environment
Social Impacts	Great negative impact on residents/community	Some negative impact on residents/community	No impact	Some benefit to residents/community	Great benefit to residents/community
Safety Impacts	High increase in risk to safety	Slight increase in risk to safety	No change in risk to safety	Slight reduction in risk to safety	High reduction in risk to safety
Economic Cost	Very High	High	Medium	Low	Very Low
Reduction in potential property damage	Large increase in AAD	Slight increase in AAD	No change in potential damage	Slight reduction in AAD (≤ $100,000)	Large reduction in AAD (> $100,000)
Community Criteria	Strongly against	Against	Neutral response	Support	Strongly support
Compatibility with Council Plans and Policies	Incompatible with planning requirements	Potentially incompatible with planning requirements	N/A	Partially compliant with planning requirements	Highly compliant with planning requirements

Note: AAD is the average annual damage. See Section 9.2.2 for further information.

Table 23 Assessment Table and Ranking of the Floodplain Risk Management Options

Option	FRMS	Description	Benefit Cost Ratio	Overall Hydraulic Impact	Engineering Feasibility	Environmental Impact	Social Impact	Safety Impact	Economic Cost	Reduction in Potential Property Damage	Community Criteria	Compatible with policies and plans	Total Score	Ranking based on total score
27	12.4.19	Vegetation control within creek channels		1	2	1	1	1	2	1	2	2	13	**1**
26	12.4.18	Regular inspection, maintentance of infrastructure		1	2	0	1	1	2	1	2§	2	11	**2**
6	12.3.2	Public awareness / education campaign	6	0	2	0	1	1	2	0	1	2	9	**3**
7	12.3.3	Flood depth indicators	0	0	2	0	1	1	2	0	1	1	8	**4**
1	12.2.1	Planning & development controls		0	2	-1	1	0	2	0	1	2	7	**5**
4	12.2.4	Flood-proofing of flood-prone properties	1.64	0	2	0	1	0	1	1	1	1	7	**5**
8	12.3.4	Obtain further info immediately after flood events	0	0	2	0	0	0	2	0	0§	2	6	**7**
15	12.4.7	Levee behind Kapunda	8.17	2	0	-1	2	1	1	2	0	-1	6	**7**
22	12.4.14	Remove kerb and gutter and re-camber Calool Crescent	0.66	1	0	0	1	1	1	1	1§	0	6	**7**
5	12.3.1	Flood forecasting, warning and evacuation planning	0	0	2	0	0	0	0	0	1	2	5	**10**
14	12.4.6	Widen Corridor Ck u/s of south Pringle culverts	7.16	2	0	-2	2	1	1	1	1	-1	5	**10**
17	12.4.9	Upgrade south Pringle culverts	0	1	0	0	1	1	0	0	1	0	4	**12**
28	12.4.20	OSD & rainwater tanks		0	1	0	0	0	1	0	0§	2	4	**12**
2	12.2.2	Voluntary purchase of flood-prone properties	0.12	0	2	1	-1	1	-2	2	0	0	3	**13**
21	12.4.13	Upgrade Elm Ave culvert	0.42	1	-1	0	0	1	0	1	1	0	3	**13**
23	12.4.15	Upgrade Calool Crescent culverts	0.25	1	-1	0	0	0	-1	1	1	0	1	**16**
3	12.2.3	Voluntary house-raising of flood-prone properties		0	-2	0	1	1	-1	2	0	0	1	**16**
9	12.4.1	Upgrade pipes from Curragundi Avenue to Pringle Avenue culverts	0.59	2	-2	-1	-1	1	-2	2	1	1	1	**16**
25	12.4.17	Divert flow from Glen St to easement east of Glenrose Shopping Centre		0	0	0	0	0	0	0	0§	0	0	**19**
29		Divert Corridor Creek flow past confluence to Elm Avenue		1	-1	-1	1	1	-1	1	1§	-2	0	**19**
30		Retarding basin in road corridor, upstream of Pringle Avenue		1	0	-1	1	0	-1	1	1§	-2	0	**19**
16	12.4.8	Upgrade stormwater pipes from Kapunda Place to Pringle Avenue	0.19	-1	0	-1	-1	0	0	1	1	0	-1	**22**
24	12.4.16	Retarding basin in Lionel Watts Park		0	0	0	0	0	-2	0	1	0	-1	**22**
20	12.4.12	Retarding basin downstream of south Pringle Ave culverts		1	0	-2	0	1	-2	1	1	-2	-2	**24**
11	12.4.3	Retarding basin at Belrose Primary School		2	-1	-1	-1	-2	-2	1	1	0	-3	**25**
12	12.4.4	Retarding basin at Munnumba Reserve		1	-2	-2	0	-1	-1	1	1	0	-3	**25**
13	12.4.5	Retarding basin in Hews Reserve		1	-2	-1	0	-1	-2	1	1	0	-3	**25**
10	12.4.2	Redirect drainage from Forest Way towards Oxford Falls		0	-1	-1	0	0	-2	0	1§	0	-3	**25**
19	12.4.11	Levee to protect properties in Winani Close	0	0	-1	-2	0	0	-1	0	0	-2	-6	**29**
18	12.4.10	Widen Frenchs Creek & Corridor Creek between Pringle Avenue and Elm Avenue culvert	0.52	-1	-2	-2	-1	0	-1	1	1	-2	-7	**30**

Note: § The Community have not ranked this option at the stage prior to the Public Exhibition of the FRMS report. Guidance on the scoring has been provided by comments from the Working Group.

13.2.2 Discussion of Scores

It should be noted that an equal weighting has been applied to each of the ranking categories in the assessment matrix. The scoring in Table 23 represents this equal weighting, but the application of weighting could be applied to the scores in the development of the Floodplain Risk Management Plan. For example, a greater weighting factor might be applied to the hydraulic impacts and potential property damage, which are key areas of importance in the Frenchs Creek catchment. Likewise, it may be considered that safety risk requires a higher weighting due to the short time to peak flood levels in the catchment.

The discussion of the scores from the ranking table will focus on the top ten ranked mitigation options, plus those with lower rankings that had a score of 2 (significant impact), but ranked lower down the table.

It is interesting to make several comments on the ranking of options before discussing options in more detail. First, out of the top ten rankings, of which there are eleven options due to there being two options with the same score at the tenth rank, only two have a significant impact on flood levels, three have a slight impact and the remaining six have no impact. In these eleven options, engineering feasibility, economic cost and compatibility with current Council policies and plans all score highly.

Secondly, the construction of retarding basins in the catchment ranked in the lower third of the options. The key factors that influenced this were the engineering feasibility of their implementation, the cost and environmental impact of their construction and the impact on the environment in removing native flora and fauna. Construction of a retarding basin also increases safety risks by having large bodies of water in publicly accessible areas that remain for some time after the main flood has passed.

Thirdly, with the exceptions of voluntary purchase and voluntary house raising of flood-prone properties (ranked 13 and 16 respectively), all the property modification and response modification options were ranked in the top ten despite none of them having a significant impact on flood levels in the catchment. All these mitigation options scored highly in engineering feasibility, mainly because they generally required little engineering in their implementation; had a positive social impact; were cheap to implement; and were compatible with Council policies and plans. It should be noted that, with the exception of vegetation control within the creek channels, voluntary purchase of flood-prone properties and planning and development controls, none of the property and response modification options had an environmental impact. This is mainly because they involve little or no construction activity.

Fourthly, most of the options that reduce flood levels involve some form of construction, which is often costly and is likely to have a negative impact on the environment. This has resulted in many of the flood modification options being scored lower than those that did not involve construction works.

Option 27 Vegetation control within creek channels

Although this option only slightly reduces flood levels in the catchment due to the clearing of fallen branches and leaf debris, it has ranked top in the matrix because it has a positive impact in all of the ranking categories. Vegetation control is easy to implement; has a positive environmental impact in controlling weed growth, especially of invasive species; is inexpensive to implement relative to engineered options; meets

all the current Council policies and plans, especially the results of the Warringah Council Creek Management Study (reference /15/); and scores highly in both the community and the Working Group.

Option 26 Regular inspection and maintenance of stormwater infrastructure

This option scored very similarly to Option 27, for similar reasons. It scored lower because it has no impact on the environment and was not part of the options presented in the community questionnaire at the start of the study.

Option 6 Public awareness / education campaign

Increasing public awareness of flooding issues in the catchment does not impact on flood levels, the environment or potential property damage, but this option has scored highly because it is not costly to implement and meets the social and local council requirements, thereby reducing slightly the risk to safety in the event of a flood.

Option 7 Flood indicators at culverts

This option is similar to Option 6 in that it informs the public of the depth of flooding at key road locations in the catchment, with the intention of reducing the risk to safety in the event of a flood.

Option 1 Planning and development controls

Planning and development controls guide future development and therefore have no impact on current flood levels, levels of property damage or risk to safety. There is little cost associated with their development and they already form a part of Council's 'review and revise policy'. Planning and development controls may be used powerfully to restrict development within flood zones and overland flow paths and to ensure the use of design and construction methods that ensure the runoff quantity and quality from the development is not increased from existing levels, thereby not increasing the flood risk and decreasing water quality to the downstream areas of the catchment. Any development is likely to have an environmental impact by removing it from land set aside for environmental benefit.

Option 4 Flood-proofing of flood-prone properties

Providing flood proofing to flood prone properties has no impact on flood levels in the catchment and limited impact on potential property damage because it relies on the residents being at home and able to install the flood-proofing before the storm occurs. This option has ranked at 5 because it is relatively cheap and easy to implement.

Option 8 Obtain further information immediately after flood events

This option has no direct impact on any flooding, environmental, social or safety factors. It is ranked at 7 because it is easy to implement, is not costly and meets local council's requirements to gather information on flood events.

Option 15 Levee at rear of properties in Kapunda Place

Provision of this levee has a significant impact on flood levels at Kapunda Place, although the construction work will have a short term impact on the environment. There is an associated large reduction in potential property damage, but it is scored down because it may encroach on the zoning in the Belrose Corridor DCP (reference /19/). If deemed to be compatible with the local development plans, this option would be raised from a ranking of 7 to a ranking of 3 or 4.

Option 22 Remove kerb and gutter and re-camber Calool Crescent
This mitigation option has been ranked on its own, not with the combined benefits of upgrading Calool Crescent culverts. Even on their own, removing the kerbs and gutters and re-cambering Calool Crescent has been ranked at 7. If this option were considered combined with upgrading the culverts (Option 23, ranked 16), it would be ranked at 12 because of the costs of implementation, plus the engineering feasibility would be associated with the replacement of the culvert with a bridge, even though the hydraulic impacts of the combined options would be improved.

Option 5 Flood forecasting, warning and evacuation planning
This mitigation option has little impact on the major factors such as flood levels, safety, the environment and local residents. The main reason that safety has been marked with no impact is that the indicative warning time of a peak flood event in the Frenchs Creek catchment is between half an hour and one hour, which does not allow sufficient time to evacuate the area before flooding commences. Although this option has been ranked at 9, it is not considered to be an effective solution. It has scored highly because it has no negative impact in any of the ranking categories that it does not have a positive impact in, i.e. it does not have any environmental, hydraulic, economic or social impacts.

Option 14 Widen Corridor Creek upstream of south Pringle Avenue culverts
This option significantly reduces flood levels in the area, but has a significant negative impact on the environment due to the damage caused by widening the creek channel. Creek widening is potentially incompatible with Council's policies on the environment (reference /15/), which state that "Works within creeks and riparian zones which impact adversely on creek values should be avoided unless they provide an overall community benefit".

The following discussions of Options 9 and 11 have been included because they have scored highly in terms of overall hydraulic impact, although they have not been ranked in the top 10.

Option 9 Upgrade pipes from Curragundi Avenue to Pringle Avenue culverts
This option has been ranked at 16 in the assessment table. Although it provides a significant improvement in flood levels in the area and will reduce the potential property damage, it is very difficult to engineer, with severely limited space for drainage easements and will be very costly to implement. This option also has an environmental impact, with disturbance of the drainage easement during construction. Because the easement mainly passes through residential gardens, there would be a great deal of social impact, with disruption to gardens and some structures, such as swimming pools, having to be reduced in size or removed. This option could be staged over a number of years to spread the cost of design and construction, but the logistics of placing the drainage easements between properties is unlikely to be overcome. A possible variation of this, which has not been investigated, is to provide additional drainage capacity down Pringle Avenue. This may or may not have a positive impact on the flood levels and property damage in Curragundi Avenue and Pringle Avenue, but would probably increase some flood levels downstream.

Option 11 Retarding basin at Belrose Primary School
Although this option may cause a significant reduction in flood levels in the catchment, is has scored low in most of the other categories, particularly economic cost and safety impact and has been ranked at 25. There was much discussion regarding the safety risk in the Working Group meeting, but it has been judged that the construction of a 1m

deep retarding basin within the primary school property constitutes a significant increase in risk to life. The basin will contain water for a period of time after the main flood has passed in an area where large numbers of young children may be present. Even if the safety impact was considered not to change, the ranking of this option would only be increased to 19.

The following mitigation options have been included in this discussion because they were been suggested as additional options by the Working Group and Council from the Working Group meeting in November 2009.

Option 29 Divert Corridor Creek flow past the confluence to Elm Avenue

This is an additional option suggested by the Working Group from their meeting on 18 November 2009 (refer to Section 13.1.3). This involves a diversion of Corridor Creek from its confluence to the east of Winani Close, through the Belrose Corridor to Elm Avenue, where it would be conveyed by culverts into Frenchs Creek. The aim of this would be to reduce flood levels, and hence property damage, to the residences between the confluence and Elm Avenue. This option has not been modelled hydraulically or assessed economically, but it has been assessed for the ranking exercise and has been ranked at 19. Although this may provide a reduction in flood levels in Frenchs Creek, the extent of this is not known. There would be a significant environmental impact, although it has been judged that this will provide a new water habitat and so this impact has been reduced to slight. This option may be costly, but it has been assumed that it may not be significant, the major costs being the provision of culverts under Elm Avenue and the purchase of the land. This area of land is currently assigned as suitable for residential development (reference /19/), which may increase the cost of its purchase. Diversion of creeks is against Council policy, but the option of piping the creek in this residential section is a worse option and would likely prevent the scheme from being considered.

Option 30 Retarding basin in road corridor, upstream of Pringle Avenue

This is an additional option suggested by the Working Group from their meeting on 18 November 2009 (refer to Section 13.1.3). An off-line retarding basin for flows down Corridor Creek was suggested in the area of land upstream of Pringle Avenue. This option has not been modelled hydraulically or assessed economically, but it has been assessed for the ranking exercise and has been ranked at 19. Such a retarding basin would take up a substantial amount of land within the Belrose Corridor which could not them be planted with native species as part of the development of the corridor. Flow would be diverted from Corridor Creek, which may reduce the need to upgrade the south Pringle Avenue culverts, although this may still be required. The amount of excavation required and the cost of the land would make this a costly option and the site levels would have to be investigated to determine the engineering feasibility of such an option. Provision of a temporary body of water may increase the safety risk in a public area, although this might be balanced with a decreased risk to safety on the road at south Pringle Avenue culverts.

14 CONCLUSIONS AND RECOMMENDATIONS

This report presents the findings and results of the Floodplain Risk Management Study of Frenchs Creek catchment. The study has identified and evaluated management options for the floodplain.

A Flood Study was previously undertaken to identify the existing flood behaviour and flood prone areas for the Frenchs Creek catchment using a calibrated and validated hydraulic model. The flood modelling tools and reported existing flood behaviour developed for the Flood Study were used as the basis for the Floodplain Risk Management Study.

A wide range of floodplain risk management options were assessed as part of the study. The options were selected from the results of the Flood Study, community consultation and discussions with the Working Group and Council. The range of options covers property modifications, response modifications and flood modifications. Where appropriate, the hydraulic model developed for the Flood Study was used to assess the hydraulic impact of the proposed flood risk management option on flood behaviour.

Consultation with the community based Working Group was undertaken and the results of the investigations into the floodplain risk management options were discussed at a meeting. The Working Group was given the opportunity to evaluate the options and their comments have been included in Section 13.1.3 of the report. Input from the wider community has been included in the evaluation of the options based on the results of the community survey undertaken in the Flood Study.

All floodplain risk management options were evaluated based on a range of flood mitigation, environmental, social, financial and planning criteria, as well as an overall appropriateness to the catchment. The results of the evaluation were presented in an assessment matrix (Table 23) and ranked according to the highest overall score. The results of this evaluation process have been discussed and will be used to develop the Floodplain Risk Management Plan in the next phase of this project.

15 REFERENCES

1. New South Wales Government (April 2005). "Floodplain Development Manual: The Management of Flood Liable Land". ISBN 0 7347 5476 0.

2. DHI Water and Environment (2010). "Frenchs Creek Flood Study". Report prepared for Warringah Council.

3. New South Wales Government (May 2005). "Floodplain Risk Management Guideline No 4: Residential Flood Damages".

4. DHI Software (2003) "MIKE Storm 2003c Technical Reference" Agern Alle 11, Horsholm Denmark

5. DHI Software (2003) "MIKE SHE 2003c Technical Reference and User Guide" Agern Alle 11, Horsholm Denmark

6. The Institution of Engineers, Australia (Reprinted Edition 2001) "Australian Rainfall and Runoff - A Guide to Flood Estimation" Volumes 1 and 2.

7. Department of Science and Technology, Bureau of Meteorology (Bulletin 53, December 1994) "The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method".

8. I Gillespie, (1989). 'Submission to Council re Flooding of Residential Properties in Curragundi Avenue, Belrose '.

9. Webb McKeown, (1997). 'Belrose Corridor Drainage Study'.

10. Flood Impacted Residents of Belrose Association, (1998). 'Report on Flood Impact/Damage from the Storm of 10 April 1998'.

11. Patterson Britton & Partners, (1999). 'Sydney Northern Beaches Stormwater Management Plan'.

12. Warringah Council, (1999). 'Stormwater Drainage Investigation Report'.

13. Patterson Britton & Partners, (1999). 'Frenchs Creek, Belrose – Verification of Council's Catchment Investigation'.

14. Webb McKeown, (2001). 'Investigation of Flood Problem – Elm Avenue to Calool Crescent' and the 'Frenchs Creek, Belrose – Compendium of Flood and Drainage Information'.

15. Montgomery Watson Harza, (2004). 'Warringah Council Creek Management Study'.

16. Webb McKeown, (2003). 'Flood Information for the Flood Event of 10 March, 2003'.

17. JBA Urban Planning Consultants (2002). "Former St Ives – Dee Why Road Corridor. Garigal National Park to Forest Way, Belrose" Rezoning Application submission to Warringah Council prepared on behalf of Planning NSW and Roads and Traffic Authority.

18. Upper Parramatta River Catchment Trust, (December 2005), 'On-Site Stormwater Detention Handbook' fourth Edition, ISBN, 0 7347 6115 5.

19. Warringah Council (July 2008), 'Warringah Development Control Plan – Belrose Corridor'.

20. Warringah Council (2009), 'Draft Warringah Local Environmental Plan'.

21. Warringah Council (2009), 'Draft Development Control Plan'.

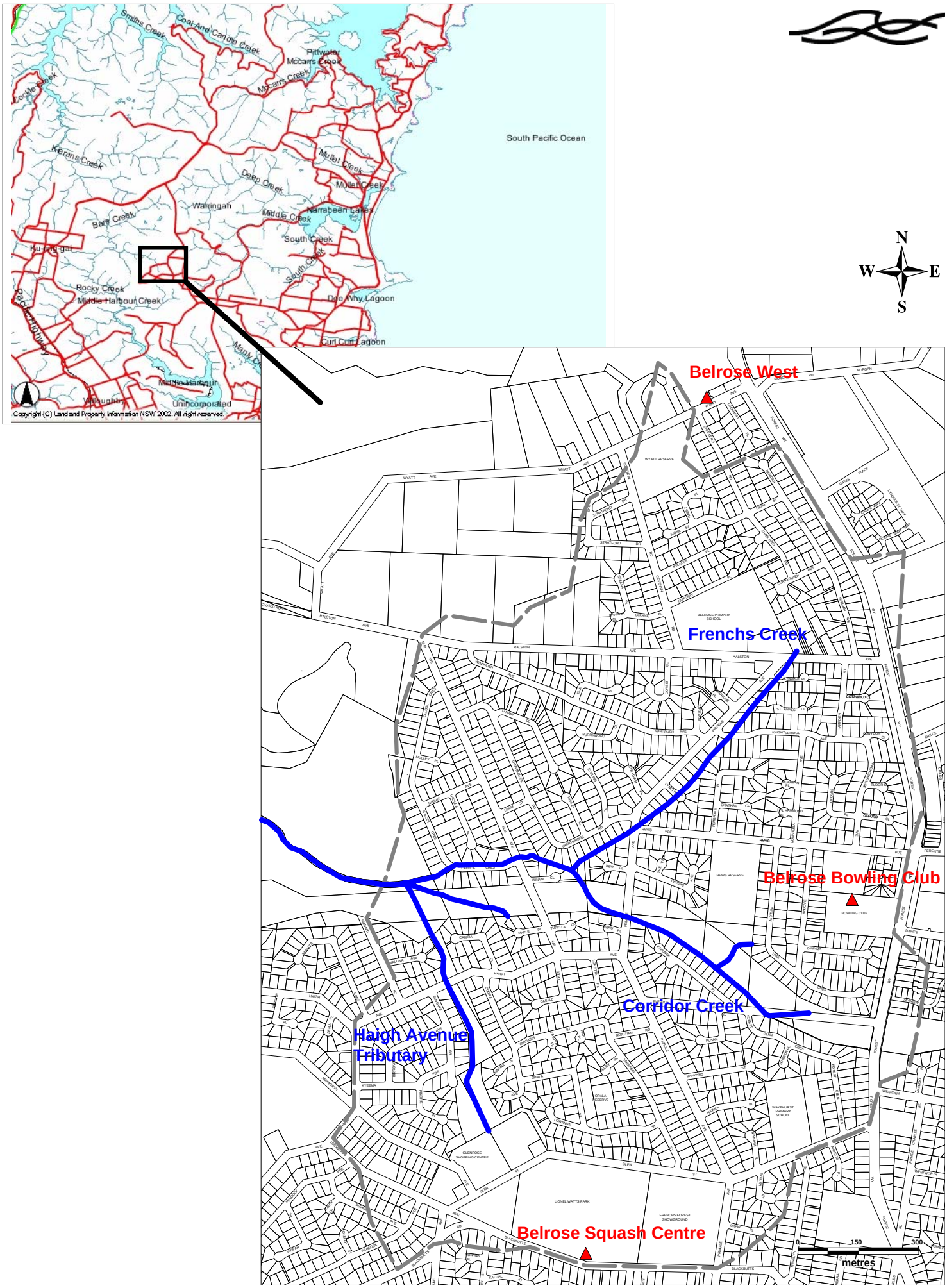
22. Warringah Council (2010), 'Protection of Waterways and Riparian Land Policy'.

23. New South Wales Government (2010), 'Water Management Act 2000'.

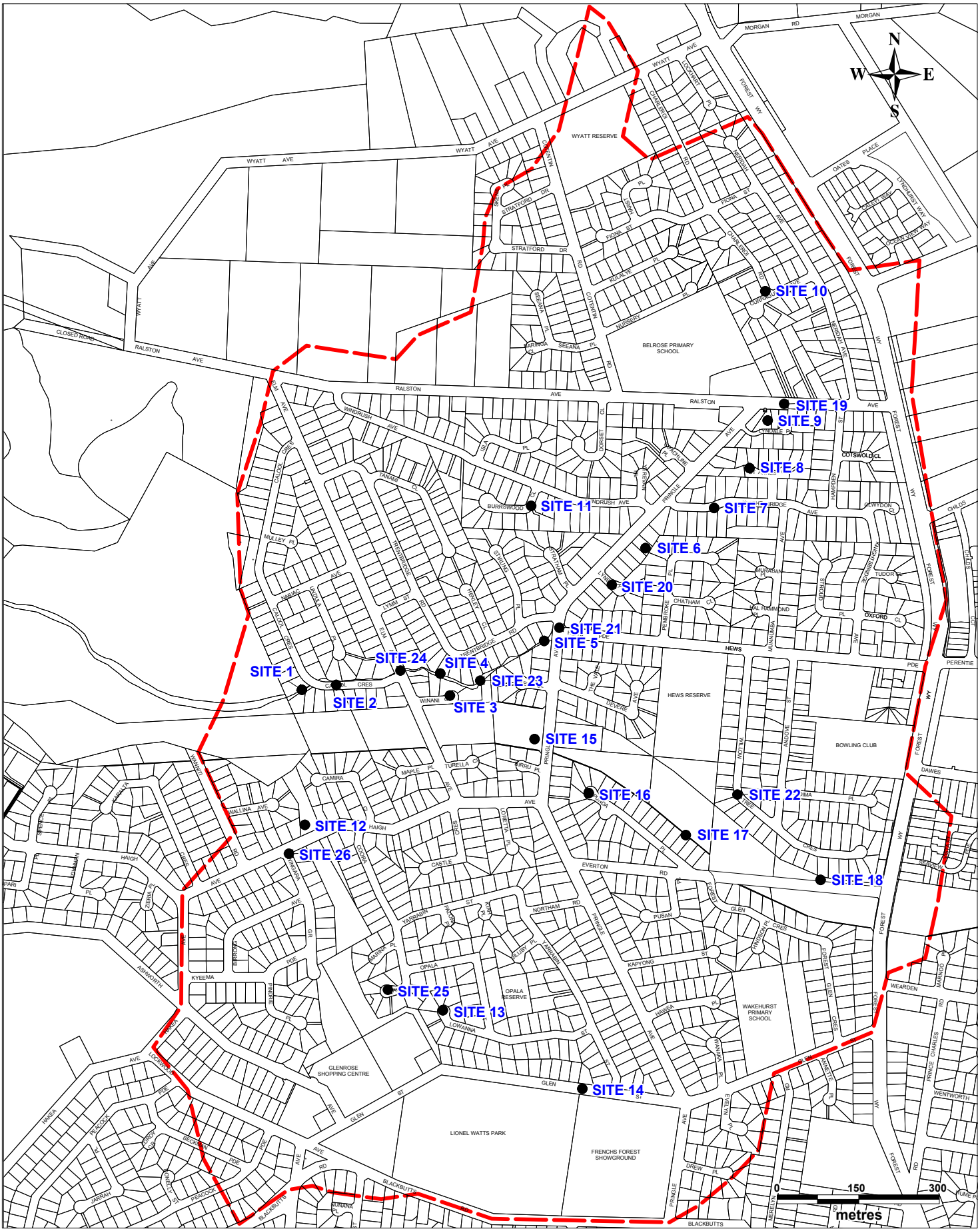
24. Department of Climate Change and Water (2008), 'Guidelines for Controlled Activities: Riparian Corridors'.

25. NSW Department of Planning (2007), 'New guideline and changes to section 117 direction and EP&A Regulation on flood prone land', PS 07-003.

F I G U R E S



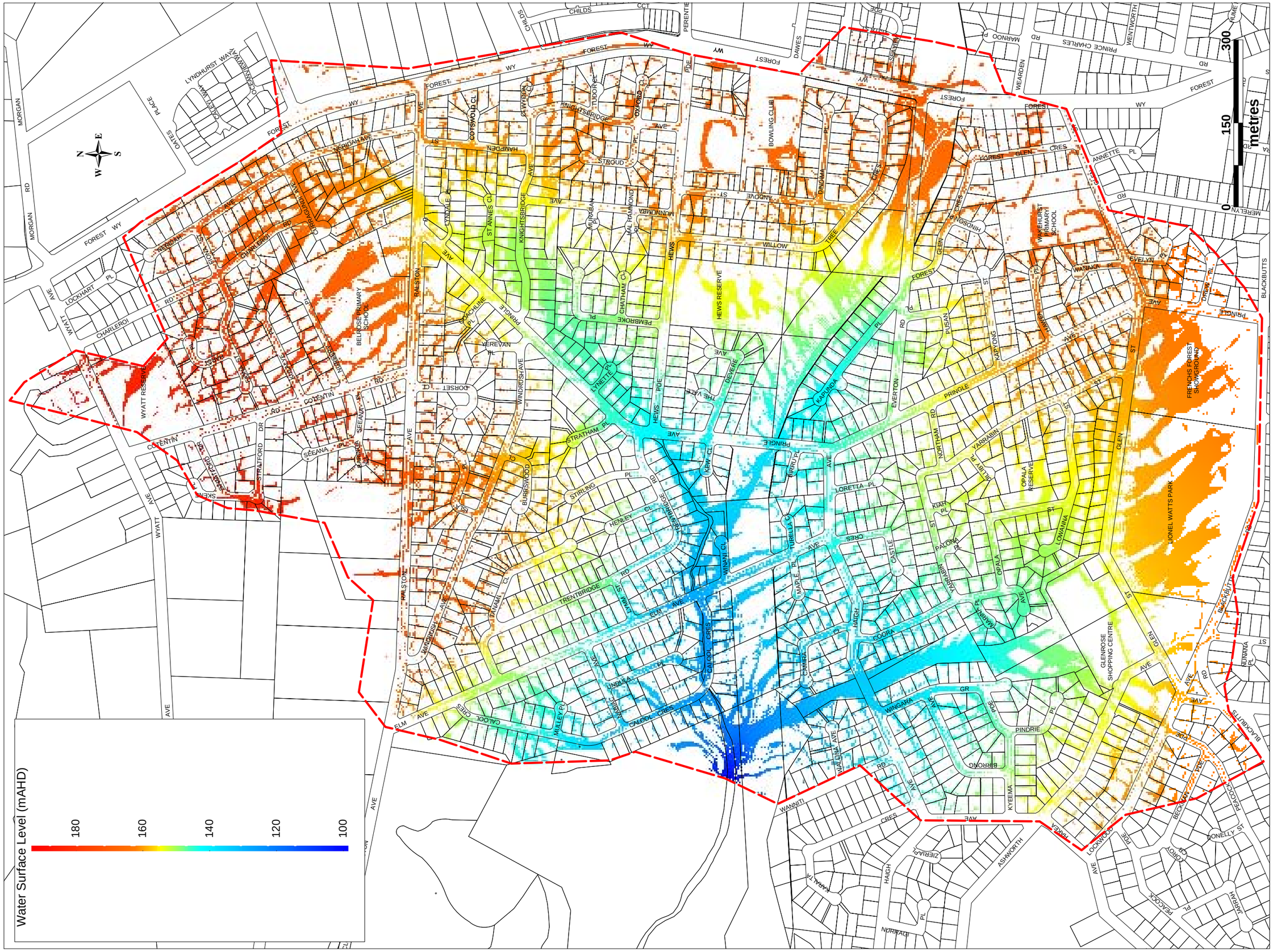
Study Area
Figure 1



Study Boundary

Reference Location

Representative Locations for Reporting
Figure 2



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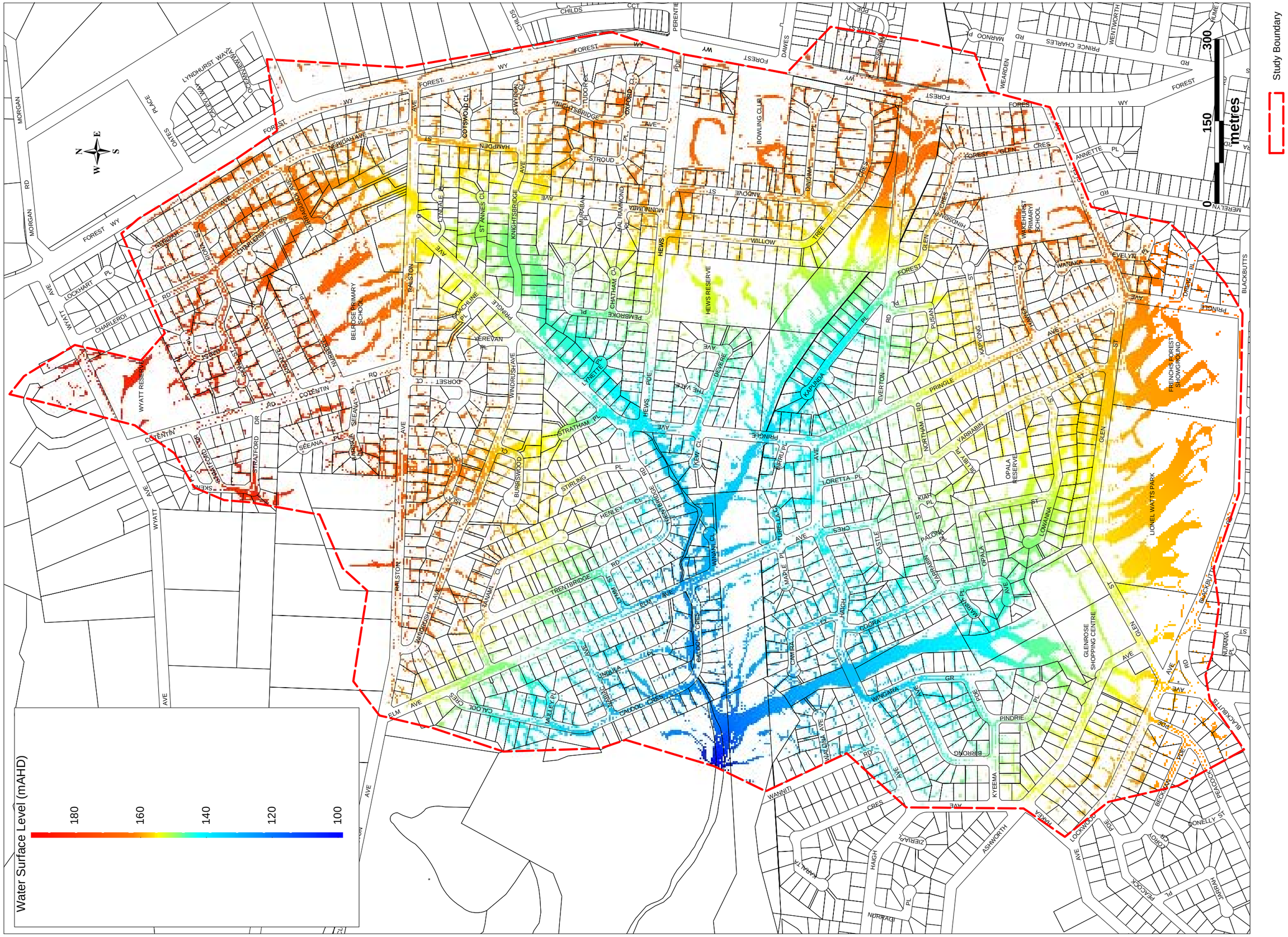
DHI Water & Environment

Water Surface Level - Probable Maximum Flood Event
Figure 3



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DHI Water & Environment

Water Surface Level - 1% AEP Event
Figure 4

a *Leaves blocking a road pit, May 2010. The leaves may be washed into the pipe system causing pipe blockage in the next rainfall event. (Courtesy of Warringah Council)*

b *Debris and vehicle blocking a road pit, May 2009. (Courtesy of Warringah Council)*

Examples of typical debris at the entrance to road pits and channel pits in Frenchs Creek catchment.

Figure 5a

c Debris caught on a grating to a pit at 12 Mactier St, May 2009. (Courtesy of Warringah Council)

Examples of typical debris at the entrance to road pits and channel pits in Frenchs Creek catchment.

Figure 5b

a Debris caught on handrails at Wallsend Dark Creek, June 2007. (Courtesy of Newcastle Council).

b Debris in creek at footbridge crossing, Wollongong, August 1998. (Courtesy of DECCW).

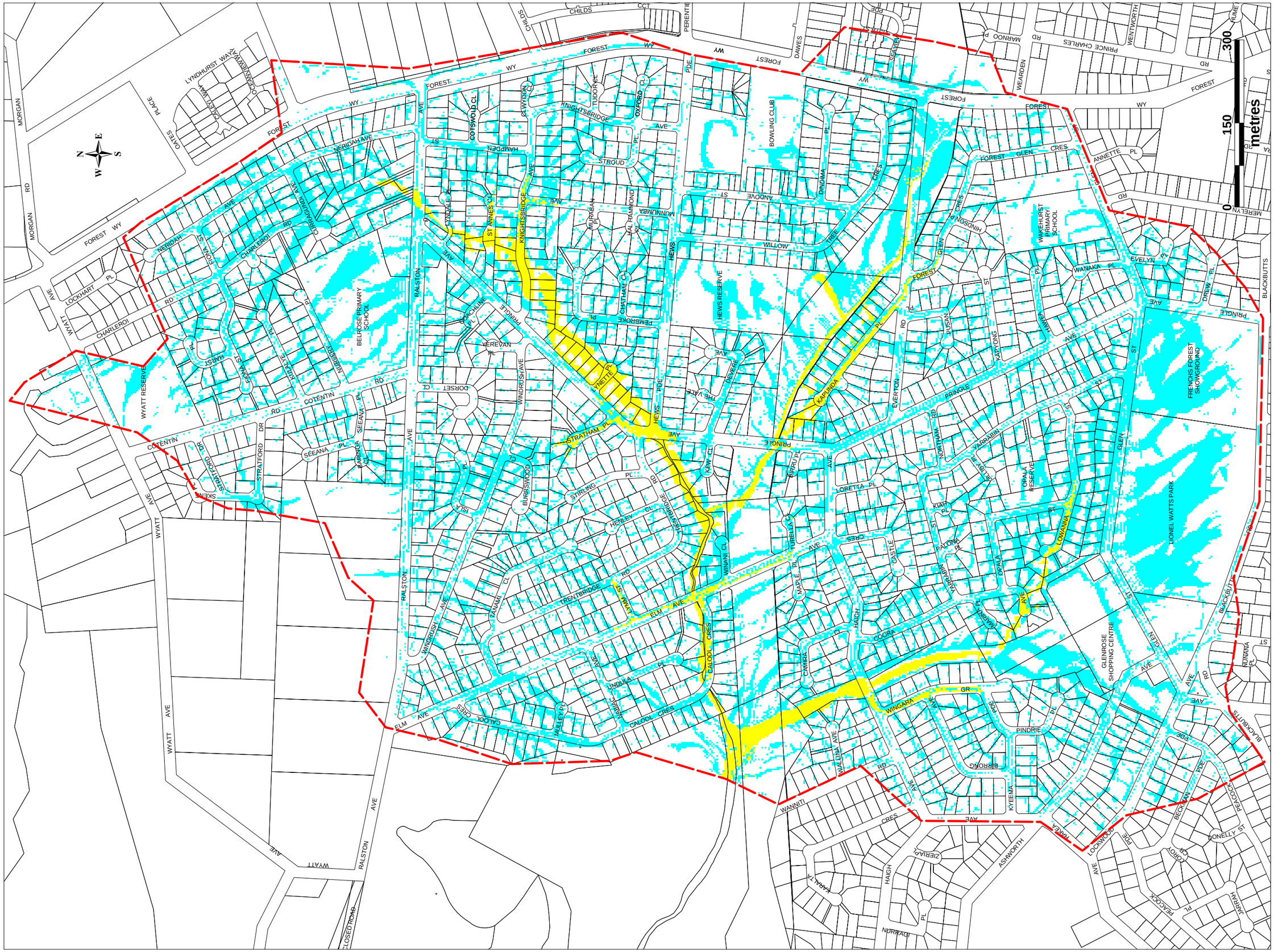
Examples of the impact of debris at culverts and bridges.

Figure 6a

c Blockage in Corridor Creek after a storm event, 26 October 2009. (Courtesy of Warringah Council).

Examples of the impact of debris at culverts and bridges.

Figure 6b



Provisional Hazard Classification - Probable Maximum Flood Event
Figure 7

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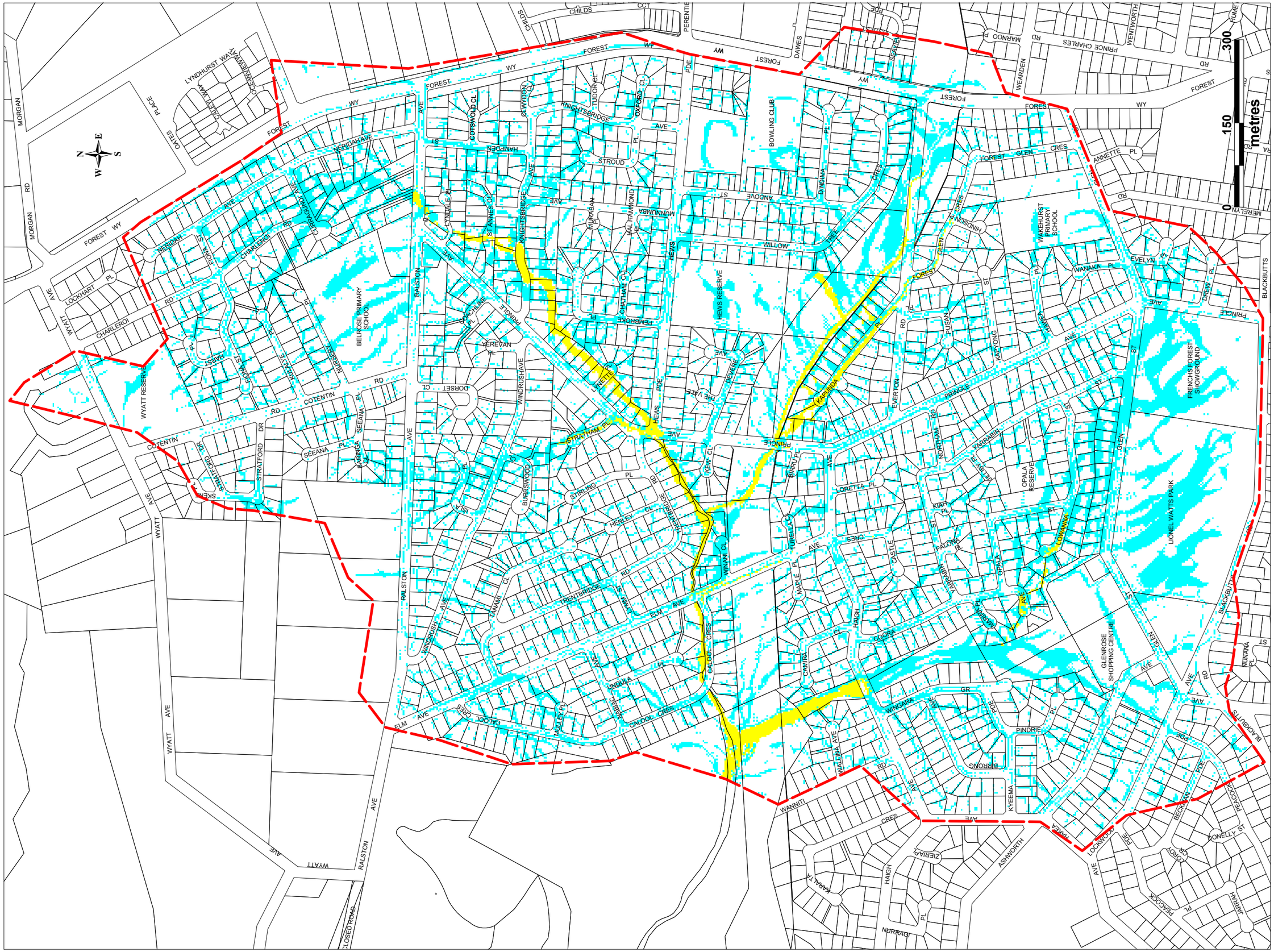

Provisional Hazard Classification - 1% AEP Flood Event
Figure 8

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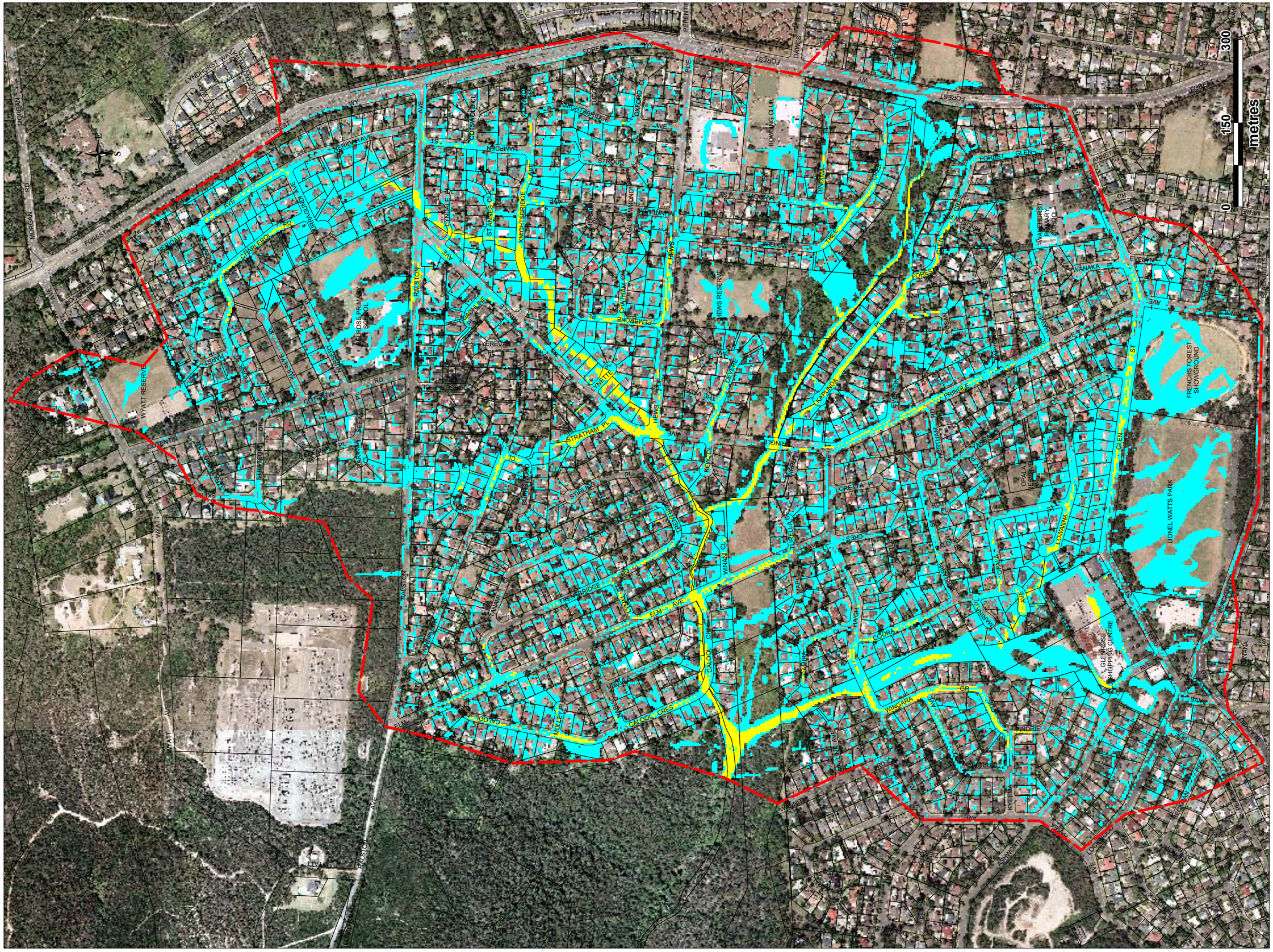
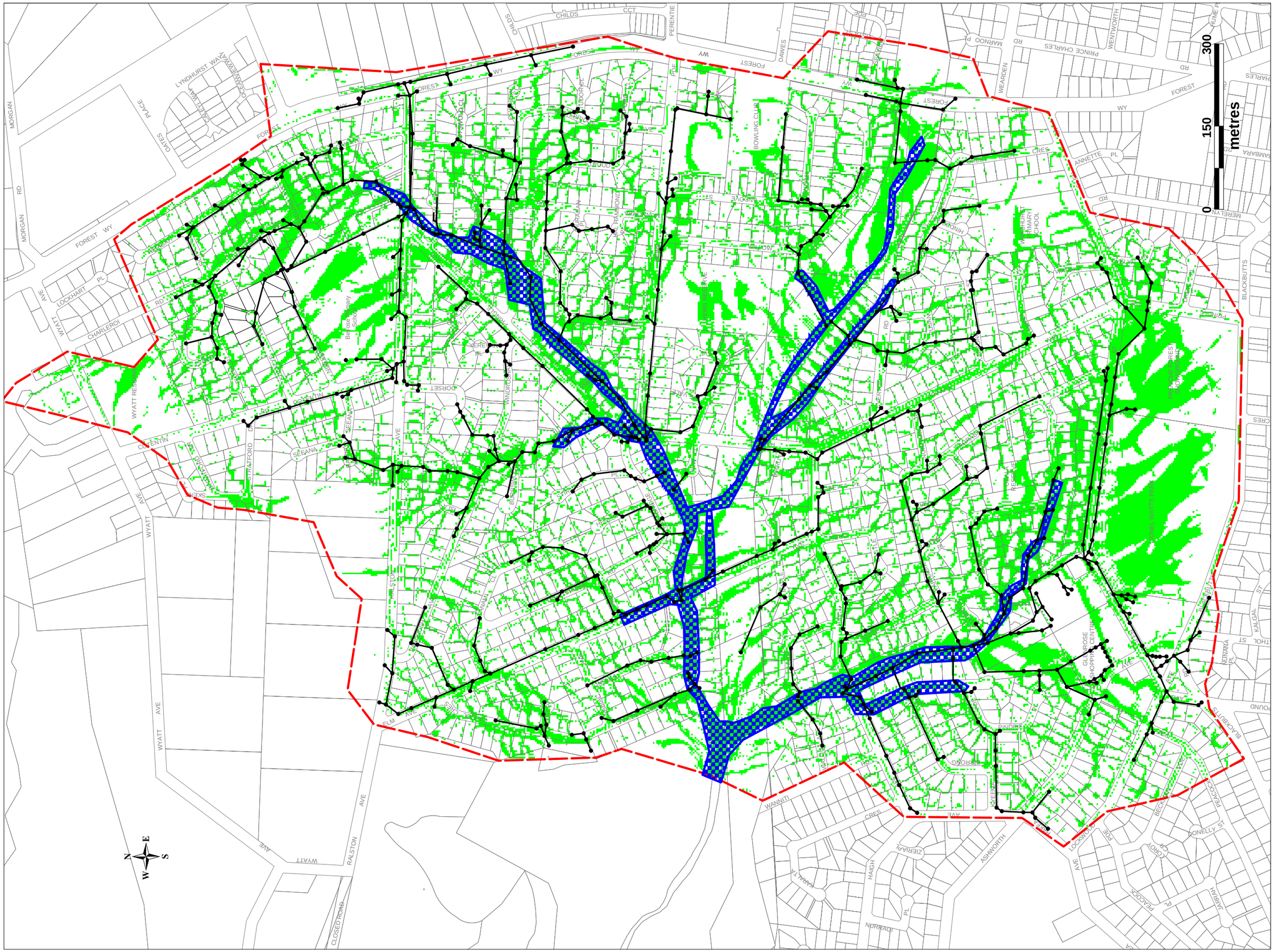


Provisional Hazard Classification - 1% AEP Event 100% Blocked Case
Figure 9



Hydraulic Category Classification - Probable Maximum Flood Event

Figure 10

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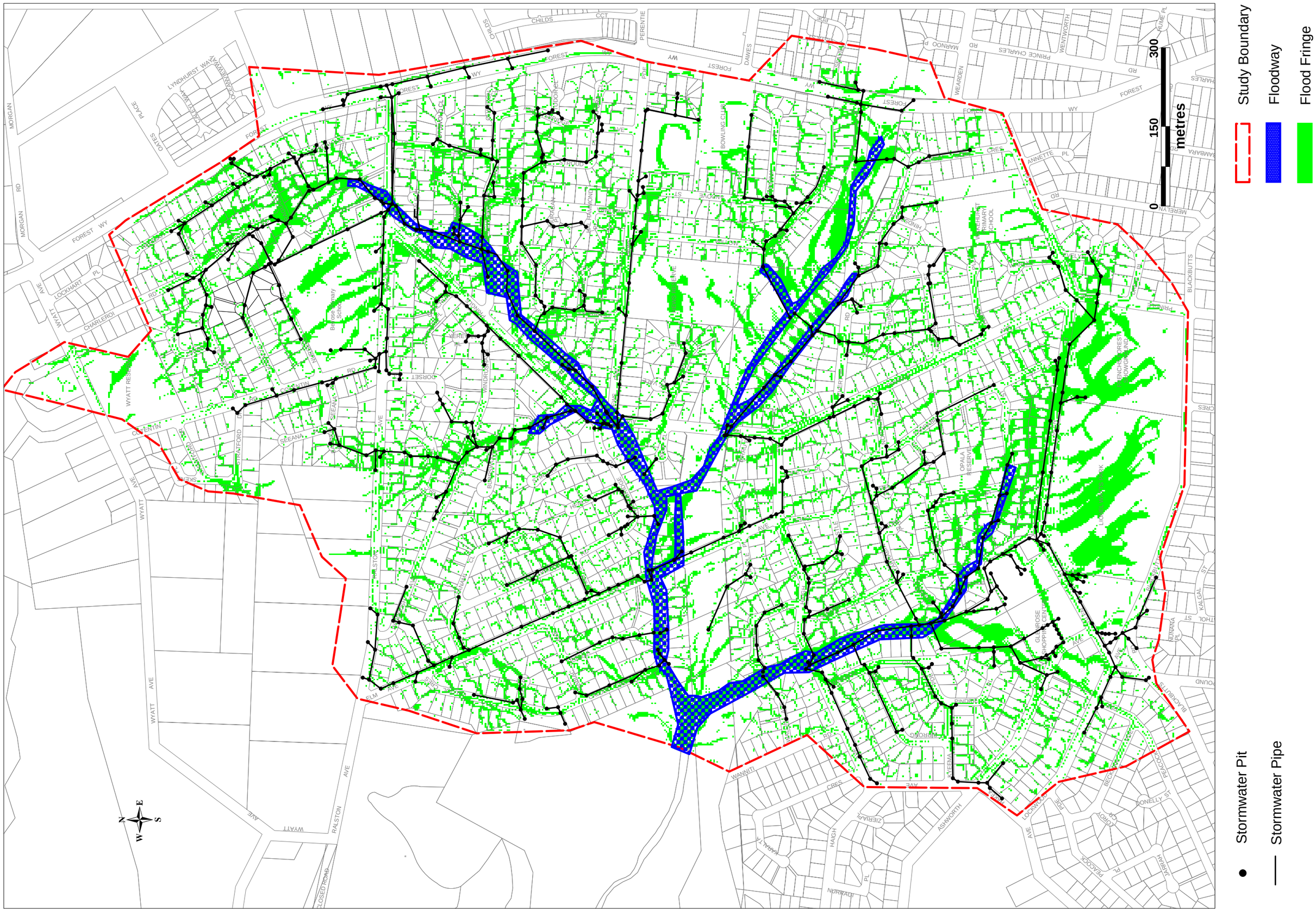
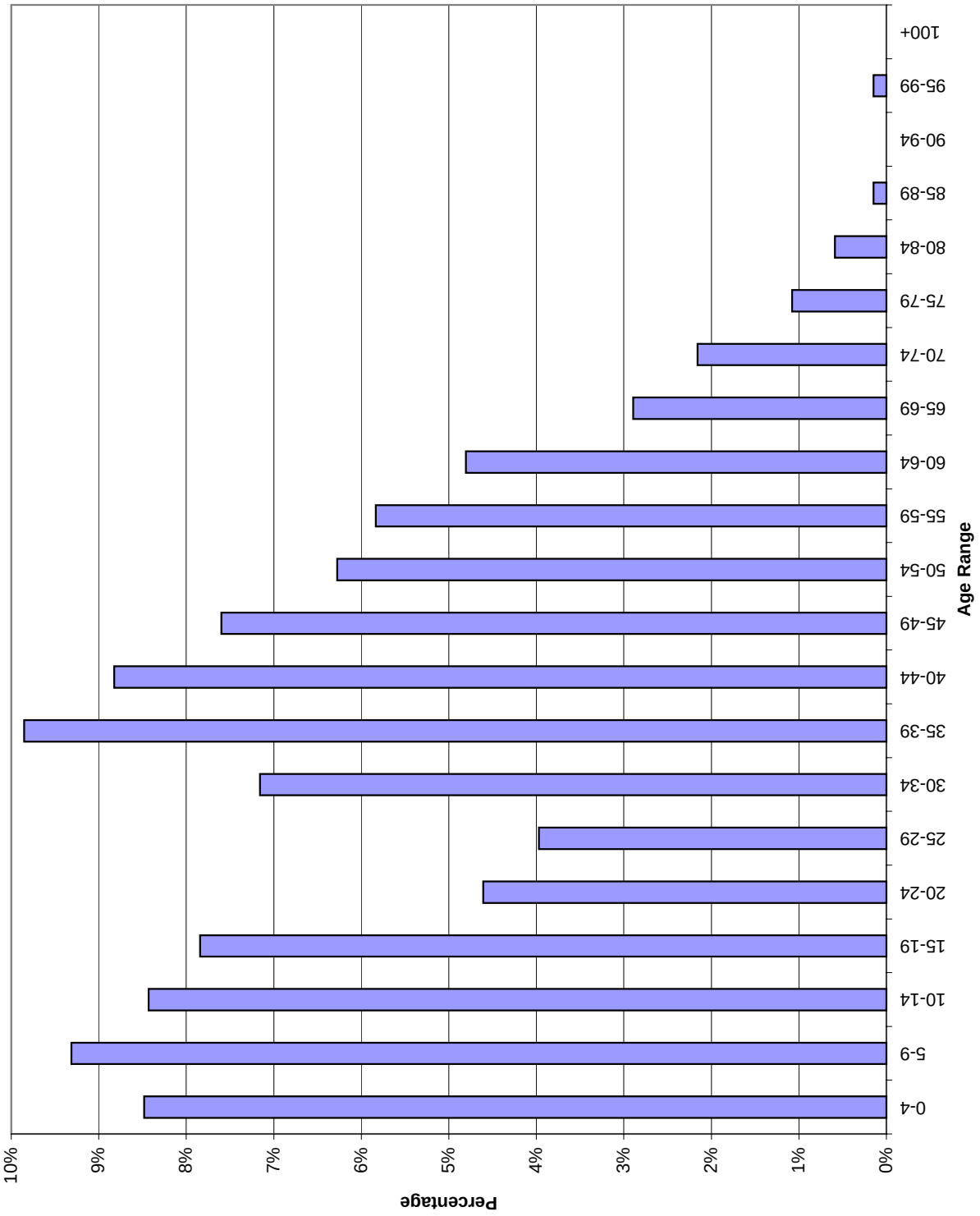
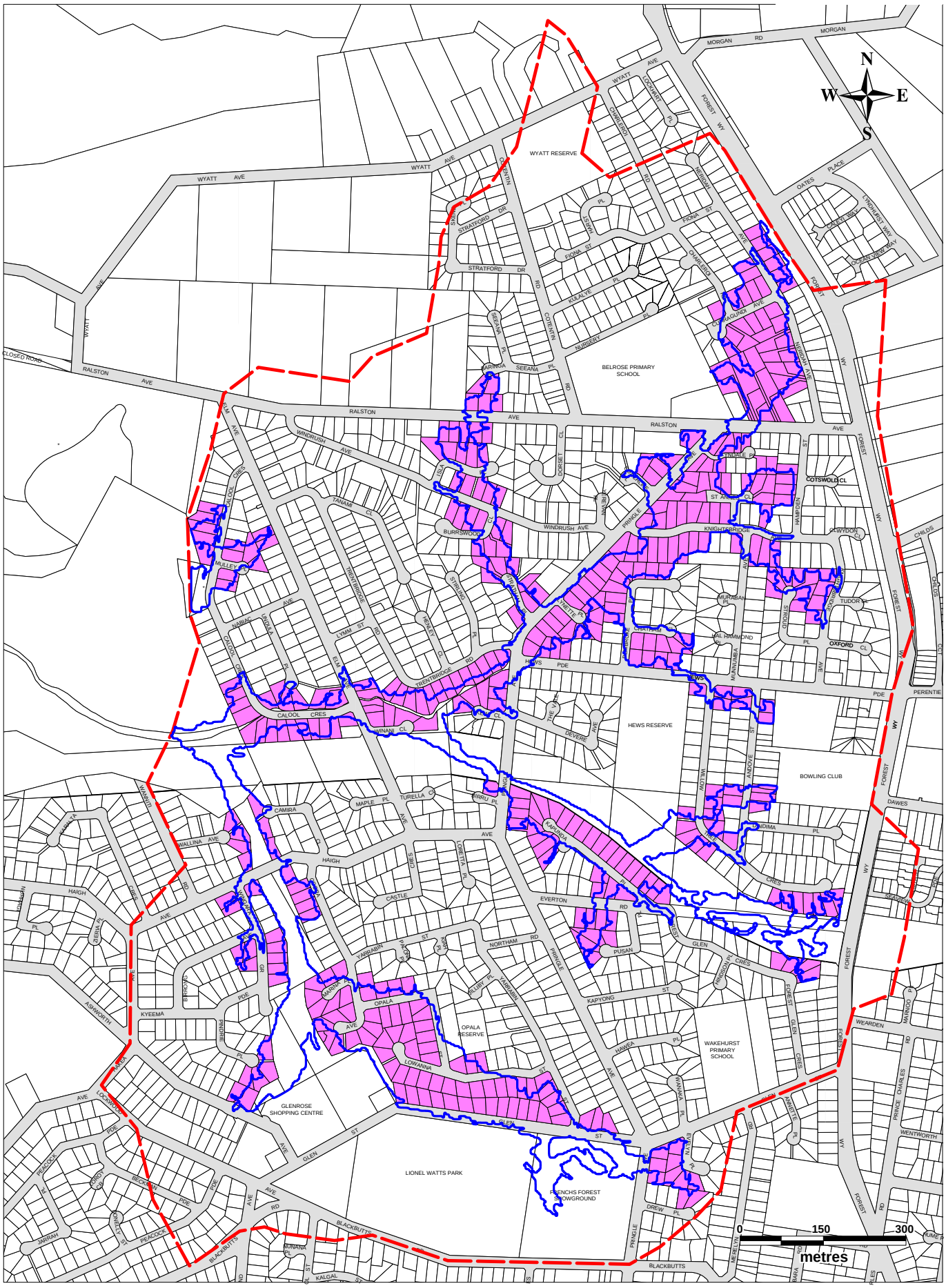


Hydraulic Category Classification - 1% AEP Flood Event
Figure 11



Population Distribution in Frenchs Creek
Taken from 2001 CENCUS data
Figure 12

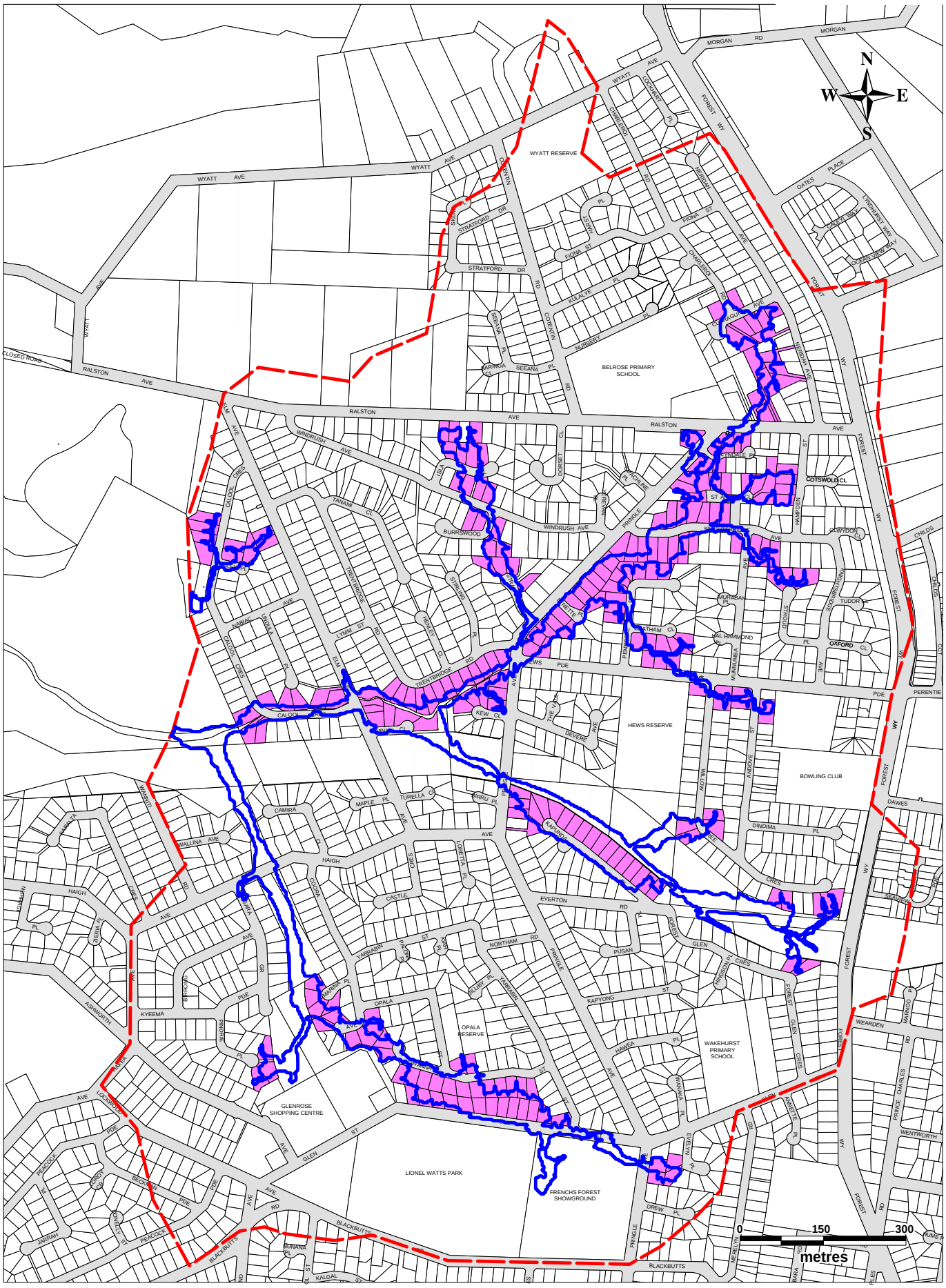


Study Boundary

PMF Flood Extent

Properties Affected by Flooding

Properties Affected by Flooding
Probable Maximum Flood Event
Figure 13

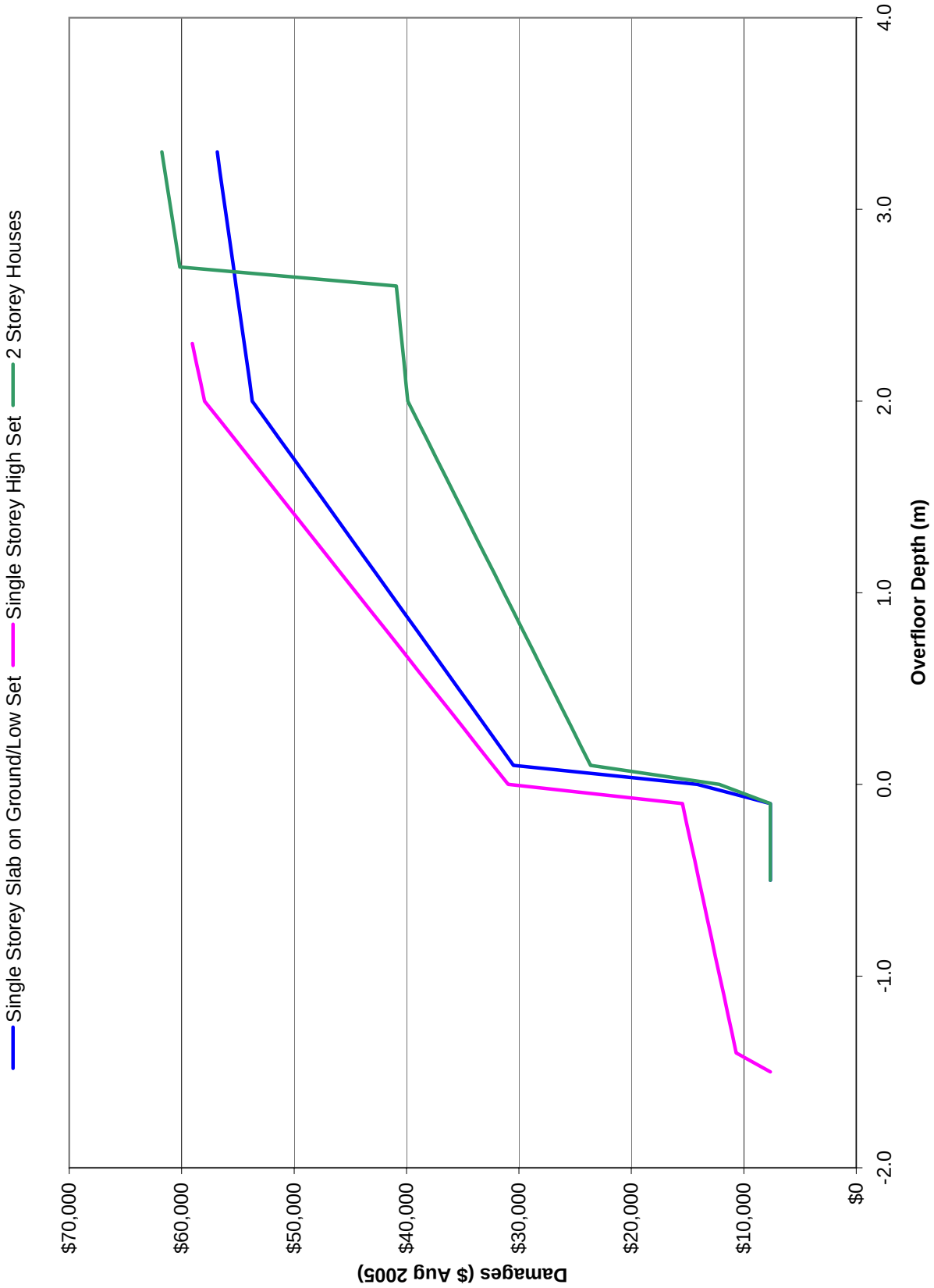


Study Boundary

1% AEP Flood Extent

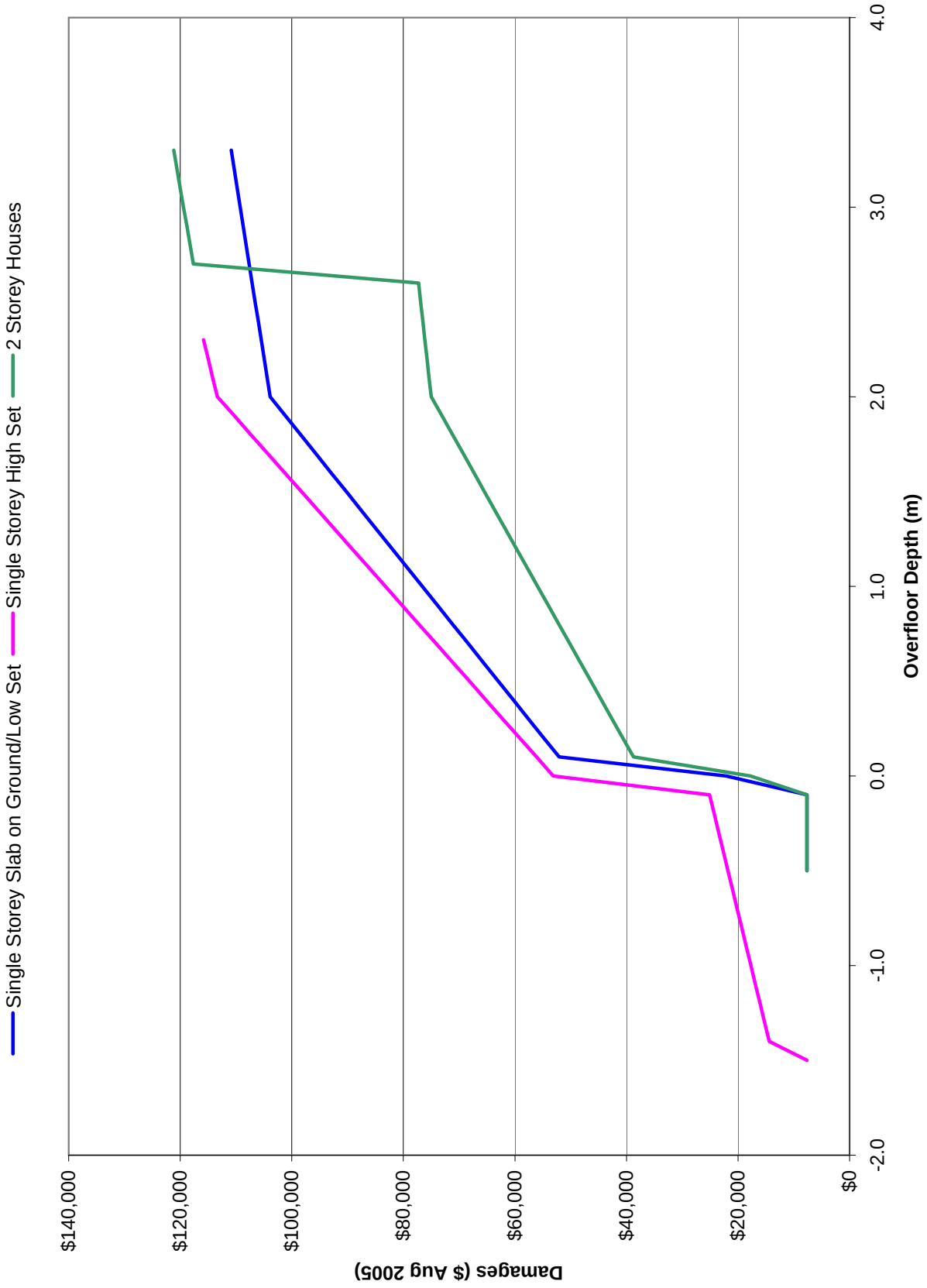
Properties Affected by Flooding

Properties Affected by Flooding
1% AEP Flood Event
Figure 14

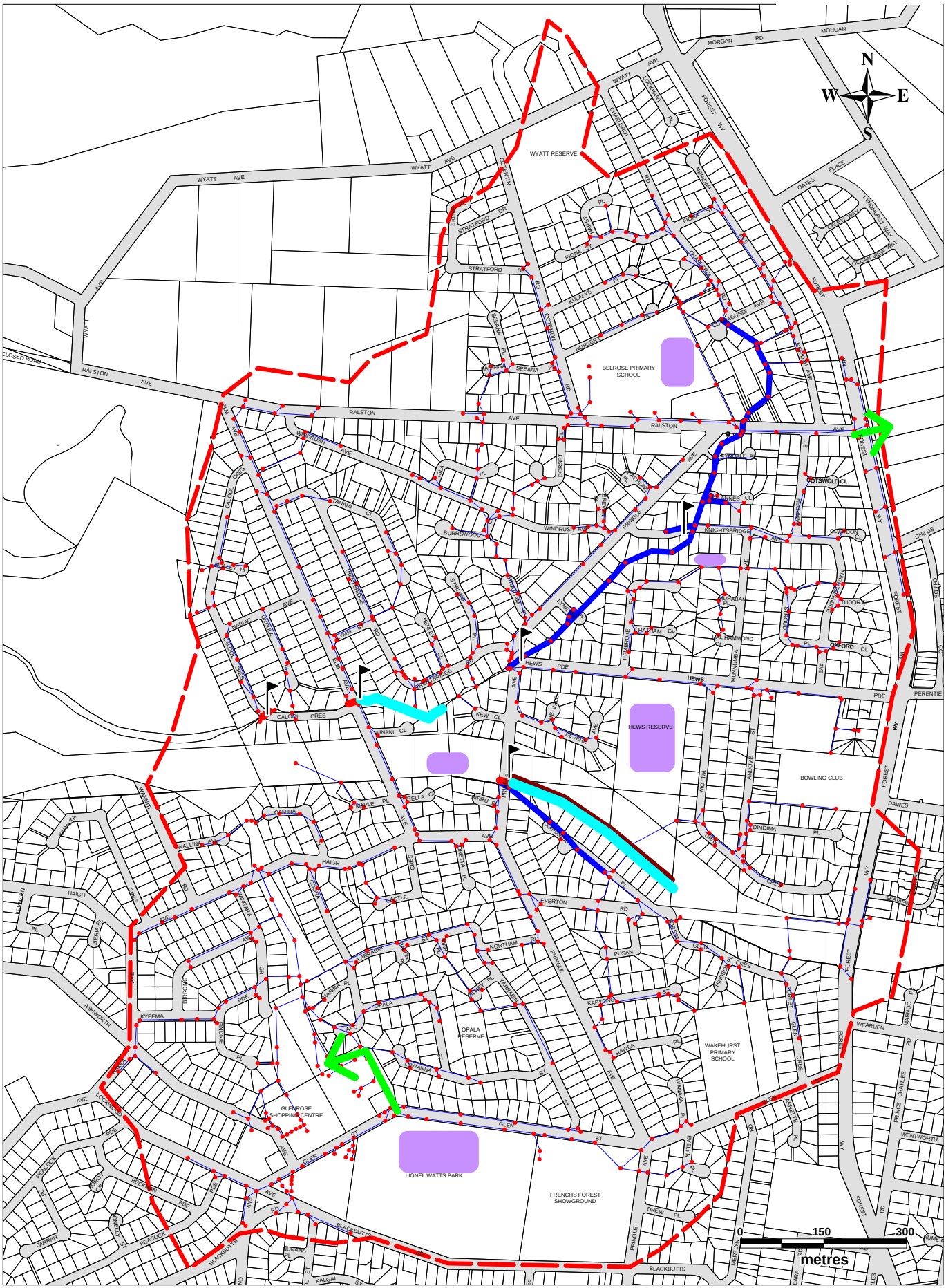


Damage Curves for Small House
Figure 15

Damage Curves for Medium House
Figure 16



Damage Curves for Large House
Figure 17



Study Boundary

Retarding Basin

Flood Depth Indicators

Channel Widening

Levee

Pipe Upgrade

Flow Diversion

Floodplain Risk Management Options Figure 18

(i) Calool Crescent Culverts (flood depth indicator).

(ii) Calool Crescent Culverts (culvert upgrade).

Floodplain Risk Management Option Location Photographs.

Figure 19a

(iii) Elm Avenue Culverts (flood depth indicator).

(iv) Elm Avenue Culverts (culvert upgrade).

Floodplain Risk Management Option Location Photographs.

Figure 19b

(v) North Pringle Avenue Culverts (flood depth indicator).

(vi) North Pringle Avenue Culverts (culvert upgrade).

Floodplain Risk Management Option Location Photographs.

Figure 19c

(vii) South Pringle Avenue Culverts (flood depth indicator).

(viii) Knightsbridge Avenue Culverts (flood depth indicator).

Floodplain Risk Management Option Location Photographs.

Figure 19d

(ix) Channel Upstream of South Pringle Avenue Culverts (channel widening and vegetation control).

(x) Creek Channel at Winani Close (channel widening and vegetation control between Pringle Avenue and Elm Avenue).

Floodplain Risk Management Option Location Photographs.

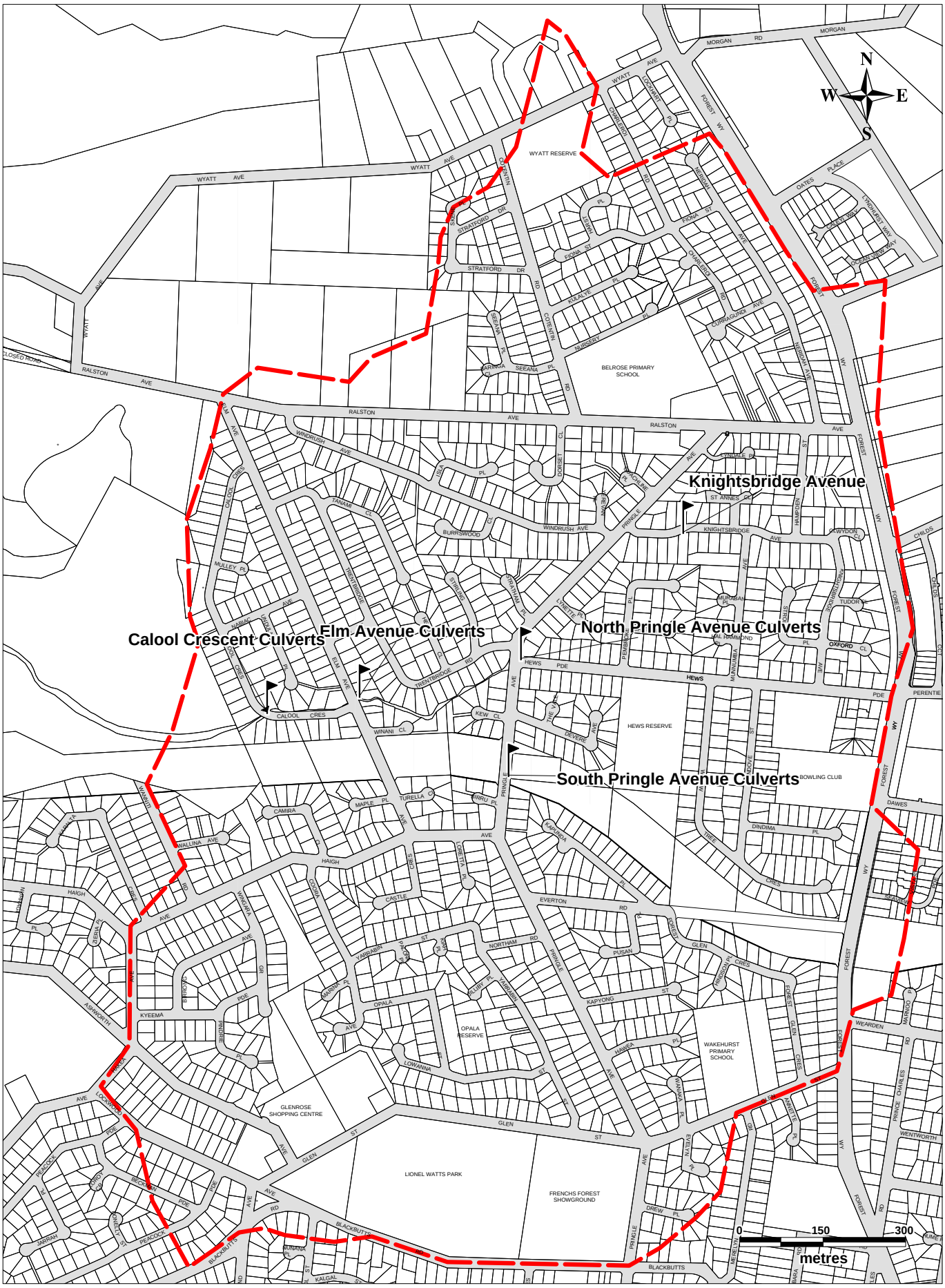
Figure 19e

(xi) Rear of Properties on Kapunda Place (levee, widening of channel and vegetation control)

(xii) Kapunda Place (upgrade of stormwater pipes).

Floodplain Risk Management Option Location Photographs.

Figure 19f



Study Boundary

Flood Depth Indicators

Location of Flood Depth Indicators
Figure 20

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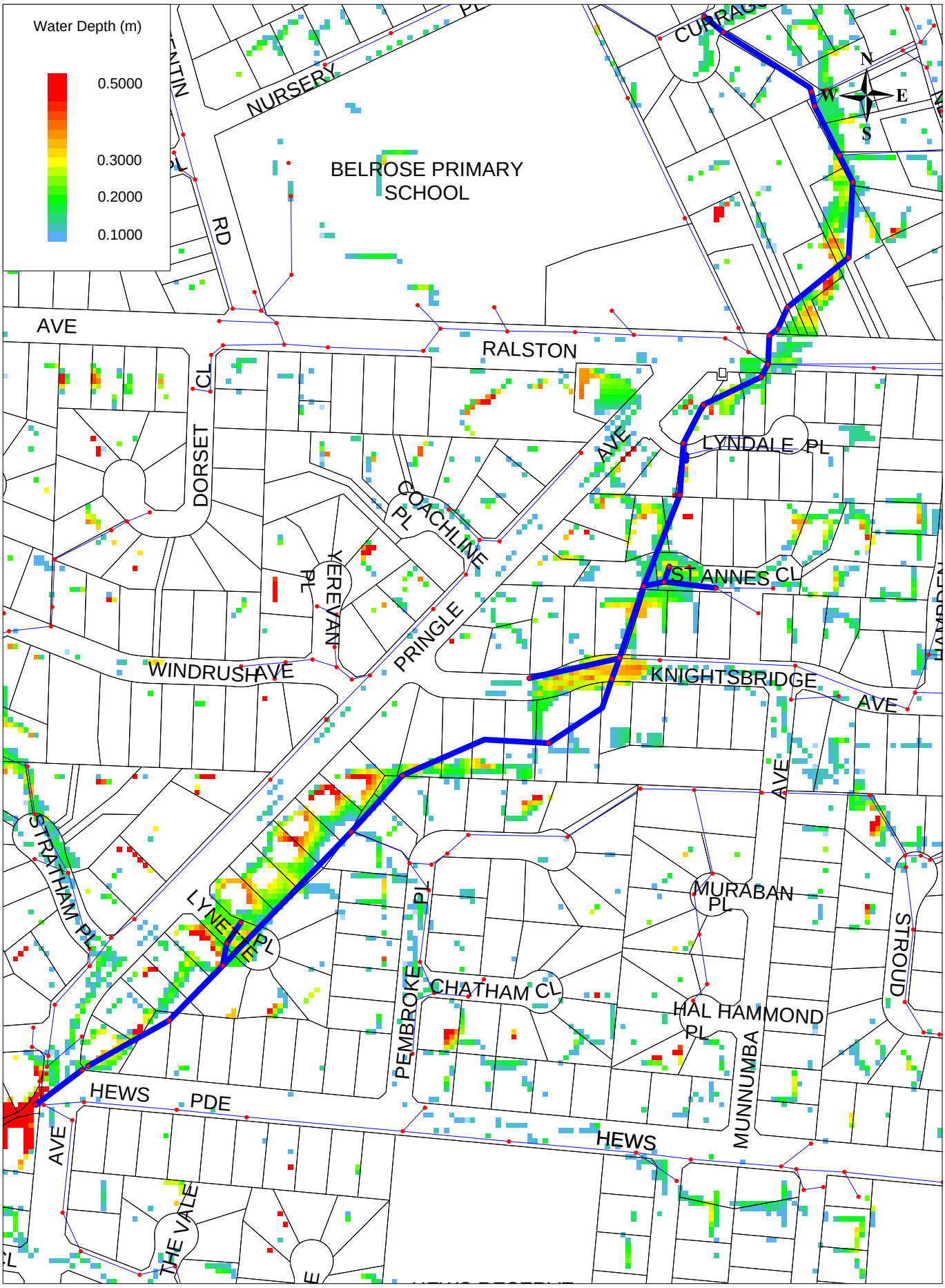
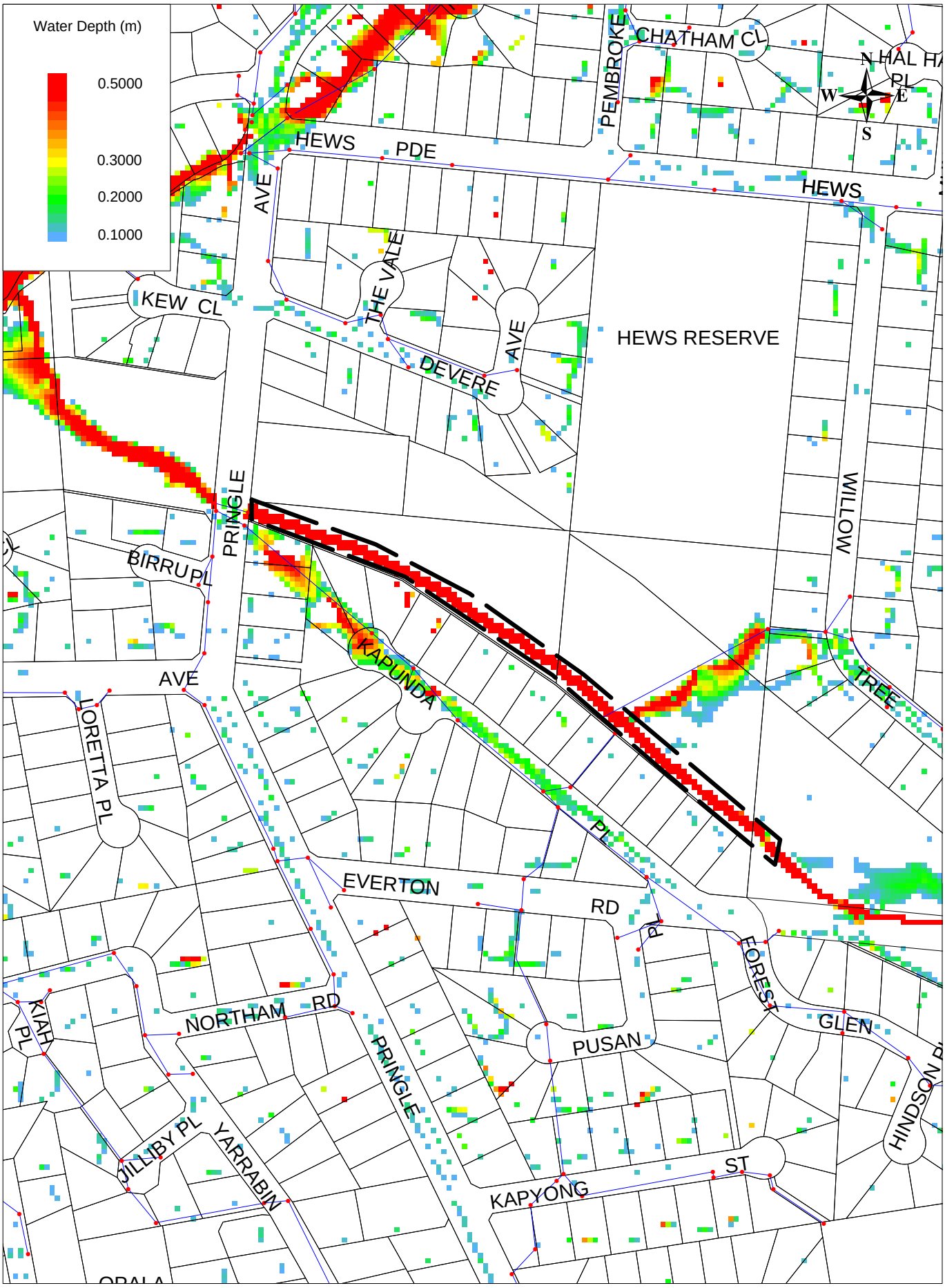
FRMS_Figure17_FloodIndicators_V4_Fig20.wor

DHI Water & Environment



Pipe Upgrade

Upgrade of Stormwater Pipes from Curragundi Avenue to Pringle Avenue
1% AEP Flood Event
Figure 21



Region of Creek to be Widened

Widening of Corridor Creek Upstream
of South Pringle Avenue Culverts
1% AEP Flood Event
Figure 22

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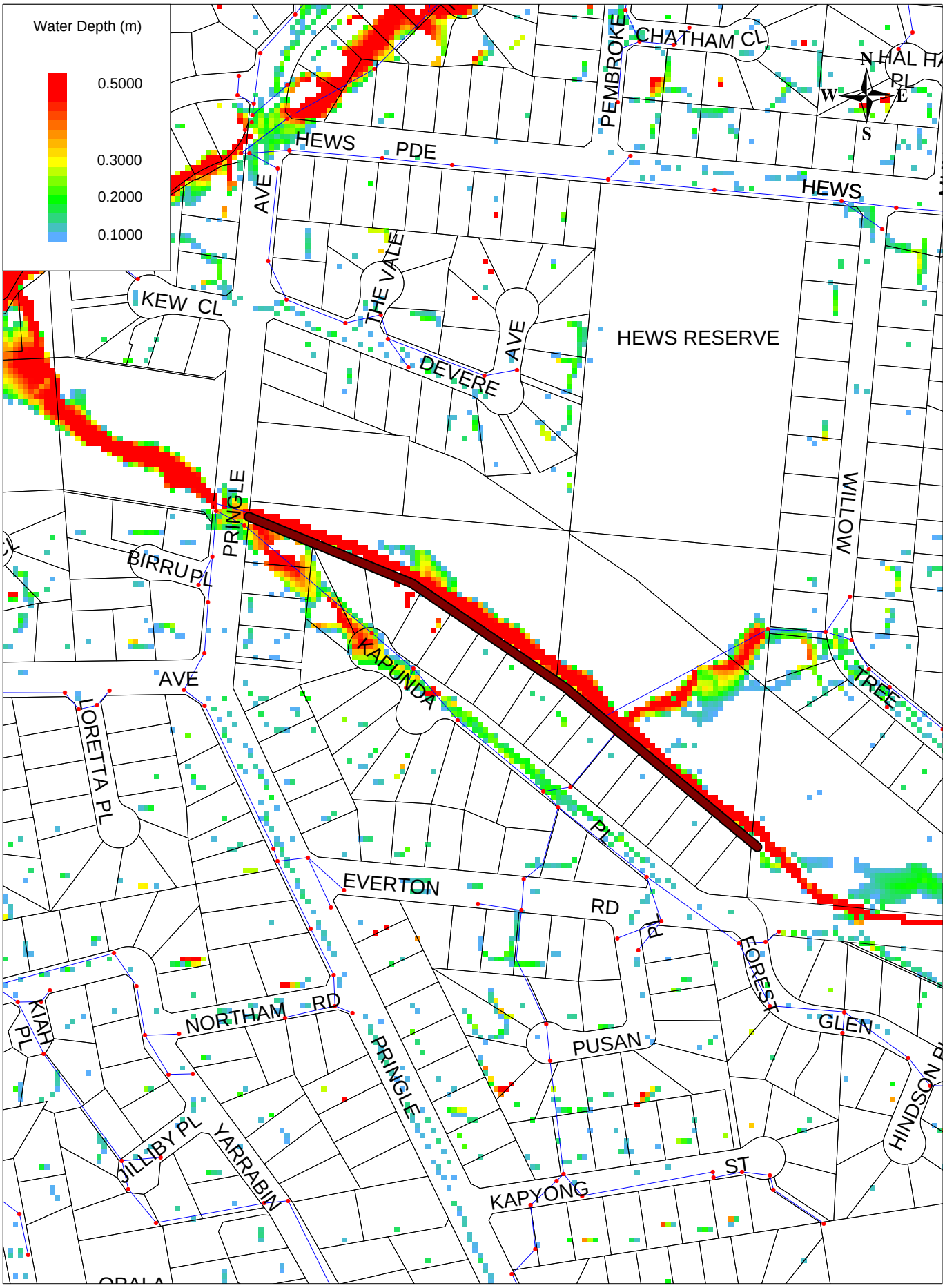
DHI Water & Environment



Levee

Levee at Rear of Properties in Kapunda Place
1% AEP Flood Event
Figure 23

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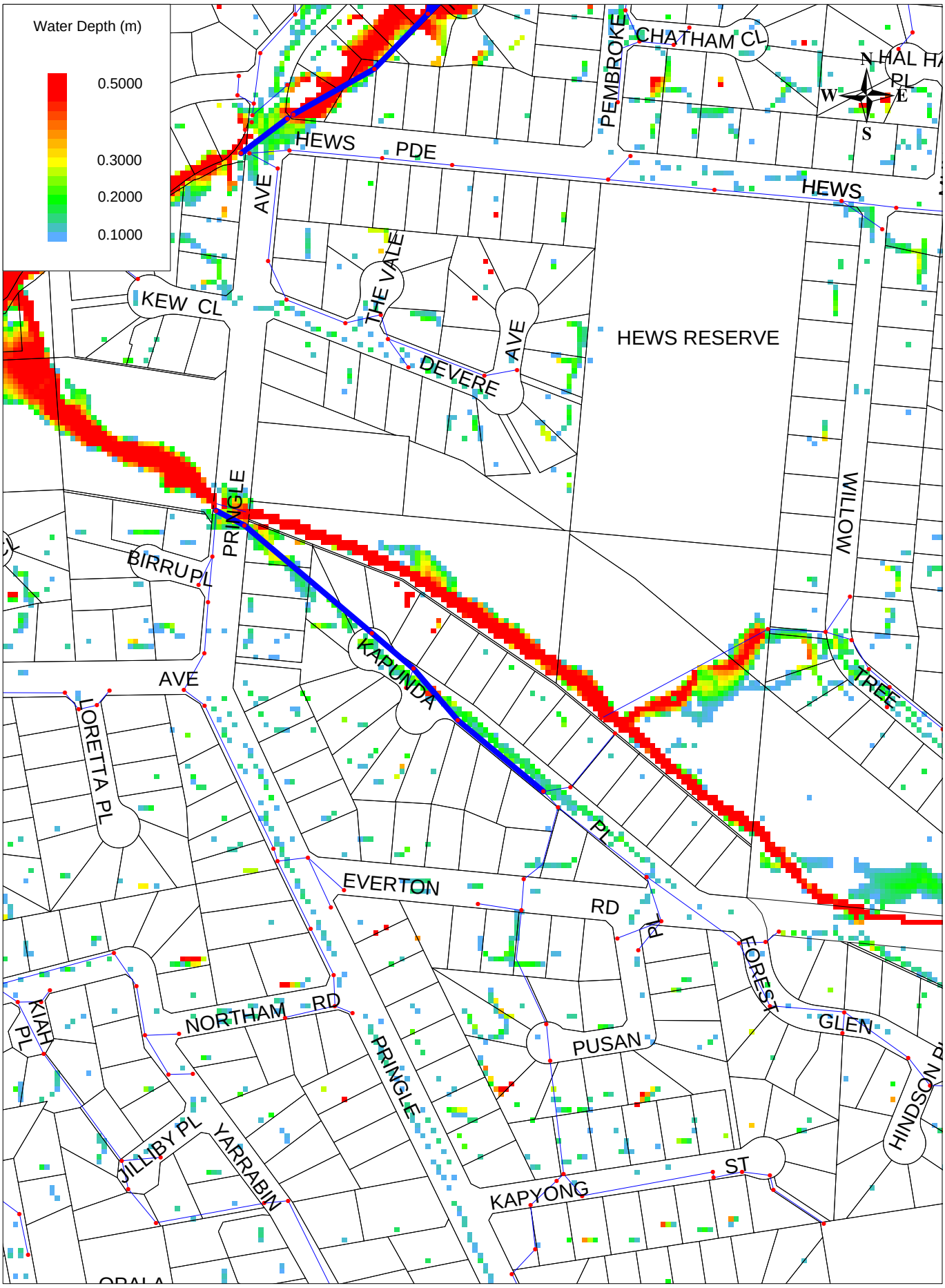
FRMS_Figure20_LeveeKapunda_V4_Fig23.wor

DHI Water & Environment



Pipe Upgrade

Upgrade of Stormwater Pipes from Kapunda Place to Pringle Avenue
1% AEP Flood Event
Figure 24

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FRMS_Figure21_PipesKapunda_V4_Fig24.wor

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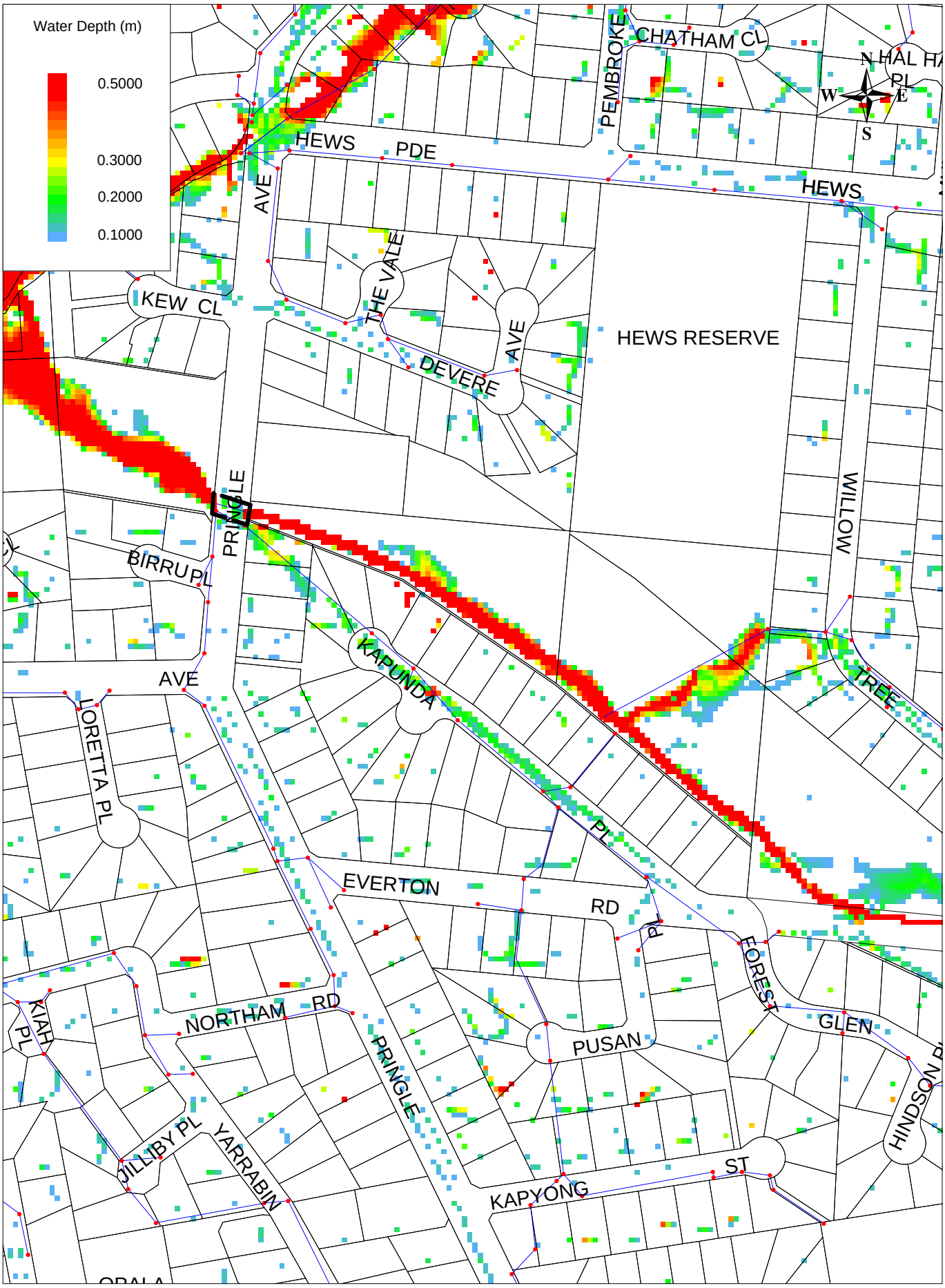

Location of Culvert Upgrade

Upgrade of South Pringle Avenue Culvert
1% AEP Flood Event
Figure 25

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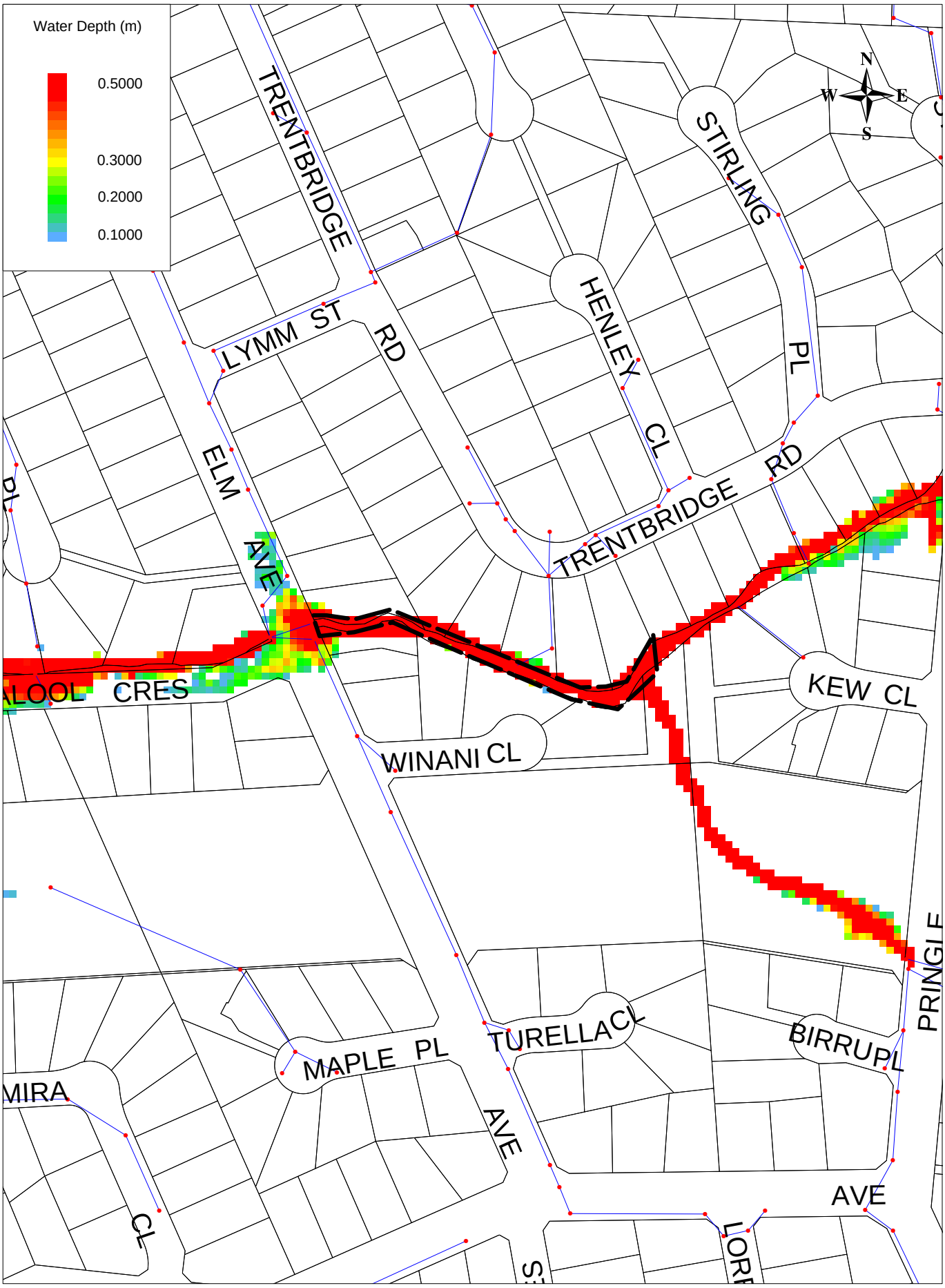
FRMS_Figure22_PringleCulvert_V4_Fig25.wor

DHI Water & Environment



Region of Creek to be Widened

Widening of Frenchs Creek
Upstream of Elm Avenue Culverts
1% AEP Flood Event
Figure 26

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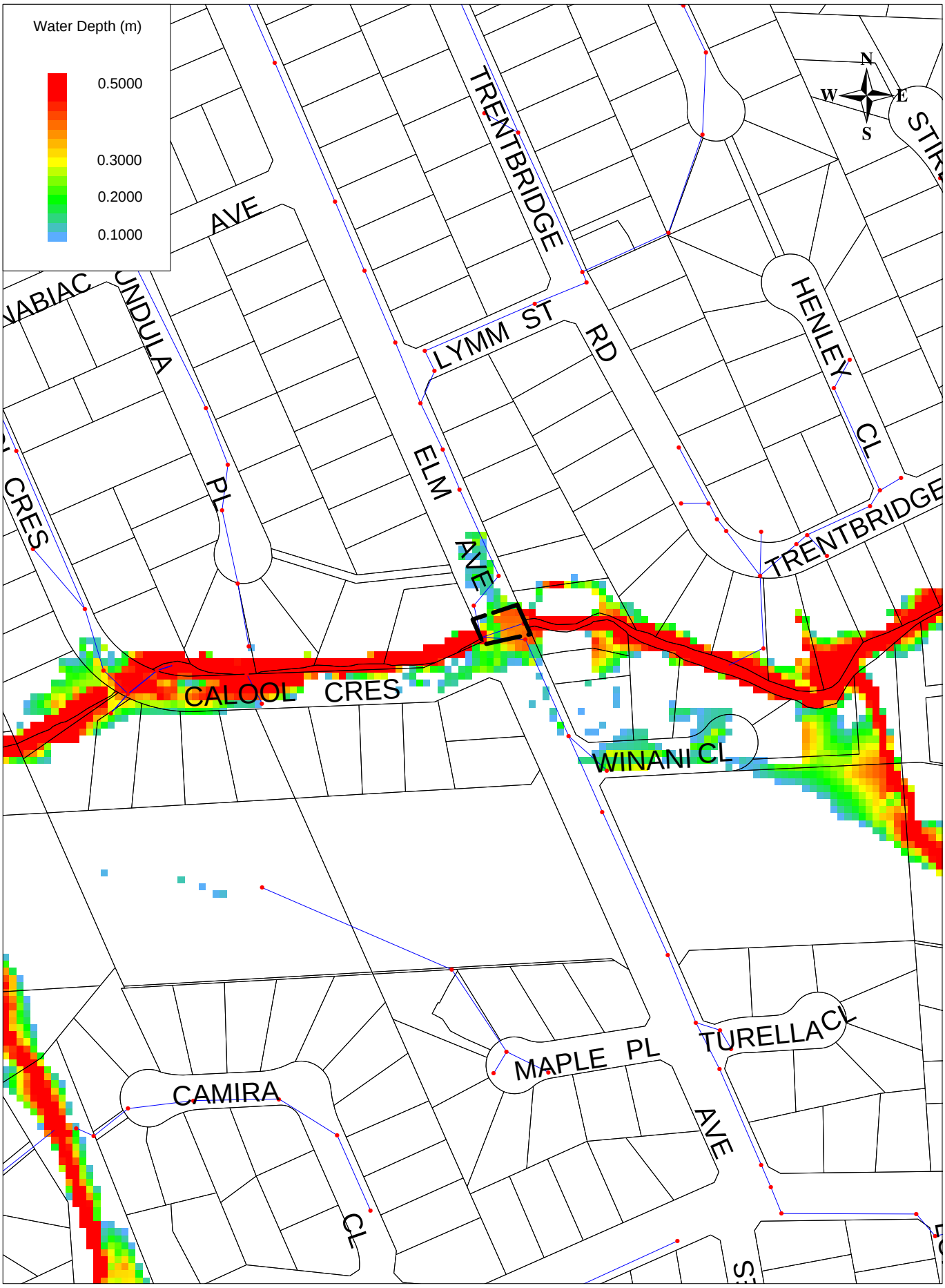
FRMS_Figure23_WidenFrenchs_V4_Fig26.wor

DHI Water & Environment



Location of Culvert Upgrade Works

Upgrade of Elm Avenue Culverts
1% AEP Flood event
Figure 27

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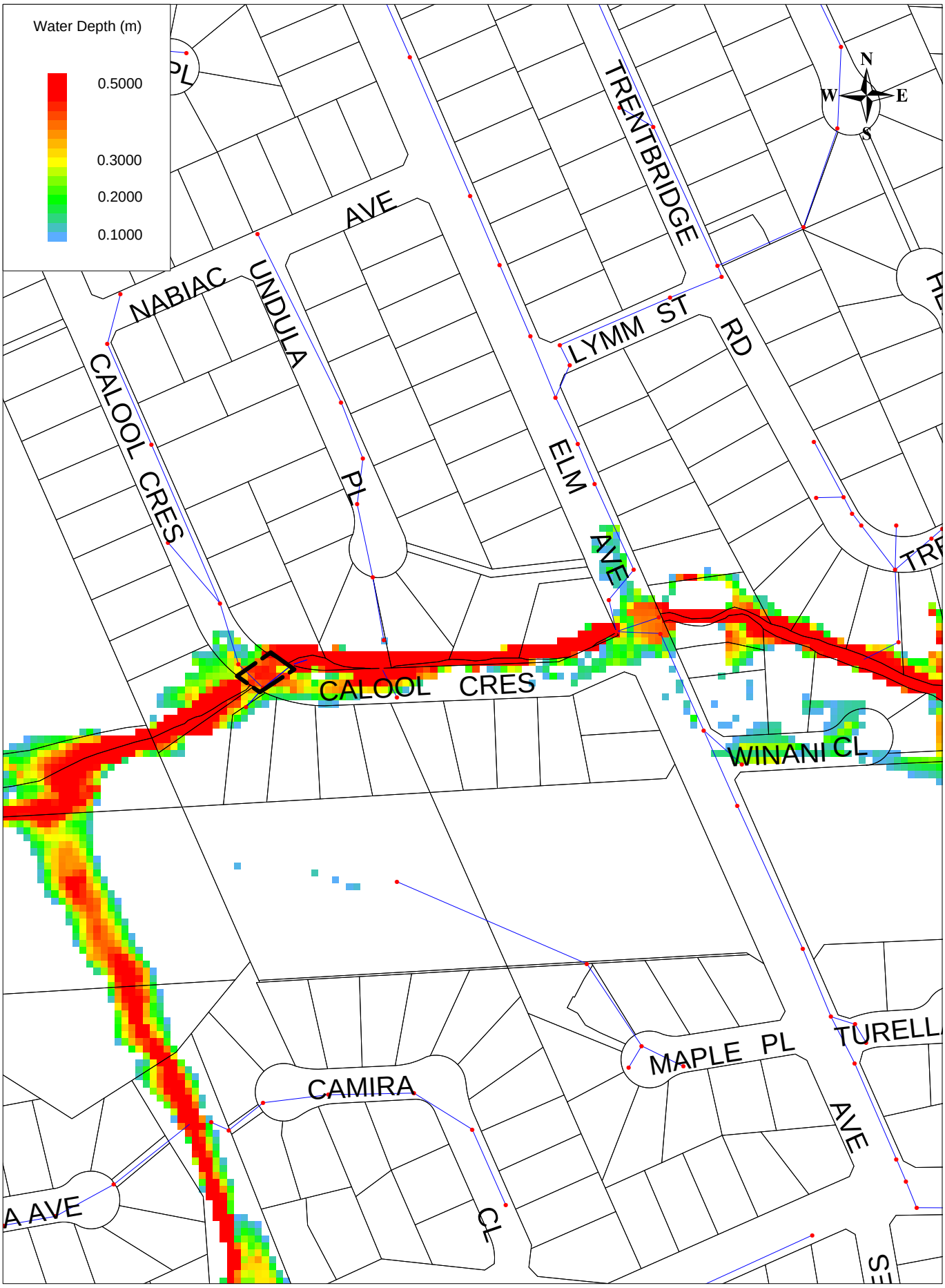
FRMS_Figure24_UpgradeElm_V4_Fig27.wor

DHI Water & Environment



Location of Culvert Upgrade Works

Upgrade of Calool Crescent Culverts
1% AEP Flood Event
Figure 28

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FRMS_Figure25_UpgradeCalool_V4_Fig28.wor

DHI Water & Environment

A P P E N D I X A

WARRINGAH COUNCIL FLOODSAFE BROCHURE

Being FloodSafe in Warringah

The Warringah area is known for its beautiful natural bushland, beaches and waterways. Some of these waterways are prone to flooding. Flooding affects people and property and can cause major losses including life, property, possessions and livelihood.

Warringah has experienced large flood events in the past. Including April 1998, Easter 1998 and March 2003. A series of smaller floods have also taken place. Even these smaller floods threatened people and property.

This brochure has been produced by Warringah Council with assistance from the NSW State Emergency Service (SES) as a guide for residents living near or in flood prone areas. It provides information on flood issues and advice for residents before, during and after flooding.

Flood types

There are two main types of floods that occur in the Warringah area.

1. Flash floods
Usually occur during storms with heavy rainfall when creeks break their banks or the capacity of drainage systems is reached. Often they are sudden and unexpected, with little or no warning. Flash floods can be dangerous with fast flowing floodwater, and can occur in rural and urban areas.

2. Lagoon flooding
When lagoons flood, it can take several days for water levels to subside. It often takes a long time for the water to be released to the sea, because tides and waves can affect the flow rate. This can make flooding last longer and result in disruption to transport over large areas and loss of services and utilities. Lagoon flooding can also be made worse when severe winds create waves on the lagoons.

Lagoon flooding is usually confined to the lagoons and their floodplains. It is important to remember that large floods are inevitable and in many cases, will overwhelm the existing stormwater network and force open lagoons.

Prepare yourself

It is important to prepare your family and property now for the possibility of flooding as floods can occur at any time of the year. Check your insurance policy. Some basic measures you can take right now include keeping a list of emergency numbers near the telephone and assembling an Emergency Kit.

Your Emergency Kit should contain at all times:
- A portable radio with spare batteries
- A torch with spare batteries
- A first aid kit (with supplies relevant for your household or business)
- Candles and waterproof matches
- A waterproof bag for valuables
- Emergency contact numbers

When flooding is likely, place in your Emergency Kit:
- Important papers and photos
- A good supply of required medications
- Any special requirements for babies and the disabled, infirm or elderly
- Strong shoes
- Suitable food and drinks

BUSINESS OWNERS AND MANAGERS
Your business should have a Business FloodSafe Plan. The SES has an interactive 'Business FloodSafe Toolkit' available on the SES website. You can use this toolkit to develop your Business FloodSafe Plan. You should decide where you will move stock and equipment to and how it will be transported. Keep backups of important records and store these in a flood free location. Check your insurance policy. Where possible ensure shop fittings are able to resist water damage. Keep a supply of boxes to move stock and records if flooding is likely. Communicate with your employees what their responsibilities will be in the event of a flood.

Every home and business should put together an Emergency Kit

How the SES can help you

The SES is responsible for responding to floods in NSW. This includes planning for floods and educating people about how to protect themselves and their property.

During floods the SES will provide flood information, safety advice and, where appropriate, conduct evacuation and flood rescue.

www.ses.nsw.gov.au

FOR EMERGENCY HELP IN FLOODS AND STORMS CALL THE SES ON

132 500

SES website	www.ses.nsw.gov.au
Warringah Council	9942 2111
Warringah Council website	www.warringah.nsw.gov.au
Bureau of Meteorology website	www.bom.gov.au

Warringah Council

SES STATE EMERGENCY SERVICE

FloodSafe Warringah

Better FloodSafe than Sorry

Protecting yourself from a flood

SES STATE EMERGENCY SERVICE

Picture: Elm Ave, Belrose 2003

Warringah

Newcastle 2007

Bankstown 1988

Bankstown 1988

Heads up on flooding

You should be alert, keep an eye on the weather and keep listening to a local radio station for further information, updates and advice.

For many of the urban areas in Warringah, very heavy rainfall lasting a couple of hours can be sufficient to produce significant flash flooding. These are often the result of severe thunderstorms or stationary weather systems.

The following actions are encouraged.

RESIDENCES

- Locate and check your Home Emergency Kit
- Locate important papers, valuables and mementoes and put them in your Home Emergency Kit
- Check if neighbours are aware of possible flooding
- Locate and prepare pets for possible evacuation
- Stack possessions, records, stock or equipment on benches and tables, placing electrical items on top
- Secure objects that are likely to float and cause damage
- Relocate waste containers, chemicals and poisons well above floor level

BUSINESS OWNERS AND MANAGERS

In addition, business owners and managers should:

- Locate and activate your Business FloodSafe Plan
- Ensure neighbouring businesses are aware of the Weather Warnings
- Where possible back up records and store in a flood free location
- Keep in contact with neighbouring businesses
- Ensure employees are able to get home before evacuation routes are closed

Newcastle 2007

How you will be advised of a coming flood

Severe Weather Warnings, Severe Thunderstorm Warnings and Flood Watches are issued by the Bureau of Meteorology and will be broadcast over radio stations such as:

702 ABC Sydney	AM 702

These warnings will also be available on the Bureau of Meteorology's website www.bom.gov.au

During a flood

- NEVER drive, ride or walk through floodwater - this is the main cause of major injuries or fatalities during floods as water may be deeper or faster flowing than people think and may contain hidden snags and debris. As little as 20 centimetres of fast flowing floodwater can knock you off your feet
- You should never enter floodwater, but if floodwaters rise around your car, get out and move to higher ground immediately. Cars can easily be swept away in moving water
- DO NOT attempt to cross floodwaters to reach your house if you are returning home – seek safe refuge at a neighbours. The duration of a flash flood is likely to be less than 2hours, so stay put
- Keep listening to a local radio station for further information, updates and advice
- Keep in contact with your neighbours
- Be prepared to evacuate but only do so if advised by the SES
- If you are trapped by floodwaters stay inside your home or business until advised otherwise by the SES

Preparing to evacuate

- Take your Home Emergency Kit with you
- Turn off the electricity and water as you leave and turn off and secure gas bottles
- Local authorities and/or emergency services will advise you of which evacuation points or evacuation centre to go to
- DO NOT leave your pets behind. Put them on leads or in pet containers and take them with you

When you evacuate

You must leave well before roads to high ground are closed by floodwater. Seek shelter with family or friends. In major floods an evacuation centre may be established by the Department of Community Services (DoCS). Information will be available from DoCS State Disaster Recovery Centre on 1800 018 444.

Assistance for animals

The NSW Department of Primary Industries (DPI) provides assistance for livestock, companion animals and wildlife during floods. This may include coordinating the rescue and housing of companion animals. If directed to evacuate, you should take your pets with you. Please search the DPI website for further information, it has an online brochure about the management of pets – www.dpi.nsw.gov.au

After a flood - returning to your home or business

- Check the stability of your property before entering (this needs to be completed by qualified people)
- Ensure that the power lines are not down before you re-enter your property
- Check safety of electrical equipment (this needs to be completed by qualified people)
- Identify slip and trip hazards
- Wear enclosed non-slip shoes, protective clothing and strong gloves when cleaning up after a flood
- Be aware of spiders and snakes
- If you do not need help, check on your neighbours

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