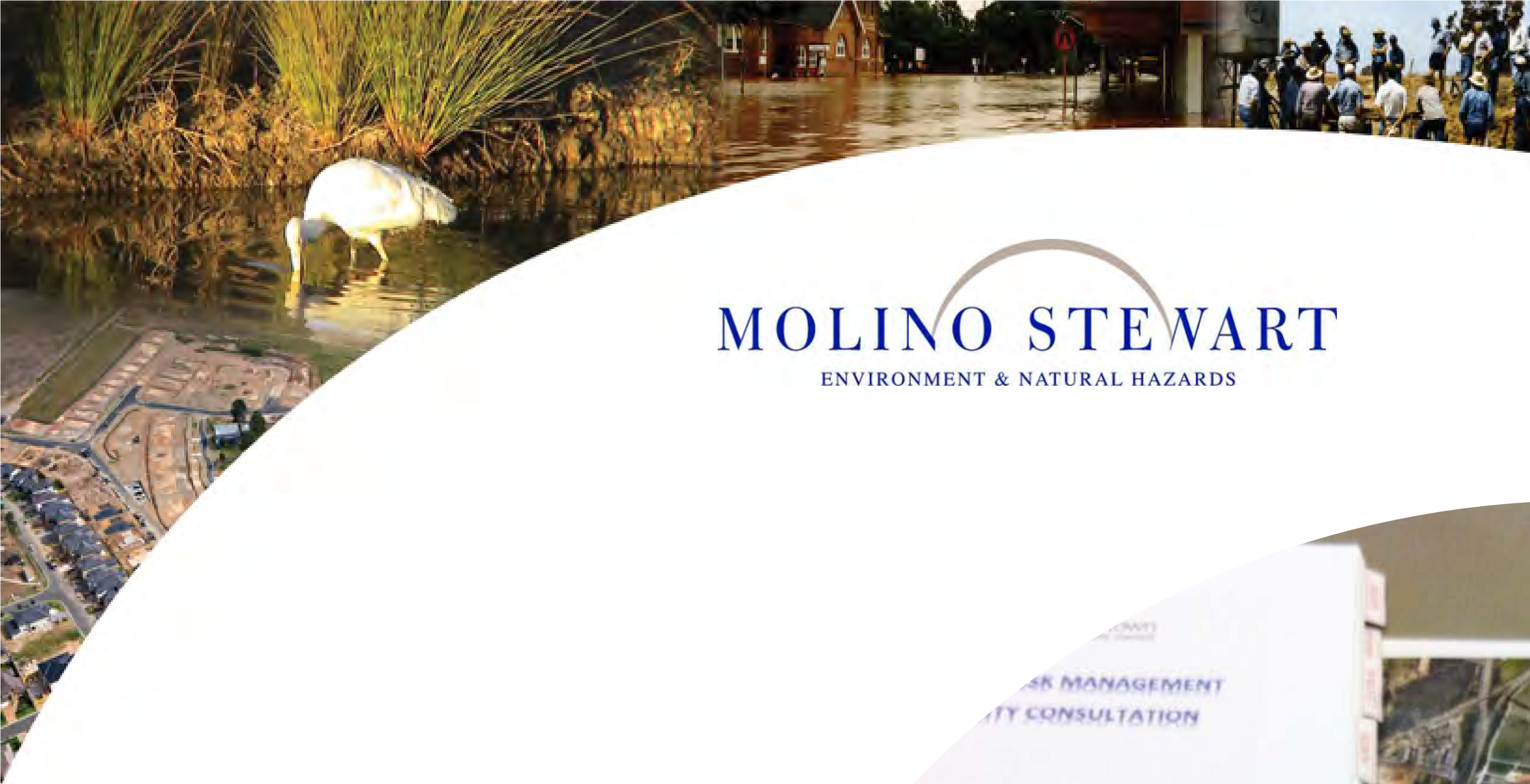

MOLINO STEWART
ENVIRONMENT & NATURAL HAZARDS

campbelltown
city council

Bow Bowing Bunbury Curran Creek Strategic Floodplain Risk Management Study and Plan

Final Draft

Bow Bowing Bunbury Curran Creek Strategic Floodplain Risk Management Study and Plan

FINAL DRAFT

for

Campbelltown City Council

by

Molino Stewart Pty Ltd

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DECEMBER 2018

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DOCUMENT CONTROL

Document Reference	0746_BBBC_FRMSP_Final_Draft_v5.docx
Project	Bow Bowing Bunbury Curran Creek Strategic Floodplain Risk Management Study and Plan
Document Type	Final Draft
Author	Filippo Dall'Osso, Steven Molino

REVISION HISTORY

Date	Version	Name	Comments
13/06/2018	1	Filippo Dall'Osso	First draft for internal review
18/06/2018	2	Steven Molino	Preliminary Draft for Council Review
13/08/2018	3	Steven Molino	Revised Draft for Council Review
14/11/2018	4	Steven Molino	Revised Draft for Council Review
4/12/2018	5	Steven Molino	Final Draft Version

DOCUMENT APPROVAL

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Position	Coordinator Stormwater and Structural Design

The Bow Bowing Bunbury Curran Strategic Floodplain Risk Management Study and Plan includes the Campbelltown Locality, Ingleburn Locality and Remainder Bow Bowing Bunbury Curran Creek projects. Campbelltown City Council has prepared this document with financial assistance from the NSW and Australian Governments through the Natural Disaster Resilience Program and with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage or the Australian Government.

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PART A: CONTEXT

1 INTRODUCTION

1.1 BACKGROUND

Campbelltown City Council adopted a Flood Mitigation Scheme in 1984 which has been jointly funded by the State and Federal Governments and Council on an ongoing basis since that time. Construction of works as part of this scheme has occurred for the past 30 years.

In 2014, Council endorsed the final draft of the Bow Bowing Bunbury Curran (BBBC) Creek Catchment Flood Studies, which comprises twelve separate sub catchment flood studies.

The present Floodplain Risk Management Study builds upon the 2014 Flood Studies to assess and address flood risk to people and assets within the study area.

1.2 FLOODPLAIN RISK MANAGEMENT PROCESS

The NSW Government's Flood Prone Land Policy as outlined in the *Floodplain Development Manual* (NSW Government, 2005) has the primary objective of reducing 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 flood. It aims to provide solutions to existing flood problems in developed areas and ensuring that new development is compatible with the flood hazard, not creating additional flooding problems in other areas and is undertaken using ecologically, economically and socially sustainable methods. Under the Policy, the management of flood prone land is the responsibility of Local Government. The NSW Government's Floodplain Management Program is administered by the Office of Environment and Heritage (OEH) and provides councils with technical and financial assistance to undertake flood studies and floodplain risk management studies and plans, and for the implementation of recommended works identified in those plans.

The implementation of the Flood Prone Land Policy generally culminates in the preparation and implementation of a Floodplain Risk Management Plan (FRMP) by Council, which is the ultimate objective of the current study. Community engagement is an important part of the process and this has been undertaken via Council's Floodplain Management Committee and public displays with the local community.

The steps in the floodplain management process are summarised in Figure 1. This report presents the Floodplain Risk Management Study and Plan (FRMS&P) for the whole of the BBBC Creek catchment, including the Campbelltown and Ingleburn Localities

Council has prepared this document with financial assistance from the NSW Government through the Office of Environment and Heritage (OEH). The report includes in a single document the work undertaken for the Ingleburn and Campbelltown localities and the BBBC remainder catchments which were covered by three separate grants from OEH. This document does not necessarily represent the opinions of the NSW Government or OEH.

The assistance of Council's Floodplain Management Committee and officers from Campbelltown City Council and OEH in preparing this document is gratefully acknowledged.

1.3 STUDY AREA

The study area (Map 1, Vol. 2) comprises the Bow Bowing Bunbury Curran Creek (BBBC) catchment, located in the City of Campbelltown, 53km south west of the Sydney CBD.

BBBC Creek runs from southwest to northeast through a combination of formalised channels and natural creek lines, discharging to the Georges River at Glenfield. The catchment has an area of approximately 90km², and includes natural BBBC creek tributaries, as well as a system of open channels and an extensive underground stormwater pipe network.

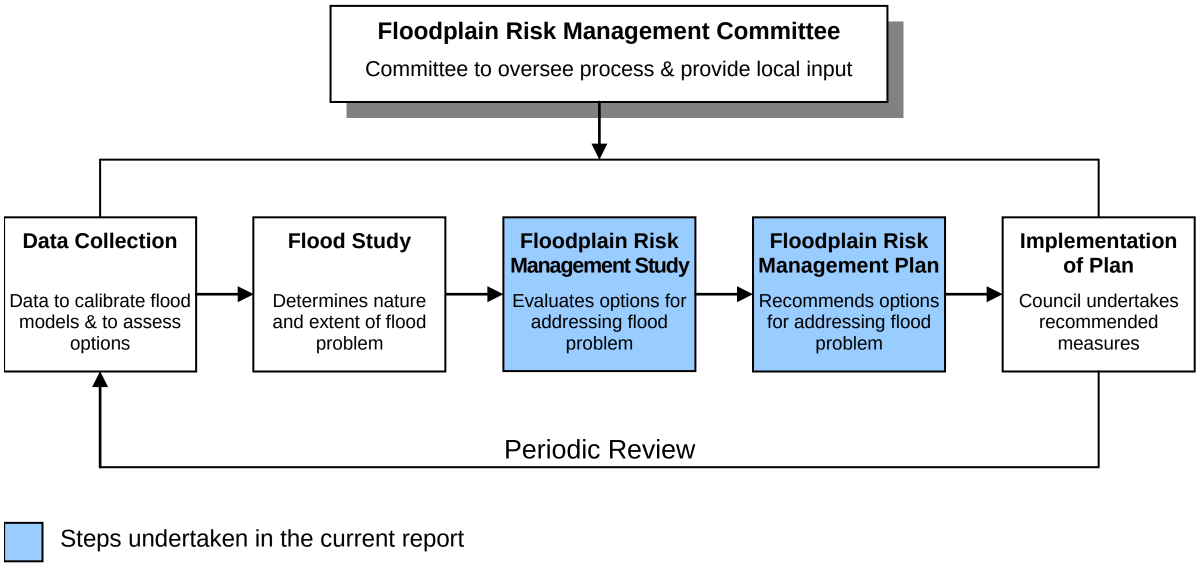


Figure 1. Floodplain risk management process in NSW (NSW Government, 2005)

Campbelltown City is home to a population of more than 150,000 people, and is a significant centre for the Macarthur region, providing a broad range of services and facilities, including a major hospital, university, two TAFE colleges, arts centre, public transport, large shopping centres and a large and growing commercial and industrial sector. The catchment is a mixture of rural, residential, commercial, industrial and open space land use. It is predominantly residential land use with large areas of open space.

There are significant localised industrial areas at both Minto and Ingleburn. The main commercial hubs are in Campbelltown/Macarthur and Ingleburn. Most other suburbs in the local government area have their own smaller commercial pockets to cater for their local needs.

Table 2 shows the suburbs located wholly or partially within the study area.

Table 1. Suburbs located within the study area

ST ANDREWS	WOODBINE	VARROVILLE
KEARNS	RABY	AIRDS
CLAYMORE	MACQUARIE FIELDS	BARDIA
ENGLORIE PARK	BLAIRMOUNT	CAMPBELLTOWN
LEUMEAH	MINTO	ESCHOL PARK
MACQUARIE LINKS	GLEN ALPINE	BRADBURY
BLAIR ATHOL	RUSE	INGLEBURN
DENHAM COURT	GLENFIELD	AMBARVALE
BOW BOWING	EAGLE VALE	

1.4 SCOPE

Campbelltown City Council is responsible for local planning and land management in the BBBC Creek Catchment, including the management of the flood prone land.

The overall purpose of this study is to find practical, affordable and acceptable measures to manage the impacts of flooding on people, property and the environment.

The BBBC FRMS&P has the following major objectives:

- To summarise flood behaviour in the catchment, drawing upon the most up to date flood studies;
- To identify problem areas and areas that will require further detailed FRMSP
- To assess potential flood damages in the study area;
- To preliminarily identify and evaluate potential works, measures and restrictions aimed at reducing the social, environmental and economic impacts of flooding, addressing existing, future and continuing flood risk, over the full range of potential flood events and taking into account the potential impacts of climate change;
- To develop an initial strategic plan to manage existing, future and continuing flood risk, ensuring that the Strategic FRMP is integrated with Council's existing corporate, business and strategic plans, existing and proposed planning proposals, meets Council's obligations under the Local Government Act, 1993, and has the support of the local community

At a later date more detailed analysis will need to be undertaken at a smaller scale at specific locations.

1.5 OUTLINE OF THIS REPORT

This report is in two volumes.

Volume 1 of the report includes ten sections within four main parts:

- Part A: Context, including sections 1 to 5;
- Part B: Flood behaviour and impacts, including sections 6 to 8;
- Part C: Flood risk management measures, including sections 9 to 11;
- Part D: Draft Floodplain Risk Management Plan (section 12);

The overall content of each section is summarised below:

- Section 1 (this section) sets the background and the project scope;
- Section 2 provides a description of the geographic, socio-economic and environmental features of the catchment;
- Section 3 provides an overview of the existing planning and regulatory system related to flood risk management;
- Section 4 sets the emergency management context;
- Section 5 outlines the work that was done as part of this FRMS to engage with key stakeholders and the broader community;
- Section 6 summarises previous and existing flood studies and numerical models;
- Section 7 provides a summary of the flood behaviour within the study area, as described by the most recent flood studies;
- Section 8 includes an assessment of direct and indirect flood damages for each modelled flood event and estimates them under existing conditions. This includes risk to people;
- Section 9 provides an overview of how flood risk mitigation can be achieved in general terms;
- Section 10 identifies and evaluates potential mitigation options to address flood risk at specific locations and presents preferred options for inclusion in the Floodplain Risk Management Plan;
- Section 11 identifies and evaluates potential mitigation options to address flood risk at the catchment scale and presents preferred options for

inclusion in the Floodplain Risk Management Plan;

- Section 12 provides a plan for the implementation of the preferred options.

To facilitate the ease of reading and correct interpretation of this report, the most detailed technical information has been included in a number of appendices.

Volume 2 of the report contains A3 maps at a suitable scale to be read in conjunction with Volume 1.

1.6 FLOOD PROBABILITY TERMINOLOGY

Appendix A provides a comprehensive glossary of technical terms and abbreviations used in this document. However, throughout the document reference is made to the magnitude of floods by reference to their probability of occurrence. This can be expressed in several different ways.

A common way in which it is expressed is in terms of an average recurrence interval (ARI). This is a statistical estimate of the average number of years between the occurrences of a flood of a given size or larger. For example, floods with a flow as great as or greater than the 20-year ARI flood event will occur, <u>on average</u>, once every 20 years over a very long period of time. A 100-year ARI is an event which is likely to occur on average once every 100 years over a very long period of time.

The ARI terminology will often be abbreviated to refer to these events as the 20 year flood or the 100 year flood. This can be misleading as it can give the impression that these events occur every 20 years or 100 years respectively. This is not the case. It is possible to have 100-year ARI floods in consecutive years as occurred in Kempsey in 1949 and 1950 or even as consecutive events. It is also possible not to have one of these floods for more than 100 years as is the case on the Georges River.

An alternative way of describing flood probability is in terms of its annual exceedance probability (AEP). This is 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 flood has an AEP of 5%, it means that there is a 5% chance (i.e., a one-in-20 chance) of this flood or larger events occurring in any one year. The 1% AEP flood has a 1 in 100 chance of occurring in any year and is equivalent to the 100-year ARI flood.

Throughout this document flood probability will be referred to in terms of AEP except where it references another document which uses ARI.

A flood with a 1 in 100 (1%) chance per year has about a 1 in 2 (50%) chance of being reached or exceeded in a 70 year period, or roughly the same probability of tossing a coin and getting a head.

Bigger floods can and do occur. There were several floods with greater than a 1 in 100 chance per year experienced in Eastern Australia in early 2011. Some reached levels which have a 1 in 1,000 (0.01%) chance per year.

A flood with a 1 in 500 (0.02%) chance per year has about a 1 in 6 chance of being reached or exceeded in a 70 year period, the same as tossing a die and getting a 6.

The largest flood that can occur is referred to as the Probable Maximum Flood (PMF). Although it has a very low probability of occurring in any one year, floods approaching a PMF have been recorded.

2 CATCHMENT CHARACTERISTICS

2.1 CATCHMENT DESCRIPTION

The BBBC Creek catchment is mostly developed. There are major industrial areas at Minto and Ingleburn adjoining BBBC Creek, and commercial areas in Campbelltown/Macarthur and Ingleburn, also located near BBBC Creek.

There are a number of lateral tributaries discharging into BBBC Creek main channel including: Macquarie Creek; Raby Main Drain; Redfern Creek; Bunbury Curran Creek; Minto Main Drain No. 1; Thompsons Creek; Minto Main Drain No. 2; Claymore Main Drain; Smiths Creek; Monastery Creek; Dumaresq Street Main Drain; Fishers Ghost Creek; Birunji Creek; Biriwiri Creek and several other minor tributaries.

The main channel takes several forms along its length as detailed in Table 2.

The current flood mitigation scheme comprises more than 86 detention basins within the catchment. Twenty-nine of these are major basins with sizes ranging from 50,000 to 1,000,000 m^3 and the rest are smaller cascading basins (less than 50,000 m^3). Most of the small basins are hydraulically interconnected. The basins generally have aesthetic, environmental and/or active recreation purposes.

The main channels, and many of the tributaries, contain numerous stormwater structures including weirs, drop structures, culverts and bridges.

Table 2. Main BBBC Channel Form

Main Channel: from	Main Channel: to	Form of Channel	Length (km)
Glen Alpine	Gilchrist Oval	Highly Modified Creek and pipe with Detention Basin Playing Fields	1.9
Gilchrist Oval	Start of Concrete Channel	Natural	1.2
Start of Concrete Channel	Campbelltown Road	Concrete Trapezoidal Channel	1.5
Campbelltown Road	Kayess Park	Grass Trapezoidal Channel with Concrete Low Flow	3.7
Kayess Park	Railway corridor	Natural	1.6
Railway corridor	Macquarie Links Golf Course	Grass Trapezoidal Channel with Concrete Low Flow	0.4
Macquarie Links Golf Course	Macquarie Fields Drop Structure	Trapezoidal Concrete Channel	0.4
Macquarie Fields Drop Structure	Railway Bridge Macquarie Fields/Glenfield	Grass Channel	1.1
Railway Bridge Macquarie Fields/Glenfield	Glenfield Drop Structure	Grass Trapezoidal Channel with Concrete Low Flow	0.7
Glenfield Drop Structure	Georges River Confluence	Natural	2.2
		Total Length	19.4

2.2 TOPOGRAPHY

The topography of the BBBC Creek catchment is generally mildly undulating with some steeper sections on the edge of the catchment and a broad flat floodplain along the route of BBBC Creek (Map 2, Vol. 2). Elevation ranges between about 3m AHD to almost 200m AHD. The lowest parts of the catchment are found in Glenfield, while the highest are along the south-east boundary of the catchment, in Ruse and Airds. In addition to the BBBC Creek, the topography is shaped by the creek's tributaries.

2.3 ENVIRONMENT

It is important to understand the environmental assets within a catchment because these may:

- be adversely impacted by flooding;
- affect flood behaviour by impeding flood flows;
- be a constraint to implementing some flood mitigation options;
- be enhanced when implementing some flood mitigation options.

The BBBC Creek floodplain features elements of the Cumberland Plain and the Georges River floodplains, which occur on low rolling hills and valleys on horizontal shales, with channels, floodplain and terraces of alluvial sediments, of mostly clayey sand and sand with limited gravel on the highest terraces. These soil landscapes give rise to a number of vegetation communities within the BBBC floodplain and catchment, a number of which are threatened ecological communities (TEC) listed under NSW or Commonwealth legislation.

Vegetation communities that are TEC mapped by the Office of Environment and Heritage (OEH) that may constrain flood mitigation include:

- Cumberland Swamp Oak Riparian Forest (Plant Community Type (PCT) 1800);
- Cumberland Riverflat Forest, (PCT 835);
- Hinterland Riverflat Forest (PCT 941);
- Cumberland Shale Plains Woodland (PCT 849);
- Castlereagh Shale Gravel Transition Forest (PCT 724);
- Cumberland Shale Hills Woodland (PCT 850).

The first three of these vegetation communities form part of the River-Flat Eucalypt Forest Endangered Ecological Community (EEC) listed under the *NSW Biodiversity Conservation (BC) Act, 2016*.

The second group of three vegetation communities form part of the Cumberland Plain Woodland which is listed as Critically Endangered under the NSW BC Act. The listing includes unmapped areas of Derived Grasslands (PCTs 806-808) cleared of trees.

The Cumberland Plain Woodland areas may also satisfy the Commonwealth Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest Critically Endangered Ecological Community (CEEC), depending on the condition of the vegetation. If so, it is protected under the Commonwealth *Environment Protection Biodiversity Conservation Act, 1999*.

Extensive clearing of the catchment for rural and urban development has resulted in a dramatic reduction in natural areas. Map 3 (Vol. 2) shows the areas of remnant vegetation within the BBBC Creek catchment (OEH, 2016).

Cumberland Plain Woodland and Riverflat Forest provide habitat for a variety of flora and fauna such as honeyeaters, cockatoos, owls and bats, including a number of threatened species shown in Map 4 and Map 5 (Vol. 2). Some of the threatened species within the BBBC Creek Catchment include Spiked Rice-flower (*Pimelea spicata*), Bynoe's wattle (*Acacia bynoeana*), Sydney Plains Greenhood (*Pterostylis saxicola*), Cumberland Plain Land Snail (*Meridolum corneovirens*), Grey-headed Flying Fox (*Pteropus poliocephalus*) and Koala (*Phascolarctos cinereus*).

Threats to their continued survival include loss, fragmentation and degradation of habitat due to clearing for urban development and infrastructure, stormwater pollution and urban runoff, weed invasion by exotic species, altered fire regimes, as well as the impacts of dogs and cats on species such as koalas.

A number of reserves within the BBBC Creek catchment contain TEC, as well as habitat for threatened species of flora and fauna. There are opportunities to enhance the environment include consolidating habitat links around creekline corridors for the movement of flora and fauna, managing vegetation in areas of high conservation significance, revegetation and regeneration, facilitating fish passage and retaining natural channels.

Enhancement could occur to strengthen linkages along naturally vegetated creekline corridors; where there may be opportunity to restore vegetation along the length or enhance biodiversity in adjacent riparian land.

This may be possible where it will not impact on flood levels on adjoining properties and is subject to further flood modelling.

There may be opportunities to enhance habitat value and water quality through installation of bioretention systems, where land permits.

These positive environmental outcomes, however, are not in and of themselves eligible for funding under the NSW Floodplain Management Program, unless a benefit in terms of flood risk management can be demonstrated.

2.4 URBAN DEVELOPMENT

The BBBC Creek Catchment includes mostly residential development and large areas of open space. The following land uses are found within the catchment:

- Roads;
- Railway;
- Industrial;
- Commercial;
- Residential;
- Parks and playing fields;
- Rural residential;
- Rural.

The Campbelltown area was originally settled in the early 1800's. The BBBC Creek system provided an intermittent water supply for the early settlers. The original creek line followed a gently meandering alignment to the confluence with the Georges River. As the need for more land for industry, commerce and housing increased, the creek was progressively formalised, straightened and managed so that encroachments into the floodplain could be achieved with reduced risk of flooding. During the 1970's Campbelltown was identified in the "Three Cities Plan - The Macarthur Area - A State Government sponsored development area" and development by the State Government included the filling of extensive sections of the natural floodplain and formalisation of the creek system with trapezoidal flood channels.

The channelisation allowed maximum use of the low-lying floodplain for development, although the methods used at this time would not be used today in view of the preference for more environmentally sustainable solutions.

Since the early 1990's, the State and Federal Governments and Campbelltown Council have jointly funded the construction of a system of detention basins and channels throughout the catchment to reduce and manage the impacts of flooding in events smaller than the 1% AEP flood.

2.5 HERITAGE VALUE

A number of items of heritage significance are located in the BBBC extent of flood prone land. Opportunities to protect these items from the adverse effects of flooding are considered in this FRMS&P. Any proposed floodplain risk management measures need to be sympathetic to the heritage values.

Clause 5.10 of Campbelltown LEP 2015 stipulates that development consent is required for a range of proposed activities including demolishing, moving or altering the exterior of a heritage item, Aboriginal object or item within a heritage conservation area. The consent authority must, before granting consent under this clause in respect of a heritage item or heritage conservation area, consider the effect of the proposed development on the heritage significance of the item or area concerned.

Map 6 (Vol. 2) shows the distribution of non-aboriginal heritage items within the BBBC Creek Catchment. Table 1 (Vol. 2) lists these items.

Regarding aboriginal heritage sites, an AHIMS search was undertaken through the NSW Office of Environment and Heritage website. The search indicated that there are hundreds of aboriginal sites, of various significance, within the study area. For this reason, aboriginal heritage sites will only be discussed in any detail in the areas where structural flood modification works are recommended.

2.6 SOCIAL PROFILE

According to the 2016 census (http://www.censusdata.abs.gov.au), the population of Campbelltown City is 157,006, with a density of 5.02 persons per hectare.

2.6.1 Age

Campbelltown Local Government Area (LGA) has a relatively young population with 21.6% of the population aged between 0 and 14, and 11.9% aged 65 years and over, compared to 18.5% and 16.2% respectively for NSW.

2.6.2 Education

Education level is slightly below the NSW average, with 15.4% of the population who have completed university, and 10% who have not progressed beyond year 9. These figures for NSW are respectively 23.4% and 9.3%.

2.6.3 Culturally and Linguistically Diverse Communities (CALD)

In terms of language, 33.4% of the residents do not speak English at home, while in NSW this figure is significantly lower at 26.5%. And while 62% of the Campbelltown LGA population were born in Australia (compared to 65.5% for NSW), only 38% of these have both parents born in Australia (compared to 45.4% in NSW). These figures indicate that the cultural, ethnic and linguistic diversity in Campbelltown LGA is significantly above the NSW average. This diversity needs to be taken into consideration when communicating about flood risks and mitigation options.

2.6.4 Employment

Unemployment rate in Campbelltown is slightly higher than in NSW (7.9% vs 6.3%), however there is a higher percentage of people working full time (61.3% vs 59.2%). The most common occupations include Clerical and Administrative Workers (16.1%), Professionals (15.3%), Technicians and Trades Workers (13.9%), Machinery Operators and Drivers (11.9%), and Community and Personal Service Workers (11.3%). The median weekly personal income for people aged 15 years and over is $632, while in NSW it is $664.

2.6.5 Dwellings

Almost all dwellings in Campbelltown LGA are occupied (94.7% vs 90.1% in NSW), and for the most part these are detached houses (78.7% vs 66.4% in NSW). The most common house design features three bedrooms (49.6% vs 37.3% in NSW), followed by four bedrooms (34.5%). In terms of tenure, figures are in line with the NSW average, with 63.4% owners (64.5% in NSW) and 32.9% renters (31.8% in NSW).

In addition to this, 82.5% of dwellings have access to the internet, and about 14.7% do not (this is the same as the NSW average).

3 URBAN PLANNING CONTEXT

3.1 OVERVIEW

Appropriate land use planning is one of the most effective measures available to floodplain managers, especially to control future risk but also to reduce existing flood risks as redevelopment occurs. The management and development of flood prone land must be undertaken within the current legislative, policy and planning framework. This Section summarises the main, relevant legislation, policy and guidelines that affect the development of land in the Campbelltown Local Government Area (LGA).

3.2 NATIONAL PROVISIONS

3.2.1 Building Code of Australia

The 2013 edition of the Building Code of Australia (BCA) (Australian Government, 2013) introduced new requirements related to building in flood hazard areas (FHAs), which provide a minimum construction standard across Australia for specified building classifications in FHAs up to the defined flood event (DFE). The DFE is typically the 1% AEP flood as is the case in Campbelltown LGA.

BCA 2013 contains new Performance Requirements and Deemed-to-Satisfy (DTS) provisions relative to construction in a FHA.

Volume One, BP1.4 and Volume Two, P2.1.2 specify the Performance Requirements for the construction of buildings in FHA. They only apply to buildings of Class 1, 2, 3, 4, (dwellings of various kinds) and 9a health-care buildings and 9c aged-care buildings. These Performance Requirements require a building in a FHA to be designed and constructed to resist flotation, collapse and significant permanent movement resulting from flood actions during the DFE. The actions and requirements to be considered to satisfy this performance requirement include but are not limited to:

- flood actions;
- elevation requirements;
- foundation and footing requirements;
- requirements for enclosures below the flood hazard level;
- requirements for structural connections;
- material requirements;
- requirements for utilities; and
- requirements for occupant egress.

The DTS provisions of Volume One, B1.6 and Volume 2, 3.10.3.0 require buildings in the classes described above and located in FHAs to comply with the ABCB *Standard for Construction of Buildings in Flood Hazard Areas 2012* (the ABCB Standard).

The ABCB Standard specifies detailed requirements for the construction of buildings to which the BCA requirements apply, including:

- resistance in the DFE to flood actions including hydrostatic actions, hydrodynamic actions, debris actions, wave actions and erosion and scour;
- floor height requirements, for example that the finished floor level of habitable rooms must be above the Flood Hazard Level (FHL) which is defined as the DFE plus freeboard (see Section 3.4.1 re freeboard provisions in Campbelltown LGA);
- the design of footing systems to prevent flotation, collapse or significant permanent movement;
- the provision in any enclosures of openings to allow for automatic entry and exit of floodwater for all floods up to the FHL;
- ensuring that any attachments to the building are structurally adequate and do not reduce the structural capacity of the building during the DFE;
- the use of flood-compatible structural materials below the FHL;
- the siting of electrical switches above the FHL, and flood proofing of electrical conduits and cables installed below the FHL; and
- the design of balconies etc. to allow a person in the building to be rescued

by emergency services personnel, if rescue during a flood event up to the DFE is required.

Building Circular BS13-004 (NSW Department of Planning and Infrastructure, 2013) summarises the scope of the BCA and how it relates to NSW planning arrangements. The scope of the ABCB Standard does not include parts of a FHA that are subject to flow velocities exceeding 1.5 m/s, or are subject to mudslide or landslide during periods of rainfall and runoff, or are subject to storm surge or coastal wave action. It is particularly noted that the Standard applies only up to the flood hazard level (FHL), which typically will correspond to the level of the 1% AEP flood plus 0.5m freeboard in NSW. The Building Circular emphasises that because of the possibility of rarer floods, the BCA provisions do not fully mitigate the risk to life from flooding.

The ABCB has also prepared an *Information Handbook for the Construction of Buildings in Flood Hazard Areas*. This Handbook provides additional information relating to the construction of buildings in FHA, but is not mandatory or regulatory in nature.

The BCA also has provisions generally for the minimum level of habitable floors above the ground in any location to prevent water entering the building. In areas such as Campbelltown LGA, the floor needs to be at least 150mm above the external finished surface or 50mm above an impermeable surface (e.g. concrete) which slopes away from the building at greater than 50mm over 1m.

In the NSW planning system, the BCA takes on importance for complying development under the *State Environmental Planning Policy (Exempt and Complying Development Codes) 2008* (see Section 3.3.2c)). The Building Circular also indicates that following development approval, an application for a construction certificate (CC) will require assessment of compliance with the BCA.

3.3 STATE PROVISIONS

3.3.1 Environmental Planning and Assessment Act 1979

The NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) creates the mechanism for development assessment and determination by providing a legislative framework for development and protection of the environment from adverse impacts arising from development. The EP&A Act outlines the level of assessment required under State, regional and local planning legislation and identifies the responsible assessing authority.

a) Section 9.1 Directions – Direction No. 4.3 (Flood Prone Land)

NSW flood related planning requirements for local councils are set out in Ministerial Direction No. 4.3 Flood Prone Land, issued in 2007 under section 117 of the EP&A Act. The Act was amended in March 2018 and Section 117 became Section 9.1 but at the time this FRMS was written the direction had not been reissued with a new title.

It requires councils to ensure that development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy as set out in the NSW Floodplain Development Manual (NSW Government, 2005). It requires provisions in a Local Environmental Plan on flood prone land to be commensurate with the flood hazard of that land. In particular, a planning proposal must not contain provisions that:

- permit development in floodway areas;
- permit development that will result in significant flood impacts to other properties;
- permit a significant increase in the development of that land;
- are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services; or
- permit development to be carried out without development consent except for the purposes of agriculture, roads or exempt development.

The Direction also requires that councils must not impose flood related development controls above the residential flood planning level (typically the 1% AEP flood plus 0.5m freeboard) for standard residential development on land, unless a relevant planning authority provides adequate justification for exceptional circumstances that require those controls to the satisfaction of the Planning Secretary.

b) Section 10.7 Planning Certificates

Planning certificates are a means of disclosing information about a parcel of land. Two types of information are provided in planning certificates: information under Section 10.7(2); and information under Section 10.7(5) of the EP&A Act. These were formerly known as Section 149 Certificates under the previous version of the Act.

A planning certificate under Section 10.7(2) discloses matters relating to the land, including whether or not the land is affected by a policy that restricts the development of land. Those policies can be based on identified hazard risks (*Environmental Planning and Assessment Regulation 2000*, Clause 279 and Schedule 4 Clause 7), and whether development on the land is subject to flood-related development controls (EP&A Regulation, Schedule 4 Clause 7A). If no flood-related development controls apply to the land, the land's flood hazard would not be indicated under Section 149(2) such as for residential development in so-called 'low' risk areas above the flood planning level, unless exceptional circumstances have been granted.

A planning certificate may also include information under Section 10.7(5). This allows a council to provide advice on other relevant matters affecting the land, including past, current or future issues. The detail provided in relation to flooding by a Council on a Section 10.7(5) certificate is at the discretion of the Council.

Inclusion of a planning certificate containing information prescribed under section 10.7(2) is a mandatory part of the property conveyancing process in NSW. The conveyancing process does not mandate the inclusion of information under section 10.7(5) but any purchaser may request such information be provided, pending payment of a fee to the issuing council.

c) Guideline on Development Controls on Low Flood Risk Areas, 2007

The *Guideline on Development Controls on Low Flood Risk Areas – Floodplain Development Manual* (the Guideline) was issued on 31 January 2007 as part of Planning Circular PS 07-003 at the same time as the Section 117 Directive described previously. The Guideline is intended to be read as part of the *Floodplain Development Manual*.

It stipulates that 'unless there are exceptional circumstances, councils should not impose flood related development controls on residential development on land … that is above the residential FPL'. There are some inconsistencies in the Guideline which also defines the FPL as "the 100-year flood plus an appropriate freeboard (typically 0.5m)".

Flood related development controls are not defined but would include any development standards relating to flooding applying to land, that are a matter for consideration under Section 4.15C of the EP&A Act.

The Guideline states that councils should not include a notation for residential development on Section 10.7(2) certificates for land above the residential FPL if no flood related development controls apply to the land. However, the Guideline does include the reminder that councils can include 'such other relevant factors affecting the land that the council may be aware [of]' under Section 10.7(5) of the EP&A Act. This would allow Councils to provide advice regarding flooding above the FPL up to the PMF.

In proposing a case for exceptional circumstances, a council would need to demonstrate that a different FPL was required for the management of residential development due to local flood behaviour, flood history, associated flood hazards or a particular historic flood. Justification for exceptional circumstances would need to be agreed by the Office of Environment and Heritage and the Department of Planning and Environment prior to exhibition of a draft local environmental plan or a draft development control plan that proposes to introduce flood related development controls on residential development.

3.3.2 State Environmental Planning Policies

State Environmental Planning Policies or SEPPs are the highest level of planning instrument and generally prevail over Local Environmental Plans.

a) SEPP (Housing for Seniors or People with a Disability) 2004

State Environmental Planning Policy (Housing for Seniors or People with a Disability) 2004 aims to encourage the provision of housing (including residential care facilities) that will increase the supply of residences that meet the needs of seniors or people with a disability. This is achieved by setting aside local planning controls that would prevent such development.

Clause 4(6) and Schedule 1 indicate that the policy does not apply to land identified in another environmental planning instrument (such as Campbelltown LEP 2015) as being, amongst other descriptors, a floodway or high flooding hazard.

b) SEPP (Infrastructure) 2007

State Environmental Planning Policy (Infrastructure) 2007 aims to facilitate the effective delivery of infrastructure across the State by identifying development permissible without consent. *SEPP (Infrastructure) 2007* allows Council to undertake stormwater and flood mitigation work without development consent.

c) SEPP (Exempt and Complying Development Codes) 2008

A very important SEPP is *State Environmental Planning Policy (Exempt and Complying Development Codes) 2008* (Codes SEPP), which defines development which is exempt from obtaining development consent and other development which does not require development consent if it complies with certain criteria.

Clause 1.5 of the Codes SEPP defines a 'flood control lot' as 'a lot to which flood related development controls apply in respect of development for the purposes of dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (other than development for the purposes of group homes or seniors housing)'. These development controls may apply through a LEP or DCP. Exempt development is not permitted on flood control lots but some complying development is permitted.

Clause 3.36C states that complying development is permitted on flood control lots where a Council or professional engineer can certify that the part of the lot proposed for development is not a flood storage area, floodway area, flow path, high hazard area or high risk area. The Codes SEPP specifies various controls in relation to floor levels, flood compatible materials, structural stability (up to the PMF if on-site refuge is proposed), flood affectation, safe evacuation, car parking and driveways.

In addition, Clause 1.18(1)(c) of the Codes SEPP indicates that complying development must meet the relevant provisions of the Building Code of Australia (refer Section 3.2.1).

3.4 LOCAL PROVISIONS

In NSW, local government councils are responsible for managing their flood risk. A Local Environmental Plan (LEP) is used to establish what land uses are permissible and/or prohibited on land within the local government area (LGA), and sets out high level flood planning objectives and requirements. A Development Control Plan (DCP) sets the standards, controls and regulations that apply when carrying out development or building work on land.

3.4.1 Campbelltown Local Environmental Plan 2015

Campbelltown Local Environmental Plan 2015 (CLEP 2015) outlines the zoning of land, what development is allowed in each land use zone and any special provisions applying to land.

a) Below Flood Planning Level

Flood planning is addressed in Clause 7.2 of CLEP 2015, which is reproduced in Figure 2. This clause is based on a non-mandatory model clause which was issued with the NSW standard instrument for a Local Environment Plan. It relates to land at or below the flood planning level, which is defined as land below the level of the 100 year ARI flood plus 0.5m freeboard.

Campbelltown Council's current practice is to use a variable freeboard depending on the nature and depth of inundation and the type of development (see Figure 3). Its view is that it would be inappropriate to apply 0.5m above the 100 year ARI flood level for the entire extent of flood prone land in Campbelltown LGA due to the complexity of overland flows in these urban areas (see Ryan et al., 2015). It would result in an unrealistically large flood planning area that in many areas would extend beyond the limit of the probable maximum flood (PMF).

However, this is not inconsistent with Clause 7.2 of CLEP 2015 which states:

Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

(a) Is compatible with the flood hazard of the land; and

(b) will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and

(c) incorporates appropriate measures to manage risk to life from flood, and

(d) will not significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and

(e) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

The process Council has followed in setting the variable FPL has taken the above factors into consideration and therefore has satisfied itself that in any particular location development between the FPL and 0.5m above the 1% flood level is appropriate.

What it does mean, however, is that any land currently below the FPL as defined in CLEP2015 should have a notation that it is affected by flood related planning controls on its Section10.7(2) certificate. Current Council practice is to only include this notation if the land is below the FPL as defined in CDCP 2015 (see Section 3.4.3).

7.2 Flood planning

(1) The objectives of this clause are as follows:

(a) to minimise the flood risk to life and property associated with the use of land,

(b) to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change,

(c) to avoid significant adverse impacts on flood behaviour and the environment.

(2) This clause applies to land at or below the flood planning level.

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

(a) is compatible with the flood hazard of the land, and

(b) will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and

(c) incorporates appropriate measures to manage risk to life from flood, and

(d) will not significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and

(e) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

(4) A word or expression used in this clause has the same meaning as it has in the *Floodplain Development Manual* (ISBN 0 7347 5476 0) published by the NSW Government in April 2005, unless it is otherwise defined in this clause.

(5) In this clause:

land at or below the flood planning level means land at or below the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard.

Figure 2. Flood planning clause from Campbelltown LEP 2015 (as of 20 February 2017)

Development Criteria	Where the depth of flow is:	Minimum Freeboard above the predicted 100yr ARI Flood level
Floor Level for any dwelling room# including all commercial or industrial areas	< 300mm	300mm
	> 300mm	500mm
Floor Level in relation to any creek or major stormwater line including detention basins for any dwelling room# including all commercial or industrial areas	Any depth	500mm
Garage or shed Floor Level**	<300mm	100mm
	>300mm	300mm
Underside of solid fencing in relation where overland flow is to be accommodated	Any depth	100mm (min)

Figure 3. Extract from Campbelltown DCP 2015 (as of 20 February 2017)

b) Between Flood Planning Level and PMF extent

At present, there is no clause in CLEP 2015 setting out objectives for the management of flood risks on land between the flood planning level and the level of the probable maximum flood (PMF).

Some Councils have an additional ‘Floodplain risk management’ clause to manage this risk, mainly in consideration of development with particular evacuation or emergency response issues, and to protect the operational capacity of emergency response facilities and critical infrastructure during extreme floods. The clause requires consideration of the safety of and evacuation from the land, prior to granting development consent, for nominated land uses.

3.4.2 Campbelltown (Sustainable City) Development Control Plan 2015

Campbelltown (Sustainable City) Development Control Plan 2015 (CDCP 2015) sets the design and construction standards that apply when carrying out development within the LGA. It supports CLEP 2015, which regulates the uses that are permissible on the land.

The existing flood risk management clauses of CDCP 2015 are provided in Table 3.

A technical addendum to the DCP called *Engineering Design for Development* (Campbelltown City Council, 2009b) is used in close conjunction with the DCP and its flood risk management clauses are in Table 4.

Table 3. Flood risk management provisions of CDCP 2015

Extract from CDCP 2015
1.4 Definitions Flood Planning Level is the 100 year Average Recurrence Interval flood level plus freeboard in accordance with Table 4.1 of Council's Engineering Design for Development
2.8 Cut, Fill and Floor Levels 2.8.2 Surface Water and Floor Levels Design requirements a) Development shall not occur on land that is affected by the 100-year ARI event unless the development is consistent with the NSW Floodplain Development Manual.
c) All development shall have a ground surface level, at or above a minimum, equal to the 100-year 'average recurrence interval' (ARI) flood level.
d) For development on land not affected by an overland flow path the minimum height of the slab above finished ground level shall be 150 mm, except in sandy, well-drained areas where the minimum height shall be 100mm. These heights can be reduced locally to 50mm near adjoining paved areas that slope away from the building in accordance with AS 2870 (Residential Slabs and Footings Construction).
e) Buildings involving basements, hospitals, seniors living dwellings and educational establishment with more than 50 students shall comply with the provisions of Council's Engineering Design Guide for Development.
f) Any solid fence constructed across an overland flow path shall be a minimum 100mm above the finished surface level of the overland flow path.
g) Where underground car parking is proposed, measures shall be taken in design and construction to ensure escape routes, pump out drainage systems (which include backup systems) and location of service utilities (including power, phone, lifts) are appropriately located in relation to the 100 year ARI event, in accordance with Section 4.13.8 of Council's Engineering Design Guide for Development.
Table 2.8.1 Floor level requirements A 'dwelling room' is any room within or attached to a dwelling excluding a garage or shed
Table 2.8.1 Floor level requirements Floor Level in relation to any creek or major stormwater line including detention basins for any dwelling room including all commercial or industrial areas
2.10 Water Cycle Management 2.10.2 Stormwater Design Requirements d) Development shall not impact on adjoining sites by way of overland flow of stormwater unless an easement is provided. All overland flow shall be directed to designated overland flow paths such as roads.
e) Safe passage of the Probable Maximum Flood (PMF) shall be demonstrated for major systems.

Table 4. Flood risk management provisions of Engineering Design for Development

Extract from Engineering Design for Development
Glossary includes definitions of terms related to flooding
4. Stormwater Design 4.5 Fill and floor levels Critical infrastructure including hospitals and evacuation centres may require fill and floor level controls higher than those set out in Table 4.1. Special consideration will also be given to evacuation routes and vulnerable development (like nursing homes) in areas above the 100 year ARI flood.
The minimum fill level for a property is the level of the 100 year ARI flood level.
Table 4.1 Floor Level and Freeboard Requirements
Where underground carparks are proposed, consideration must be given to escape routes, pumpout drainage systems (which must include backup pumpout systems), location of service utilities (including power, phone, lifts) for the flood planning level, as well as the PMF. Additional requirements are detailed in Section 4.13.8.
Where an application is lodged for additions to a property which is currently flood affected, it will be assessed on the merit of the individual circumstances, however, as a general rule; if the additions constitute 10% or less of the existing floor area, the additions will be approved at the current level. Where the additions constitute more than 10% of the existing floor area, the additions will be required to be constructed at the levels determined by the above controls. Council reserves the right to impose flood-proofing requirements on additions located in flood-affected areas (Through the use of flood compatible materials, location of electrical infrastructure, etc).
4.13 Major System Flood warning signs are required in all locations where floodwaters may pond or flow and special consideration will need to be given to car parks used as floodways, detention basins and channels.
Council requirements are aimed at ensuring that all properties are protected against the 100 year ARI flood. Properties are to be free from inundation from floods of up to 100-year average ARI recurrence interval. No buildings or other structures are permitted within areas inundated by such flows.
4.13.1 PMF Requirements Safe passage of the PMF must be demonstrated on major systems. Where there is risk to property and/or life it will be necessary to check the results for the Probable Maximum Flood (PMF).
All developments must consider the impact of storms greater than the 100 year ARI event in terms of evacuation routes. No properties should be isolated or become islands in events greater than the 100 year ARI event. Flooding risks should increase incrementally, i.e. no small increase in runoff should generate major increases in affectation.
4.13.8 Underground Car Parks Special consideration must be given to underground carparks and services adjoining roadways carrying major flows. These facilities must demonstrate that access and entry

points are not affected by the 100 yr ARI flood. This includes ventilation openings, windows and access points. The following considerations will be evaluated for any proposal for underground car parking:

Provision for safe and clearly sign posted flood free pedestrian escape routes for events in excess of the 100 yr ARI must be demonstrated separate to the vehicular access ramps;

Consideration must also be given to evacuation of disabled persons;

Pumpout systems must have at least 2 independent pumps each sized to satisfy the pumpout volumes individually;

The two (2) pumps are to be designed to work in tandem to ensure that both pumps receive equal usage and neither pump remains continuously idle;

The lip of the driveway must be located at or above the 100 yr ARI flood level;

Any ramp down to an underground carpark must be covered to minimise rainwater intrusion;

The basement parking area must be graded to fall to the sump;

The pump-out system must be independent of any gravity stormwater lines except at the site boundary where a grated surface inlet pit is to be constructed providing connection to Council’s road drainage system; and

Engineering details and manufacturers specifications for the pumps, switching system and sump are to be submitted for approval prior to issue of the Construction Certificate.

4.14.3 Sites Affected by Overland Flow

Development sites that are impacted by overland flows from upstream catchments need to account for the following:

The proposed development is not to have an adverse impact on adjoining properties through the diversion, concentration or damming of such flows;

The proposed development is to accommodate the passage of overland flow through the site and where applicable is to be designed to withstand damage due to scour, debris or buoyancy forces so that the risk of incidental damage is minimised;

The proposed development is not to be sited where flows will create a hazardous situation for future occupants in terms of depth and velocity of flows through the property;

Floor levels within the development are to be set to comply with the freeboard requirements as set out in Section 4.5; and

The proposed development is compatible with any future mitigation strategies to be implemented by Council in terms of such overland flows.

3.4.3 Campbelltown S10.7Certificates

The wording on the Campbelltown S10.7 certificates reflects legal advice provided to Council that the certificates should not provide more information than the absolute minimum necessary required by law. For this reason S10.7 (5) certificates do not provide explicit details of the flood affectation on any individual property.

a) S10.2(2)

Campbelltown Council issues certificates under S10.7(2) of the EP&A Act, in relation to Part 7A of Schedule 4 of the *Environmental Planning and Assessment Regulation 2000*.

Two templates are used, depending whether the land is subject to flood-related development controls or not. Council uses the definition of the FPL in CDCP2015 to determine whether development controls apply rather than the FPL as defined in the CLEP2015 which would encompass many more properties. The notation is either:

FLOODAFF

(1) Development on all or part of the land subject of this certificate for the purposes of dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (not including development for the purposes of group homes or seniors housing) is subject to flood related controls.

(2) Development on all or part of the land subject of this certificate for any other purpose is subject to flood related development controls.

(3) Words and expressions in this clause have the same meanings as in the instrument set out in the Schedule to the Standard Instrument (Local Environmental Plans) Order 2006.

Please note that some additional information regarding flooding and flood related development controls may be provided as advice under section 149(5) of the Act.

Or -

FLOODNOAFF

(1) Development on all or part of the land subject of this certificate for the purposes of dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (not including development for the purposes of group homes or seniors housing) is not subject to flood related controls.

(2) Development on all or part of the land subject of this certificate for any other purpose is not subject to flood related development controls.

(3) Words and expressions in this clause have the same meanings as in the instrument set out in the Schedule to the Standard Instrument (Local Environmental Plans) Order 2006.

Please note that Some additional information regarding flooding and flood related development controls may be provided as advice under section 149(5) of the Act.

b) S10.7(5)

Campbelltown Council also issues certificates under S10.7(5) of the EP&A Act, providing additional information:

On all parcels in the LGA:

FLOODADD

All properties within the Campbelltown City local government area may be affected by flooding caused by overland flow or local topography. Applicants will need to make their own assessment of the risk associated with these matters. For more information, contact Council's Flood Mitigation and Drainage Section in writing.

On parcels within the Bow Bowing/Bunbury Curran Creek catchment:

FLOODS1

Council is currently undertaking a flood study of the Bow Bowing / Bunbury Curran Creek Catchment, of which this property is a part. The results of this study will improve Council's understanding of flood behaviour in the catchment, and the flood affectation of all properties will be reassessed when this study is finalised. It is anticipated that the Floodplain Risk Management Plan will be finalised by the end of 2015.

When the current FRMS&P is finalised, there will be opportunity to amend the 'FLOODS1' wording. For example, plain language describing the hydraulic hazard in a 1% AEP event and the PMF could be included.

3.5 STRATEGIC PLANNING

3.5.1 State Government

a) A Plan for Growing Sydney

A Plan for Growing Sydney (NSW Government, 2014) is a plan for the future of the Sydney Metropolitan Area over the next 20 years. The Plan provides key directions and actions to guide Sydney's productivity, environmental management, and liveability – including the delivery of housing, employment, infrastructure and open space.

It identifies Campbelltown-Macarthur as a Regional City Centre and has the following sub regional priorities which are relevant to development and redevelopment in floodprone areas of Campbelltown LGA:

- Protect land to serve Sydney's future transport needs, including intermodal sites and associated corridors. (this includes the Macarthur Intermodal Shipping Terminal at Minto);
- Identify and protect strategically important industrial-zoned land;
- Identify suitable locations for housing, employment and urban renewal – particularly around established and new centres and along key public transport corridors;
- Continue delivery of the South West Growth Centre through greenfield housing development and the expansion of local employment.

In relation to the Campbelltown-Macarthur Strategic Centre, the Plan sets the following priorities which may have implications for floodplain development:

- Work with council to retain a commercial core in Campbelltown-Macarthur, as required for long-term employment growth.
- Work with council to provide capacity for additional mixed-use development in Campbelltown-Macarthur including offices, retail, services and housing.
- Support health-related land uses and infrastructure around Campbelltown Hospital.
- Support education-related land uses and infrastructure around the University of Western Sydney.
- Work with council to investigate potential business park opportunities on the western side of the train line.

b) Draft Greater Sydney Region Plan

The NSW Government has established the Greater Sydney Commission and it has released a Draft Greater Sydney Region Plan (Greater Sydney Commission, 2017a) which sets a 40-year vision (up to 2056) and establishes a 20-year plan to manage growth and change for Greater Sydney. It also sets the planning framework for the five districts which make up the region and informs district and local plans and the assessment of planning proposals.

Within this strategic planning framework Campbelltown is part of the Western City district which extends from Hawkesbury in the North to Wollondilly in the south and as far west as Blue Mountains LGA.

The Plan:

- identifies the need for investment in health infrastructure around Campbelltown Hospital
- recommends that car parks and drop-off bays be designed so that they can be adapted to alternative uses (commercial uses, storage, logistics hubs, depots or community uses) in the event that autonomous vehicles reduce the requirements for car parking
- identifies Campbelltown-Macarthur as a collaborative area for 2018-19 where the Commission will facilitate a strategic, whole-of government approach with District Commissioners chairing the collaborations to support the coordination of activities across agencies and governments to deliver significant productivity, sustainability and liveability outcomes.

- Identifies the Glenfield Macarthur corridor as an urban renewal area
- Identifies Campbelltown as a metropolitan city cluster.

c) Draft Western City District Plan

The Draft Western City District Plan (Greater Sydney Commission, 2017b) (Figure 4) provides more specifics in relation to the planning objectives and actions that come out of the Draft Greater Sydney Region Plan. For example it:

- estimates there will be an increase in jobs in Campbelltown-Macarthur from 20,400 in 2016 to between 27,000 and 31,000 with most of these clustered along the rail corridor;
- sets a target of 6,800 new houses in Campbelltown LGA by 2021;
- identifies Rosemeadow, Ambarvale, Bradbury, Blair Athol, Eagle Vale, Minto and Macquarie Fields as small local neighbourhood centres and Ingleburn as a large local centre (Figure 5);
- Identifies the Glenfield Macarthur corridor as an urban renewal area (Figure 6);
- Identifies Ingleburn and Minto as the second and third largest industrial and urban services precincts in Western Sydney;
- Identifies 13ha of undeveloped industrial land in Ingleburn and 16ha of undeveloped industrial land in Minto;
- Indicates that following the $134m Stage 1 redevelopment of Campbelltown Hospital a further $632m is committed for Stage 2
- Identifies Bunbury Curran Creek and Bow Bowing Creek as an open space corridor which can be utilised for open space, urban greening, active transport and stormwater treatment along the corridor.

d) Glenfield to Macarthur Urban Renewal Corridor

The Glenfield to Macarthur Urban Renewal Corridor Strategy (NSW Government, 2015) provides a detailed Precinct Analysis for each of the Glenfield, Macquarie Fields, Ingleburn, Minto, Leumeah, Campbelltown and Macarthur station precincts (Figure 7). The Strategy outlines the future vision and character of each area, the types and number of new homes and jobs that could be delivered by 2036, and the improvements to community facilities, public spaces, the transport network and other infrastructure needed to achieve sustainable growth. It maps potential land rezoning to encourage urban renewal and consolidation. Many of the areas recommended for rezoning are flood prone. Figure 7 shows the extent of the corridor and the draft zonings.

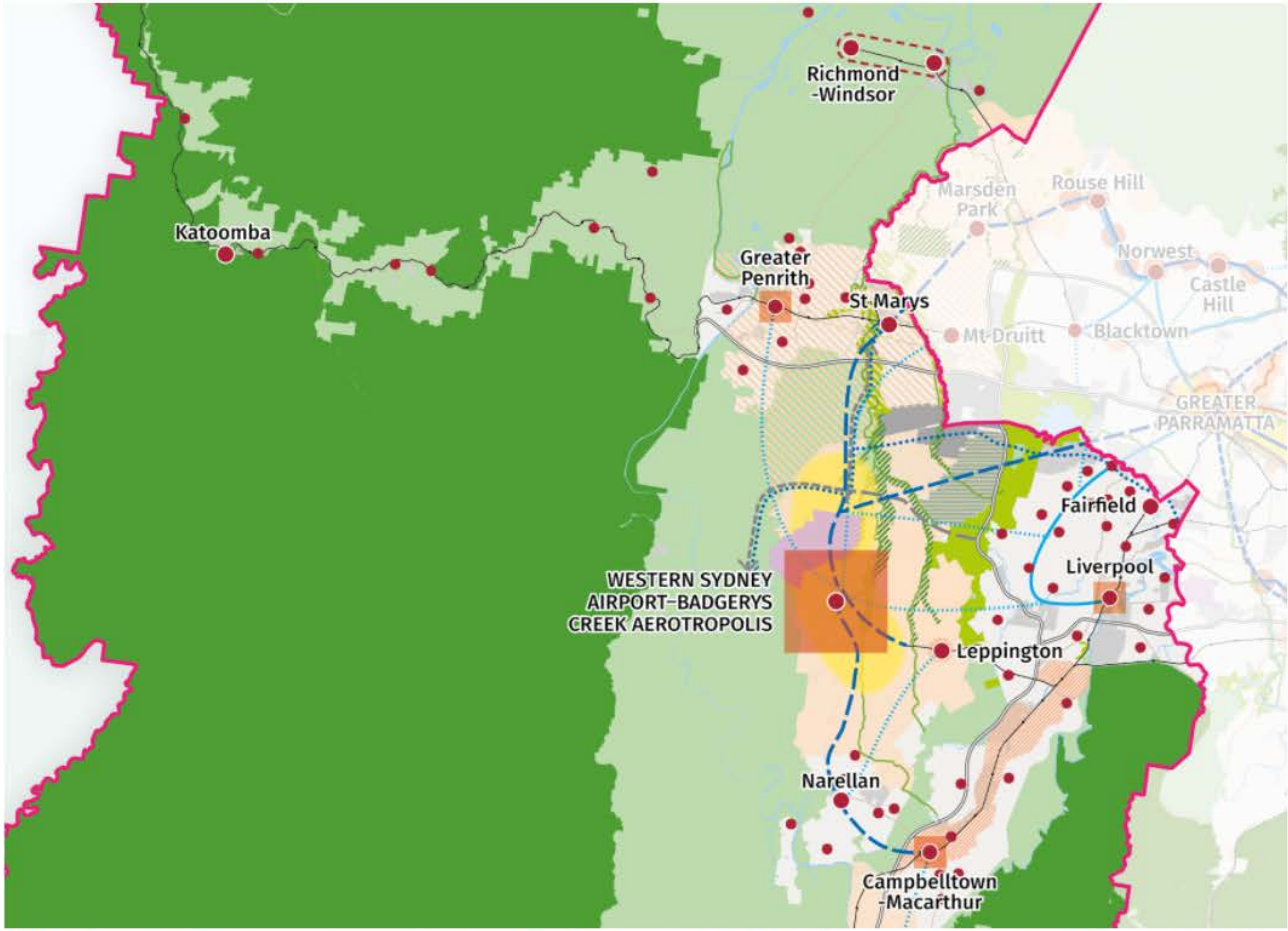
e) Land and Housing Corporation

Land and Housing Corporation (LAHC) is a State owned corporation which provides low cost housing to people who are socially disadvantaged. This includes many people who are aged, frail or have a disability.

It owns hundreds of dwellings throughout the Campbelltown LGA, and has recently redeveloped large areas of public housing in Campbelltown LGA including at Airds, Bradbury, Claymore, Minto and Macquarie Fields.

LAHC is currently reviewing its portfolio to determine which of its other properties need to be redeveloped. As part of this review it is considering flood risk to determine whether:

- they need to dispose of properties where the risks would be too high for their tenants
- they need to dispose of properties where satisfying minimum floor level criteria would provide access challenges for their tenants
- there are locations where the redevelopment needs to be responsive to the flood risks.



NOTE: *Committed projects of: Western Harbour Tunnel & Beaches Link, F6 – WestConnex to President Avenue Kogarah, Parramatta Light Rail Stage 2 and Sydney Metro West are subject to final business case, no investment decision yet. Routes and stops for some transport corridors/projects are indicative only.*

Download

Download and print the Western City District Plan on a page (PDF, 788 KB)

Figure 4. Overview of the Draft Western City District Plan

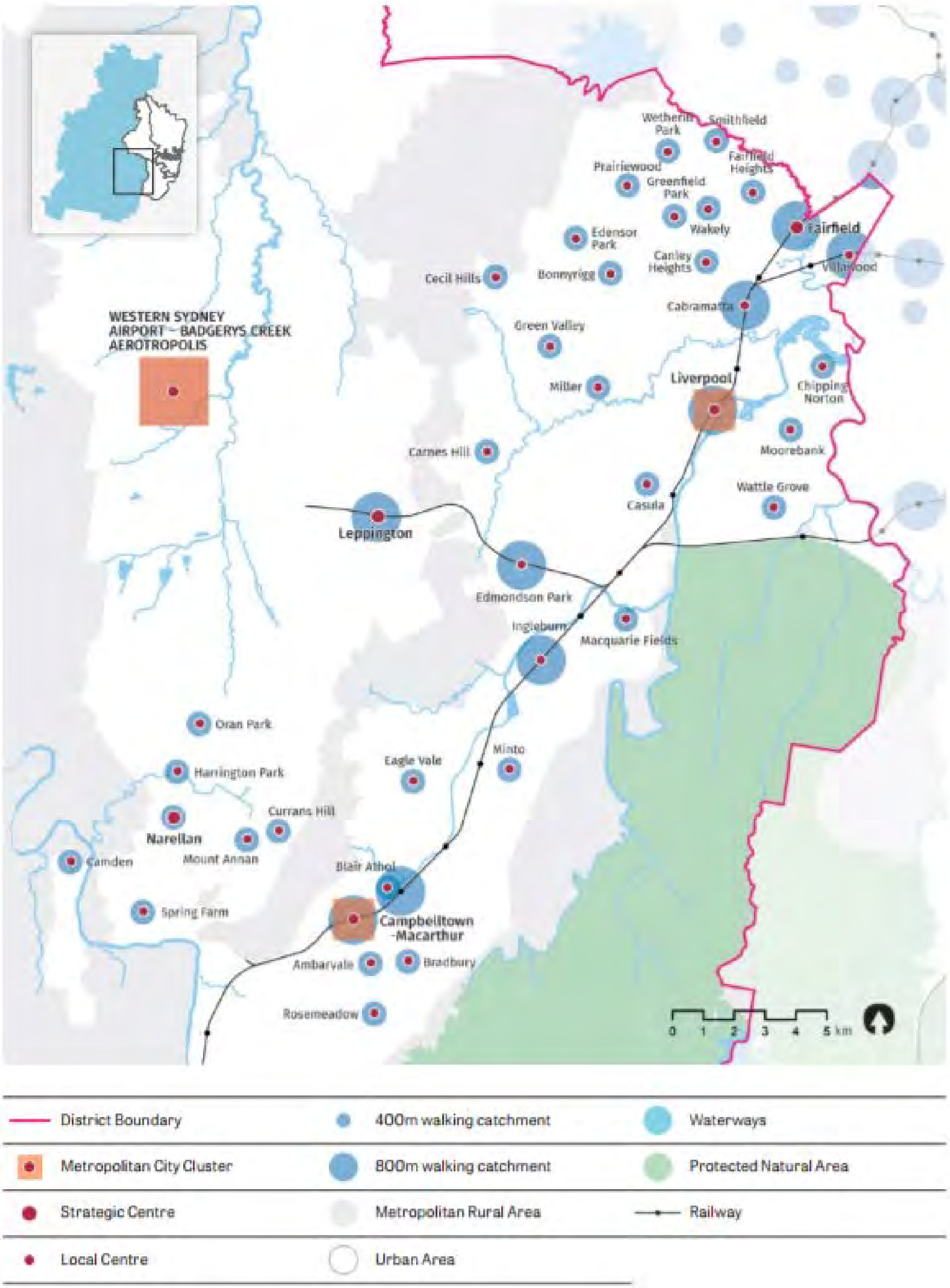


Figure 5. Detail of the Draft Western City District Plan

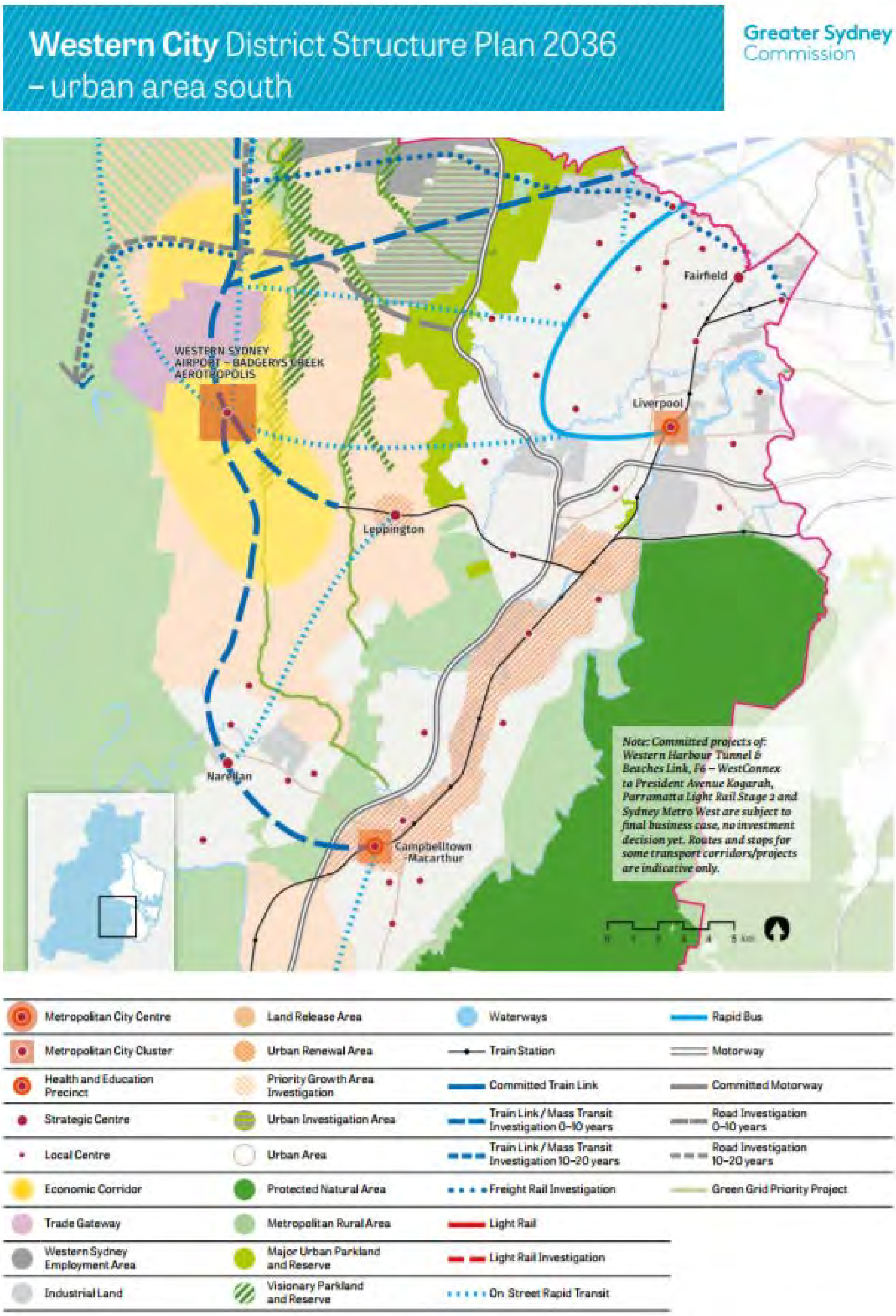


Figure 6. Western City District Plan: urban area south

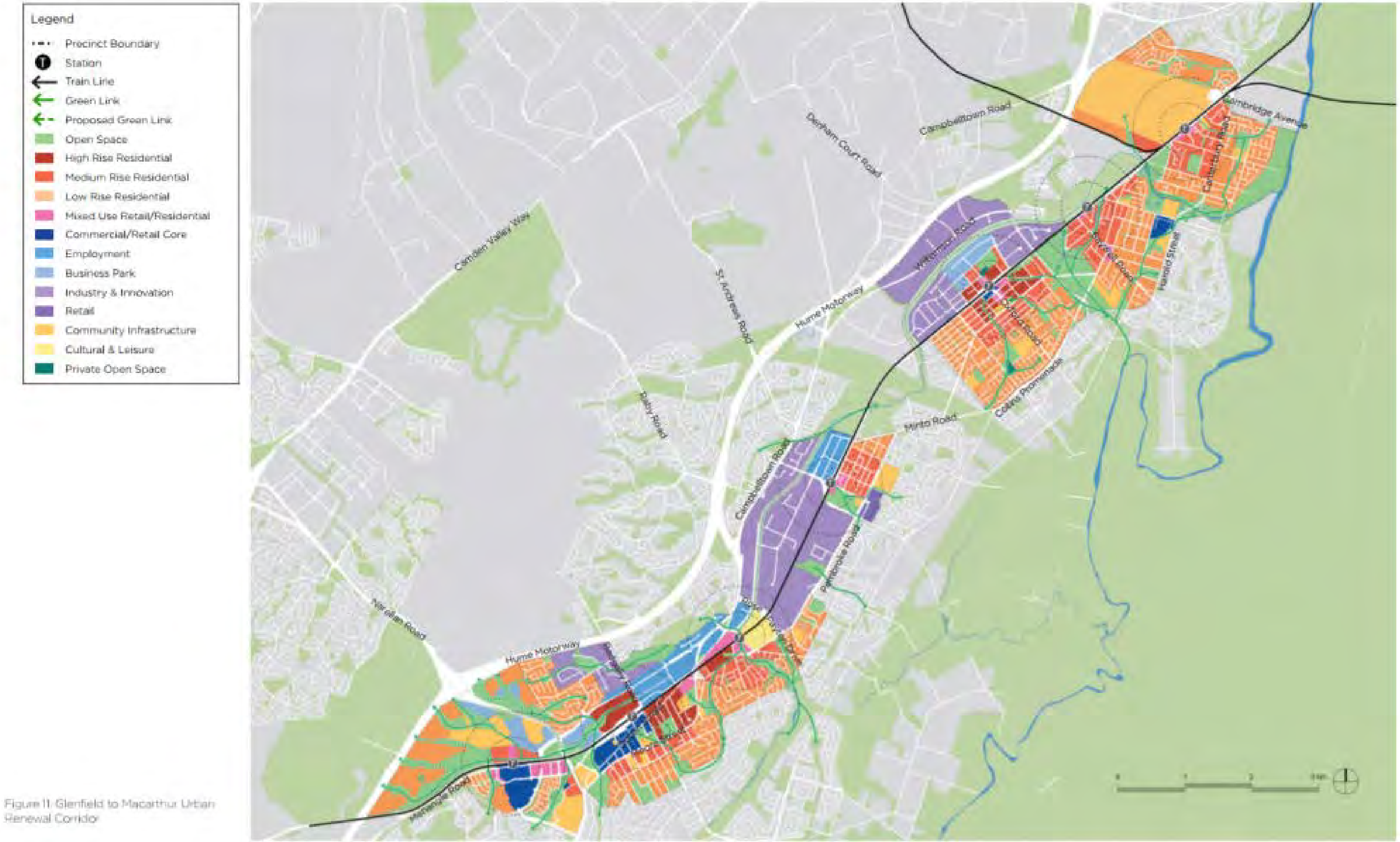


Figure 7. Glenfield to Macarthur Urban Renewal Corridor Strategy

3.5.2 Campbelltown City Council

a) Residential Development Strategy

The Residential Development Strategy (RDS) (Campbelltown City Council, 2014) is a background document which informed the preparation of Campbelltown Local Environmental Plan 2015 (LEP 2015). It pre-dated the most recent State Government regional strategic plans.

The LEP zoned land according to the needs identified in the residential development strategy and there are areas which were rezoned to permit greater residential dwelling densities. Many of these areas have flood risks which means there is the potential under existing zonings for more people to be placed in areas with a significant flood risk.

b) Draft Open Space Strategic Plan

Most of the existing creeks, drains and flood mitigation works are within areas of public open space. Creating open space in developed areas which currently have a high flood risk is one potential way of mitigating flood impacts.

Council's draft Open Space Strategic Plan (Campbelltown City Council, 2016) proposes several planning actions which are relevant to floodplain management:

- Ensure that new development areas include an adequate amount of Open Space for the Open Space Strategy full range of open space types; for active recreation including team sports; informal recreation including playgrounds; and for environmental protection, biodiversity conservation and heritage conservation where these assets are present.
- Prepare a S94 plan, incorporating information from the Sports and Recreation and Playspaces S94 Plan Strategies to validate the existing population needs for sport and recreation areas and forecast future population growth. Ensure that the plan includes other Open Space needs, including passive recreation (see next section).
- Implement a benchmark provision model for new developments to ensure that there is Open Space Strategy adequate provision of good quality land for Public Open Space, not just drainage or flood prone land or landscape buffers to busy roads, and that the land is integrated into the existing Open Space network.
- Develop a Land Dedication Policy, with Open Space acquisitions being considered as part of Biodiversity Conservation Strategy of the strategic planning process rather than at development assessment.

c) S94 Contribution Plans

Many councils in NSW have developer contributions plans under the former Section 94 of the Environmental Planning and Assessment Act (now S7.11).

Of these, many include a provision for developer contributions to pay for the construction and maintenance of flood mitigation and drainage works. The size of the contribution towards these works will generally reflect the proportional contribution to incremental downstream runoff from the development or the benefit to the development of mitigation works. There needs to be a clear nexus between the development and the works and cost of the works needs to be supported by appropriately costed engineering designs.

A Council might also include in its S94 contributions plan a contribution for the acquisition of land for public open space as identified in an open space strategic plan (see previous section). Similarly, there will need to be a demonstrable nexus between increased development and the need for additional open space and a transparent basis for estimating the cost of open space acquisition and development. Campbelltown Council's S94 Contributions Plan (Campbelltown City Council, 2011) does not link developer charges to specific open space, drainage or flood mitigation needs. Rather, it charges a flat percentage of the development cost for developments over $100,000 in value. The contributions plans list numerous road works, three car parking stations and a library which the money will be spent on.

4 EMERGENCY MANAGEMENT CONTEXT

Emergency management represents one of the three pillars of floodplain risk management. It is generally not affordable to treat all flood risk up to and including the PMF through flood modification and property modification measures, especially where there is a legacy of existing risk but also for future risk. Emergency management measures such as evacuation planning and community flood education are aimed at increasing resilience to reduce risk to people and property, both for frequent flood events and for very rare but extreme flood events.

This Section sets out the context for the detailed evaluation of flood response modification measures, further discussed in Section 9.

4.1 NSW STATE EMERGENCY SERVICE ROLE

As stipulated in the *State Emergency Service Act 1989*, the NSW State Emergency Service (SES) acts as the combat agency for dealing with floods (including the establishment of flood warning systems) and to co-ordinate the evacuation and welfare of affected communities. NSW SES is tasked to protect persons from dangers to their safety and health, and to protect property from destruction or damage, arising from floods.

Details of the roles and responsibilities of NSW SES (and other emergency services and affected parties) can be found in the *State Flood Sub Plan*, a Sub Plan of the New South Wales Disaster Plan (NSW SES, 2008). This role covers:

- **Prevention:** includes providing emergency management advice to councils;
- **Preparedness:** includes preparing and maintaining Flood Sub Plans and developing and maintaining flood intelligence systems. It also involves community education and preparing communication messages and systems for the delivery of flood information during flooding;
- **Response:** includes controlling and coordinating flood operations, communicating flood advice to at-risk communities and coordinating evacuation and rescue operations;
- **Recovery:** includes debriefs following flood operations and long term management of the flood impacts.

4.2 FLOOD PLANS

At the time this Floodplain Risk Management Study was being prepared, the NSW SES had issued Volume 1 of the Campbelltown LGA Local Flood Plan (LFP) (NSW SES, 2015), while Volume 2, including a description of flood behaviour and possible impacts on communities, had not been completed.

Volume 1 of the LFP covers preparedness measures, the conduct of response operations and the coordination of immediate recovery measures from flooding within Campbelltown LGA. The Plan covers all operations for all levels of flooding within the LGA.

According to the LFP, the NSW SES Campbelltown City Local Controller is invested with the responsibility of dealing with floods as detailed in the *State Flood Sub Plan*, within the LGA. In terms of flood preparedness, this includes:

- Maintaining a Local Headquarters in Minto (corner of Alderney and Townson Street);
- Ensuring that the NSW SES members are trained;
- Coordinating the development and operation of a flood warning service for the community;
- Participating in flood related initiatives organised by Council;
- Coordinating a public flood education program;
- Identifying and monitoring people and communities at risk;
- Ensuring that the Plan is maintained and current.

With regard to flood emergency response, the Local Controller responsibilities include appointing an Incident Controller to undertake all response roles.

In the flood recovery phase, the Local Controller will ensure that appropriate After Action Reviews are held after floods, and provide appropriate representation to the Recovery Committee for the duration of the response phase of an event and as agreed during the recovery phase.

Among the many responsibilities set out in the LFP, the Australian Government Bureau of Meteorology has an important role in flood warning including providing:

- Flood Watches for the Georges River and the Hawkesbury-Nepean River Basins;
- Flood Warnings for Menangle gauge; and
- Severe weather warnings when flash flooding is likely to occur.

The LFP recognises that Campbelltown City Council is a significant player in flood preparedness, response and recovery. This includes:

In the preparedness phase:

- Develop and implement floodplain risk management plans in accordance with the NSW Government's Flood Prone Land Policy and the Floodplain Development Manual;
- Establish and maintain floodplain risk management committees;
- Provide flood related studies to the NSW SES;
- Maintain Dam Safety Emergency Plans;
- Maintain a plant and equipment resource list;
- Contribute to the development and implementation of a community engagement and capacity building program;
- Coordinate the development of warning services for catchments prone to flash flooding (small catchments), where appropriate;
- Maintain and operate council-owned flood warning systems.

In the response phase:

- At the request of the NSW SES Incident Controller, deploy personnel and resources for flood related activities;
- Close and reopen council roads and provide information on the road status;
- Provide filled sandbags to urban and village areas in which flooding is expected.

In the recovery phase:

- Provide for the management of health hazards associated with flooding;
- Ensure premises are fit and safe for reoccupation and assess any need for demolition;
- Arrange for storage of evacuees' furniture as required.

4.3 FLOOD RESPONSE

There are two principle ways in which risk to people can be managed in a flood emergency. They may either evacuate out of the flooded area or they can take refuge on high ground or within a building which is isolated by floodwaters or even flooded. Taking refuge rather than evacuating is often referred to as sheltering-in-place (SIP).

The NSW SES has prepared or contributed to a number of publications on this topic, which are summarised in the following sub-sections. These views are expected to inform its preferred flood response measures for BBC Creek Catchment.

a) Opper and Toniato (2008)

NSW SES holds the position that if development is to occur on floodplains, it must be possible to evacuate people out of the floodplain in advance of floods.

NSW SES has recognised that in an existing flash flood context, and only in that context, causing residents to attempt to evacuate at the time of flash flooding is occurring, could be a serious risk to life. Only in areas where urban redevelopment cannot be prevented under existing planning policy, it has therefore been proposed that the DCP for any new or redeveloped dwelling will require an internal refuge area above the level of the PMF. This concession has been seized upon to wrongly apply it to all flood contexts and to justify any new development.

In response, NSW SES may have no choice but to adopt a harder line and to not support any redevelopment or development in flash flood areas.

Two elements of flood isolation risk are particularly significant: structural fire and medical emergency.

An example of the problems that can arise due to isolation and the vagaries of human behaviour occurred during flooding in June 2007, when a nursing home at Wyong needed to be urgently evacuated due to its rapid isolation by floodwater and the threat of further inundation. This required six ambulance crews and other emergency services to deal with just this one facility. The management and residents had ignored early advice to evacuate before they were isolated and then had a change of mind once they were surrounded by floodwater.

b) Opper et al. (2011); AFAC (2013)

The safest place to be in a flash flood is well away from the affected area. Evacuation is the most effective strategy, provided that evacuation can be safely implemented. Properly planned and executed evacuation is demonstrably the most effective strategy in terms of a reliable public safety outcome.

Late evacuation may be worse than not evacuating at all because of the dangers inherent in moving through floodwaters, particularly fast-moving flash flood waters. If evacuation has not occurred prior to the arrival of floodwater, taking refuge inside a building may generally be safer than trying to escape by entering the floodwater.

Remaining in buildings likely to be affected by flash flooding is not low risk and should never be a default strategy for pre-incident planning. It is not equivalent to evacuation.

The risks of 'shelter-in-place' include:

- Floodwater reaching the place of shelter (unless the shelter is above the PMF level);
- Structural collapse of the building that is providing the place of shelter (unless the building is designed to withstand the forces of floodwater, buoyancy and debris in a PMF);
- Isolation, with no known basis for determining a tolerable duration of isolation;
- People's behaviour (drowning if they change their mind and attempt to leave after entrapment);
- People's mobility (not being able to reach the highest part of the building);
- People's personal safety (fire and accident); and
- People's health (pre-existing condition or sudden onset e.g. heart attack).

For evacuation to be a defensible strategy, the risk associated with the evacuation must be lower than the risk people may be exposed to if they were left to take refuge within a building which could either be directly exposed to or isolated by floodwater.

Pre-incident planning needs to include a realistic assessment of the time required to evacuate a given location via safe evacuation routes. This requires consideration of barriers to evacuation posed by available warning time, availability of safe routes and resources available.

Successful evacuation strategies require a warning system that delivers enough lead time to accommodate the operational decisions, the mobilisation of the necessary resources, the warning and the movement of people at risk.

Effective evacuation typically requires lead times of longer than just a couple of hours and this creates a dilemma for flash flood emergency managers. Due to the nature of flash flood catchments, flash flood warning systems based on detection of rainfall or water level generally yield short lead times (often as short as 30 minutes) and as a result provide limited prospects for using such systems to trigger planned and effective evacuation.

Initiating evacuation of large numbers of people from areas prone to flash flooding based only on forecasts may be theoretically defensible in a purely risk-avoidance context but it is likely to be viewed as socially and economically unsustainable. Frequent evacuations in which no flooding occurs, which statistically will be the outcome of forecast-based warning and evacuation, could also lead to a situation where warnings are eventually ignored by the community.

c) NSW SES (2014)

In the context of future development, self-evacuation of the community should be achievable in a manner which is consistent with the NSW SES's principles for evacuation.

Development must not conflict with the NSW SES's flood response and evacuation strategy for the existing community.

Evacuation must not require people to drive or walk through flood water.

Development strategies relying on deliberate isolation or sheltering in buildings surrounded by flood water are not equivalent, in risk management terms, to evacuation.

Development strategies relying on an assumption that mass rescue may be possible where evacuation either fails or is not implemented are not acceptable to the NSW SES.

The NSW SES is opposed to the imposition of development consent conditions requiring private flood evacuation plans rather than the application of sound land use planning and flood risk management.

d) Summary

The NSW SES holds that evacuation is the preferred emergency response for floodplain communities, where this can safely be achieved. Late evacuation, through floodwater, may be a recipe for disaster and in that situation it might be safer to remain inside the building, though sheltering-in-place has a number of direct and indirect risks associated with it. Evacuating prior to flooding is therefore much preferred. Where current hydro-meteorological monitoring systems, communications systems, road infrastructure and expected community behaviours do not allow this, the SES advocates improvements to these so that evacuation can proceed safely. However, the AFAC (2013) guide makes clear that even with improvements in monitoring, insufficient time may be available to inform evacuation decisions with any confidence.

5 COMMUNITY AND STAKEHOLDER ENGAGEMENT

5.1 GENERAL

The success of any floodplain management plan hinges on its acceptance by the local community and other stakeholders. This can only be achieved by engaging the community at all stages of the decision-making process. It includes collecting the community members' knowledge about flood behaviour in the study area, consulting about management options, and discussing the issues and outcomes of the study with them.

Community engagement has been an essential component of the BBBC FRMS&P. This has aimed to inform the community about the development of the floodplain management study and its likely outcomes. It has also aided learning about community flood awareness and preparedness. The engagement process has also provided an opportunity for the community to participate in the study by submitting ideas about potential floodplain management measures.

5.2 PRELIMINARY CONSULTATION PROGRAM

As part of its proposal, Molino Stewart provided Council with a Preliminary Community and Stakeholder Consultation Program as an initial plan for community consultation.

The Program included details about:

- The community in the study area;
- Consultation objectives;
- Target audiences;
- Possible consultation risks;
- Consultation techniques.

The Program adopted a community and consultation process based on three phases:

- **Phase I**, to inform the community and stakeholders on the outcomes of the Flood Studies, advise that the Floodplain Risk Management Study was being undertaken, and obtain feedback on flood affectation and possible risks;
- **Phase II**, to discuss the preferred mitigation options in consultation with the local community through Council's Floodplain Risk Management Steering Committee ;
- **Phase III**, to obtain feedback from the Community about the final draft of Floodplain Risk Management Study and Plan. This phase focused on the public exhibition of the FRMS&P.

5.3 REGIONS

For the purposes of community consultation, the Bow Bowing Bunbury Curran Creek Catchment was initially divided into three regions: North, Central and South (Figure 8).

5.4 PLANNING

Using the Preliminary Community and Stakeholder Consultation Program as a starting point, two meetings were held between Molino Stewart and Council staff (floodplain management, community engagement, communications) to further refine the consultation program.

An initial consultation was planned for Campbelltown CBD (part of the South region) to trial possible consultation processes and to advise business owners that the results of the flood study were available. A public information session for this trial consultation was held on 16 December 2015.

5.5 FLOODPLAIN RISK MANAGEMENT COMMITTEE

As part of the NSW Government required processes for floodplain management (Figure 1), the Campbelltown City Floodplain Risk Management Committee (FRMC) was established. Terms of Reference for the FRMC were developed and reviewed at the first Committee meeting held on 3 February 2016. The meeting also provided advice on the planned consultation processes for the three regions.

The date and main agenda items of each FRMC meetings are summarised in Table 5

Table 5. Meetings with the Floodplain Management Committee

Date of meeting	Main agenda items
3 February 2016	Inception meeting – FRMC Terms of Reference presented, presentation of flood study results, presentation of FRMS&P project, Briefing on community consultation for the flood studies,
8 February 2017	Adoption of the Committee's draft Terms of Reference, provided background to the study, presented overview of the flood studies and damages assessment methodology.
12 July 2017	Presentation of risk hotspots and preliminary flood risk mitigation options
August 2018	Presentation of shortlisted flood mitigation options and Preliminary Draft FRMS

5.6 CONSULTATION PROCESSES: PHASE I

The community consultation centred on public information sessions which were held in the three regions as follows:

- South region. Wednesday 24 February 2016 (5PM-8PM) Civic Hall, Queen Street, Campbelltown
- Central region. Wednesday 2 March 2016 (5PM-8PM) Eagle Vale Community Centre, Eagle Vale
- North region. Monday 14 March 2016 (5PM-8PM) Greg Percival Community Centre, Ingleburn

The public information sessions (Figure 9 and Figure 10) enabled participants to view flood risk maps and several poster displays about local floodplain management. Council staff and consultants were on hand to answer questions and discuss matters of interest.

The public information sessions were advertised using a web page, articles in Council's community newsletter, media releases, advertisements in local papers and notifications to the main stakeholders (e.g. Chambers of Commerce).

5.6.1 Results

a) Attendees

The number of attendees for each public information session is provided in Table 6.

Table 6. Number of people attending public information sessions

Location	# attending
Campbelltown CBD (trial)	1
South region	3
Central region	4
North region	8

b) Issues raised

Molino Stewart recorded issues raised by attendees at each of the public information sessions. The main issues were:

South region

- General interest about flood risk across the LGA;
- Concern about perceived restrictions to development in Campbelltown CBD;
- Concern about development options on property on Menangle Rd which has flow from several angles.

Central region

- Questions about local flood issues and wet detention basin;
- Concern about the possible depth of flooding in a property;
- Concern about stormwater drain and blockage from rubbish;
- Interest about flood risk in the suburb.

North region

- Concern about being in a flood area for insurance;
- Concern about the possible depth of flooding in the property;
- Concern about the possible depth of flooding on road outside property;
- Concern about local blockage in property;
- Impact of flooding on Ingleburn businesses.

Those attending were provided with Council contact details if they wished to follow up enquiries.

5.6.2 Discussion on Phase I Results

Although several processes were used, only a small proportion of those at risk of flooding in the study area were involved in the public information sessions and other aspects of the Phase 1 community consultation.

This low level of interest is comparable with that experienced in similar community consultations held in other metropolitan LGAs. Flooding does not appear to be high on the risk agenda of most people in the study area, and more than 20% of residents are unaware of any flood risks (even though they live in a floodplain). The dry, summer spell at the time of the consultations probably added to the disinterest.

As a result of the lack of interest, there were not enough people to be involved in the Advisory Groups for each region. However, there were two attendees that showed broad interest in flooding issues, and these two were invited to be community members on the FRMC.

The issues raised were considered in the development of flood mitigation options (Phase 2). This was coupled with intelligence received from consultation with other stakeholders (e.g. government agencies, local hospital, TAFE, University of Western Sydney).

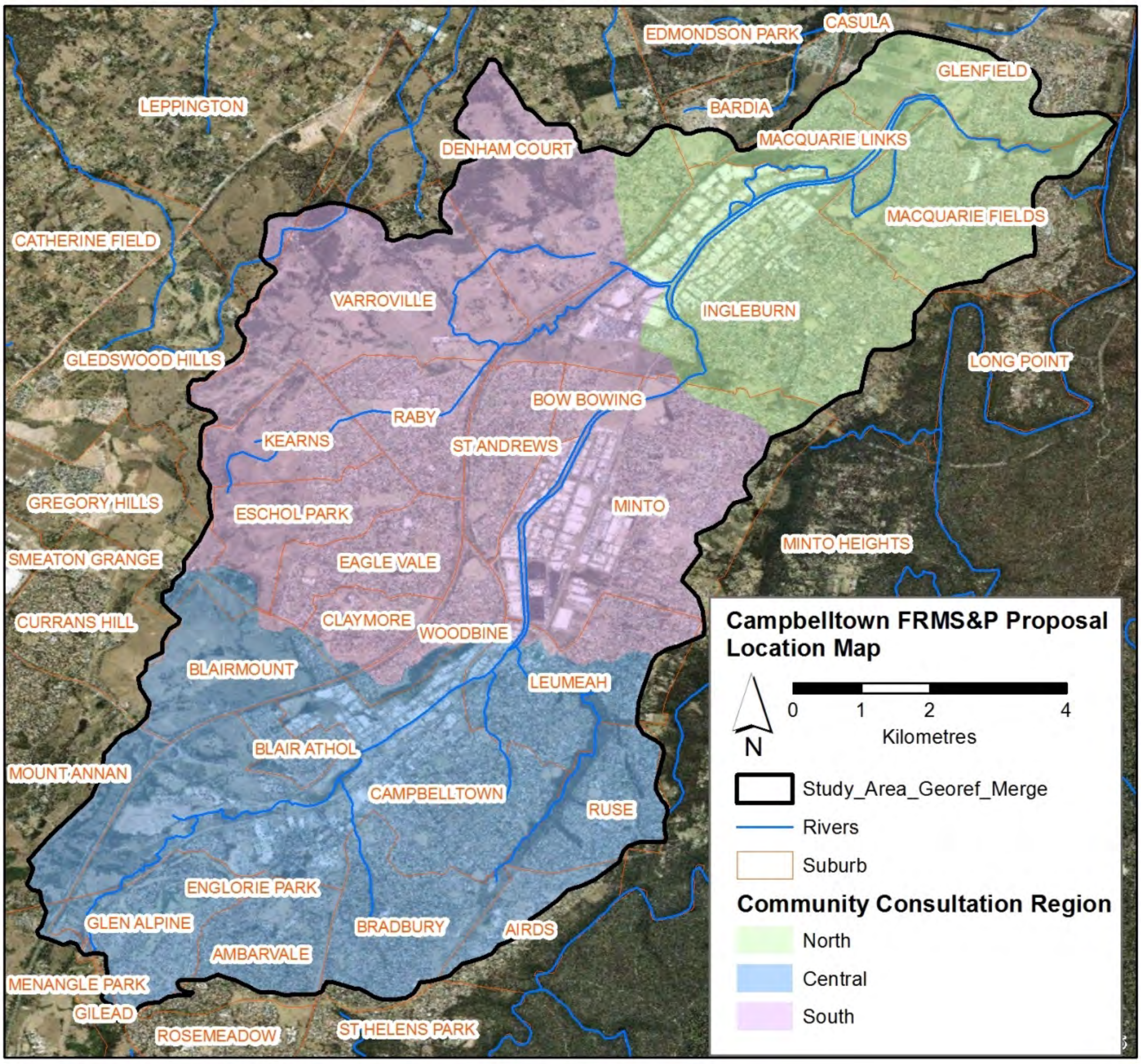


Figure 8. The three regions for community consultation

Figure 9. Public information session in North Region

Figure 10. Sign placed outside to advertise public information sessions on the day

5.7 CONSULTATION PROCESSES: PHASE II

Phase II involved discussion regarding the preferred mitigation options in consultation with the local community through Council's Floodplain Risk Management Steering Committee. Details about this process are provided in Section 5.5.

5.8 CONSULTATION PROCESSES: PHASE III

The Phase III community consultation focussed on the public exhibition of the draft FRMS&P. The public exhibition period of 30 days extended throughout September 2018.

The public exhibition involved two community information sessions to discuss the draft FRMS&P and details of how to comment on Council's website.

The community information sessions were advertised using Council's website, a media release, advertisement in the local papers and notifications to the main stakeholders (e.g. Chambers of Commerce).

5.8.1 Material for Public Exhibition

Ten posters were prepared to help community information session attendees learn more about the FRMS&P and the preferred mitigation options in the plan. The posters were prepared on the following topics:

- Bow Bowing Bunbury Curran Creek Floodplain Risk Management and Plan;
- Identification of Flood Risk 'Hotspots';
- Flood Modification: Ingleburn CBD;
- Flood Modification: Epping Forest Drive, Kearns;
- Flood Modification: Greenoaks Avenue, Bradbury;
- Flood Modification: Harrow Road, Glenfield;
- Flood Modification: Oxford Road, Ingleburn;
- Flood Modification: Sopwith Avenue and Spitfire Drive, Raby;
- Flood Modification: Dumaresq Street, Campbelltown;
- Property and Response Modification Options.

Figure 11 shows one of the posters as an example.

5.8.2 Community Information Session

Two community information sessions were held at the Civic Centre, Campbelltown on Thursday 20 September 2018. One session was held during the day (11AM-1PM) and the other in the evening (5PM-7PM).

Three people attended the evening session and none attended the day session

5.8.3 Collation and Assessment of Community Feedback

None of the community information session attendees provided formal comment on the draft FRMS&P. Generally, their informal comments were supportive of the draft FRMS&P including the mitigation options analysis displayed using the posters.

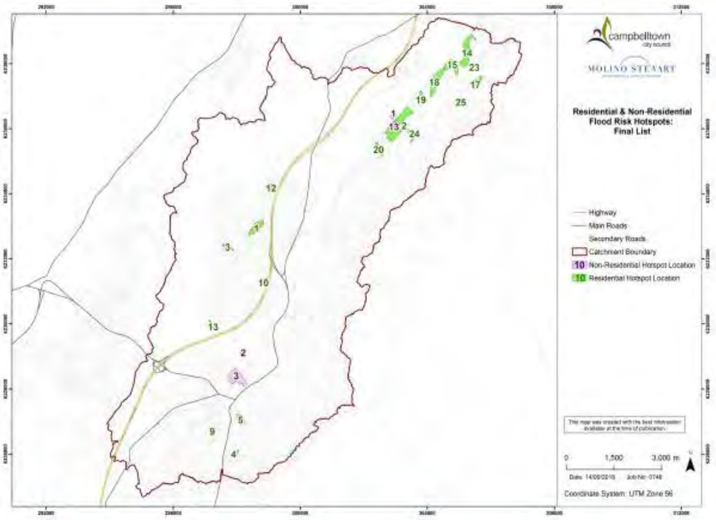
There was one comment about the draft FRMS&P received by Council from a resident. The resident was concerned about the flood risk to the property, possible mitigation options to reduce the risk and if this has an impact on the property's flood insurance. Council provided a detailed response to this comment which was accepted by the resident.

5.8.4 Public Exhibition

From the public exhibition there were no changes recommended to the draft FRMS&P.

Property and Response Modification Options

Property Modification



Glenfield to Macarthur Urban Renewal Corridor Strategy

Property Modification for Hotspots

Description	Applies to:
Acknowledge and address flood risk through redevelopment and development outside of high hazard zones where possible as part of Glenfield to Macarthur Urban Renewal Corridor Strategy	Residential Hotspots ID no. 2, 14, 15, 18, 19, 24. All Commercial Hotspots
Use locality specific development controls to reduce risk to life and property	Residential Hotspots ID no. 2, 14, 15, 18, 19, 24. All Commercial Hotspots.

Property Modification for whole Catchment

- Find opportunities to reduce flood risks through redeveloping public housing, particularly for vulnerable residents.
- Council undertakes a comprehensive review of the Development Control Plan (CDCP 2015) and the Engineering Design for Development with respect to flooding, as recommended in Section 11.
- Development Controls. Consider amending the Local Environmental Plan so that it makes provision for variable a Flood Planning Level (FPL) as Defined in CDCP 2015. Apply for "exceptional circumstances" to ensure variable FPL is consistent with S117 Direction 4.3

Response Modification

- The warning time available was deemed too short, as a result of quick rate of rise and the topography of the local area. As a result a warning system was deemed unsuitable.
- Council to work with the NSW State Emergency Service (SES) to develop and implement a community education strategy to encourage appropriate responses.
- Council to work with the NSW SES to encourage the preparation of Emergency Response Plans for businesses and households where appropriate
- Where redevelopment under the Glenfield to Macarthur Urban Renewal Strategy is likely, there may be an opportunity to use locality-specific development controls to deliver improved flood response outcomes

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Figure 11. Example of one of the posters prepared for the Community Information Sessions as part of the Public Exhibition of the FRMS&P

PART B: FLOOD BEHAVIOUR AND IMPACTS

6 FLOOD STUDIES

An essential foundation for the BBBC Floodplain Risk Strategic Management Study and Plan are the Flood Studies describing flood behaviour for a range of events up to and including the Probable Maximum Flood (PMF).

This Floodplain Risk Management Strategic Study and Plan is underpinned by coordinated Flood Studies, describing flood behaviour in each of the twelve sub-catchments of BBBC Creek.

The sub-catchment flood studies were completed between 2010 and 2014, and revised in 2018 (Table 7) to address the main limitations of previous flood investigations. These were:

- Previous studies were typically completed a significant time ago and did not represent the existing degree of development within the BBBC Creek flood-prone land;
- Previous studies utilised simplified computer models;
- Previous studies did not consider the PMF;
- Previous studies only considered mainstream flooding; and,
- Previous studies did not cover the entire BBBC Creek catchment.

The flood studies completed in 2014 were then further updated in 2018, to integrate current input data on topography, stormwater system and land use, and to refine some of the modelling technical assumptions. A detailed description of the updates undertaken in 2018 is provided in Appendix B.

This section provides a summary of the current flood studies, as well as an overview of previous flood investigations. For more detailed information regarding the flood studies, please refer to the relevant reports (Table 7)

Table 7. Sub-catchment flood studies underpinning the BBBC Floodplain Risk Management Study.

No.	Sub-Catchment (in alphabetical order)	Flood Study (Author, Year)*
1	Birunji Creek	Birunji Creek Flood Study (CSS, 2018a)
2	Blairmount	Blairmount Locality Flood Study (CSS, 2018b)
3	Campbelltown	Campbelltown Locality Flood Study (CSS, 2018c)
4	Claymore	Claymore Main Drain Flood Study (CSS, 2018d)
5	Glenfield	Glenfield and Macquarie Fields Flood Study (CSS, 2018e)
6	Ingleburn	Ingleburn Locality Flood Study (CSS, 2018f)
7	Minto	Minto/McBarron Creek Flood Study (J.Windham Prince, 2010), study revised by CSS (2018)
8	Mc Barron Creek	Minto/McBarron Creek Flood Study (J.Windham Prince, 2010), study revised by CSS (2018)
9	Smiths Creek	Smiths Creek Flood Study (CSS, 2018g)
10	Thompson Creek	Thompson Creek Flood Study (CSS, 2018h)
11	Upper Bow Bowing Creek	Upper Bow Bowing Creek Flood Study (CSS, 2018i)
12	Upper Bunbury Curran	Upper Bunbury Curran Flood Study (CSS, 2018l)

* it should be noted that all flood studies were further refined in 2016 by CSS to create a single water surface across the whole BBCC Creek catchment for each design event

6.1 PREVIOUS INVESTIGATIONS

A number of previous flooding investigations were prepared from the early 1980's in an effort to better understand flood behaviour and the relative merits of a range of flood mitigation options across the BBBC Creek catchment. The BBBC Creek Flood Study (Campbelltown City Council, 2009a) provides a comprehensive review of all the previous flood-related investigations.

The majority of the previous investigations considered main stream flooding only. That is, the previous studies did not consider overland flows as required by the 2005 'Floodplain Development Manual' (NSW Government, 2005). The previous studies also did not consider the full range of floods up to and including the Probable Maximum Flood (PMF) or include consideration of climate change (CSS, 2012d).

The review of previous flood studies included in the BBBC Creek Flood Study determined that the design discharge and peak flood level estimates documented in previous reports were no longer considered to be valid due to the significant increases in development across the catchment since these reports were originally prepared. The review also noted that the previous flood level estimates were generated using simplified hydraulic computer models that, in some circumstances, failed to consider the complex two-dimensional flow patterns that can occur across the BBBC Creek catchment (CSS, 2012d).

In recognition of these limitations, the report concluded that it was necessary to prepare updated hydrologic and hydraulic computer models in order to provide a more reliable description of existing as well as future flood behaviour and, at the same time, fully comply with the requirements of the 'Floodplain Development Manual'. Such a model was then developed as part of the 2009 BBBC Creek Flood Study (Campbelltown City Council, 2009a) and subsequent updates, as described in Section 6.2.

6.2 CURRENT STUDIES

6.2.1 Hydrologic Modelling

The flood studies listed in Table 7 are based on a detailed hydrologic model developed by CSS for Council in 2011 (CSS, 2011), including the studies prepared by J.Wyndham Prince and subsequently revised by CSS. The model was an improved version of a previous hydrologic model built as part of the 2009 BBBC Creek Flood Study (Campbelltown City Council, 2009a).

Both the 2009 and the 2011 versions of the hydrologic model used the software XP-RAFTS (XP Software, 2009). XP-RAFTS is a lumped runoff routing model that can be used to generate discharge hydrographs for recorded and design floods in urban and rural catchments. This makes it appropriate for the BBBC Creek catchment which comprises both rural and urban land uses.

The model was used to estimate design rainfall events using the methodologies described in Australian Rainfall and Runoff (Engineers Australia, 1987) and convert the rainfall to runoff, taking into account the catchment characteristics.

The 2009 version of the model, subsequently superseded by the 2011 version, was built using a 10m grid-based Digital Elevation Model (DEM) covering the whole BBBC Creek catchment. The model outputs were validated against historical events, and further tested with sensitivity analysis

Overall, it was considered that the 2009 BBBC XP-RAFTS model provided a reasonable description of design discharges across the lower areas of the catchment. However, across the upper areas of the catchment, the 2009 BBBC XP-RAFTS model sub-catchment was not considered sufficiently detailed and reliable.

To ensure a more consistent and detailed modelling approach, in 2011 Council engaged CSS to prepare an improved hydrologic model covering all of the BBBC Creek catchment.

Council divided the BBBC Creek catchment into 12 subcatchments and CSS developed a specific and highly detailed hydrologic model for each of these.

6.2.2 Hydraulic Modelling

The 2011 hydrologic model served as a key input to the detailed hydraulic models used to simulate the passage of floodwaters across each of the sub-catchments comprising the BBBC Creek catchment.

Initially, ten of the twelve sub-catchments were modelled by Catchment Simulation Solutions, and the remainder by J.Windham Prince, who merged Minto Locality and McBarron Creek into the same flood study (Table 7). However in 2018, as part of this FRMS, CSS further refined all hydraulic models, including those previously undertaken by J. Wyndham Prince. As part of this process, CSS merged all the revised studies to obtain a single water surface for each modelled design flood. This was done in response to a request from the community to harmonise the outcomes of the flood studies across the whole study area.

All hydraulic models were undertaken using the software TUFLOW (Two-dimension Unsteady Flow). TUFLOW is a computer program that provides two-dimensional (2D) and one- dimensional (1D) solutions of the free-surface flow equations and is typically used to simulate flood behaviour. It is particularly beneficial where the hydrodynamic behaviour of rivers, floodplains and urban drainage environments have complex 2D flow patterns that would be awkward to represent using traditional 1D network models.

The TUFLOW hydraulic model was used to simulate flood behaviour across each sub-catchment for a range of Annual Exceedance Probabilities (AEP) and a range of storm durations. The following events were modelled:

- 20% AEP;
- 5% AEP;
- 1% AEP;
- 0.2% AEP;
- 0.1% AEP;
- PMF.

The model produced information on flood levels, depths and velocities for each design flood and each duration, and considered both mainstream and local overland flooding.

The consequences of blockages of stormwater inlets and pipes, which is a problem commonly observed during large flood events, were also considered in the model.

This was achieved by applying blockage factors to all stormwater inlets and culverts. A blockage factor of 50% was applied to all minor (i.e., < 3 metre diameter) culvert crossings. A 50% blockage factor was also applied to all sag stormwater inlets and 20% blockage was applied to grade stormwater inlets in accordance with Council's *Engineering Design for Development* (Campbelltown City Council, 2009b). The impact of alternative blockage scenarios (i.e. full blockage and no blockage) on flood behaviour was also analysed as part of the TUFLOW model sensitivity analysis. Results showed that while the full blockage scenario would result in a significant increase of the peak flood level immediately upstream of the blockage, the difference was much smaller when comparing the ‘standard” blockage scenario (the partial blockage one adopted in the flood studies) with the “no blockage” scenario, because most pipe systems are typically at full capacity with a 50% blockage of the pits. These three scenarios allowed areas which are sensitive to blockage to be identified.

The aim of the modelling exercise was to determine the “worst case” flooding conditions produced for each flood frequency. The reason this is done is because different storm durations will have different impacts in various parts of the catchment.

For a given frequency of rainfall (e.g. 1% AEP) it is possible to have a short duration storm (say 5 minutes) of very intense rainfall (223mm/hr) or a long duration storm (say 3 days) of less intense rainfall (4.5mm/hr). Both have the same probability of occurrence but the short duration storm produces a total of 18.5mm of rain in a very short space of time while the long duration storm produces 324mm over a long period of time.

Generally the short duration storm would cause the most significant impacts in the upper parts of a catchment where the duration of the rainfall is close to the time it takes for the water to runoff and impact a particular location (the time of concentration). By contrast as one moves down the catchment and the time of concentration increases, a longer duration storm will have greater impacts because more water is running off and reaching this point.

Because events with different storm durations result in different flood extents, levels and velocities in each sub catchment and in different parts of each sub catchment, a worst-case design flood "envelope" was developed for each AEP event based on analysis of each storm duration at each grid cell.

Hydraulic categories and provisional hazard categories were also determined. The results were then presented in the flood studies shown in Table 7 (i.e. the current flood studies).

6.2.3 Effects of Climate Change on Flooding

OEH's 'Practical Consideration of Climate Change' (Department of Environment and Climate Change, 2007) indicates that because rainfall intensities are predicted to increase in the future as an effect of climate change, additional simulations with 10%, 20% and 30% increases in rainfall intensities are recommended.

These increases in rainfall intensities were simulated in the hydrologic models developed as part of the flood studies, and the correspondent increases in peak discharge were obtained for each catchment for the 1% AEP event. Results showed that, on average, an increase in rain intensity of +10% would cause increased discharges between +10% and +13%, while a rainfall intensity increase of +20% would result in peak discharges exceeding +22%.

In addition to this, the flood study for Macquarie Fields and Glenfield Locality (CSS, 2014) used the increased discharges and the estimated increased tailwater levels in the Georges River due to sea level rise to re-run the hydraulic model in future climate conditions. Results showed that increases in rainfall intensity will increase current 1% AEP flood levels throughout the Macquarie Fields / Glenfield Locality with a magnitude up to 1 metre along the main Bunbury Curran Creek channel.

Table 8. Estimate of climate change impact on average peak discharges in the 1% AEP event

No.	Sub-Catchment	Average peak discharge increase caused by a +10% rainfall intensity	Average peak discharge increase caused by a +20% rainfall intensity
1	Birunji Creek (CSS, 2018a)	11%	23%
2	Blairmount (CSS, 2018b)	12%	24%
3	Campbelltown (CSS, 2018c)	10-13%	24%
4	Claymore (CSS, 2018d)	11%	22%
5	Glenfield (CSS, 2018e)	11%	23%
6	Ingleburn (CSS, 2018f)	11%	23%
7	Minto	NA	NA
8	McBarron Creek	NA	NA
9	Smiths Creek (CSS, 2018g)	11%	22%
10	Thompson Creek (CSS, 2018h)	11%	22%
11	Upper Bow Bowing Creek (CSS, 2018i)	11%	22%
12	Upper Bunbury Curran (CSS, 2018l)	12%	24%

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7 SUMMARY OF FLOOD BEHAVIOUR

7.1 FLOOD BEHAVIOUR

This section describes the overall flood behaviour in the BBBC Creek catchment, and provides an overview of the areas and AEP events in which some affectation of the built environment can be observed. A more detailed analysis of flood damages to buildings and properties exposed to flooding is provided in Section 8 and Section 9 respectively.

In this section, flood behaviour is described using the flood extents of each AEP event obtained from the relevant flood studies (Map 7 to Map 10, Vol. 2). The extents described reflect the worst case, design flood "envelope" for each AEP. However, because the models are set up to reflect overland flow behaviour they include flows of relatively small depths and velocities, which do not generally cause impacts other than a nuisance.

Figure 12 shows an example of the flood extents for all events when all depths and velocities of overland flow are included.

To filter out insignificant flows, hazard mapping was produced which took into account the combination of flood depth and velocity using the method described in Section 7.2.2. Figure 13 shows the extent of hazardous flooding for the same area shown in Figure 12 but where the flood extents were adjusted to show only the areas in which the depth and velocity of water creates a flood hazard.

When assessing flood damages the actual flood depths, without any filtering applied, were compared with building floor level estimates to determine whether a building was likely to experience above floor flooding. When assessing the risk to pedestrian, vehicle or building stability, the hazards were used.

For clarity of mapping and to aid the following discussions, Map 7 to Map 10 in Vol. 2 only show the extent of the hazardous flooding.

As described in earlier sections, Council adopted the Flood Mitigation Scheme in 1984 and has implemented various flood mitigation works in the 30 years since. The result of these works is a small number of areas where private property has a flooding issue in frequent flood events. Those areas which do have a flood issue generally suffer from shallow overland flows and not deep mainstream flooding in frequent events or they only have flooding issues in rare flood events.

In addition to this, it should be noted that the hydraulic models used in the flood studies do not account for private drainage infrastructure on private property, the details of which are not available to Council. This includes pits and pipes which convey runoff from rooves and paved areas or which may intercept overland flows and divert them around buildings. In many instances this drainage infrastructure is likely to prevent minor overland flooding from entering buildings and causing damage, especially in commercial and industrial areas where the size of properties can be quite extensive and the private drainage infrastructure can be substantial.

Because of the extent and complexity of the BBBC Creek catchment. Section 7 is broken down as follows:

- 7.1.1 describes flooding from the main creek. ;
- 7.1.2 describes flooding from the tributaries;
- 7.1.3 describes overland flooding. This was distinguished from main creek and tributaries by inspecting the water behaviour at various time-steps throughout the modelled flooding process;
- 7.1.4 provides an overview of flood durations and rates of rise across the catchment.

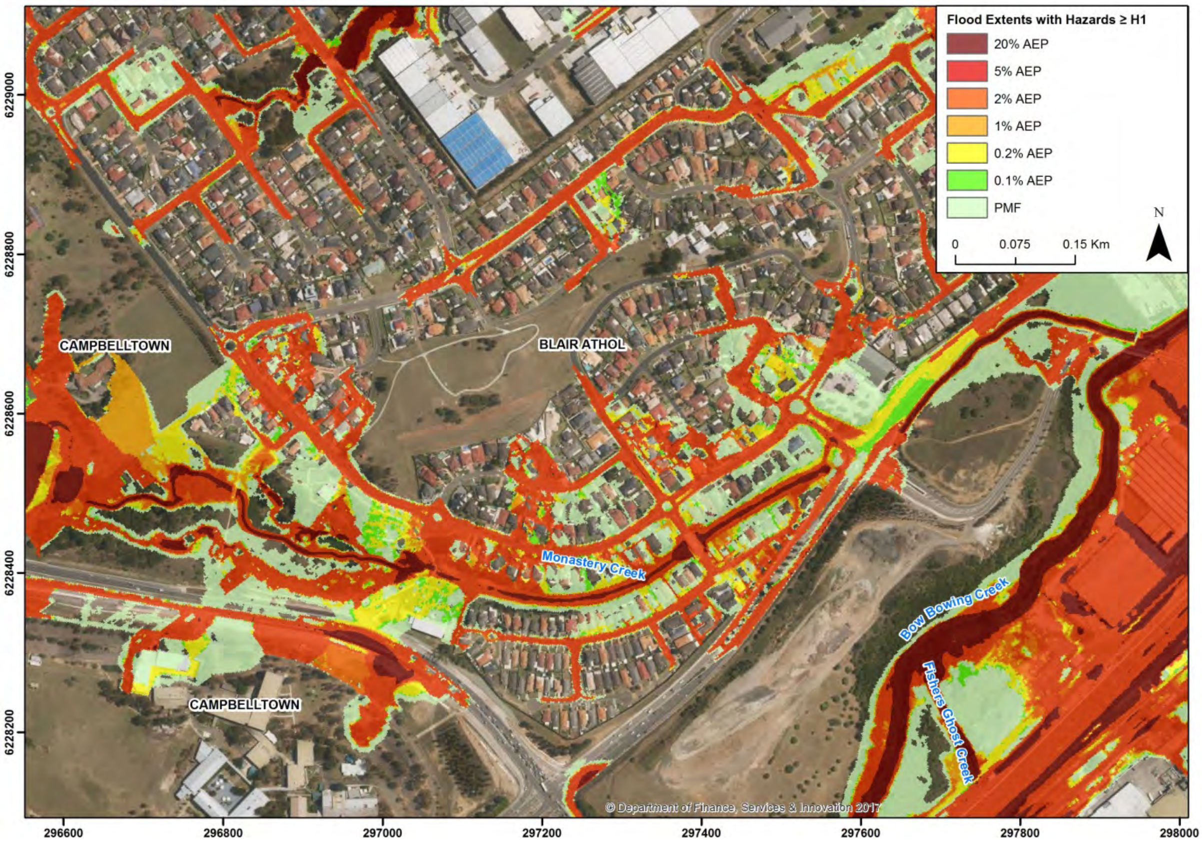

Figure 12. Example of flood extent map including all flooding

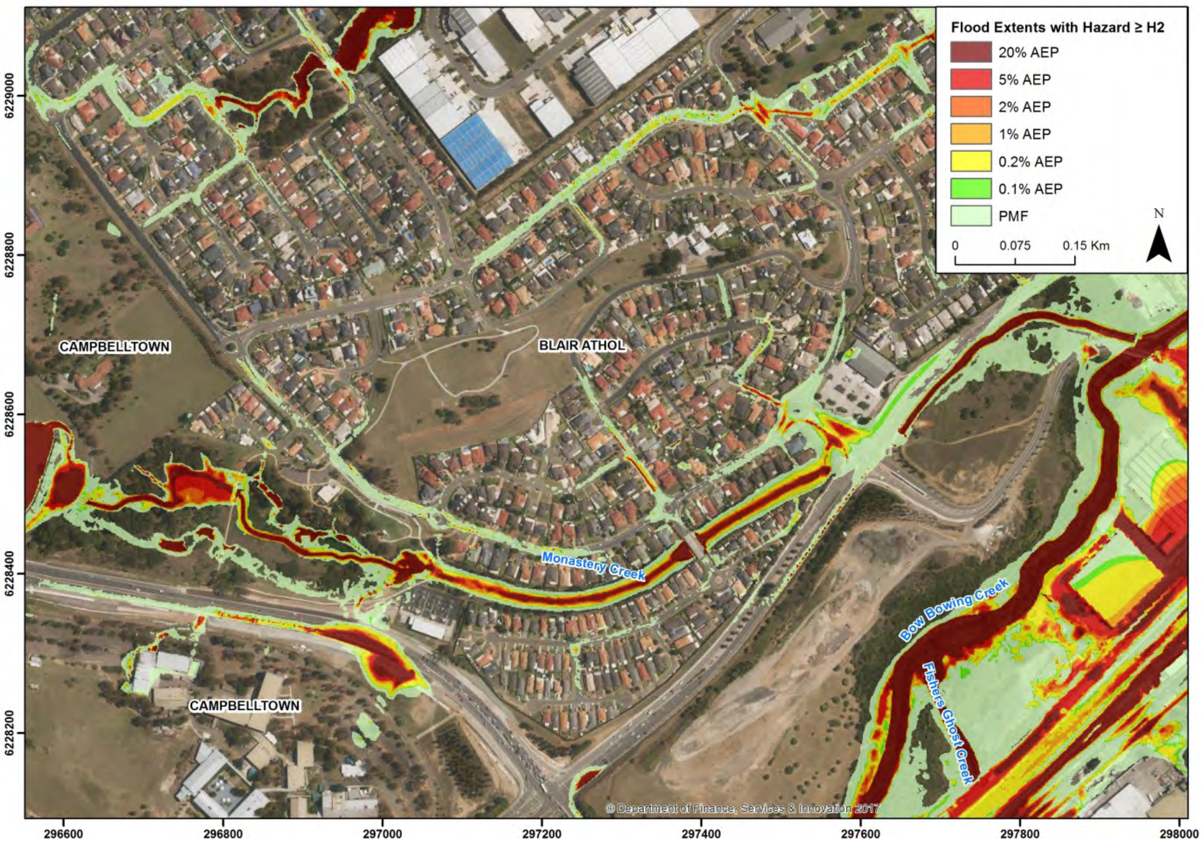

Figure 13 Example of flood extent map excluding areas without hazardous flooding

7.1.1 Main Creeks

a) Bow Bowing Creek

At the southern end of the catchment (Map 8, Vol. 2), up to the confluence with Birunji Creek, flooding from the Bow Bowing Creek is mostly contained within the creek's banks or detention basins, and where flooding can be seen this happens in the PMF and affects mostly public open space areas only.

North of Birunjii Creek the flood extent increases moderately, affecting the following industrial areas:

- The area downstream of Monastery Creek, between Bow Bowing Creek and the railway line, where at least two large industrial buildings show flood affectation from the 20% AEP;
- The area north east of Blair Athol, with flooding observed only in events greater than the 0.2% AEP, although in more frequent events some of the local roads get cut (e.g. Blaxland Road). No significant affectation of residential or commercial buildings can be observed here.

From Biriwiri Creek to Leumeah Creek, the creek overflows its banks only in the PMF, affecting the industrial areas in Leumeah and Minto. It continues like this through Minto to the confluence with Thompson Creek (Map 9, Vol. 2).

As it passes through the Leumeah and Minto industrial areas, flooding from the main creek overlaps with local runoff (i.e. overland flooding).

Thompson Creek joins Bow Bowing Creek just upstream of Minto Basin. The detention basin begins to fill in the 20% AEP event. Downstream of the railway the flooding affects the electrical substation in Minto from the 20% AEP but this is caused by local overland flows passing through the substation on their way to the creek.

From here the creek remains within its banks in each AEP event, other than the PMF, up to its confluence with Bunbury Curran Creek.

b) Bunbury Curran Creek

Bunbury Curran Creek runs from Kearns through Raby, and is joined by Cottage Creek just before merging with Bow Bowing Creek upstream of Ingleburn (Map 9, Vol. 2). In Kearns and most of Raby, the flooding is well managed by the existing detention basins. However, where the creek passes under the motorway the build-up of water in the PMF is sufficient to flood some residential properties around Matra Pl, Spitfire Dr and Wessex Pl in Raby.

The confluence with Bow Bowing Creek causes extensive flooding in the PMF in the Ingleburn industrial area (Map 10, Vol. 2). Part of this flooding is caused by overland runoff and may be less significant than modelled because of the effects of local stormwater systems within the industrial estates, which are likely to be effective in more frequent events but will not affect the extent of flooding in the PMF.

Moving north it is joined by Redfern Creek west of the Main South Rail Line and floods parts of Macquarie Links Golf Course south of the South West Rail Line (from the 5% AEP event) and parts of the Hurlstone Agricultural High School campus north of the South West Rail Link. However, the latter is only affected in the PMF

East of the Main South Rail Line the creek overtops its banks and affects residential properties along Newtown Rd and Fawcett St in Glenfield (in events greater than the 0.2% AEP), and in Macquarie Fields (in the PMF only).

7.1.2 Tributaries

This section provides a description of flood behaviour of the main creek's tributaries, starting from the top of the catchment (at the south-west end of the study area).

a) Creek flowing through Glen Alpine

This creek runs from the south west end of the Campbelltown Golf Course through a series of cascading detention basins across Glen Alpine (Map 8, Vol. 2). The Creek overtops its banks within the Golf Course from about the 0.2% AEP, but it does not affect any buildings. More flooding is observed further downstream, before and after the culvert under Heritage Way, as well as after Glen Alpine Drive. Here the Creek causes significant flooding from the 20% AEP event, without affecting any of the neighbouring properties up to the PMF.

b) Birunji Creek

Birunji Creek (Map 8, Vol. 2) runs through Ambarvale and joins Bow Bowing Creek downstream of Campbelltown. Flooding from Birunji Creek is generally well contained within the creek's banks and within the numerous detention basins in Ambarvale. The only area in which there are properties affected by flooding from Birunji Creek is Tigg Pl. Here, in events less frequent than the 0.2% AEP, the creek's flow exceeds the capacity of the culvert under Therry Rd and overtops its banks, affecting residential properties in Tigg Pl. It should be noted that some of these properties experience local overland flooding also in events more frequent than the 0.2% AEP, but this is not caused by Birunji Creek and is discussed in more detail in Section 7.1.3.

Further downstream, in Campbelltown, the creek causes some minor flooding along Centennial Dr, however the neighbouring properties are only affected in the PMF. Further flooding is seen just upstream of the junction with Bow Bowing Creek, where it affects Kellicar Rd (from the 0.2% AEP event), Tindall St (from the 20% AEP event), and the car parking areas surrounding the adjacent industrial properties (from the 0.2% AEP event)

c) Fishers Ghost Creek

Fishers Ghost Creek (Map 8, Vol. 2) starts in the southern parts of Bradbury and remains within its banks for most of its length up to the culvert under The Parkway, where the Gordon Fetterplace Aquatic Centre is partly affected from the 20% AEP, while some of the properties in Olympic Ct show minor flooding in the PMF only. Further downstream, more flooding is observed where the Creek passes under Hurley St and the railway line, with Hurley St cut in frequent events (i.e. from the 20% AEP).

d) Monastery Creek

Monastery Creek, which flows through Blair Athol, is largely contained within its banks or detention basins in all AEP events.

e) Biriwiri Creek

Biriwiri Creek (Map 8, Vol. 2) starts in rural areas of Gregory Hills and Blairmount. It causes some local flooding in Blairmount upstream of where it passes under the motorway. Here the flooding affects mostly undeveloped areas, but in the PMF a small number of residential properties flood. Downstream of the Motorway, floodwaters affect only open space until the creek passes through the Blair Athol industrial estate. For the most part the industrial properties only flood in the PMF, however more frequent events can cause flooding of the roads and properties around the intersection of Badgally Rd and Blaxland Rd which become flow paths for the creek water which cannot pass through the culverts under the industrial estate.

f) Leumeah Creek

In Leumeah, Leumeah Creek (Map 8, Vol. 2) is well contained within its banks, although some road and property flooding can be seen in the PMF downstream of Campbelltown North Detention Basin, between Leumeah Creek and Campbelltown Rd. There is also some flooding occurring along Leumeah Creek, upstream of the railway culvert, but this affects mostly open space and only a couple of properties from the 20% AEP.

g) Smiths Creek

Smiths Creek has its headwaters in Bradbury (Map 8, Vol. 2) and runs through open space for most of its length including a small gorge which separates Leumeah from Ruse and in which there is not development. The creek causes some flooding between Pembroke Rd and the railway, affecting some of the nearby properties in very rare events (i.e. from the 0.2% AEP) and the stadium car park from the

20% AEP. Smiths Creek is joined by three minor creeks flowing from the south-east to north-west between Airds and Ruse. These remain within their banks in almost all events, however in the PMF one of these causes minor flooding in Ruse, north-east of the crossroad between Junction Rd and Cook Rd.

h) McBarron Creek

McBarron Creek (Map 9, Vol. 2) flows from Minto Heights to Minto and remains mostly within its banks in each AEP event but the PMF. Even in the PMF there is no significant property affectation. Floodwaters build up against Townson Ave, Pembroke Rd and the railway culvert in Minto, causing some local flooding from the 20% AEP. However, this flooding ponds for the most part in open space areas, although a small number of the neighbouring properties are affected in the rarest event (i.e. the PMF).

i) Claymore Main Drain

Claymore Main Drain has its headwaters in rural land in Gregory Hills and flows in a general easterly direction between the suburbs of Claymore and Eagle Vale. A series of detention basins keep most of the flows in Claymore Main Drain (Map 9, Vol. 2) within public open space. Where the drain flows under the motorway, water backs up in extreme events resulting in the floodwaters affecting some residential properties along Gould Rd. Further downstream, at the confluence with Bow Bowing Creek, more flooding of industrial properties can be observed, largely from events rarer than the 0.2% AEP event. This flooding is caused by the drain not being able to discharge quickly enough into Bow Bowing Creek.

j) Minto Main Drain no.2

Minto Main Drain no.2 starts in Rose Park upstream of the intersection of Pembroke Rd and Ben Lomond Rd, and runs north-west along Ben Lomond Rd. The drain remains within its banks up to the railway line in all events but the PMF, in which it causes minor localised flooding that does not significantly affect any buildings. The drain however causes some flooding in frequent events (from the 20% AEP) before and after the railway culvert, with potential minor affectation of the railway from events greater than the 20% AEP. More flooding can be seen further downstream, around the culvert under Airds Rd, which may result in Airds Rd being cut from the 0.2% AEP.

k) Thompson Creek

Eagle Creek is a major tributary of Thompson Creek with its headwaters in the rural areas of Eschol Park. Flooding from Eagle Creek is very well contained by a series of cascading detention basins upstream of Eagle Vale Dr and in Thompsons Creek by a similar series of basins upstream of Gould Rd and there are no properties affected by PMF flooding along these reaches of the creeks. Between these roads and the motorway flooding is contained within the open space reserves but the PMF flows overflow Eagle Vale Dr and also back up behind the motorway and many homes would experience above floor flooding. Between the motorway and Bow Bowing Creek, there is basically no property affectation in any AEP event smaller than the PMF, however, in the PMF numerous residential properties located in proximity of the creek would be affected, particularly upstream and downstream of the culvert under Campbelltown Rd.

l) Minto Main Drain no.1

Minto's other main drain (no. 1) runs from south-east of Durham St in a north-west direction up to Pembroke Rd, where it continues north along Pembroke Rd up to Minto Rd. The drain then passes through an open vegetated area of one property in a north-west direction and continues through Victoria Park until it joins with Bow Bowing Creek, just upstream of Ingleburn. The drain remains within its banks in all events but in the PMF, when it may cause minor flooding to some of the properties in Pembroke Rd.

m) Redfern Creek

Redfern Creek (Map 10, Vol. 2) runs in north-west direction from Porter Reserve, at the north end of Minto, towards Ingleburn CBD.

Past Cumberland Rd, the creek is channelled into two culverts that run underneath the CBD, and resurfaces at the north end of Ingleburn Rd. The creek then continues in north-east direction towards Macquarie Fields, and from there it veers towards Bow Bowing Creek, which it joins north of Macquarie Links Golf Club.

Overall, Redfern Creek remains within its banks until the culvert under Cumberland Rd, with minor flooding of the nearest properties downstream of Matthews Square. However, this is only observed in the PMF. Downstream of Cumberland Rd, the creek flows exceed the CBD culvert capacity from the 20% AEP upwards, resulting in overland flooding running through Ingleburn CBD. This is described in more detail in next section.

Upon exiting the CBD culvert, the creek receives floodwaters from an overland flow path and from Koala Walk Drain, a short section of creek running in a north-west direction from Kingfisher Reserve to the corner of Carlisle St and Macquarie Rd. This confluence causes flooding of some properties between Macquarie Rd, the railway and James St, with those closer to Macquarie Rd experiencing flooding from the 20% AEP. Further flooding, but mostly from the 0.2%AEP event, is seen where Redfern Creek crosses James St and Henderson Rd, due to the culvert capacity being exceeded.

Past Henderson Rd, Redfern Creek overtops its banks again in Milton Park, affecting some of the properties north of the park from the 1% AEP event. Further downstream, more flooding is observed before the culvert under the railway, with some of the roads and properties around Clarence Reserve affected from the 1% AEP event.

n) Macquarie Creek

Macquarie Creek (Map 10, Vol. 2) runs from Hazlett Park, in Macquarie Fields, in a northern direction through Saywell Rd, Third Ave and Parliament Rd. From there, it veers east to join Bow Bowing Creek past Harold St and Victoria Rd. Overall, the creek is well contained within its banks, with some minor property affectation in Brooks St. Further downstream, past Harold St (at Coronata Way), the creek is joined by an overland flow path forming in Bass Reserve. The creek and the overland flow path join right before the culvert under Victoria Rd, which results in flood affectation of some residential properties around Coronata Way. In most instances this happens only in the PMF, although one of the properties along Coronata Wy is affected from the 0.2% AEP event. Past Victoria Rd, more flooding can be observed before the confluence with Bow Bowing Creek, however with no significant affectation of residential properties in events smaller than the PMF.

7.1.3 Overland Flooding

Overland flooding is caused by rainwater running downhill. This is called an overland flow path. In an overland flow path, flow depth and velocity can reach levels high enough to become a risk to property and life.

Overland flow paths may be managed through the installation of stormwater systems, such as kerb and guttering, drainage pits and underground pipes to contain and direct flows to an open drain, creek or a river.

In some instances, rainwater may pond within topographic depressions, creating large puddles. These puddles, although still considered overland flooding, have negligible flow velocity and are much less of a concern.

Overland flow paths in the BBBC Creek catchment form on both sides of the main creek, and generally run along roads or through properties, until they join the main creek or one of the tributaries (Map 11 to Map 16, Vol. 2). The main overland flow paths within the BBBC Creek catchment which affect properties are:

- In Ambarvale, an overland flow path runs off in east to west direction along the southern end of Therry Rd, at the back of the residential properties in Tigg Pl and Miggs Pl. Some of these properties experience mild flooding from the 5% AEP (Map 11, Vol. 2). From the 0.2% AEP event, the site is affected by mainstream flooding from Birunji Creek.

- In Bradbury, water runs off The Parkway across St Johns Rd and down Campbellfield Ave to the corner of Poplar Cr. From there it cuts across numerous properties between Campbellfield Ave and Greenoaks Ave, continuing down Greenoaks Ave, then through residential properties towards Fishers Ghost Creek. Here, minor property flooding is observed from the 20% AEP (Map 12, Vol. 2).
- There is another overland flow path in Bradbury which starts in Alliot St and runs northwest along the rear of properties along Guise Rd with another flow route running along Guise Rd. These converge at Karri Pl then the water flows along Bloodwood Pl as well as along the rear of houses in Bloodwood Pl and into Ash Pl before joining Fishers Ghost Creek. It causes flooding from the 20% AEP event to some properties in Bloodwood Pl, Karri Pl and Ash Pl (Map 13, Vol. 2).
- In Airds a flow path originates near the crossroad between Maitland Wy and Merino Cr. From this point, the flow path runs north into Kullaroo Av, and it reaches further north until it is channelled in Creigan Rd. From this point to the confluence with Smiths Creek, floodwaters become relatively hazardous, even in events as frequent as the 5% AEP. However, flooding in frequent events is generally contained within Creigan Rd, with the adjacent properties experiencing minor affectation from the 1% AEP, and more significant affectation in the PMF (Map 14, Vol. 2).
- In Kearns, an overland flow path runs south along Epping Forest Drive until it reaches a low spot in front of some houses which back onto Vale Brooke Reserve. From here the flow heads through the residential properties to join Thompson Creek (Map 15, Vol. 2).
- In Raby a flow path forms between Raby Rd and Harrier Ave, then runs north through properties towards the corner of Starfighter Ave and Sopwith Ave and then further north through the back of residential properties to Spitfire Dr. Here, some properties experience flooding from the 20% AEP. The flow path then continues north along Spitfire Dr all the way to Bunbury Curran Creek (Map 16).
- In Minto, the electric power substation is affected by local overland flooding from the 20% AEP event. The flooding locally runs off towards Bow Bowing Creek (Map 17, Vol. 2).
- At the southern end of Ingleburn, two overland flow paths run parallel to each other from Euroka St to Ingleburn Rd, in a south-east to north-west direction. These affect several properties, however mostly in rare events (i.e. from the 0.2% AEP) (Map 18, Vol. 2).
- A significant overland flow path runs from south-east to north-west direction through Ingleburn CBD. This starts south-west of the CBD, downstream of the culvert under Cumberland St, on Redfern Creek. Here, Redfern Creek exceeds the culvert capacity from the 5% AEP event, resulting in floodwaters affecting residential and commercial properties north and south of Norfolk St, and continuing downstream towards the CBD through properties on Carlisle St, Albert St, Oxford Rd and Ingleburn St. The overland flow path rejoins Redfern Creek once this exits the CBD culvert system, north-west of the crossroad between Macquarie Rd and Ingleburn St (Map 19, Vol. 2).
- At the eastern end of Ingleburn CBD, an overland flow path runs from Oxford Rd in a north-west direction towards Koala Walk Reserve, where it joins Koala Walk Drain. The path causes above floor flooding from the 20% AEP in four buildings in Oxford Rd (Map 19, Vol. 2);
- In Glenfield, a flow path flows from the corner of Fawcett St and Canterbury Rd south-west towards Bow Bowing Creek, passing through Harrow Rd and affecting some residential properties from the 20% AEP event. (Map 20 Vol. 2).
- In Macquarie Fields, an overland flow path runs from the south end of Bass Reserve in a north direction through Eucalyptus Dr to Coronata Wy, where it joins Macquarie Creek. The path

may cause moderate flooding of some of the properties east of Eucalyptus Dr, in Berrigan Cres and both in and to the north of Rosewood Dr. However this would result in above floor flooding only in three buildings (from the 2% AEP) (Map 21, Vol. 2).

7.1.4 Rate of Rise and Flood Duration

Results of the Flood Studies show that flooding in the BBBC Creek catchment is characterised by a quick rate of rise and short-duration. The rate of rise and duration of flooding increase slightly as one moves down the catchment.

Figure 14 to Figure 19 show hydrographs of the 1% AEP event, extracted at various locations in creeks from the upper to the lower parts of the catchment. Note that some display multiple flood peaks which reflects the relative timing of flows arriving from different sub-catchments. The following discussion focuses on the maximum peak.

It can be seen how in the upper catchment the peak depth is reached within 6 hours from the beginning of the rain, after which the level drops rapidly. This happens both in the tributaries (Figure 14) and in the main creek (Figure 15 and Figure 16). As one moves downstream, the peak level is reached after six hours, and the overall flood duration increases (Figure 17 and Figure 19).

The hydrograph extracted in Ingleburn CBD (Figure 18) shows a significantly different behaviour, which is typical of overland flash flooding where flood depths are shallower and the flood durations are much shorter.

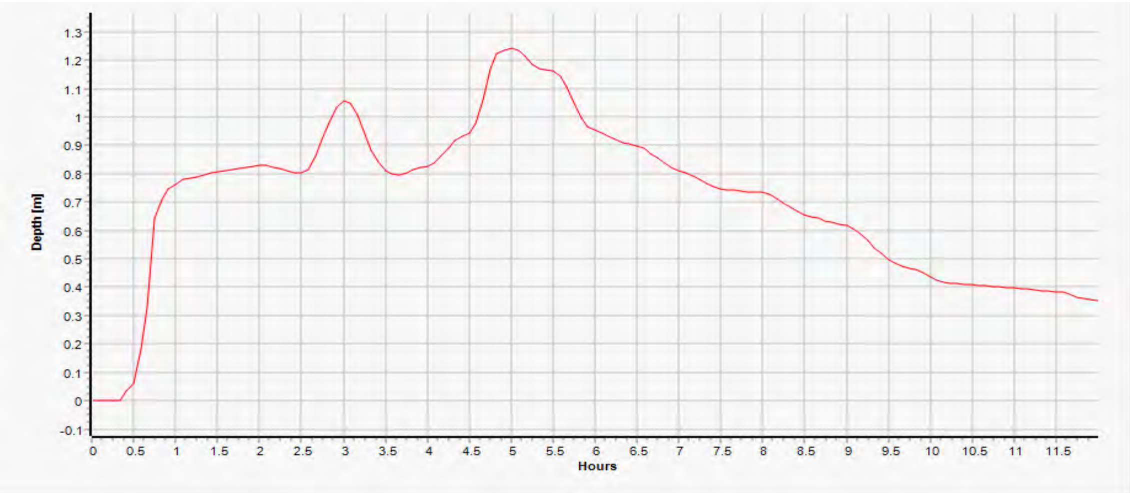

Figure 14. 1% AEP hydrograph: Fishers Ghost Creek (in Bradbury, downstream of Greenoaks Ave)

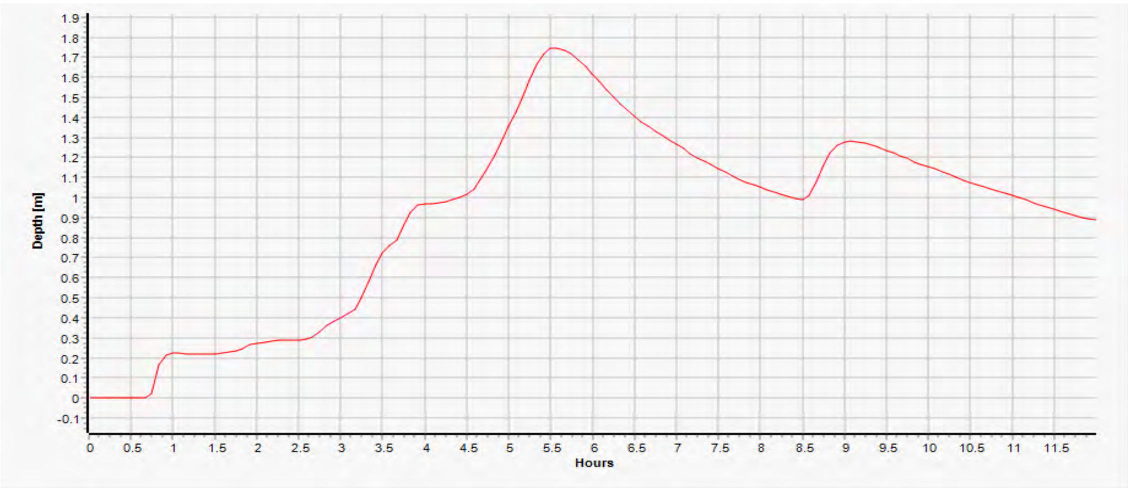

Figure 15. 1% AEP hydrograph: Upper Bow Bowing Creek (Campbelltown, upstream of Gilchrist Dr).

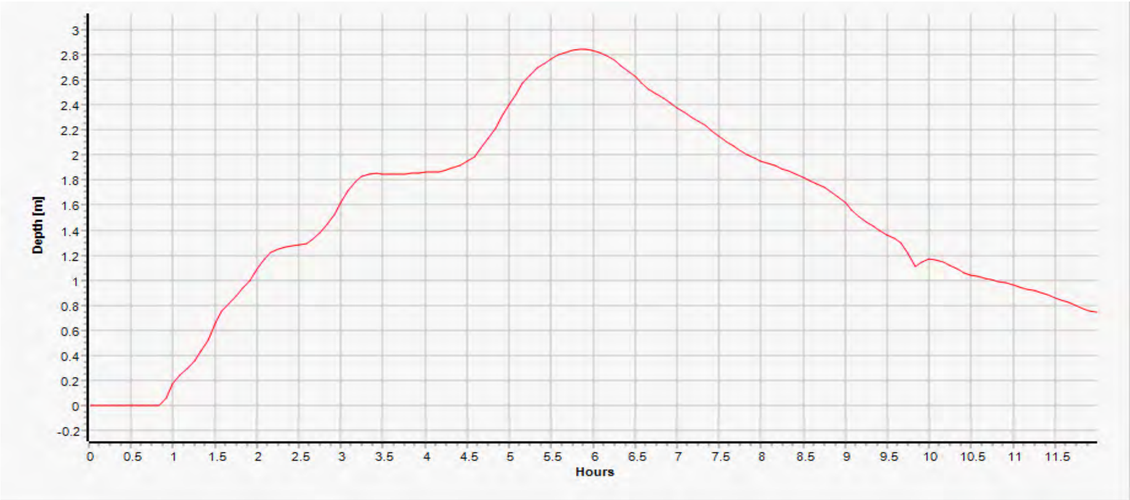

Figure 16. 1% AEP hydrograph: Bow Bowing Creek (Minto, upstream of Thompson Creek)

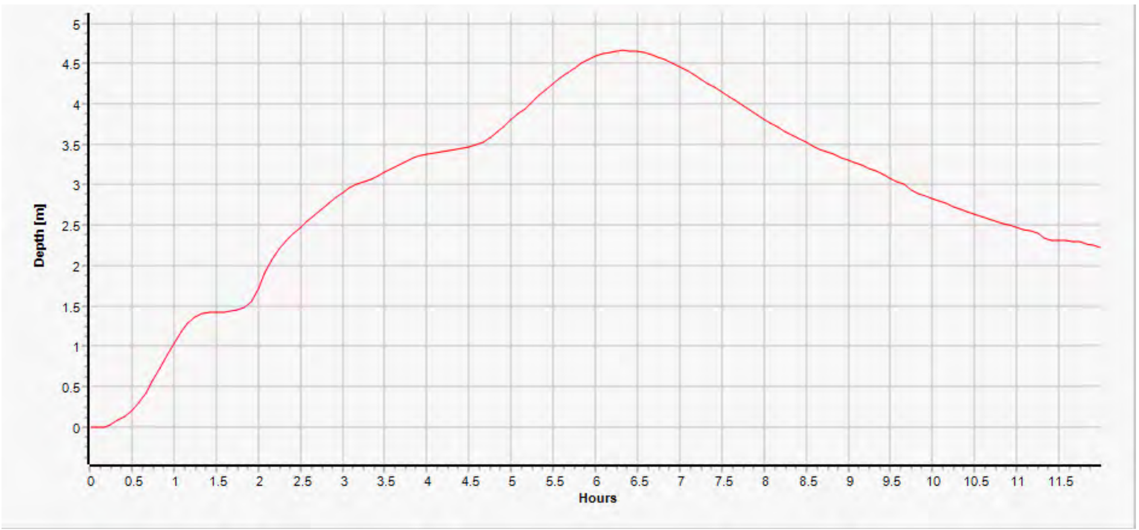

Figure 17. 1% AEP hydrograph: Bunbury Curran Creek (Ingleburn, upstream of Henderson Rd)

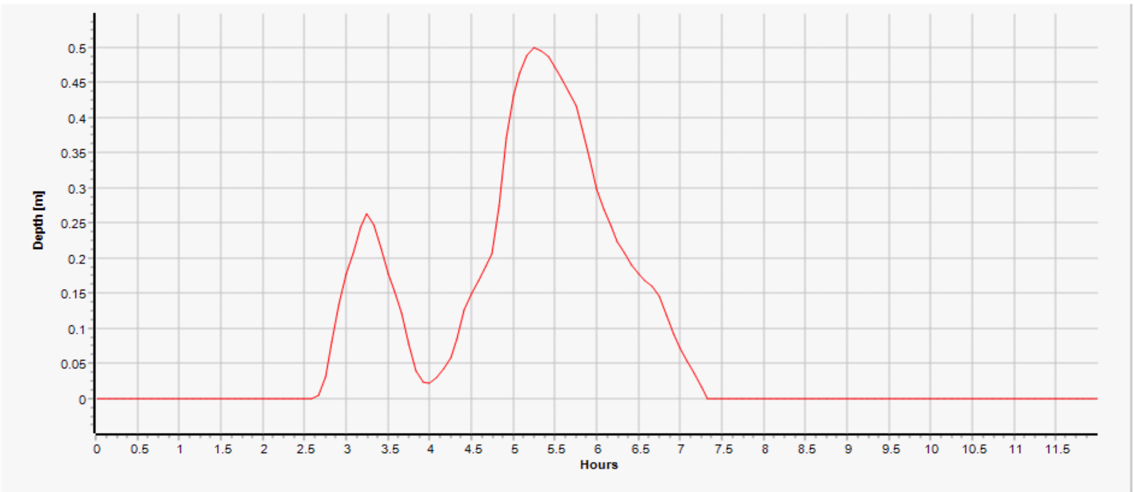

Figure 18. 1% AEP hydrograph: overland flooding in Ingleburn CBD (Macquarie Rd and Boots Ln)

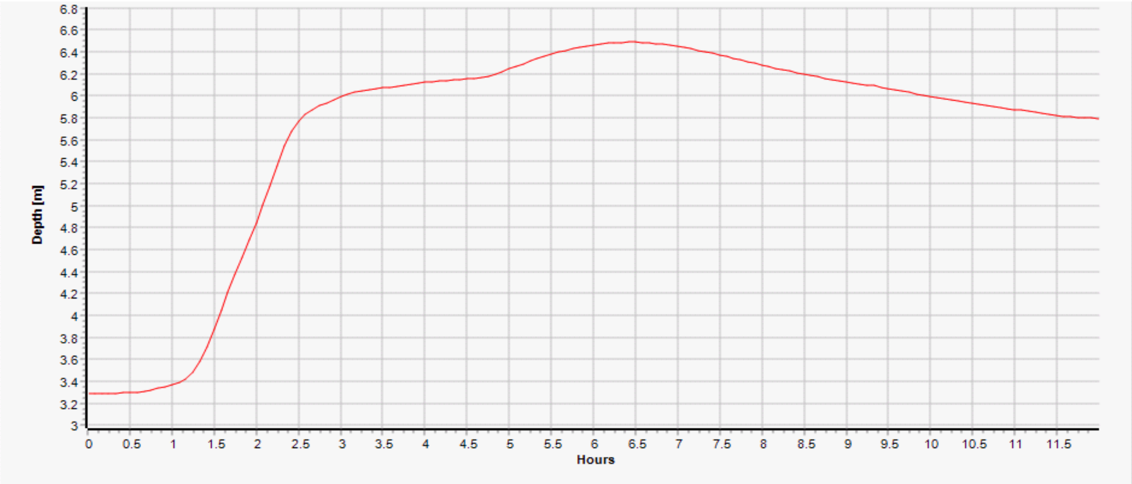

Figure 19. 1% AEP hydrograph: Bunbury Curran Creek (Macquarie Fields, upstream of the railway culvert)

7.2 FLOOD RISK MAPPING

While mapping flood extents, depths and velocities is useful, some form of classification of flood behaviour is required for determining what risks flooding poses and what are appropriate land uses in the floodplain. This is done by means of:

- hydraulic classification;
- flood hazard classification; and
- emergency response classification.

7.2.1 Hydraulic Classification

Hydraulic classification divides the floodplain according to its hydraulic function. The NSW Floodplain Development Manual (2005) recommends three hydraulic categories: floodway, flood storage and flood fringe.

These hydraulic categories provide an indication of the potential for development across different sections of the flood-prone land to impact on existing flood behaviour and highlights areas that should be retained for the conveyance or storage of floodwaters.

It is not feasible to provide explicitly quantitative criteria for defining these classes, as the significance of such areas is site specific. Often, the following criteria are applied:

- Floodways – areas conveying a significant proportion of the flood flow and where even partial blocking would cause a significant redistribution of flood flow or a significant increase in flood levels;
- Flood storage areas – those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas:
- Flood fringe areas – the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

Due to the relative uniformity of planning controls, development type, stormwater design standards and topography across the BBBC Creek catchment, Council developed “ad-hoc” quantitative criteria to define and map hydraulic categories. These are based on combinations of flow velocity, depth and land use (i.e. drainage areas vs. urban/other). Council’s quantitative criteria are detailed in Table 9 (CSS, 2011) and graphically represented in Figure 20 and Figure 21.

Table 9. Criteria for Hydraulic Classification adopted by Council for the broad BBBC Creek catchment only (CSS, 2011)

Hydraulic Category	Definition from Flood Manual	Criterion Adopted By Council
FLOODWAY	Those areas where a significant volume of water flows during floods, often aligned with obvious natural channels and drainage depressions. They are areas that, even if only partially blocked, would have a significant impact on upstream water levels and/or would divert water from existing flow paths resulting in the development of new flow paths. They are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.	A part of the BBBC extent of flood-prone land that is not classified as Flood Fringe or Flood Storage.
FLOOD STORAGE	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. If the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows	A part of the BBBC extent of flood-prone land that is not classified as Flood Fringe, and: If the land use is classified as “drainage”: Depth (D) ≤ 2m AND Flow Velocity (V) ≤ (-0.3D+0.8) OR D ≥ 2m, AND V ≤ 0.2m/s If land use is classified as “urban”: V ≤0.2 m/s
FLOOD FRINGE	The remaining area of land affected by flooding, after floodway and flood storage areas have been defined. Development (e.g., filling) in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.	V ≤ 0.2m/s, AND V ≤ (-40D = 6)

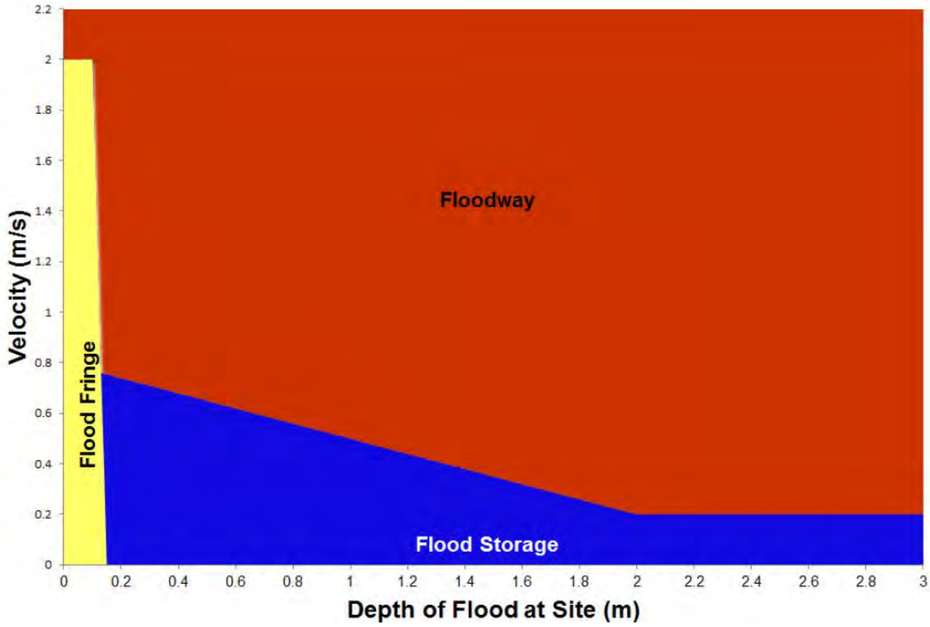

Figure 20. Adopted hydraulic category criteria for land classified as "drainage"(CSS, 2011)

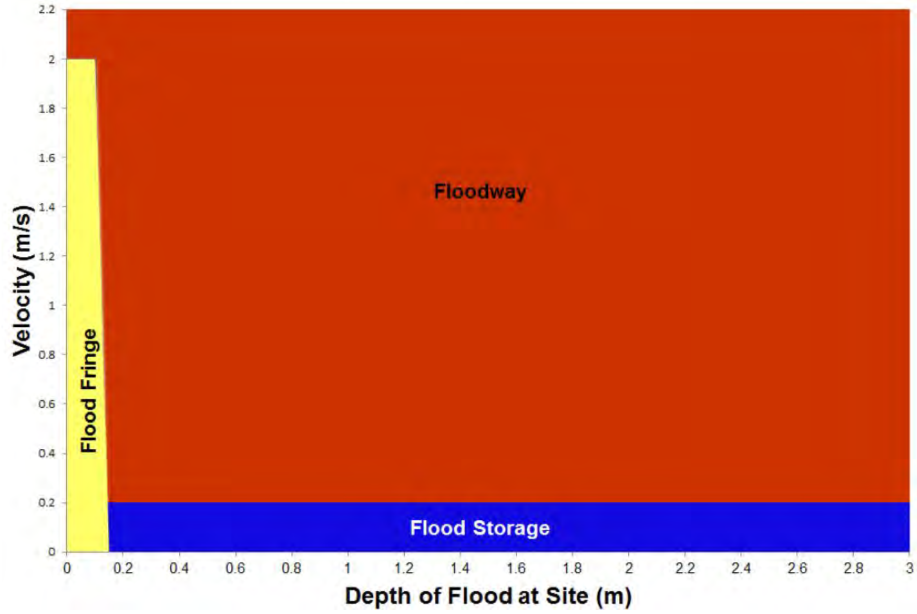

Figure 21. Adopted hydraulic category criteria for land classified as "urban" (CSS, 2011)

7.2.2 Provisional Hazard Categories

Flood hazard is a parameter defined to encapsulate a measure of the potential damage that floodwaters can cause to life and property. Flood hazard is obtained as the product between flow velocity and depth.

The NSW Floodplain Development Manual (2005) distinguishes high hazard, low hazard and a 'transitional' hazard using peak flood depths, velocities and depth-velocity product. This classification is then used as a starting point for mapping flood risk precincts.

For the purposes of the BBBC Floodplain Risk Management Study, consideration has also been given to a more finely divided classification presented in AIDR (2017). This combined previous research on the impact of floodwaters on people, vehicles and buildings to generate a comprehensive flood hazard classification. This classification includes six categories, ranging from H1 (no restrictions), to H6 (not suitable for people, vehicles or buildings). These six hazard categories are shown in Figure 22.

Provisional flood hazard categorisation based around depth and velocity combinations does not consider a range of other factors that influence flood hazard. Therefore provisional hazard categorisation should be used in conjunction with the following factors to determine true hazard categories:

- Extent of flood;
- Effective warning time;
- Flood preparedness;
- Rate of rise of floodwaters;
- Duration of flooding;
- Evacuation problems;
- Effective flood access; and
- Type of development.

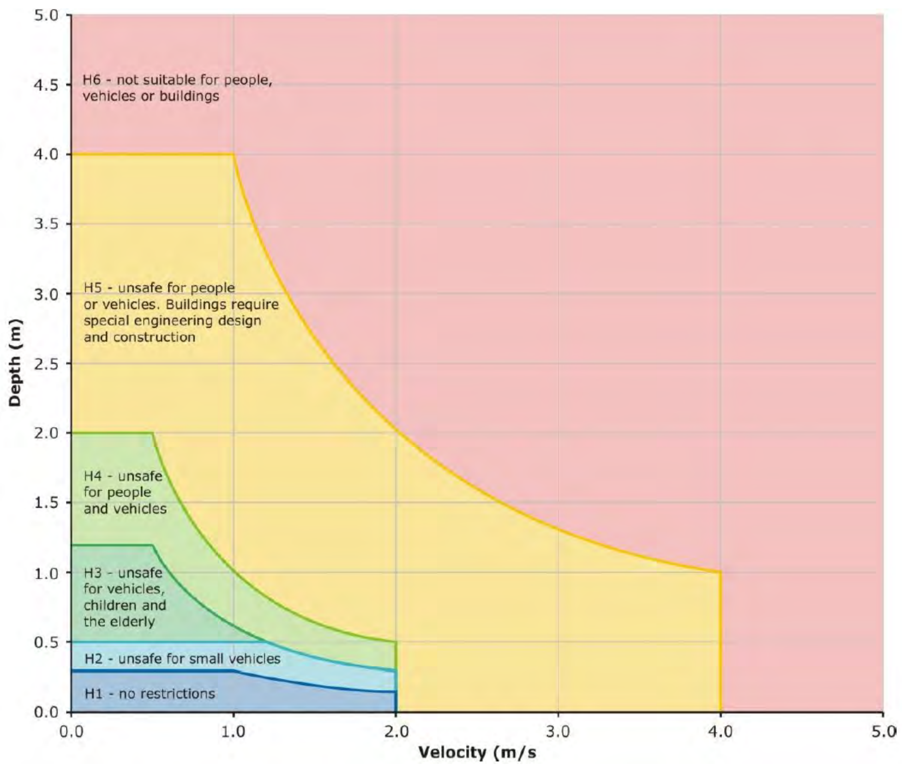

Figure 22. Provisional Flood Hazard Categories (AIDR, 2017)

7.2.3 Emergency Response Classification

In addition to a classification of floodwaters based on hydraulic type and hazard level, flood risk to people can be further described using the NSW SES's Flood Emergency Response Planning (ERP) Classification of Communities (DECC, 2007b).

This classification provides a way to measure the relative vulnerability of communities when they are responding to a flood threat, which is from immediately before to immediately after the flood event.

During a flood, a community is deemed more vulnerable if evacuation, resupply and rescue operations are difficult. The NSW SES's ERP classification proposes to use the PMF to identify and map the following categories of land (in order of significance from higher to lower risk):

- Low Flood Islands (LFI) and Low Trapped Perimeters (LTP)
- High Flood Islands (HFI) and High Trapped Perimeters (HTP);
- Areas with Overland Escape Route (OER);
- Areas with Rising Rd Access (RRA);
- Indirectly Affected Areas.

Flood Islands are defined as "inhabited or potentially habitable areas of high ground within a floodplain linked to the flood- free valley sides by a road across the floodplain and with no alternative overland access. The road can be cut by floodwater, closing the only evacuation route and creating an island. After closure of the road the only access to the area is by boat or by aircraft". Flood Islands include High Flood Islands (HFI) – and Low Flood Islands (LFI).

Low flood islands are those areas where the escape routes are cut before premises are inundated, but as floodwaters rise there is insufficient area, or no land, on which to shelter and they can be overwhelmed by floodwaters. People trapped in LFI are at life risk and the only safe response option is to evacuate early (i.e. before they are surrounded by floodwaters) or to take shelter at the higher levels of buildings, provided that these can withstand the forces of a PMF.

High flood islands are those areas whose escape routes are cut by floodwaters but there is sufficient available high ground for occupants of the isolated area to retreat to should floodwaters continue to rise and enter their building. Late evacuation is not a safe option for people isolated in HFIs, and resupply and rescue operations can be difficult.

Trapped Perimeter Areas are defined as “habited or potentially habitable areas at the fringe of the floodplain where the only practical road or overland access is through flood prone land and unavailable during a flood event. The ability to retreat to higher ground does not exist due to topography or impassable structures”. Trapped Perimeter Areas are similar to Flood Islands, and can also be classified in high and low, depending on whether these are completely submerged with floodwaters in the PMF.

Areas with Overland Escape Routes (OER) are areas whose road access gets cut in the PMF but from which evacuation is possible by walking or driving overland to higher ground.

Areas with Rising Road Access (RRA) are areas whose access road rises steadily uphill and away from floodwaters. Even though these areas will eventually flood in the PMF, evacuation can take place by vehicle or on foot along the road as floodwater advances.

Indirectly affected areas are areas outside the extent of flood-prone land which may be indirectly affected by the flooding because of impacts on infrastructure such as the transport network.

The extent of flood-prone land within the BBBC Creek catchment was classified according to the NSW SES’s ERP. This was done to provide information to the NSW SES, and to support the identification of risk “hotspots”, in which local flood mitigation measures may be required (see Section 9).

For the purposes of this FRMS only the high and low flood islands were identified to determine where risk to people was most significant.

Trapped Perimeter Areas were not mapped because of the difficulties in identifying all possible barriers to evacuation on an area as vast as the BBBC Creek catchment. This would have required recognising even small-scale items such as property fences, which in an evacuation would become an obstacle for elderly people or people with disabilities. However, where major obstacles were identified, such as railways or motorways embankments, these were considered in the identification of flood islands.

Flood islands were mapped using the PMF and a flood hazard threshold of H2 or higher.

The classification was performed using the software Water Ride, which can provide a time-dependent, dynamic representation of the flood extent, and ESRI ArcGIS, which was used for the spatial analysis and for the delineation of the flood islands.

Map 22 (Vol. 2) shows the size and distribution of the flood islands. It should be noted that while each flood island is identified using the PMF, some flood island are isolated starting from more frequent events; these are the islands of greatest concern..

It should also be noted that the HFIs and LFIs identified may be overestimated as Council’s flood model does not include private stormwater drainage systems which, particularly in the industrial areas, may convey significant amounts of water. This would reduce the incidence of both HFIs and LFIs.

8 ASSESSMENT OF FLOOD IMPACTS

To be able to determine how best to manage flooding in the BBBC Creek catchment, it is first necessary to understand the types and extents of flood impact on property and people.

This section explains how the results of the BBBC Creek Catchment Flood Studies were combined with other information to estimate:

- Direct and indirect flood damages to buildings;
- Road inundation; and
- Risk to people.

It should be noted that the information provided in this section is subject to the following assumptions and limitations:

- The analysis was undertaken with the best available information at the time of publication. The quality of each dataset used, as well as implications for accuracy of the results, are discussed in the text;
- The flood models used in the Flood Studies represent the worst case scenario for each probability event;
- The flood models used in the Flood Studies do not include the contribution of private drainage systems. These would significantly reduce flooding of industrial and larger commercial buildings, particularly in the more frequent events;
- Where surveyed floor levels were not available, conservative assumptions were made. As such, for these buildings, the estimated Above Floor Flooding (AFF) levels represent a worst case scenario.
- Buildings were assumed to experience Above Floor Flooding (AFF) where the model results showed, at any point around the building perimeter, a water level higher than the estimated building floor level. However in some instances there may not be ways for floodwaters to enter the building (e.g. doors, windows or other openings), even when the water level is higher than the building floor level. As such, the flood impact estimates presented in this section are conservative and should be regarded as the worst case scenario.

8.1 BUILDING DATABASE

A building database was prepared to better understand the spatial distribution of building inundation, and to quantify the impacts of flooding in the BBBC Creek study area. This also facilitated an economic appraisal of floodplain management options. The database contained the following information for each building:

- Location, shape and area
- Number of storeys (i.e. single storey vs multi-storey)
- Ground level
- Floor level
- Land use, namely: Residential (R); Commercial (CM); Industrial (I); Education Facilities (ED); Health Care (HC); Emergency Services Facilities (ES); Police Stations (PS).

A detailed description of how the building database was generated starting from the data that was available is provided in Appendix C of this Study.

8.2 DAMAGES ASSESSMENT

8.2.1 Types of Flood Damage

The definitions and methodology used in estimating flood damages are well established. Figure 23 summarises all the types of flood damages examined in this study. The two main categories are tangible and intangible damages. Tangible flood damages are those that can be more readily evaluated in monetary terms.

Tangible flood damages are further divided into direct and indirect damages. Direct flood damages relate to the loss (or loss in value) of an object or a piece of property caused by direct contact with floodwaters, flood-borne debris or sediment deposited by the flood.

Indirect flood damages relate to loss in production or profits, loss of wages, additional accommodation costs and living expenses, cost of transport detours and any extra outlays that occur because of the flood.

Intangible damages relate to the social cost of flooding and are more difficult to quantify in monetary terms and often difficult to quantify using other metrics. Intangible damages can also be subdivided into direct or indirect damages.

Direct intangible damages include environmental damage, loss of items of sentimental value, and mortality or morbidity caused by direct contact with flood waters. Indirect intangible damages include additional losses induced by the direct tangible and intangible losses which can include impacts due to financial hardship and stress.

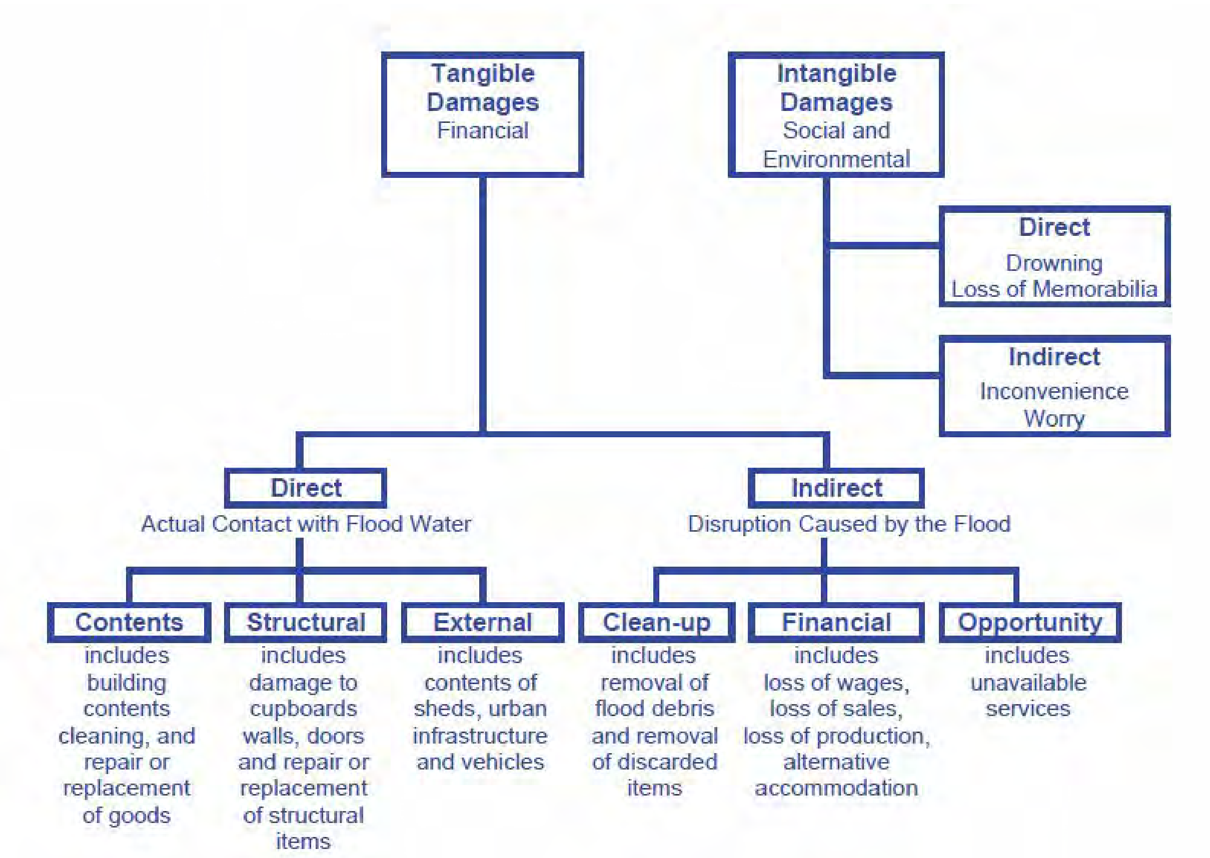

Figure 23. Types of flood damage

Source: Floodplain Development Manual (DIPNR, 2005)

8.2.2 Flood Damages Calculations

Direct flood damages have been estimated by applying one of several stage-damage curves to every building included in the database. It should be noted that these results represent the worst case scenario as they were obtained under the assumptions listed in the disclaimer at the beginning of Section 8.

The stage-damage curves relate the amount of flood damage that would potentially occur at different depths of inundation, for a particular building type, both residential and non-residential.

a) Residential

i) Direct Damages

In October 2007, the then Department of Environment and Climate Change, now Office of Environment and Heritage (OEH), released guidelines to facilitate a standard methodology for assessing residential flood damages (DECC, 2007a). It is a requirement of OEH grant funded projects that the OEH standard procedure be employed in order that the merits of funding flood mitigation projects can be compared consistently across NSW.

The OEH method can be applied using a dedicated computational tool, provided in the form of an MS Excel spreadsheet. The tool requires some input parameters to tailor the calculations to the characteristics of each particular study area. The parameters used in this study for all flood ranges and dwelling sizes are detailed in Appendix B.

The OEH spreadsheet also requires that the flood level for each design scenario is entered for each building. The maximum flood level impacting each building was extracted from the flood model results by applying a 0.5m buffer around the building footprint and selecting the maximum flood level within the buffered area.

The resultant stage-damage curves (for residential buildings) are shown in Figure 24.

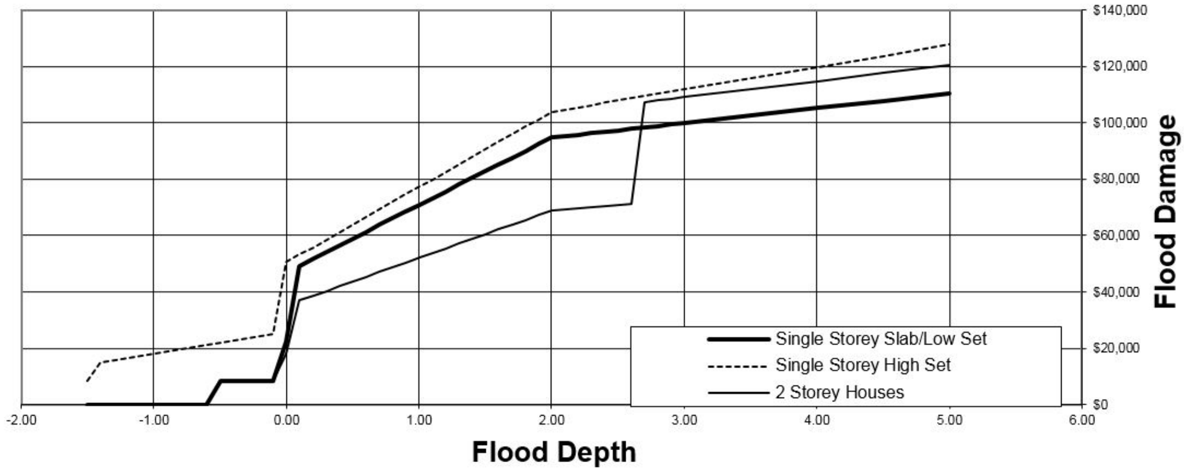

Figure 24: Residential stage-damage curves for BBBC Creek catchment

ii) Indirect Damages

For the residential sector, indirect damages include clean-up costs, the costs of alternative accommodation, the costs of moving, loss of wages and additional living expenses. A number of methods have been put forward for estimating these costs either individually or in aggregate.

The simplest method used has estimated indirect damages as a percentage of direct damages. Past research into the percentages assumed has indicated ranges of between 5% and 40% depending on what was included in the damage estimates (for example, the lower end of the range excluded clean-up costs) and the scale of the flood impacts.

The OEH damage calculation spreadsheet includes an allowance for alternative accommodation and an allowance for clean-up costs, with the recommended clean-up cost being $4,000 (2001 dollars). This value was adjusted to 2016 dollars, which produced a value of $6,890, and was used to estimate clean-up costs in this study area for each building experiencing external damages.

In regards to alternative accommodation, OEH's recommended value of $220/week (inflated to $379 in 2016 dollars) was also used in this study, assuming that alternative accommodation will be required for two weeks.

Together these two contributions to indirect residential damages make up a total cost of $7,648, which is the same for every home irrespective of the depth of flooding which it experiences or the frequency of the event. Due to the relatively low flood depth that would be observed in the study area, this cost was considered a realistic estimate of the total residential indirect costs per building and compared well with other indirect damage estimation methods.

b) Non-Residential Buildings

i) Direct Damages

Presently there is no adopted industry standard suite of stage-damage curves for calculating direct commercial and industrial flood damages in Australia.

The most widely adopted stage-damage functions in Australia are those developed for the ANUFLOOD model, developed in 1983 and revised in 1994. Many studies have used the ANUFLOOD functions with adjustment factors to derive current values, based on Consumer Price Index (CPI) or Average Weekly Earnings (AWE).

Other studies in Australia adopt the FLDAMAGE model developed by Water Studies in 1992. FLDAMAGE is similar to ANUFLOOD in that it derives an estimate of total flood damages for inundated buildings by applying stage-damage curves appropriate to each type of property.

Both of these sets of stage damage curves were derived from data collected following Australian floods in the 1970s and 1980s when the contents of commercial and industrial premises were very different to today.

An international literature search has shown that the most up to date stage damage curves have been developed by the Flood Hazard Research Centre (FHRC, 2013) at Middlesex University in the UK. These stage-damage curves are based on field observations made in the UK between 2003 and 2005. As such, they provide a contemporary evaluation of the damage to buildings and building contents. They are referred to as FLOODSite MCM.

The MCM curves are derived empirically (i.e. using damage estimates after real flood events) and represent a great diversity of residential, commercial, industrial and other building uses.

Residential dwellings in the UK differ significantly in design and contents to those in Australia and the residential stage damage curves are therefore difficult to compare with the OEH residential stage damage curves. However, contemporary Australian industrial and commercial premises are more likely to have similar contents to equivalent contemporary premises in the UK than they would to equivalent Australian premises from the 1970s and 1980s. For this reason it was considered that the MCM stage damage curves were more appropriate to use for this study than the ANUFLOOD or FLDAMAGE curves.

It is noted that commercial and industrial building uses often change so to apply specific curves to individual buildings in the Campbelltown flood prone land may not be accurate over time.

Therefore for this study six different stage-damage curves for non-residential premises were used: commercial, industrial, education facilities, healthcare facilities, emergency services and police stations. The relevant stage damage curves are shown in Figure 25.

The commercial and industrial curves are derived from average values across the full range of MCM commercial and industrial curves respectively, which the other categories used the actual MCM curves. The original MCM curves were converted to Australian dollars and adjusted to 2016 values.

Figure 25 shows how the curve for education buildings stands out from the other curves as being the steepest. This can be explained by taking into account the following considerations:

- Education buildings are usually larger than other buildings, making it more difficult to manage flood risk to contents.
- Education buildings can have valuable contents such as computers, laboratories, workshops, audio visual facilities and music equipment
- Education buildings are empty more often than other buildings, and are

supervised by a small number of staff. If a flood occurred when the building is empty, there would be no capacity to move valuable items to higher levels, assuming that there are higher levels.

- If a flooding occurred when the education building is being used, the main aim of the staff would be to protect students, not the building contents.

- In comparison, a hospital has arguably more valuable contents. However a hospital is constantly open, has a larger staff and usually has a contingency plan to respond to natural hazards and minimise risk to people and damages. In fact, most of the equipment in a hospital is easily movable and in most instances would need to be moved at higher levels together with the patients who are using it.

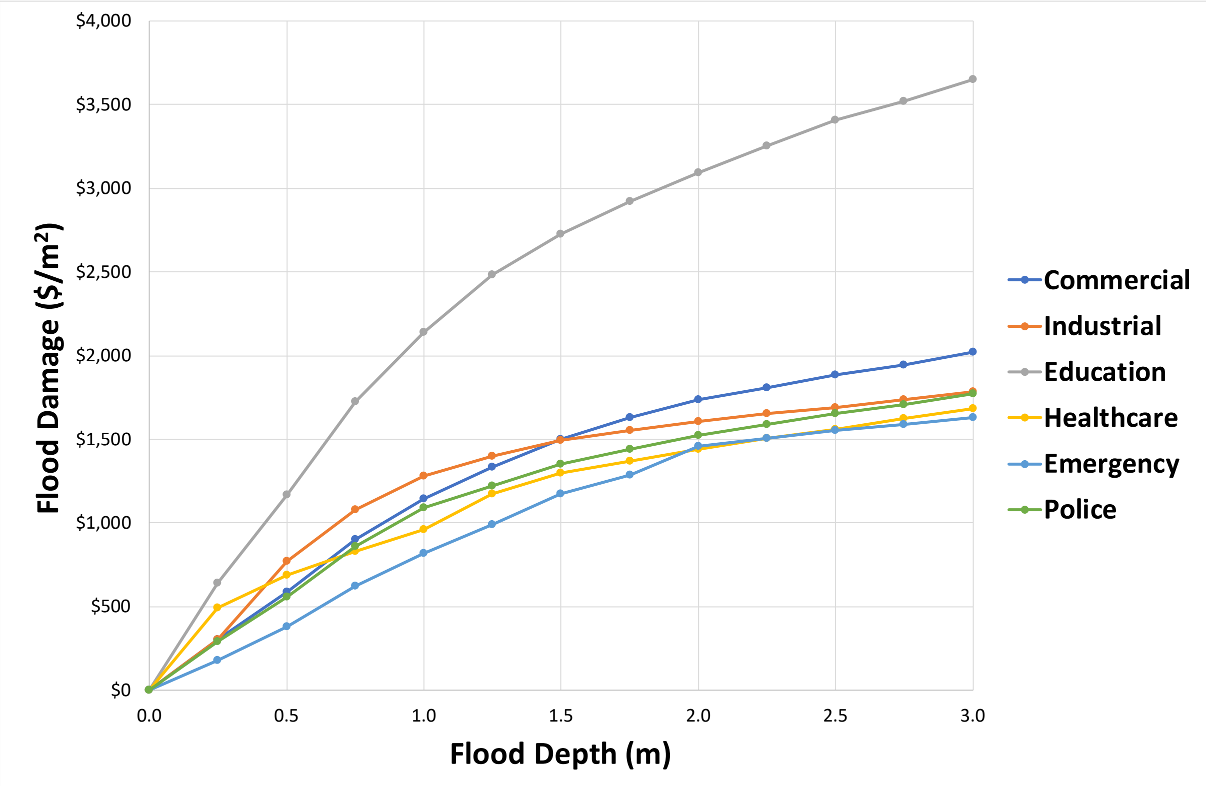

Figure 25: Commercial and industrial stage damage curves

ii) Indirect Damages

Indirect business damages include:

- removal and storage costs;
- clean-up costs;
- payments to workforce for unproductive work ;
- extra payments to the workforce (e.g. additional staff or overtime) to make up for lost production or to maintain production;
- costs of transferring production including use of alternative premises or less efficient plant, equipment or systems;
- long term efficiency losses;
- losses to customers;
- loss of production in non-flooded businesses due to interruption of workforce, supplies or sales;

- downturn in trade due to changed regional expenditure patterns caused by flooding;
- loss of business confidence through cancellation of contracts;
- loss of market position and possible closure of business.
- There are several methods which have been suggested to estimate indirect commercial and industrial damages, either in part or in aggregate.
- The Bureau of Transport Economics (BTE, 2001) cites NRC (1999) as international evidence that indirect costs increase as a proportion of total disaster costs with the size of disaster. It also notes that estimation of indirect damages as a percentage of total direct damages is common but varies widely as there is no simple relationship between the two types of damages.
- In a review of flood damages research undertaken for the Warragamba Flood Mitigation Dam EIS (Sydney Water, 1995), indirect damages for commercial and industrial buildings ranged from 25% to 150% of direct damages, depending on the type of business and flooding severity. The higher values were derived from research in Nyngan following the flood there in 1990 which resulted in much of the town being flooded, the entire town being evacuated for three weeks and spending patterns being highly abnormal when people returned. This is unlikely to be the case in Campbelltown LGA.
- QNRM (2002) recommends the ANUFLOOD model estimations of indirect commercial damages as 55% of direct commercial damages. Bewsher Consulting (2003) cites studies that suggest an estimate for indirect commercial/industrial damages as 5% of actual direct damage for every day of trading that is lost. In later studies, Bewsher Consulting (2011a & b) calculated the indirect commercial damages as 20% of direct commercial damages, in keeping with advice from DECCW. This was in a flash flood catchment where part of a shopping precinct would be flooded and is perhaps analogous to Campbelltown commercial precincts, but not necessarily the industrial areas.
- In contrast to residential clean-up costs, the clean-up costs for commercial and industrial damages are estimated by BTE (2001) as ranging between $2,000 and $10,000 (in 1999 dollars) and clean-up times to be between only 1 and 3 days.
- Reese and Ramsay (2010) estimate clean-up costs for commercial and industrial buildings by multiplying clean-up time by an hourly labour rate ($80/hr and $45/hr respectively).
- Disruption to business involves the estimation of value added foregone, or loss in profits, not including the value of lost sales or stock (EMA, 2002; BTE, 2001; QNRM, 2002). This value is influenced by the length of disruption, whether the business can be transferred within or beyond the affected area and availability of alternative resources (BTE, 2001; Scawthorn et al., 2006). Smith (1979) estimated the cost of lost business accounting for 67% of indirect commercial damages and 71% of indirect industrial damages.
- Reese and Ramsay (2010) measure business disruption by functional downtime and loss of income. Functional downtime is assessed as the time (in days) the business cannot operate and is scaled according to a building damage threshold of 10%. Loss of income is ascertained by determining daily income per employee.
- Given the large number and diverse types of commercial and industrial premises across the catchment it is not practical to estimate functional downtime and loss of income per business therefore the indirect losses have been estimated as a percentage of direct losses.

We assumed that indirect damages commercial premises would be 20% of direct costs and that they would be 50% of direct costs at industrial premises for the reasons detailed in Appendix B.

c) Other Types of Damage

In some floodplain risk management studies, an estimate of 15% of total residential and commercial/industrial damages has been added to make a provision for damages to infrastructure.

Direct intangible damages can include fatalities, injuries and illnesses caused by coming in contact with flood waters, loss of pets and memorabilia, erosion and sedimentation, pollution, weed invasion and loss of biodiversity. The indirect intangible losses from flooding can be varied, complex and substantial and can include business liquidations and personal financial stress or bankruptcy, mental health impacts and other stress induced illnesses including aggravation of pre-existing medical conditions, and the impacts of disruption to essential services and infrastructure including the inconvenience of alternative transport, accommodation or supply arrangements.

Some studies include a tangible estimate (sometimes 20-25% of total residential and commercial/ industrial damages) in an attempt to measure intangible damages. These include the impacts of flooding on health – physically and emotionally. OEH has also indicated that this is an accepted approach in NSW.

Consistently with previous work, this study considered:

- a damage to infrastructure equal to 15% of total residential and commercial/ industrial damages, and
- a social/intangible damage estimated to be 25% of total residential and commercial/industrial damages.

d) Economic Analysis

An economic appraisal is required for all proposed capital works in NSW, including flood mitigation measures, in order to attract funding from the State Government's Capital Works Program. The NSW Government has published a Treasury Policy Paper to guide this process: *NSW Government Guide to Cost-Benefit Analysis* (NSW Treasury, 2017).

An economic appraisal is a systematic means of analysing all the costs and benefits of a variety of proposals. In terms of flood mitigation measures, benefits of a proposal are generally quantified as *the avoided costs associated with flood damages*. The avoided costs of flood damage are then compared to the capital (and on-going) costs of a particular proposal in the economic appraisal process.

Average annual damage (AAD) is a measure of the cost of flood damage that could be expected each year by the community, on average. It is a convenient yardstick to compare the economic benefits of various proposed mitigation measures with each other and the existing situation. Figure 26 describes how AAD relates to actual flood losses recorded over a long period. For the current study, AAD is assessed using the potential damages derived for each design event.

Based on Council's judgment that drains in the BBBC Creek catchment are designed to convey 20% AEP flows, the calculation of AAD assumes that damages to buildings commence at about that frequency. Based on input from CSS the PMF is estimated to have an AEP of 1 in 10 million.

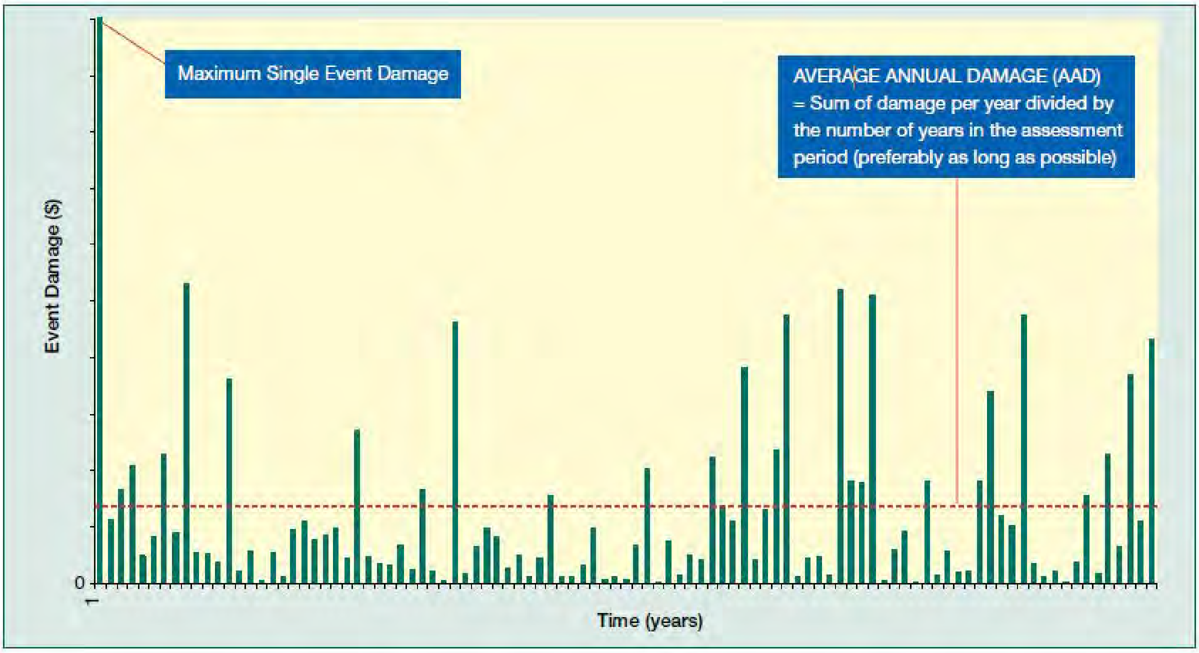

Figure 26. Randomly occurring flood damage as annual average damage

Source: Managing Flood Risk through Planning Opportunities (HNFMSC, 2006)

The present value of flood damage is the sum of all future flood damages that can be expected over a fixed period (typically 20 or 50 years) expressed as a cost in today's value. The present value is determined by discounting the future flood damage costs back to the present day situation, using a discount rate (typically 7% as recommended by NSW Treasury).

A flood mitigation proposal may be considered to be economically potentially worthwhile if the benefit–cost ratio (the present value of benefits divided by the present value of costs) is greater than 1.0. That is, the present value of benefits (in terms of flood damage avoided) exceeds the present value of (capital and on-going) costs of the project.

However, whilst this direct economic analysis is important, it is not unusual to proceed with urban flood mitigation schemes largely on social grounds, that is, on the basis of the reduction of intangible costs and social and community disruption. In other words, the benefit–cost ratio could be calculated to be less than 1.0 but a mitigation option considered to still be worthwhile.

The number of buildings with above floor flooding can be used as a surrogate to quantitatively compare the relative intangible benefits of different mitigation of different mitigation options.

8.2.3 Flood Damages Results

a) Tangible Damages

Calculated flood damages and AAD for the study area are presented in Table 10 (residential buildings) and Table 11 (non-residential buildings). Distinctive features include:

- The annual average damage is about $27 million for residential buildings and $12 million for non-residential buildings, which is a measure of the cost of flood damage that could be expected each year, on average, by the community;
- Total damages for residential and non-residential buildings are of comparable magnitude in each design event, except for the PMF, in which damages to non-residential buildings exceed $2 billion. This is due to the high number of commercial/industrial buildings located along Bow Bowing Creek that would be flooded above floor level.

Table 10. Tangible Flood damages and average annual damage for residential buildings

Event	Number of buildings with AFF	Total $m (Includes Direct & Indirect Damages)
20% AEP	368	$103.6
5% AEP	571	$131.4
2% AEP	677	$142.2
1% AEP	939	$160.8
0.2% AEP	1,330	$196.0
0.1% AEP	1508	$210.5
PMF	6318	$502.8
	AAD total $m	$25.3
	AAD per affected building $	$1,279

Table 11 . Tangible Flood damages and average annual damage for non-residential buildings

Event	Number of buildings with AFF	Direct Damages $m	Indirect Damages $m	Total $m
20% AEP	89	$8.4	$3.8	$12.2
5% AEP	127	$31.4	$13.7	$45.1
2% AEP	145	$33.2	$14.2	$47.4
1% AEP	170	$43.0	$18.3	$61.3
0.2% AEP	264	$93.9	$37.7	$131.6
0.1% AEP	318	$132.0	$55.0	$187.0
PMF	1167	$2,320.1	$1,045.2	$3,365.2
			AAD total $m	$9.0
			AAD per affected building $	$13,783

Table 11 and Table 12 summarise the number of residential and non-residential buildings affected by Above Floor Flooding (AFF) in relation to the total number of buildings exposed to above ground inundation (i.e. with and without AFF).

Results show that 371 dwellings are exposed to AFF in the 20% AEP event, with the number increasing to 944 in the 1% AEP event and 4,663 in the PMF. For non-residential buildings, 87 are affected by AFF in the 20% AEP event, 168 in the 1% AEP event and 786 in the PMF.

Even though the number of non-residential buildings with AFF is significantly smaller than the residential ones in each design flood event, non-residential buildings are proportionately significantly more affected. This can be partly attributed to the fact that non-residential buildings generally have a lower floor level than residential ones, so if there is water surrounding the building it is more likely that this will be able to cause AFF. In addition to this, the geographical distribution of non-residential buildings differs from that of residential ones, the area of non-residential buildings is significantly greater, and as such they are more exposed to flooding.

Table 13 and Table14 provide an appreciation of the depth of above floor inundation for the 1% AEP and PMF events, respectively. For the 1% AEP event, 94% of all dwellings subject to AFF are inundated to relatively shallow depths (<0.25m). The equivalent statistic for non-residential buildings is 84%. No buildings are estimated to be inundated above floor to depths exceeding 1.0m in the 1% AEP flood. For the PMF, 66% of all dwellings subject to AFF are inundated to relatively shallow depths (<0.25m). The equivalent statistic for non-residential buildings is only 27%. Many buildings are estimated to be inundated above floor to depths exceeding 1.0m in the PMF.

Table 11. Number of residential buildings experiencing flooding by design event

RESIDENTIAL	20% AEP	5% AEP	2% AEP	1% AEP	0.2% AEP	0.1% AEP	PMF
Buildings with adjacent Above Ground Flooding (AGF)	9,830	11,590	12,238	13,047	14,746	15,385	19,697
Buildings with AFF	368	571	677	939	1,330	1,508	6,318
Percentage of buildings with AFF with respect to those with AGF	4%	5%	6%	7%	9%	10%	32%

Table 12. Number of non-residential buildings experiencing flooding by design event

NON-RESIDENTIAL	20% AEP	5% AEP	2% AEP	1% AEP	0.2% AEP	0.1% AEP	PMF
Buildings exposed to AGF	734	841	883	945	1,094	1,162	1,454
Buildings exposed to AFF	87	127	145	170	264	318	1,167
Percentage of buildings with AFF with respect to those with AGF	12%	15%	16%	18%	24%	27%	80%

*Table 13. Number of buildings by overfloor depth in the 1% AEP event**

1% AEP event	0-0.25m	0.25-0.5m	0.5-0.75m	0.75-1.0m	1.0-1.25m	>1.25m
Residential	881 (94%)	49 (7%)	7 (7%)	2 (0.2%)	0	0
Non-Residential	143 (84%)	19 (11%)	7 (4%)	1 (1%)	0	0

*percentages are expressed with respect to the total number of residential or non-residential buildings with AFF

*Table14. Number of buildings by overfloor depth in the PMF**

PMF	0-0.25 m	0.25-0.5 m	0.5-0.75m	0.75-1.0m	1.0-1.25 m	>1.25 m
Residential	3,699 (59%)	1186 (19%)	525 (8%)	273 (4%)	156 (2%)	479 (8%)
Non-Residential	226 (19%)	159 (14%)	127 (11%)	92 (8%)	111 (10%)	452 (39%)

*percentages are expressed with respect to the total number of residential or non-residential buildings with AFF

b) Building Failure

The tangible damage stage damage curves are principally related to contents damage with an allowance for repairs to the building structure such as relining of walls etc. However, they do not account for the losses incurred if the forces of floodwaters and debris loads cause such significant structural damage that the building needs to be completely rebuilt.

Recently published research associated with the revision of Australian Rainfall and Runoff (AR&R) suggests that building failure will occur when particular depth and velocity thresholds are exceeded (Smith et al., 2014). This work has created six flood hazard categories (H1-H6) based on the potential impacts of particular combinations of water depth and velocity (AIDR, 2017).

According to the national flood hazard guidelines (AIDR, 2017), buildings affected by floodwaters with a hazard level of H5 would need a qualified engineer to assess their capability to withstand the flood forces, while buildings exposed to a flood hazard equal to H6 should not be considered safe regardless.

The analysis shows that no buildings would be exposed to these hazard categories except in the PMF. The number of buildings exposed to each category in this event is shown in Table 15. Figure 27 provides an example of buildings completely surrounded by floodwaters with hazard equal to H5, or touched by floodwaters with hazard equal to H6.

Importantly,

Table 15 shows that no buildings are completely surrounded by floodwaters classified as H6, and the number of buildings surrounded by floodwaters classified as H5 is relatively small. Nonetheless, the risk posed to the structural integrity of these buildings should be considered when planning the emergency response strategy.

Table 15. Buildings at risk of structural instability in the PMF (flood hazard classified according to Smith et al., 2014)

PMF event	Flood Hazard = H5	Flood Hazard = H6
Buildings touched by highly hazardous floodwaters	3,215	207
Buildings completely surrounded by highly hazardous floodwaters	200	none

c) Infrastructure Damages

An allowance has been included for infrastructure damages. This includes the cleaning and repair of roads, drains and creeks, parks and recreational facilities, water and sewage infrastructure, gas and electricity infrastructure and telecommunications infrastructure.

An allowance has been made for these damages by estimating them to be 15% of total residential and commercial/industrial damages.

These damages are summarised for each event in Table 16.

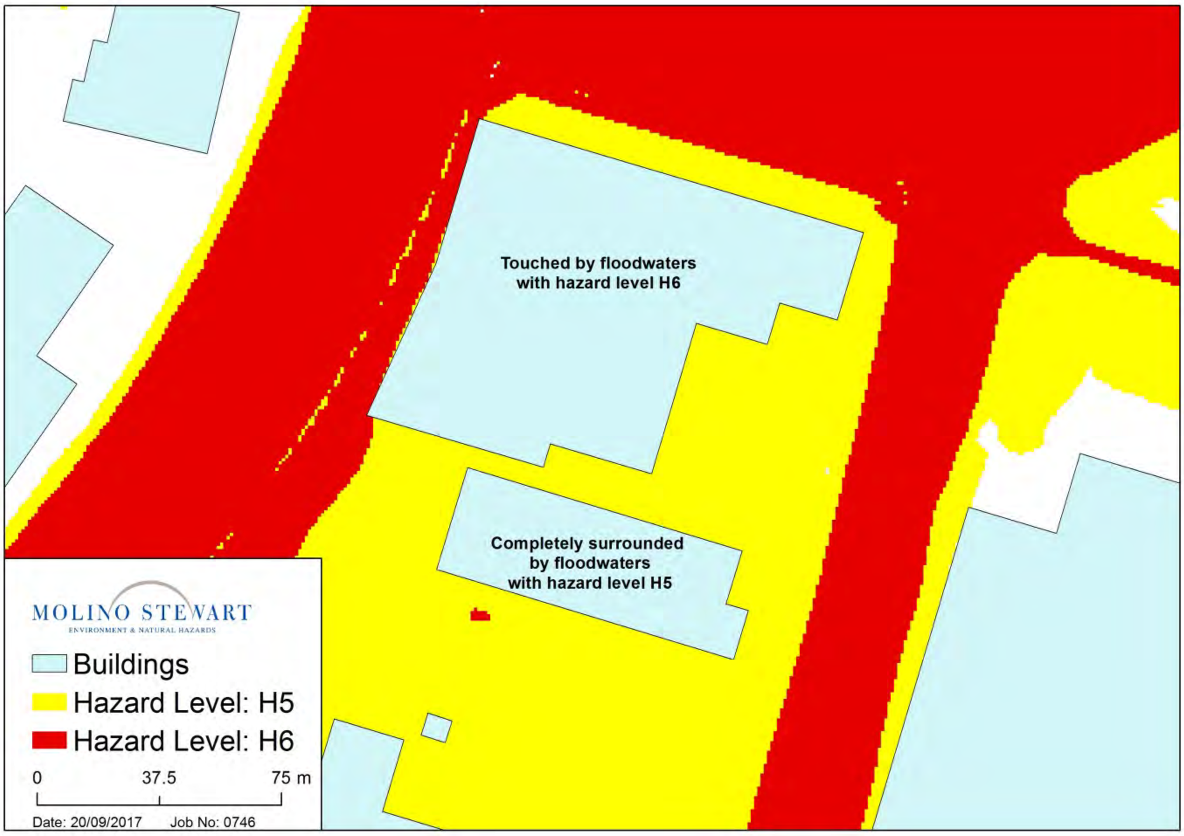

Figure 27. Example of buildings touched by floodwaters with hazard level equal to H6, or completely surrounded by floodwaters with hazard level equal to H5.

d) Intangible Damages

Intangible damages can include the loss of pets and memorabilia which are worth more to people than their replacement value, financial hardship caused by flood losses, the stress and anxiety caused by experiencing flooding and dealing with its direct and indirect impacts, health impacts from coming into direct contact with floodwaters as well as stress induced illnesses or exacerbation of existing health conditions.

To some extent these damages will be proportional to the number or premises flooding and the numbers of buildings affected as set out in Table 11 , Table 12, Table 13 and Table14.

Those numbers can act as a surrogate for estimating the relative intangible impacts of the different magnitude floods.

However a dollar value has been set for the intangibles by estimating them to be worth 25% of total residential and commercial/industrial damages.

These damages are summarised for each event in Table 16.

Table 16. Estimates of infrastructure and intangible damages

Event	Total residential and non-residential damages $m	Infrastructure Damages $m	Intangible Damages $m	TOTAL $m
20% AEP	$127.9	$19.2	$32.0	$179
5% AEP	$207.6	$31.1	$51.9	$291
2% AEP	$223.5	$33.5	$55.9	$313
1% AEP	$266.3	$39.9	$66.6	$373
0.2% AEP	$411.4	$61.7	$102.9	$576
0.1% AEP	$510.0	$76.5	$127.5	$714
PMF	$3,128.1	$469.2	$782.0	$4,379
AAD total $m	$39.2	$5.9	$9.8	$54.9
AAD per affected building $	$31,749.0	$4,762	$7,937	$44,449

e) Flood Risk

In order to identify any flood risk clusters, the following thematic maps and tables were generated:

- Tables and maps of the depth of AFF in the 1% AEP event and in the PMF (Table 13, Table14 and Maps 23 to 26 (Vol. 2);
- Maps of the frequency of AFF (Maps 27 and 28, Vol. 2) ;
- List of vulnerable facilities that according to the model results would experience AFF in any event (Appendix D). These include utilities (i.e. electricity sub-station), educational institutions, emergency services buildings, health care facilities and police stations.

This analysis provided a preliminary list of locations where specific flood risk reduction measures might be necessary. These locations were then further investigated in Section 9 to obtain a final list of flood risk hot-spots. Results of this preliminary analysis showed that:

- In the 1% AEP event, 939 residential buildings and 170 non-residential buildings would experience AFF. AFF depth for residential buildings would be in almost all instances (94%) lower than 0.25m (Table 13), although two clusters of buildings in Ingleburn, at the south-western end of Macquarie Rd and east of the train station would experience AFF up to 0.75m (Map 23, Vol. 2). A similar spatial pattern is observed in the 1% AEP event for non–residential buildings, with a cluster of higher AFF depths in Ingleburn, at the northern end of Oxford Road;
- In the PMF, 6,318 residential buildings and 1,167 non-residential buildings would experience AFF. Over half of the residential buildings affected by AFF would experience AFF depths below 0.25m, however 10% of the buildings experiencing AFF would be affected by a depth greater than 1m (Table14). Non-residential buildings show a peak of 452 buildings affected by AFF depth greater than 1.25m, representing 39% of the total non-residential buildings with AFF.
- The AFF depth map of the PMF for residential buildings (Map 26, Vol. 2) displays a few clusters of buildings

with AFF depth exceeding 1.25m. These are distributed in a north-south direction along Bow Bowing Creek, but are generally contained in the area south of the suburb of Bow Bowing.

- The AFF depth map of the PMF for non-residential buildings (Map 26, Vol. 2) shows a large number of buildings with AFF depth exceeding 1.25m. These form a single well-defined cluster located along Bow Bowing Creek, in a north-south direction, from Minto to Blair Athol. However, the relevant frequency of AFF map (Map 28, Vol. 2) shows that most buildings in this cluster would experience AFF only in the PMF;
- In regards to vulnerable buildings, Appendix D shows that three of these may be exposed to AFF from the 20% AEP event to the PMF. These include two buildings that are part of the Campbelltown Hospital, the St. Andrews Public School, and the Frank Whiddon Masonic Homes facility in Glenfield. It should be emphasized that due to the conservative assumptions made about the floor levels and the flood model, these results are likely to overestimate the frequency of AFF. In addition to this, even though these buildings flood relatively often, the AFF depth is generally below 0.2m, with the exception of St Andrews Public School where depth reaches 0.6m in the PMF;

8.3 ROAD INUNDATION

An assessment of the frequency and depths of road inundation is important for understanding:

- the risk of vehicles becoming unstable, posing a risk to people for their drivers and passengers;
- evacuation risks, which also informs the classification of communities according to flood emergency response planning considerations;
- disruptions which flooding can cause to general traffic flow which itself can have economic impacts.

Recently published research associated with the revision of Australian Rainfall and Runoff (Smith et al., 2014) suggests that vehicles become unstable when depth and velocity combinations put the flood hazard in category H2 or above (see Figure 22).

While the NSW SES rightly advises that vehicles should not drive through any floodwaters, the reality is that H1 flood water is likely to slow but not halt traffic. However, drivers cannot tell the difference between category H1 and higher hazard levels, which is the reason why the NSW SES advises the general population not to drive through floodwaters, regardless of how hazardous these look.

For the purposes of this analysis, the extent of H2 and above floodwater was mapped for each event and superimposed on a road network GIS layer and aerial photography. Where the mapping showed that all lanes in a particular direction on a road would be covered by H2 or higher floodwater then the road in that direction was deemed to have been cut by flooding.

This analysis was limited to the Hume Motorway, state roads, regional roads and a number of key local collector roads. Map 29 (Vol. 2) shows the frequency of road closures for the selected roads.

Table 17 describes the roads that are closed in the 20% AEP event. Given that the majority of flood fatalities in Australia are a result of people deliberately driving through floodwaters and the rescue of people from vehicles places a high demand on emergency resources during a flood, the roads of greatest concern are those which are frequently flooded and which normally have high daily traffic flows.

Table 17. Road closures in 20% AEP event

Road	Road Class	Comments
Menangle Rd	State Road	North and south bound between Glen Alpine Dr and South bound, north of Glen Alpine Dr
Tindall Street	State Road	North and south bound at Menangle Rd
Narellan Road	State Road	North bound, north of Blaxland Rd
Hume Motorway/Narellan Road Exit	Highway State Road	Hume Motorway exit to Narellan Rd
Appin Road	State Road	South bound, south of Narellan Rd
Oxley Street	State Road	South bound, south of Dumaresq St
Collaroy Rd	Local Collector Road	South bound at Campbelltown Rd
Collins Promenade	State Road	North bound, south of Eagleview Rd
Pembroke Rd	State Road	North bound, between Minto Rd and Burrendong Rd; south bound, north of Ben Lomond Rd
Townson Ave	Local Collector Road	North bound towards Ben Lomond Rd and south bound towards Katherine St
Brooks Rd	Regional Road	In both directions at Williamson Rd
Williamson Rd	Regional Road	North-east towards Henderson Rd
Leumeah Rd	Regional Road	East bound at Wyangalla Crescent
Junction Rd	Regional Rd	In both directions north of Cook Rd
Blaxland Rd	Regional Rd	In both directions, south west of Rose St
Queen St	Local Collector Road	In both directions, west of Campbelltown Rd
Badgally Rd	Regional Rd	North bound, north of Johnson Rd
Hurley St	Regional Rd	West bound towards Narellan Rd, east bound towards Dumaresq St and Broughton St
Dumaresq St	Local Collector Road	In both directions at Hurley St

8.4 RISK TO PEOPLE

Risk to people was assessed using the NSW OEH's guideline "Flood Emergency Response Planning Classification of Communities Floodplain Risk Management Guideline" (DECC, 2007b).

Table 18 summarises the number of buildings that in the PMF would be isolated in low and high flood islands. It is noted that 367 of the residential buildings isolated on some of the high flood islands were not included in the original property database because they were clear of the estimated PMF extent.

The flood islands which are isolated by the 20% AEP flood event are:

- A townhouse development between Greenoaks Ave and The Parkway Bradbury;
- Houses in Ash Pl and Bloodwood Pl Bradbury;
- The Campbelltown industrial area from west of Badgally Rd through to Plough Inn Rd;
- Shops and townhouses on the corner of Queen St and Chamberlain St Campbelltown;
- Houses between Rudd Rd, Hughes St and Moore St Campbelltown;
- Town house developments on Queen St Campbelltown north of Rudd Rd;
- The Minto industrial area between Bow Bowing Creek and the railway from Rose Payten Dr north to Essex St;
- Houses between Campbelltown Rd and Wyperfeld Pl St Andrews;
- Houses between Sandeford Wy and Murphy Wy Minto;
- Townhouses in Fletcher St Minto;
- A house in Clifford Cr Ingleburn;
- Houses on the corner of Chester Rd and Brett Pl Ingleburn;
- Houses and townhouses in Packard Cl Ingleburn;
- Houses on Chester Rd Ingleburn between Belford St and Ingleburn Rd;
- Houses in Koala Ave Ingleburn;
- Houses at the northern end of Bronzewing St, Jacana Pl and Wonga Pl;
- Ingleburn commercial area bounded by Ingleburn Rd, Cambridge St, Carlisle St and Norfolk St;
- Houses between Cambridge St, Carlisle St and Macquarie Rd Ingleburn;
- Townhouses between Macquarie Rd and the railway Ingleburn;
- The majority of the Ingleburn industrial area;
- Houses between James St and Henderson Rd Ingleburn;
- Houses in Atchinson Rd and Adrian St Macquarie Fields;
- Dwellings in the Good Samaritan Sisters Village in Victoria Rd Macquarie Fields;
- Shops and dwellings on Railway Pde Glenfield between Belmont Rd and Hosking Cr.

Many of these are only isolated by H1 flooding in the 20% AEP event but by higher hazard flooding in less frequent events. It should be noted that in most instances flood islands are isolated for a short duration, which in the PMF ranges between about 2 hours (in the upper catchment) and 5 hours (in the lower catchment).

Table 18. Number of buildings on flood islands (PMF)

	Residential	Non-Residential
High Flood Island	1,448	145
Low Flood Island	757	616

8.5 RISK TO CRITICAL INFRASTRUCTURE

8.5.1 Regional Health Facilities

Regional health facilities are located in Campbelltown and include:

- Campbelltown Public Hospital;
- Campbelltown Private Hospital;
- NSW Ambulance Station.

The flood model results show no significant flood affectation for these facilities in any probability events, with the exception of the PMF.

Although some of the access roads get cut in frequent events (e.g. exit on Woodhouse Dr may be cut from the 20% AEP, Appin Rd's southbound lane may be cut from the 5% AEP), access to and egress from the health district is available through alternate routes in any event up to the PMF.

In the PMF, all access roads are cut, and the ambulance station may experience high hazard flooding. However in this event both hospitals show minor flood affectation (Figure 28).

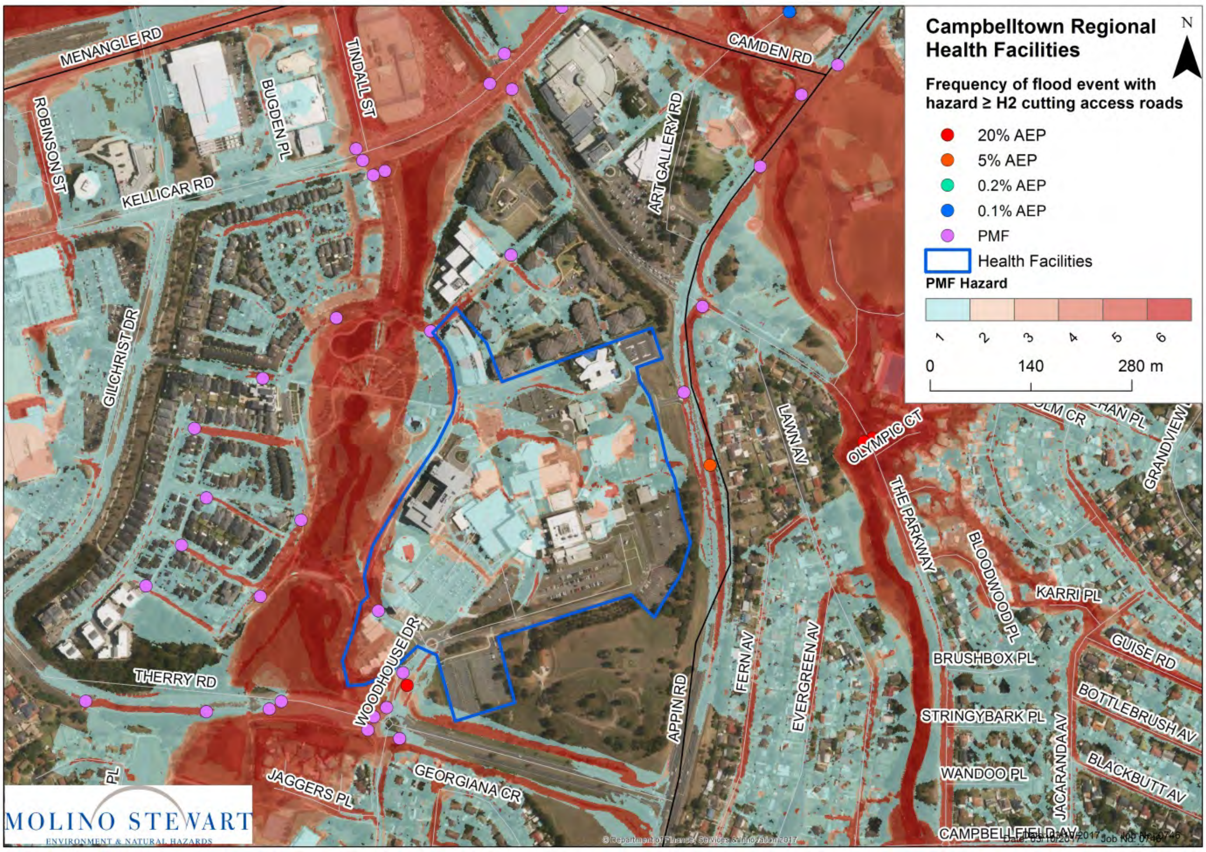

Figure 28. Flood risk to the regional health facilities in Campbelltown

8.5.2 Minto Sub-Station

The electricity substation's switchyard in Minto experiences only shallow overland flooding in frequent events (which would not stop it from operating), and would have its main access cut from the 20% AEP event. Its alternative access from the north would remain open up to the 1% AEP event, but it would be dangerous to enter the substation because there might be a risk of electrocution. More extensive flooding is observed from the 0.2% AEP, with significant inundation depth in the PMF (up to 4.0m), which may have implications for emergency response purposes.

8.5.3 Proposed Evacuation Centres

The NSW SES has advised that a Local Flood Plan covering Campbelltown LGA is currently under preparation. In the process of drafting the LFP, the NSW SES has identified three possible flood evacuation centres within the LGA. These are:

- Campbelltown Catholic Club, located in 20-22 Camden Rd, Campbelltown;
- West Leagues Club, located in 10 Old Leumeah Rd, Leumeah; and
- Ingleburn RSL Club, located at 70 Chester Rd, Ingleburn.

The results of the risk mapping exercise (Section 7.2), and the analysis of road inundation (Section 8.4) were used to assess flood risk to each of the proposed evacuation centres. Specifically, risk was assessed in terms of:

- Frequency of flooding
- The NSW SES ERP classification (i.e. is the building in a flood island?)
- The frequency of event when all access roads are cut by floodwaters. A threshold of flood hazard = H2 was used to define isolation.

Results of the assessment are summarised in Table 19, while Figure 29 to Figure 31 show the PMF flood extent, hazard classification and frequency of flooding of the access roads for each proposed centre.

Table 19. Summary of flood risk to the proposed flood evacuation centres

Proposed Evacuation Centre	Frequency of Flooding	Flood Island?	Road access
Campbelltown Catholic Club **20-22 Camden Rd, Campbelltown**	Car park floods from the 20% AEP, main building is not flood affected in the PMF	No	All access roads are cut in the PMF, however Queen St. is cut from the 20% AEP
West Leagues Club **10 Old Leumeah Rd, Leumeah**	The model indicates that central part of the site may flood from the 5% AEP, with the flood affecting also the western part of the site in greater events.	No	All access roads are cut in the PMF, however: - The 20% AEP event cuts O'Sullivan Rd. - The 0.2% AEP event cuts Old Leumeah Rd. entrance to centre
Ingleburn RSL Club **70 Chester Rd, Ingleburn**	The building is surrounded by very low hazard floodwaters (H1) in every event from the 20% AEP to the PMF. Floodwaters do not enter the building in any event. The car park is not flood affected.	The building itself may be considered a high flood island, but is surrounded by very low hazard floodwaters	All access roads are cut from the 5% AEP event, however: - The 20% AEP event cuts Chester Rd south east bound towards Warbler Ave. - The 20% AEP event cuts Lorikeet Ave. - The 20% AEP event cuts Wagtail Cres.

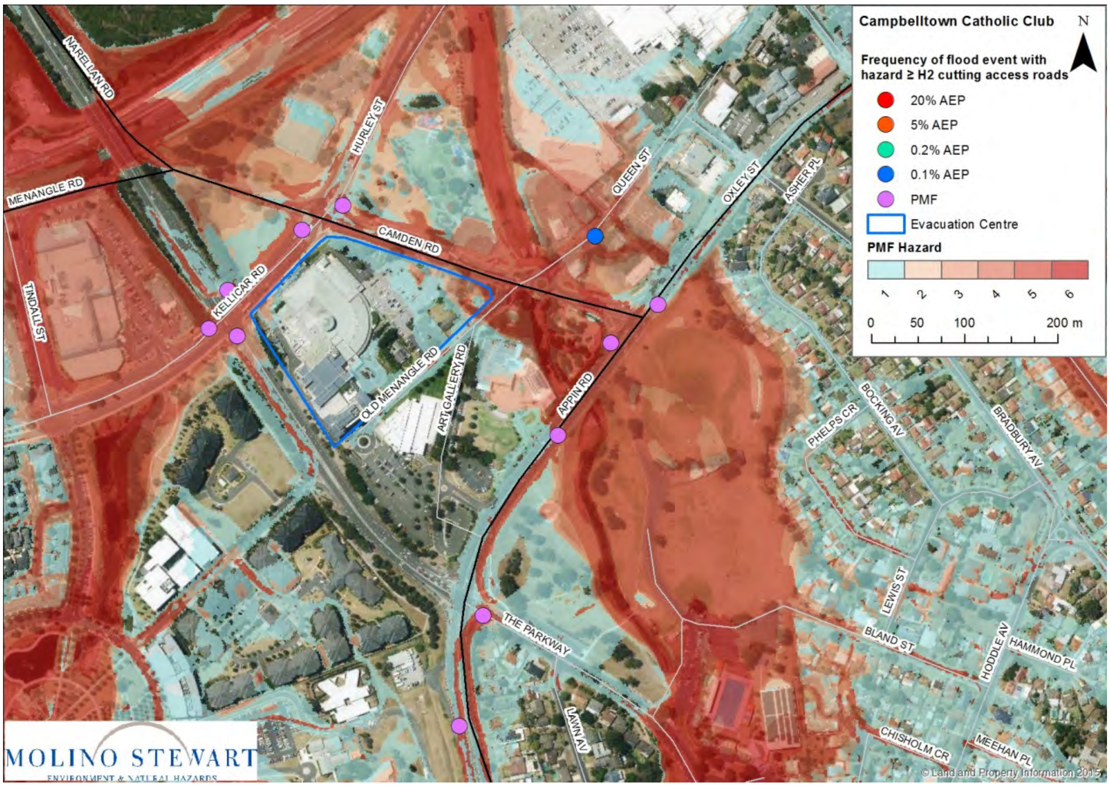

Figure 29. Flood risk to the proposed evacuation centre at Campbelltown Catholic Club

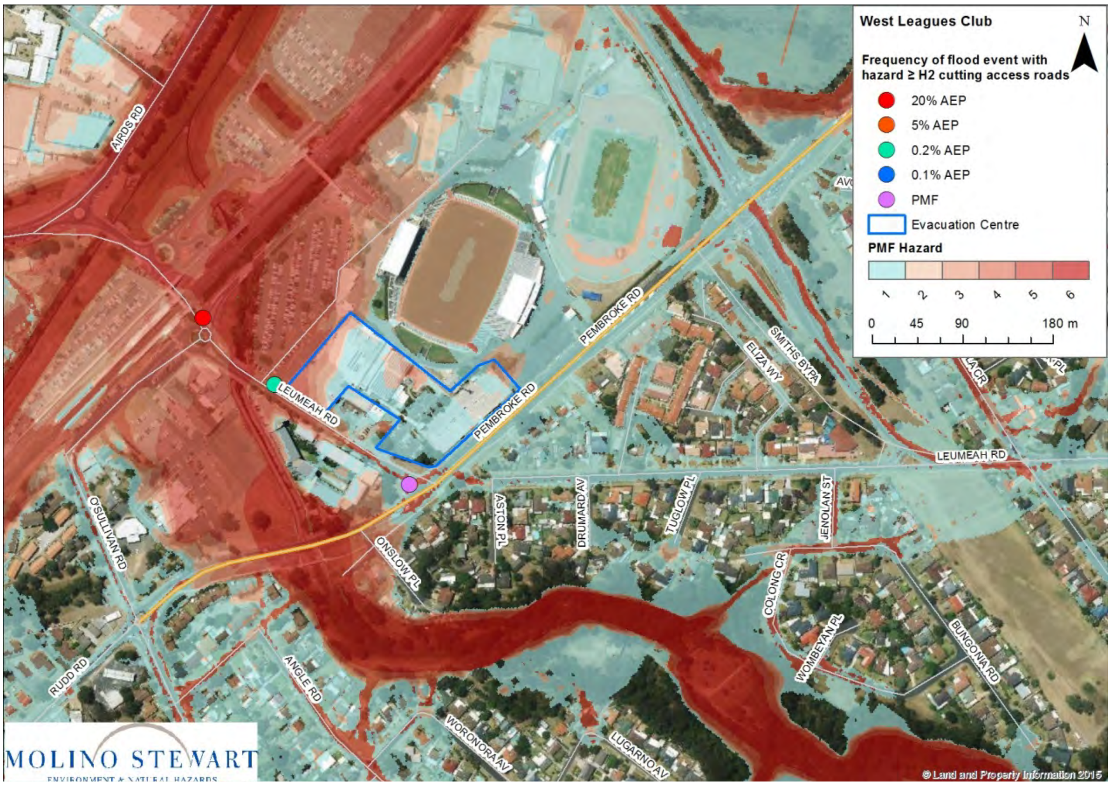

Figure 30. Flood risk to the proposed evacuation centre at West Leagues Club

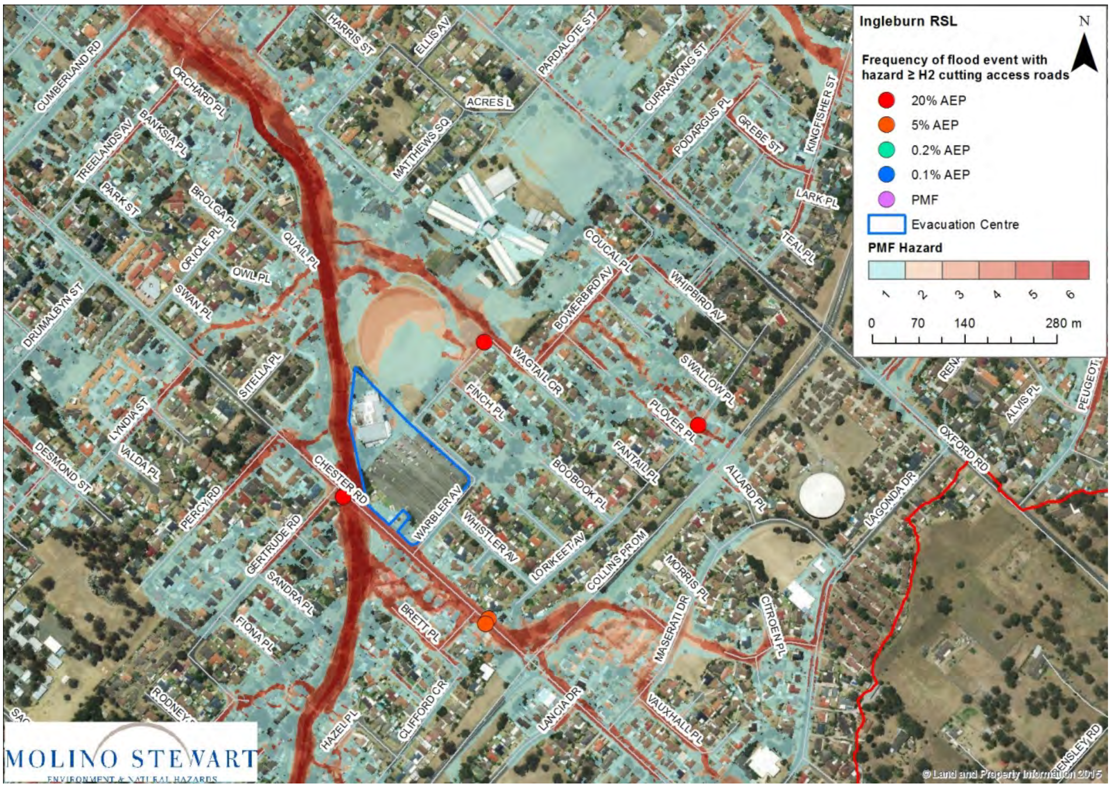

Figure 31. Flood risk to the proposed evacuation centre at Ingleburn RSL.

8.5.4 Hazardous Facilities

Three facilities classified as potentially “hazardous" were identified across the BBBC Creek catchment. These are:

- Pax Australia, 9 Williamson Rd, Ingleburn;
- Australian Petro-Chemical Storage, 14 Williamson Rd, Ingleburn;
- Toll Jalco Distribution, 4 Inglis Rd, Ingleburn.

The NSW SES considers these facilities hazardous because, if severely damaged by flooding, they could trigger cascading hazards such as the release of harmful pollutants in the environment.

The flood model shows that one of these facilities (i.e. Toll Jalco Distribution) is flood-free in all AEP events, and the remaining two are affected by floodwaters with hazard greater than H1 only in the PMF.

PART C: FLOODPLAIN RISK MANAGEMENT MEASURES

9 OVERVIEW OF RISK MITIGATION OPTIONS

9.1 BACKGROUND

There are three consequences of flooding which the FRMS will need to consider:

- risk to property;
- risk to people;
- risk to community function.

Risk to property was measured as part of the hotspot identification using the following criteria:

- frequency of above floor flooding;
- depth of above floor flooding in rare events;
- number of buildings impacted by H5 and H6 flooding.

Similarly, risk to people was measured in terms of:

- frequency of above flood flooding;
- depth of above floor flooding in rare events;
- number of buildings impacted by H5 and H6 flooding;
- number of buildings on high flood islands;
- number of buildings on low flood islands;
- frequency of low flood island isolation;
- frequency of major road inundation.

Finally, risk to community function was assessed using the following criteria:

- frequency of above floor flooding for critical facilities;
- frequency of road inundation.

9.2 THE APPROACH

Flood risk mitigation measures fall into three categories:

- flood modification;
- property modification;
- response modification.

Across the BBBC flood-prone area there are locations where clusters of assets are impacted by flooding. These locations are herein named "hotspots" and may benefit from local flood risk mitigation options. There are also additional scattered assets across the whole catchment which have unacceptable risks and may benefit from catchment-wide mitigation options.

This Section describes the structured approach that was followed to:

- identify assets and localities (i.e. "hotspots") which would benefit from flood risk mitigation measures (Section 9.3);
- identify suitable flood risk mitigation options (Section 9.4).

The following Sections discuss in detail the shortlisted flood risk mitigation options for each hotspot (Section 10) and those that address the whole BBBC Creek catchment (Section 11).

It should be noted that the information provided in this section is subject to the following assumptions and limitations:

- The analysis was undertaken with the best available information at the time of publication. The quality of each dataset used, as well as implications for accuracy of the results, are discussed in the text;
- The flood models used in the Flood Studies represent the worst case scenario for each probability event;
- The flood models used in the Flood Studies do not include the contribution of private drainage systems. These would significantly reduce flooding of industrial and larger commercial buildings, particularly in the more frequent events;
- Where surveyed floor levels were not available, conservative assumptions were made. As such, for these buildings, the estimated Above Floor Flooding (AFF) levels represent a worst case scenario.
- Buildings were assumed to experience Above Floor Flooding (AFF) where the model results showed, at any point around the

building perimeter, a water level higher than the estimated building floor level. However in some instances there may not be ways for floodwaters to enter the building (e.g. doors, windows or other openings), even when the water level is higher than the building floor level. As such, the flood impact estimates presented in this section are conservative and should be regarded as the worst case scenario.

9.3 IDENTIFICATION OF RISK HOTSPOTS

A first large-scale analysis of the locations with relatively high flood risk was undertaken as described in Sections 8.2.3 (risk to buildings), 8.3 (risk to roads), and 8.4 (risk to people). The large-scale analysis informed the identification of hotspots where flood risk is such that mitigation options may be required.

Three types of flood risk hotspots were identified and mapped:

- Residential hotspots (including residential properties only);
- Commercial/industrial hotspots (including commercial and industrial properties only); and
- Road hotspots (including roads only).

9.3.1 Residential Hotspots

a) Preliminary List of Residential Hotspots

Residential hotspots were identified using criteria based on risk to property and life. These are:

- Criterion 1 - Risk to people: building touched by floodwaters with hazard level of H6 or completely surrounded by floodwaters with hazard level of H5 in the PMF. These hazard levels are likely to compromise the building structural stability;
- Criterion 2 -Risk to Property: building affected by Above Floor Flooding (AFF) from the 20% AEP event, with a AFF depth exceeding 0.05m;
- Criterion 3 - Risk to people: one-storey buildings with AFF depth exceeding 0.5m in the PMF. In a PMF event, occupants of these buildings will be at increased risk because they would not have a shelter above the floodwaters within the building;
- Criterion 4 - Risk to people: buildings on Low Flood Islands (LFI) in the 20%AEP and with AFF in PMF. These buildings are isolated in relatively frequent events, and in a PMF the water would keep rising until the building's ground floor floods. Evacuation from these buildings in a PMF may be difficult due to the building being isolated early.

These criteria were used to identify an initial group of hotspots requiring further analysis. The list included only clusters of two or more buildings fulfilling at least one of the selection criteria.

Following an initial desktop analysis run with the GIS, the floor level of each hotspot was validated through field surveys. This was necessary because for some residential properties floor levels were not available and had been conservatively inferred based on the building age (Appendix C). Where the floor level was found to be higher than what had been estimated using the assumptions described in the Section 8, the relevant AFF figure was reduced accordingly.

Modelled flood extents were also examined in more detail to determine to what extent the flood surface interacted with the building outline in the model.

This process produced a preliminary list of 29 residential hotspots (Map 30 and Table 2, Vol. 2).

b) Final List of Residential Hotspots

The preliminary list of residential hotspots was then examined in detail to retain only the hotspots in which:

- the risk to property criterion is satisfied, or
- at least two risk to people criteria are satisfied.

This resulted in four hotspots being eliminated from the preliminary list. The final list of residential hotspots was then obtained by applying the following additional conditions:

- The apparent above floor flooding (AFF) is not caused by small scale, local "puddles" that are unlikely to result in AFF if there is adequate private drainage infrastructure on the property or it can only be managed by improvements to the private drainage system of the affected buildings;
- For buildings satisfying Criterion 4, LFI are created by floodwaters with a hazard level of at least H2 in the 20% AEP. The reason behind this is that floodwaters with a hazard of H1 do not represent a real obstacle for vehicles or pedestrians.

This resulted in six additional hotspots being removed from the preliminary list, and produced a final list of 19 residential hotspots (Table 2, Vol. 2). These are discussed individually in Section 10.2.

9.3.2 Commercial and Industrial Hotspots

a) Preliminary List of Industrial and Commercial Hotspots

All clusters of two or more non-residential buildings with AFF from the 5% AEP event were identified and mapped.

This was done under the assumptions that industrial buildings will have their ground floor at ground level and commercial buildings will have it 100mm above ground level. These are the same assumptions used in the damages assessment exercise.

This analysis generated a preliminary list of 13 commercial and industrial hotspots (Map 31 and Table 3, Vol 2). It should be noted that the list includes commercial buildings in Ingleburn CBD which was also shortlisted as a residential hotspot. As such, any flood risk mitigation measures targeting this area will apply to both residential and non-residential buildings.

b) Final List of Commercial and Industrial Hotspots

Each commercial and industrial hotspot in the preliminary list was inspected in detail to determine whether:

- The AFF observed from the 5% AEP was likely to be real. This was done by inspecting the building on Google Street View and looking at the actual floor level, then comparing it with the 5% AEP AFF depth shown by the model;
- If the flooding seemed possible, it was assessed whether the problem was likely to be caused by puddles within the property which could be managed by the private drainage system;
- If the problem was not local, or likely to be caused by a shortcoming of the public drainage system, the hotspot was included in the final list.

This analysis reduced the preliminary list of commercial and industrial hotspots to the following four hotspots:

- Louise Avenue, Ingleburn;
- Blaxland and Badgally Road, Campbelltown;
- Farrow Road, Campbelltown;
- Ingleburn CBD (already shortlisted as a residential hotspot)
- These are discussed individually in Section 10.3.

9.3.3 Road Hotspots

A risk analysis was undertaken which considered the frequency of road flooding with a H2 hazard and the consequences of that flooding taking into account the hierarchic classification of each road. Risk categories were then assigned based on flood frequency and road hierarchy as set out in Table 20, and it was determined that any locations which fell into the high or extreme risk category should be investigated for flood mitigation options.

Table 20. Risk Hierarchy for Road Inundation

	Probability of H2 or greater flooding		
Road Hierarchy	<5% AEP	5% AEP	20% AEP
Collector Roads	Low	Low	Low
Regional Roads	Low	Low	Medium
State Roads	Low	Medium	High
Hume Motorway	Medium	High	Extreme

Map 29 (Vol. 2) shows the road classification and the locations which are impacted by H2 flooding in the 20% AEP and 1% AEP events. Table 21 shows the number of locations that are cut-off more frequently (i.e. in the 5% AEP and 20% AEP) for each road class. Eleven of these cut-off points are classified as being at high risk (i.e. cells colour-coded in orange).

Table 21. Number of Road Locations Cut by H2 or Greater Flooding in 5% and 20% AEP Floods

	Probability of H2 or greater flooding	
Road Hierarchy	5% AEP	20% AEP
Regional Roads	7	10
State Roads	11	11
Hume Motorway	0	0

These were grouped in six road hotspots needing further investigation, namely:

- Menangle Rd (Glen Alpine). The road is cut from the 20% AEP at three locations: (1) north and south bound, between Glen Alpine Dr and Gilchrist Dr; (2) south bound and (3) north bound, at two different locations north of Glenlee Rd.
- Tindall St (Campbelltown), cut north and south bound, near the crossroad with Menangle Rd.
- Appin Rd (between Bradbury and Campbelltown), cut south-bound, south of Narellan Rd.
- Oxley St (Campbelltown), cut south bound, south of Dumaresq St.
- Collins Prom (Ingleburn), cut north bound, south of Eagleview Rd.
- Pembroke Rd (Minto). The road is cut from the 20% AEP at three locations: (1) north and south bound, south of Westmoreland Rd; (2) south bound, north of Ben Lomond Dr; (3) north bound, north of Derby St.

In addition to the hotspots listed above, two further hotspots were identified at the exit from the Hume Motorway onto Narellan Rd, and on Narellan Rd (north of Blaxland Rd). These sections of road underwent extensive road works after the flood modelling was completed and therefore the model does not represent the current drainage conditions in these locations.

The shortlisted road hot spots are discussed individually in Section 10.4.

9.4 FLOOD MODIFICATION

The purpose of flood modification measures is to modify the behaviour of the flood itself by reducing flood levels or velocities or by excluding floodwaters from areas under threat.

Flood modification generally requires the construction of civil works and is usually cost-effective only where there are clusters of properties which would benefit from the same flood modification measure.

It was decided that the clusters would be investigated with regard to flood modification but not the scattered properties. Priority was given to residential properties over commercial and industrial properties in line with NSW Government policy regarding the funding of flood mitigation works.

9.4.1 Blockage Reduction

The flood modelling for Campbelltown was undertaken assuming that openings throughout the drainage system would be partially blocked by debris during any flood.

A standard blockage scenario applied across the entire catchment which assumed:

- 20% blockage for on-grade pits
- 50% blockage for sag pits
- 50% blockage of any openings (culverts, bridges etc) with a diagonal dimension less than 3m across.

The only exception to this rule was the three Smiths Creek detention basin outlets as they are protected by debris control structures. So even though their diagonal dimension was less than 3m, no blockage was applied to these structures as part of the design simulations.

A sensitivity test was undertaken to determine what difference it would make to flood levels if it were assumed that there was no blockage of any of these openings and pits. A difference map was created by subtracting the flood level for the 1% AEP flood with assumed blockage from the flood level of the 1% AEP flood with no blockage.

If there was no significant difference in levels between the two it was concluded that blockage reduction would not be effective. If there was a significant difference this option was investigated further.

9.4.2 Pipe Capacity Upgrade

The next step in the investigation was to analyse underground pipe capacity in the 20% AEP event in the hotspot areas to see whether this may be contributing to the flood impacts. Where a cluster had pipes operating at capacity in the 20% AEP event, a query was performed to identify any hotspot buildings in the area showing AFF in relatively frequent events (i.e. from the 5% AEP). These buildings were deemed likely to benefit from a pipe capacity upgrade, which was further investigated as a possible flood modification option for that hotspot (Section 10).

Where AFF was caused only by rarer events (i.e. 1% AEP event or rarer), upgrading pipe capacity was deemed unlikely to resolve those flood risks and this was not investigated further as an option.

9.5 PROPERTY MODIFICATION

Property modification generally involves measures such as:

- Removing buildings from the area which floods;
- Ensuring floor levels are at a level with a low probability of flooding;
- Constructing with flood compatible building materials.

Building modification can be applied to either existing development or future development. Modification to existing development involves either:

- Voluntary house purchase (VP) and demolition;
- Voluntary house raising (VHR);
- Renovation with flood compatible building materials.

Modification to future development may involve:

- Strategic planning to move inappropriate development away from high flood risk areas ;
- Development controls to ensure development, redevelopment or renovation reduces flood risks to an acceptable level for each property which can include, amongst the measures, requirements for minimum floor levels and building material compatibility.

The current Campbelltown Local Environment Plan (LEP) was gazetted in 2015 and there are many areas which are zoned to permit higher density residential development and so it is expected that over time these areas will be redeveloped. This will provide an opportunity for redevelopment which is more compatible with the flood risk. Existing development controls or new development controls in relation to flooding can be applied to this redevelopment. However, flood risks did not have a strong influence in the zoning of land under the LEP, particularly as much of the residential zoning is a legacy the 2002 LEP and even earlier planning instruments when overland flooding throughout the catchment had not been modelled and was not well understood.

Investigations are currently progressing for the Glenfield to Macarthur Urban Renewal Corridor and many of the locations identified in this are areas within the BBBC Creek catchment which have significant flood risks. This provides an opportunity to include strategic planning solutions to flood risks as part of this urban renewal strategy.

9.5.1 Strategic Planning

Strategic planning solutions which shift development out of the floodplain were first investigated. This involves rezoning flood affected land as public or private open space. This could be either as part of open space provisions for increased housing density in nearby areas or as part of the open space requirements of a reconfigured precinct of which the hotspot forms part.

The next level of strategic planning solution is to rezone the land to permit development which lifts development above the flooding or enables it to span the flooding. This could, for example, involve rezoning the land to permit high rise development instead of low rise.

Strategic planning solutions are location-specific and often cover a precinct sized area determined by a suite of planning considerations, not just flooding.

9.5.2 Development Controls

Development controls on the other hand are best applied across a whole LGA for any new development or redevelopment, including those subject to rezoning as part of strategic planning.

A review of the existing flood development controls was undertaken to see if better controls can be imposed on future development, redevelopment and renovation

Development controls may be a suitable means of dealing with flood problems for scattered, individual buildings. The downside is that they require redevelopment to take place and that may take some time. Development controls were investigated as a means of dealing with flood risks throughout the LGA. In assessing their effectiveness in particular locations, the age of existing development and its potential for redevelopment were considered.

9.5.3 Voluntary House Raising

Where strategic planning or Catchment-wide development controls were not expected to deal with unacceptable flood risks in an acceptable time frame, modification of existing buildings through a voluntary assistance scheme was investigated. These were only considered for residential dwellings in accordance with State and Federal Government funding eligibility criteria.

The first option to be investigated for the remaining buildings was a voluntary house raising (VHR) scheme. A VHR involves home owners receiving a subsidy from government to lift their existing house to reduce the probability of above floor flooding.

VHR will only be worthwhile where the cost of raising the house is less than the present value (PV) of annual average damages (AAD) amortised over about 50 years. Single storey, clad, timber framed houses are the least expensive to raise and it is not usually worth investigating house raising for other constructions. The more frequent the above floor flooding (AFF), the more worthwhile is house raising and the deeper the AFF in each event the more worthwhile the house raising.

As a first pass to assess whether VHR was worthwhile in Campbelltown, the PV of damages for the houses with the highest AADs was estimated and compared with house raising cost estimates. If the PV exceeded the costs, then further filters were applied to identify which houses may benefit. The filters were applied in this order:

- Verified actual floor level (part of ground truthing of all 20% AFF properties);
- Verified number of storeys and construction type (e.g. clad timber framed, construction).

It is noted that most house in the BBBC catchment are built of bricks, which makes house raising a complex and expensive exercise.

9.5.4 Voluntary Purchase

Voluntary purchase (VP) can be considered when there is risk to people. It involves government purchase of a property at market value and then demolishing the building and ensuring no further unsuitable development takes place on the land. VP is only considered where all other flood modification and building modification options have been exhausted. VP will only be economically worthwhile where the present value (PV) of the annual average damages (AAD) over about 50years exceeds the cost of purchasing the house minus the value of the land for a lower value use. However, the decision to voluntarily purchase a property may involve non-monetary considerations such as risk to people. VP was investigated for properties which would have an unacceptable residual risk when all other mitigation options had been exhausted.

9.6 RESPONSE MODIFICATION

Improved flood response by community members can reduce loss of property and life in floods and is worth discussing in consultation with NSW SES.

Specific flood response measures which were investigated are:

- Improved flood warning including installation of warning systems;
- Improved agency response including closure of high risk roads;
- Options for evacuation;
- Improved community response through community education.

10 HOTSPOT MITIGATION OPTIONS

This Section presents the outcomes of the investigations for specific flood risk mitigation options that may be used to reduce flood risk at each of the hotspots shortlisted in Section 9.3.

10.1 METHODOLOGY

A systematic process of investigation was used to determine the most appropriate mitigation options for each location. Flood modification options were considered first, followed by property modification measures and finally response modification measures.

In doing so, data from the flood models and estimates of building floor levels were used to quantify impacts, prepare concept designs and evaluate costs and benefits. It is recognised that these analyses were undertaken using the best available information at the time of publication but that the methods used for deriving the data provide approximations suitable for a broad scale catchment wide study to identify locations where there are apparent flood issues which need to be addressed.

The particular data limitations which are recognised are:

- The flood models used in the flood studies assume full development of the catchments under current zoning provisions which represents maximum possible future runoff from the catchments;
- The extent of flooding represents an envelope of the maximum flood extent for various durations of rainfall for each probability event;
- The flood models used do not include the contribution of private drainage systems. These would significantly reduce overland flooding for industrial and larger commercial premises, particularly in the more frequent events;
- Where surveyed floor levels were not available estimates were made based on building type and estimated age. These may underestimate floor levels in commercial and industrial buildings but may over or underestimate floor levels in residential buildings.

The above listed limitations are typical of floodplain risk management studies of this scale. The quality of each dataset used, as well as implications for accuracy of the results, are discussed in the text where appropriate.

Future investigations may use more precise measurements taken in specific locations to provide more accurate estimates for detailed design, evaluation and implementation of options identified in this study.

10.1.1 Flood Modification

As explained in Section 9.4, with regards to flood modification options, the flood model was run in each location without blockages of inlets or culverts to determine whether measures to reduce blockages would make a significant difference to flood impacts.

An analysis of the capacity of the existing pipe network was then undertaken to determine whether increased pipe capacities might reduce the frequency of above floor flooding.

Where neither blockage reduction nor pipe capacity increases would significantly reduce flood impacts additional flood modification measures were explored including:

- Diversion of floodwaters around the area impacted;
- Detention of floodwaters upstream of the area impacted.

Where none of these would be effective in events up to and including the 1% AEP event, flood modification options were dismissed as not being a viable option for that hot spot.

Where the modelling suggested significant impact reduction would be possible, an iterative process of concept design and flood modelling was undertaken until one or more combinations of flow capacity increase, flow diversion and flow detention was identified which optimised the reduction in flood impacts.

A concept design of each short listed flood modification option was then prepared and used to estimate the costs of construction, operation and maintenance of the required flood modification infrastructure.

The flood damages were then calculated with and without the option in place and the economic benefits were deemed to be the reduction in the total annual average damages over the life of the project.

For each hotspot, costs and benefits were then discounted to present time under the following assumptions:

- A life span of 50 years for all structural works;
- A discount rate of 7% (as per NSW Treasury Guidelines).

A cost-benefit analysis was then undertaken for each hotspot which compared the present values of the costs with the benefits.

Where the economic value of benefits exceeded the costs, i.e., the benefit cost ratio (BCR) exceeded 1.0 then the option was considered to be economically worthwhile. The social and environmental costs and benefits of the option were then investigated and if these costs were not sufficient to outweigh the benefits of the option, the option was recommended for detailed investigation as part of the flood risk management plan.

If the BCR was less than 1.0 the social and environmental costs of the option were considered and if there were substantial non-economic benefits associated with the options it was recommended for detailed investigation as part of the flood risk management plan. Otherwise it was dismissed as not being a worthwhile option.

Appendix E includes the concept design of each flood modification option and the details of the estimated costs.

Appendix F shows the details of the cost-benefit analysis for each flood modification option.

10.1.2 Property Modification

a) Existing buildings

Property modification options were then considered. As explained in Section 9.5, an analysis of all properties across the BBBC Creek catchment revealed that there were none where house raising or voluntary purchase could be justified on economic grounds as a means of reducing flood damages. Therefore, at each of the hotspots, property modification measures for existing buildings focussed on their benefits in reducing risk to people.

There are essentially two ways in which existing buildings might be modified to reduce risk to occupants:

i) Elevated refuge

Where deep flooding could enter a building, the provision of a refuge above the reach of floodwaters may be a viable means of keeping people beyond the reach of floodwaters. This might be through provision of a mezzanine level in a commercial or industrial building or the construction of a second storey on a residential building.

Such provisions cannot be mandated by Council nor does Council or OEH provide funding for their construction. Any decision to provide such a building modification measure to reduce flood risks would be entirely up to the property owner. Factors that owners might want to take into consideration in such a decision are:

- The probability that hazardous flooding will enter the building
- The probability that the building will be occupied when it floods
- The duration of the flooding
- The mobility of occupants and their ability to reach an upper level
- The potential loss of electricity supply during a flood
- The stability of the building during high hazard flooding
- The cost of providing the building modification
- The value the modification adds to the overall property value

While the option analysis in this Section of the FRMS does not evaluate the provision of refuges as a property modification measure, it does provide information about flood behaviour and potential property impacts which can be used by property owners to inform their own investigations. Such investigations need to take into account the data limitations which are discussed at the beginning of this section.

b) Building strengthening

Sheltering within a building beyond the reach of floodwaters may not be safe if the building becomes structurally unstable due to the impacts of flooding. There may therefore be benefit in strengthening a building to reduce risk to the occupants. As with the provision of elevated refuges, such building modifications would neither be mandated nor funded by Council.

When considering the costs and benefits of such building modifications, a property owner should consider, amongst other things:

- The potential hydrostatic, dynamic and debris loads might place on a building
- The probability that such loads will be imposed on the building
- The probability that the building will be occupied when it floods
- The cost of providing the building modification
- The value the modification adds to the overall property value

Again, the discussion of hotspots provides information about the current estimated flood risks which can be used by property owners as a starting point for their own investigations. .

10.1.3 Future Buildings

Some of the hotspots have been identified for future redevelopment as part of the Glenfield to Macarthur Urban Renewal Corridor (NSW Govt., 2015) and, where appropriate, the potential for this wholesale modification of properties is discussed as a mitigation option.

10.1.4 Response Modification

Finally, response modification measures were investigated as a means of managing the residual risks that are not dealt with by flood or property modification measures.

People will have a choice to either evacuate or shelter in place and should be guided by advice provided by the NSW SES in this regard. The ability to respond appropriately and safely can be dependent on the amount of warning time available to respond and having knowledge how to respond appropriately. Section 10 deals with the evaluation of catchment wide warnings systems and community education.

Accordingly, in the analysis of the hotspots, information about flood probabilities, hazards, rates of rise, potential to enter buildings and durations are provided to inform decisions by NSW SES and occupants regarding the most appropriate response modification measures at each hotspot.

10.2 RESIDENTIAL HOTSPOTS

This section describes the shortlisted flood risk reduction options for each residential hotspot, which are listed in no particular order.

At the beginning of each hotspot description, a summary of the selection criteria satisfied by that hotspot is provided. Hotspot selection criteria are described in Section 9.3.

It should be noted that:

- Where flood modification was deemed economically worthwhile, a detailed survey and design of the proposed works will be necessary before these are implemented.
- The estimated cost and benefit figures of the shortlisted flood modification options were rounded to the nearest \$100,000. The exact figures, which were used to calculate the benefit to cost ratio, are presented in Appendix F.

10.2.1 Spitfire Dr and Sopwith Ave, Raby

Residential Hotspot ID number: 1

Selection Criteria Satisfied:

- Criterion 2 (risk to property)
- Criterion 3 (risk to people)

This location is presented in detail in Map 32 (Vol.2).

a) Flood Behaviour

i) 20% AEP

The water forms a pond more than a metre deep at the intersection of Starfighter Ave and Sopwith Ave before heading north along a flow path between the houses in Sopwith Ave and Spitfire Dr, and then flowing between houses into Spitfire Drive. On its way, two houses in Sopwith Ave and one in Spitfire Dr may experience Above Floor Flooding (AFF). In addition to these, the model shows four buildings in Starfighter Ave with mild AFF depths from the 20% AEP, however upon close inspection it was observed that this is caused by local puddles that are likely to be managed by the private stormwater system of the affected buildings.

ii) 1% AEP

In the 1% AEP flood, the above flow paths are wider and deeper and there are about eight houses potentially affected by AFF in Sopwith Ave and Spitfire Dr. In addition to these, AFF may be experienced by two houses between Kittyhawk Cres and Hurricane Dr.

iii) PMF

In the PMF 22 houses are surrounded by flooding around 1m deep, with peaks of 1.5m. All of these could have AFF exceeding 0.5m deep. In this event there are also 26 single-storey houses, some of which are part of the 22 mentioned above, which experience over 0.5m deep AFF, and the flood model suggests two of these may be at risk of structural instability, because they are affected by floodwaters with hazard of H5 and H6.

b) Flood Modification Options

i) Background Analysis

Analysis of existing pipe capacities showed that the pipe network from Raby Rd to Spitfire Dr is operating at capacity in the 20% AEP event and an increase in capacity may reduce the risks for about half a dozen houses between Sopwith Ave and Spitfire Dr.

The blockage difference mapping showed that there is less than a 10mm difference in flood levels if it is assumed no blockage occurs, so reducing blockages at pit inlets would not make a significant difference to flood risks in this area.

There is a pocket park (Sopwith Reserve) adjacent to the intersection of Starfighter Ave and Sopwith Ave where water ponds up to 1m deep.

ii) Identification of potential flood modification options

If a detention basin were to be set up in Sopwith Reserve, this would have to have a capacity of about 13,500m^3 for it to prevent overland flow in a 1% AEP event. Given that the park is only about 20m by 33m, the basin would have to be about 21m deep to create this capacity.

However, the above capacity is based on the existing pipe diameter of 1.2m which has been shown to be operating at capacity in a 20% AEP flood. Therefore it was thought that a combination of increased pipe capacity and provision of detention storage in this location might provide some benefit to the houses between Sopwith Ave and Spitfire Dr in floods more frequent than the 1% AEP event.

These options were integrated in the flood model and their benefits assessed in terms of reduction in flood levels.

It was found that the configuration providing the greatest benefits included the following items:

- The introduction of a new pipe between Kittyhawk Cres and Harrier Ave;
- Duplication of the existing pipe to downstream of Kittyhawk Cres;
- An additional surcharge pit in the carpark south-west of Hurricane Drive;
- A detention basin in Sopwith Reserve, including additional pits and three pumps, each one diverting water from the basin into a new pipe connected to the existing downstream pipes in Spitfire Drive.

The first configuration that was tested did not include pumps within the detention basin in

Sopwith Reserve, and had only one pipe through Spitfire Dr. However this configuration did not offer a sufficient flood level reduction.

A configuration with a 6,000 m^3 detention basin in Raby Shopping Centre car park was also tested, however the model did not show sufficient flood reduction and no feasible alternatives to such a basin could be identified.

The overall layout and details of the shortlisted flood modification option for this hotspot are shown in Figure 32.

c) Property Modification Options

There are 26 single storey houses which could experience deep above floor flooding in an extreme flood event and may not be a safe refuge.

Apart from a local shopping centre in Hurricane Dr and Sopwith Reserve, all of the land in this hotspot is zoned R2 low density residential. Furthermore, it is not close to the railway line and therefore does not figure in the Glenfield to Macarthur Urban Renewal Corridor. This means that there are no town planning opportunities to replace the existing houses with dwellings which are more compatible with the flood risks.

d) Response Modification Options

Flooding in this area will occur with little warning and will be of very short duration. Leaving premises after they are surrounded by high hazard floodwaters would be dangerous.

e) Shortlisted Options

In light of the preceding discussion, it was decided that the shortlisted flood modification option warranted further investigation.

f) Evaluation of the Shortlisted Option

A cost-benefit analysis was undertaken for the shortlisted flood modification option to assess if this would be economically worthwhile. Table 22 shows a summary of the results for this hotspot (please refer to Appendix E and F for more details).

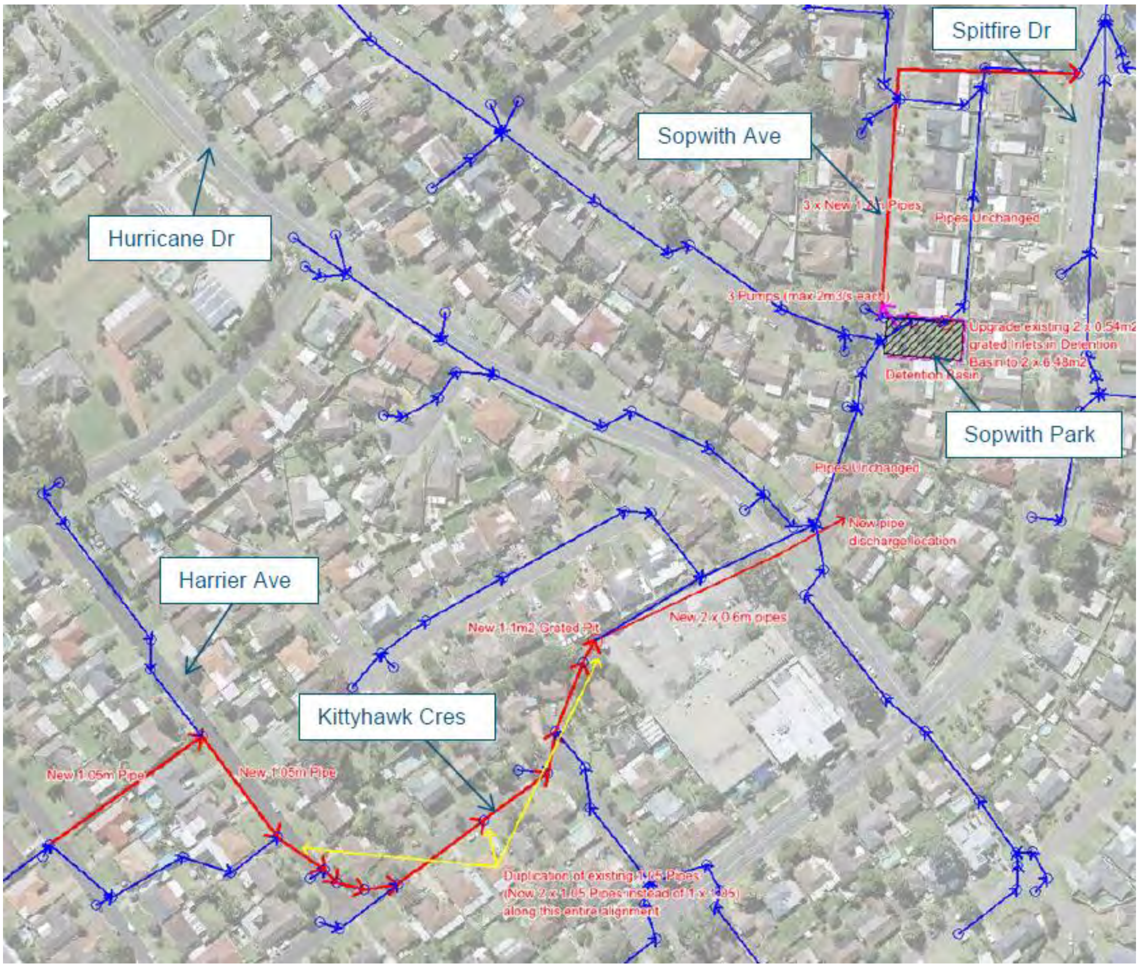

Figure 32. Layout and details of flood modification options for residential buildings in Spitfire Dr, Rabi.

Table 22. Results of Cost Benefit Analysis for Flood Modification Options in Spitfire Dr, Raby

Total Option Costs	$5.742M
Total Option Benefits	$1.182M
Benefit/Cost Ratio	0.21

The cost/benefit analysis showed that flood modification at this location would not be economically worthwhile, having a benefit to cost ratio of only 0.21. In addition to this, the shortlisted flood modification option would have minimum effects on flood levels in less frequent floods.

For these reasons, it is not recommend that flood modification be investigated further at this location.

10.2.2 Ingleburn CBD

Residential Hotspot ID number: 2

Selection Criteria Satisfied:

- Criterion 2 (risk to property)
- Criteria 1, 3, 4 (risk to people)

This location is presented in detail in Map 33, Vol. 2.

In this area there are 189 residential buildings and numerous commercial buildings satisfying the hotspot selection criteria. It should be noted that some of the commercial buildings host multiple tenancies. This section addresses risk to residential buildings, while commercial buildings are discussed in Section 10.3.4. However, given the proximity of residential and non–residential buildings in this area, these would benefit from the same flood risk mitigation measures. As such, the cost-benefit analysis of the shortlisted flood modification options considers residential and commercial buildings.

a) Flood Behaviour

Floodwaters are conveyed towards and through Ingleburn CBD by two main flow paths:

- Redfern Creek, running in a NW direction and approaching Ingleburn CBD through Cumberland Rd and Norfolk St; and
- A flow path along Koala Walk drain from Kingfisher Reserve, entering the northern end of the CBD across Carlisle St and Macquarie Rd.

i) 20% AEP

The area experiences overland flooding and high hazard levels from the 20% AEP event. Modelling suggests that in a 20% AEP flood, 15 residential buildings may experience above floor flooding. More than 50 residential buildings would be isolated by flooding in the 20% AEP event.

ii) 1% AEP

In a 1% AEP flood about 37 residential buildings may experience above floor flooding. Flooding as deep as 0.8m may be experienced in roadways.

iii) PMF

About 100 single-storey residential buildings may experience above floor flooding in a PMF more than 0.5m deep. Of these, the model shows that 71 are located in low flood islands and 12 would be exposed to flood hazards which may affect their structural stability.

b) Flood Modification Options

i) Background Analysis

The influence of partial blockage of the stormwater system on the 1% AEP flood level was first assessed. Results showed that a slight reduction of the 1%AEP flood level could be achieved if there was no blockage in any part of the system. However, even without considering the significant technical challenges that achieving a no-blockage scenario would present, the 1% AEP level would generally be reduced by a negligible amount (less than 0.1m overall). As such blockage reduction, even if it were practically achievable, would not be an effective option for Ingleburn CBD.

The analysis identified 31 residential buildings which may benefit from an increase in flow conveyance by augmenting the existing underground pipe capacity with larger pipes, additional pipes or an open channel. The stormwater system around these buildings operates at full capacity from the 20% AEP event, when many of these buildings begin to experience AFF.

Increasing outflows from this area is an option that was deemed worth investigating further.

In a 1% event, about 58m^3/s is flowing into the CBD but the culverts that carry flow beneath the CBD have sufficient capacity to convey only 18m^3/s (assuming no culvert blockage). This could be addressed by a conveyance of at least 40m^3/s in addition to what is currently flowing through the existing pipes.

ii) Identification of potential flood modification options

Several configurations of flood modification options to increase outflows from the CBD area were considered and tested with the hydraulic model. These included:

- A new 2.1m diameter pipe from the existing open channel downstream of Cumberland Rd to BBBC Creek (under the railway). This showed significant flood level reduction and was considered in some of the following configurations with additional capacity in the drainage line.
- A new pipe from the crossroad of Ingleburn Rd and Norfolk Rd to BBBC Creek (under the railway), charged by increased pipe capacity along Norfolk Rd and Ingleburn Rd. This provided a significant reduction of flood levels, but after closer examination the rail line crossing at this location was deemed too difficult.
- A new detention basin at the crossroad on Cumberland Rd and Norfolk Rd (storage of 15,000 m^3). As this area is currently occupied by flood-affected dwellings, this option would also entail voluntary house purchase (VP) of up to four dwellings. To minimise the uptake of land and maximise storage capacity, the use of an underground water detention tank and submersible pump would be necessary. This would convey water from the underground tank to a pipe along Cumberland Rd discharging to Milton Park. Flood depth reductions in this configuration were not significant, so the same configuration was then tested in combination with the above mentioned new 2.1m diameter pipe to BBBC Creek.
- The previous configuration was then amended to include the 2.1m diameter pipe from the existing open channel downstream of Cumberland Rd to BBBC Creek (under the railway). However, this configuration still did not provide quite enough flood reduction in the CBD. It also showed that the underground tank and associated pumping system would not provide significant advantages over the new 2.1m diameter pipe to BBBC Creek alone.
- Upgrade of the existing CBD culvert through duplication of existing pipes with blockage prevention devices installed upstream. This option was discarded because of the practical difficulties associated with the construction works as the existing pipe runs under numerous private properties and recent developments (e.g. Ingleburn Fair).
- Open channel through the CBD to connect the existing open channel downstream of Cumberland Rd to the open channel downstream of Macquarie Rd. This would require a significant rebuild of the CBD and would have to be considered in conjunction with a strategic planning solution. At this stage this option was discarded because of the practical difficulties associated with construction works, co-operation of multiple property owners and necessary extensive land acquisition by Council.
- A detention basin in Wood Park about 1km upstream of the CBD. It was estimated that to create a 2m deep basin in Wood Park, the height of the existing embankment would have to be increased (the existing embankment is ~0.8m high) and/or excavation of the existing playing field undertaken. Alternatively, the basin footprint could be enlarged (e.g., through the inclusion of an additional playing field). Making the park larger was deemed not practical because the downstream area in the park, where there is space for another oval, supports an endangered ecological

community. Furthermore, the whole area is underlaid by rock so excavation would be extremely expensive. In addition to these practical difficulties, the model results showed that this option alone would not provide sufficient flood level reductions in the CBD. For these reasons this option was not investigated further.

- Culvert modifications along Ingleburn Rd to Devon Rd, including the removal of the blockage applied to the culvert under the railway, and the redirection of some drainage towards the culvert under the railway (rather than towards the CBD). The model showed that this configuration did not provide sufficient flood level reductions to warrant further investigations.
- Regrading and realignment of the drain in Koala Walk and its confluence with Redfern Creek. This was not further investigated because it produced flood level reductions only localised to within the channel.
- Upgrade of the culvert in Koala Walk, achieved by replacing the open channel with a 3m wide by 1.2m high culvert running from the south side of Carlisle St to the existing open channel on the north side of Macquarie Rd. This configuration was not further investigated because it showed too localised flood level reductions.

The set of flood modification options that produced the most significant flood level reductions throughout the CBD (Figure 33) included the following upgrades to the stormwater system:

- Filling the existing open channel downstream of Cumberland Rd and replacing it with two new 2.1m wide by 1.5m high culverts, as well as a new 3m wide by 2.7m high culvert that connects into the existing trunk drainage line. This culvert would continue along Norfolk St up to Ingleburn Rd;
- A new 3.6m wide by 3m high culvert to then convey flows to the open channel downstream of Macquarie Rd;
- A new 3.6m wide by 1.5m high culvert introduced along Ingleburn Rd upstream of Norfolk St which would be charged by several new 3.8m^2 grated inlets.

Figure 33. Layout and details of flood modification options in Ingleburn CBD

c) Property Modification Options

While the shortlisted flood modification options may reduce flood risk to the CBD, there may also be the opportunity to reduce flood risks in the CBD through property modification.

Ingleburn CBD was rezoned in 2015 to allow higher-density redevelopment. It is currently under investigation for further rezoning as part of the Glenfield to Macarthur Urban Renewal Corridor.

This provides an opportunity to further reduce risk to property and life by doing one or more of the following:

- Designing a new CBD layout with buildings outside of the highest flood risk areas;
- Redeveloping some of the flood-affected buildings.

Building redevelopment could incorporate:

- Car parking at ground level through which overland flows could pass;
- Buildings with elevated ground floor slabs under which overland flows would pass;
- Buildings with sealable ground floors to prevent entry of floodwaters;
- Buildings with ground floor uses and materials which are compatible with occasional flooding.

There are also areas immediately adjacent to the CBD which are significantly affected by flooding. These includes low-rise buildings along Macquarie Rd north east of the CBD. That land is currently zoned for medium density which would permit townhouses to be constructed similar to those closer to the CBD on Macquarie Road. Although many of these dwellings would experience reduced flood levels if the proposed flood modification options were put in place, a better flood risk outcome may be possible if all of these blocks (including the existing townhouses) were zoned for high density residential which would allow private open space to be made available for overland flows and ensure no dwellings were at ground level. It is noted that the Glenfield to Macarthur Urban Renewal Corridor Landuse and Infrastructure Summary (NSW Govt, 2015) identifies this area as potential high rise development of seven storeys or more (Figure 34).

d) Response Modification Options

The rezoning and redevelopment of Ingleburn CBD to replace existing low rise buildings with high rise buildings and implementation of flood modification measures could completely change the risk profile of this hot spot. Response modification measures need to adapt to the changing risk profile taking into account the rapid rate of rise and short duration of flooding in this area.

e) Shortlisted Options

In light of the preceding analysis, the following local food risk reduction options were evaluated in detail:

i) Flood Modification Options

- The shortlisted configuration of flood modification options described in section 10..2.b and shown in Figure 33.

ii) Property Modification Options

- As part of the rezoning and redevelopment of Ingleburn CBD:
  - Relocating buildings outside high hazard zones; Redeveloping some of the flood-affected properties to reduce their exposure to floodwaters.
  - Rezoning the land containing the low-rise buildings along Macquarie Rd north east of the CBD from medium to high density residential to allow the construction of less vulnerable buildings.
- Use locality-specific development controls throughout the area to reduce risk to property.

iii) Response Modification Options

- Consider the adoption of locality-specific development controls to improve flood response outcomes.

f) Evaluation of the Shortlisted Options

i) Flood Modification

A cost-benefit analysis was undertaken for the shortlisted flood modification options to assess if these would be economically worthwhile. Table 23 shows a summary of the results for this hotspot (please refer to Appendix E and F for more details).

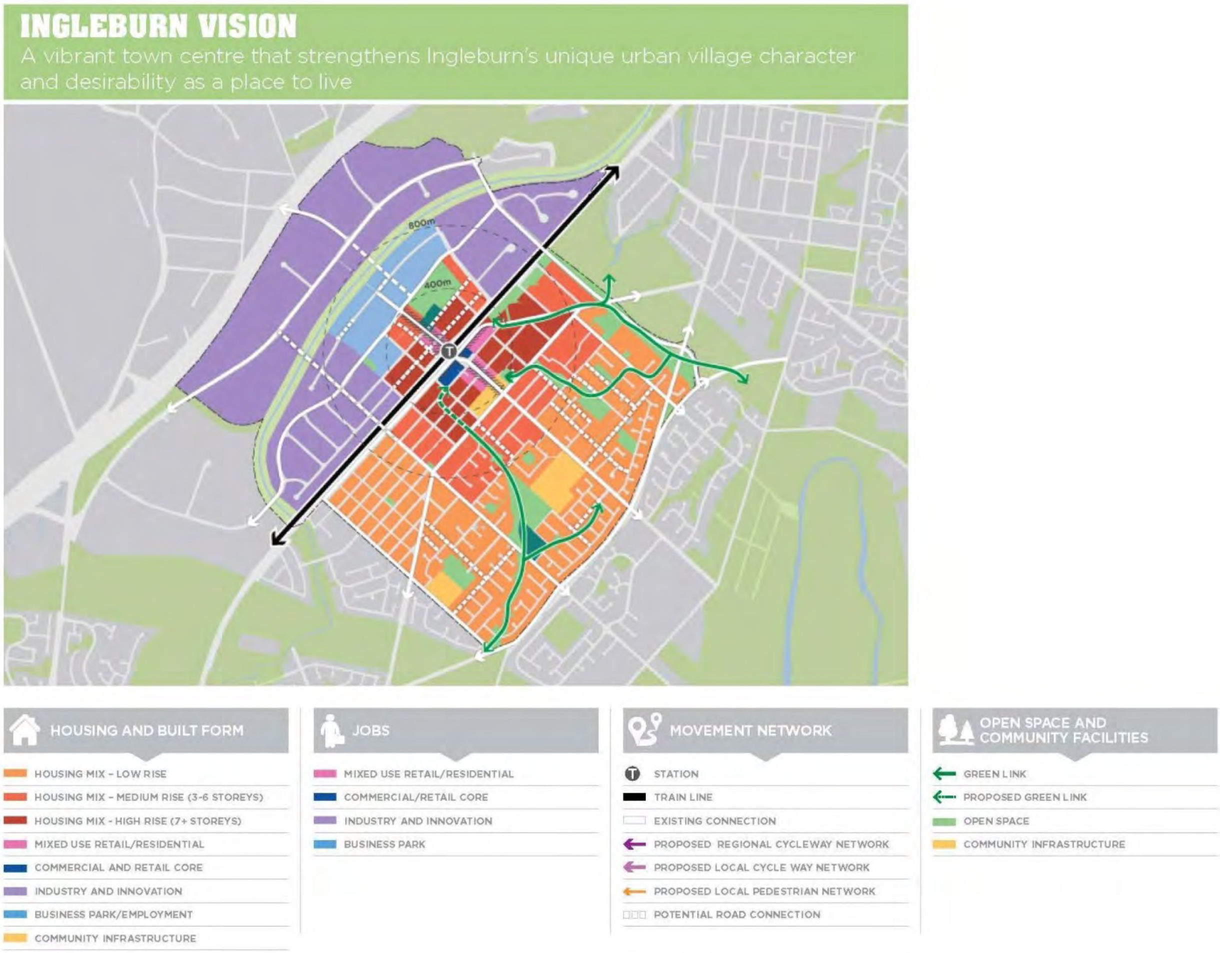

Figure 34. Ingleburn Precinct from Glenfield to Macarthur Urban Renewal Strategy

Table 23. Results of Cost Benefit Analysis for Flood Modification Options in Ingleburn CBD

Total Option Costs	$13.487M
Total Option Benefits	$23.486M
Benefit/Cost Ratio	1.74

The cost/benefit analysis showed that flood modification at this location would be economically worthwhile, having a benefit to cost ratio of 1.74.

In terms of social and environmental costs, the shortlisted flood modification option would cause some inconvenience during construction and maintenance operations. For instance, closing Norfolk St and Ingleburn Rd would have significant impact on the local traffic flows during construction. However, these impacts would be temporary and would be further reduced if the construction works were undertaken as part of the CBD redevelopment.

However, the following feasibility issues were identified:

- Major Service's assets exist along the alignment of Ingleburn Road in the vicinity of stormwater upgrades.
- Of particular note are sewer mains present along Norfolk Street and Ingleburn Road ranging in size from Ø225mm to Ø450mm.
- Given the relatively large size of the proposed culverts it is likely that conflicts with existing services will arise.

For these reasons, it is recommended that the culvert amplification option proceed to detailed design.

ii) Property Modification

The redevelopment of Ingleburn CBD as part of the Glenfield to MacArthur Urban Renewal Corridor Strategy (NSW Govt., 2015) provides an additional opportunity to reduce flood risk through property modification measures.

The advantage of addressing flood risk with property modification as part of redevelopment to high rise buildings is that the associated costs are distributed across many property owners, making the benefit to cost ratio much greater than it would be in low rise dwellings.

In this location, property modification measures could be used in combination with flood modification in a number of different ways. For instance, property modification could be used to manage residual risks after the recommended flood modification option has been implemented.

Alternatively, property modification under the Glenfield to Macarthur Urban Renewal Corridor could be used as the main way to reduce flood risks in Ingleburn CBD. This could be achieved with more substantial investments in the design and construction of a CBD that is less vulnerable to flood damage. In this scenario, flood modification would be used to manage residual risks and would require smaller investments.

From a theoretical perspective, in Ingleburn CBD, any combinations of flood modification and property modification could be used to reduce risks to the same extent, and each of them would have different economic and social costs. A cost/benefit analysis of the all possible combinations is not practical; however the following observations can be made to inform Council's preferred approach:

- If property modification were used as the main risk reduction measure, this would come at a significant economic and social cost for the community. For instance, building to a higher FPL would have higher construction costs. Similarly, more stringent development controls may become a deterrent for developers. In addition to this, a floor level that is significantly raised over ground level may not be suitable or ideal for commercial uses (e.g. retail).
- On the other hand, if flood modification were used as the main risk reduction measure, property modification could have less stringent requirements and there would be more flexibility in the design and construction of the CBD. For instance, building to a lower FPL, or in an area that, because of flood modification, is now above the FPL, would be less onerous to developers and would allow to create spaces at the ground floor that are suitable for a larger number of commercial uses. In addition to this, the cost of flood modification could be partly reduced via developer's contributions, which would become a more viable option in a context in which development controls are less stringent.

Regardless of the preferred approach to flood risk reduction in Ingleburn CBD, it is recommended that Council work with the NSW Department of Planning and Environment to ensure that flood risk is acknowledged and addressed as part of the redevelopment. This could be achieved through locality–specific development controls to complement flood modification measures and reduce risk to property and life.

10.2.3 Epping Forest Dr, Kearns

Residential Hotspot ID number: 3

Selection Criteria Satisfied:

- Criterion 2 (risk to property) satisfied by three buildings
- Criterion 3 (risk to people) satisfied by six buildings

This location is presented in detail in Map 34, Vol 2.

a) Flood Behaviour

There is an overland flow path running south along Epping Forest Dr until it reaches a low spot in front of some houses which back onto Vale Brooke Reserve. From here the flow heads through the residential properties to join the main flow path through the reserve.

There is also a second flow path running north-east from Trebbiano Pl to Epping Forest Dr, along a pedestrian pathway.

i) 20% AEP

In a 20% AEP event, modelling suggests that two houses in Epping Forest Dr and one house in Trebbiano Pl may expect above floor flooding.

ii) 1% AEP

In a 1% AEP event, above floor flooding is occurring at four houses in Epping Forest Dr (including the two mentioned above) and at the house in Trebbiano Pl.

iii) PMF

In a PMF, six buildings in Epping Forest Dr and the above-mentioned building in Trebbiano Pl are surrounded by flooding up to 1m deep, and can experience more than 0.5m depth of above floor flooding. These are all single-storey buildings.

b) Flood Modification Options

i) Background Analysis

Most of the pipe network in this area is operating at capacity during a 20% AEP event. This suggests that increasing pipe capacity may reduce local flood levels

The modelling of the system without blockages reduced flood levels by less than 30mm in the 1% AEP event, so this would not significantly reduce flood risks.

Finally, there are no areas upstream which are suitable locations for providing flood detention.

ii) Identification of Potential Flood Modification Options

A major component of this flooding is the flow path coming from the north, along Epping Forest Dr. This flow is currently unable to enter Vale Brook Reserve as Epping Forest Dr is lower than the reserve. The flood modification options that were assessed for this hotpot aimed at diverting the flow into Vale Brook Reserve, to alleviate the flooding at the houses described above. These included combinations of:

- Local pipe capacity upgrades, particularly along the walkway between number 36 and 38 Epping Forest Dr, connecting Epping Forest Dr to Vale Brook Reserve. This was achieved through an increased diameter of the existing pipe and the addition of a new pipe following the same alignment as the walkway;
- Regrading the above mentioned walkway to allow water to flow under gravity from a trapped sag point on Epping Forest Dr through to Vale Brooke Reserve.
- Adding a speed hump on Epping Forest Dr, upstream of the sag point, to divert as much water as early as possible across the road towards the reserve, rather than having floodwater running down Epping Forest Dr towards the currently affected properties.

The model showed that a sufficient flood level reduction would be achieved by coupling the speed hump and the regrading works along the walkway. This configuration is shown in Figure 35.

c) Property Modification Options

All the affected dwellings are single storey. Apart from the local parks, all of the land in this hotspot is zoned R2 low density residential. Furthermore, it is not close to the railway line and therefore does not figure in the Glenfield to Macarthur Urban Renewal Corridor. This means that there are no town planning opportunities to replace the existing houses with dwellings which are more compatible with the flood risks.

d) Response Modification Options

Flooding in this area will occur with little warning and will be of short duration. Leaving premises after they are surrounded by high hazard floodwaters would be dangerous. For more detail on flood response across the BBBC Creek catchment, please refer to Section 11.2.1.

e) Shortlisted Options

In light of the preceding discussion, the following flood risk reduction options were evaluated in detail:

- The shortlisted flood modification options, coupling a speed hump across Epping Forest Dr and a regrading of the walkway between number 36 and 38 Epping Forest Dr, to facilitate drainage towards Vale Brook Reserve;

Figure 35. Layout and details of the shortlisted flood modification options in Epping Forest Drive, Kearns.

f) Evaluation of the Shortlisted Options

i) Flood Modification

A cost-benefit analysis was undertaken for the shortlisted flood modification option to assess if this would be economically worthwhile. Table 24 shows a summary of the results for this hotspot (please refer to Appendix E and F for more details).

Table 24. Results of Cost Benefit Analysis for Flood Modification Options in Epping Forest Drive, Kearns

Total Option Costs	$118k
Total Option Benefits	$733k
Benefit/Cost Ratio	6.23

The cost/benefit analysis showed that flood modification at this location would be economically worthwhile, having a benefit to cost ratio of 6.23.

In terms of social or environmental costs, the shortlisted flood modification options would cause only minor inconvenience during construction and maintenance operations, and these would be temporary. The proposed speed hump would have to be adequately designed to suit local traffic conditions and avoid or minimise any traffic disruptions. The slopes along the regraded walkway would have to be properly stabilised to avoid any scouring caused by concentration of flows. In conclusion, social costs associated with the proposed flood modification options at this location are negligible and can be reduced if appropriate action is taken during design and construction. No environmental costs were identified.

For these reasons, it is recommended that the shortlisted flood modification option at this location proceed to detailed design.

10.2.4 Greenoaks Ave, Bradbury

Residential Hotspot ID number: 4

Selection Criteria Satisfied:

- Criterion 2 (risk to property) satisfied by three buildings
- Criteria 1, 3 and 4 (risk to people) satisfied by multiple buildings

This location is presented in detail in Map 35, Vol 2.

a) Flood Behaviour

There is an overland flow path which runs north along Campbellfield Ave then heads east to Greenoaks Ave, then north along Greenoaks Ave, and then east again towards Fishers Ghost Creek which runs between Greenoaks Ave and The Parkway. As it cuts between streets and the Creek, it passes through residential properties. It should be noted that floor levels were surveyed by inspecting the front of the building and were assumed to be the same throughout the ground floor of the building. As such, AFF may be overestimated for buildings with split floor levels, particularly where flooding is approaching the building from the back. In addition to this, the floor level of some of these buildings could not be obtained during the field surveys because of restricted accessibility to the site.

i) 20% AEP

In the 20% AEP event flooding exceeds 0.5m deep in places and may cause AFF in three dwellings. A total of 12 dwellings are isolated in the 20% AEP event and all are in a townhouse complex between Greenoaks Ave and The Parkway.

ii) 1% AEP

In the 1% AEP event flooding up to 0.6m deep may occur in the roadways and eight houses may experience AFF.

iii) PMF

In the PMF flooding up to 1.5m deep occurs and about 20 dwellings experience more than 0.5m of above floor flooding. Of these, those in the above mentioned townhouse complex between Greenoaks Ave and the Parkway are located in a low flood island. The flood model shows that one building in Campbellfield Ave may experience structural instability in a PMF.

b) Flood Modification Options

i) Background Analysis

The flood model shows that most pipes at this location run at capacity from the 20% AEP event, and eight buildings may have a reduced risk if pipe capacity is increased.

A model run with no blockages revealed that flood levels would only be reduced by less than 50mm even where there are sag points in the road, but this may be partly due to the fact that pipes run at capacity from the 20% AEP.

Manooka Reserve is a large park southwest of this hot spot and could be a potential location for a detention basin.

ii) Identification of Potential Flood Modification Options

The following combinations of flood modification options were tested for this hotpot:

- A detention basin at Manooka Park., providing approximately 19,000 m^3 of storage. This could be achieved through a maximum of 0.6m of storage depth along the northern side of the proposed basin wall/spillway.
- Regrading on The Parkway to the east of Pinaroo Cres, in an effort to direct flow from The Parkway into the basin. It was assumed that the installation of a “speed hump” at this location would assist in this regard, as well as lowering of the existing kerb height and adjoining verge.
- Modified local stormwater network to divert upstream pipe flows into the proposed basin at Manooka Park. This produced considerable flood level reductions locally, but significant depths were still predicted through many of the problematic downstream properties.
- Additional stormwater upgrades upstream of the proposed basin at Manooka Park to help drain the trapped low point at Manooka Cres into the basin.
- Drainage upgrades (i.e. duplication of existing pipes) from the intersection of Campbellfield Ave and Poplar Cres right down to the outlet at Fishers Ghost Creek. These were trialled to manage the above mentioned depths through the properties downstream of Manooka Park.

The model results showed that of all the above mentioned options would contribute significantly to reducing flood levels, however it was observed that even with all these options the basin would be spilling in frequent events, despite the significant storage volume provided. The storage of the basin was then increased from 19,000 m^3 to about 33,000m^3 by means of the following design changes:

- The basin footprint was marginally increased (most significantly near the north-eastern corner);
- The basin invert was lowered from 120m AHD to 117 m AHD; and
- The top of the downstream basin wall was increased from 120.25 m AHD to 120.45 m AHD.

The final option configuration, including the 33,000m^3 storage basin in Manooka Park and the upgrades to the stormwater system, is shown in Figure 36.

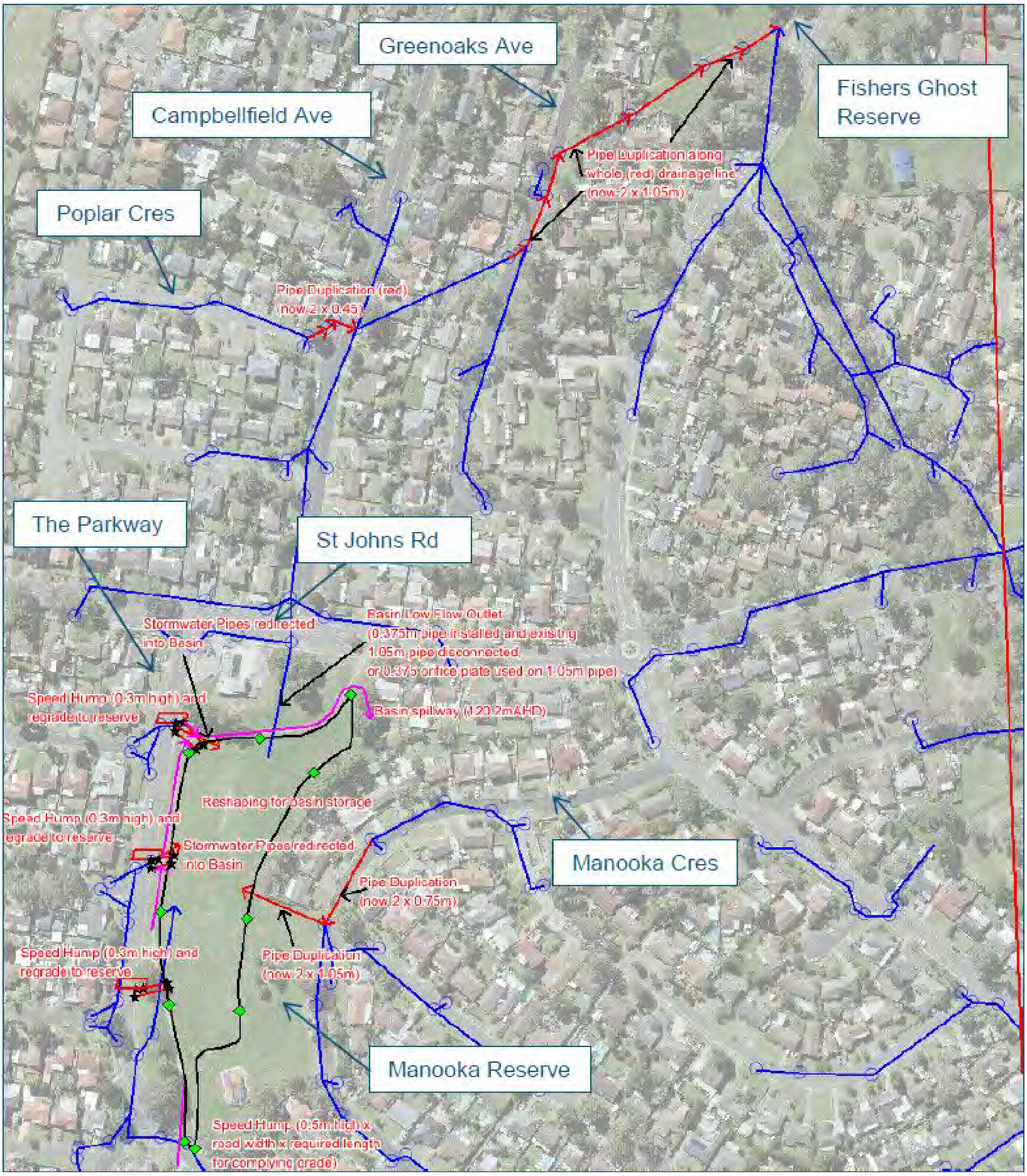

Figure 36. Layout and details of the shortlisted flood modification options in Greenoaks Ave, Bradbury.

c) Property Modification Options

Apart from the local parks, all of the land in this hotspot is zoned R2 low density residential and is no part of the vision for the Glenfield to Macarthur Urban Renewal Corridor. This means that there are no town planning opportunities to replace the existing houses with dwellings which are more compatible with the flood risks.

d) Response Modification Options

Flooding in this area will occur with little warning and will be of short duration. Leaving premises after they are surrounded by high hazard floodwaters would be dangerous..

For more detail on flood response across the BBBC Creek catchment, please refer to Section 11.2.1.

e) Shortlisted Options

In light of the preceding discussion, the following flood risk reduction options were evaluated in detail:

- The shortlisted flood modification option, coupling a detention basin in Manooka Park and upgrades of the stormwater system;

f) Evaluation of the Shortlisted Options

i) Flood Modification

A cost-benefit analysis was undertaken for the shortlisted flood modification options to assess if these would be economically worthwhile. Table 25 shows a summary of the results for this hotspot (please refer to Appendix E and F for more details).

Table 25. Results of Cost Benefit Analysis for Flood Modification Options in Greenoaks Ave, Bradbury.

Total Option Costs	$4.051M
Total Option Benefits	$1.224M
Benefit/Cost Ratio	0.30

The cost/benefit analysis showed that flood modification at this location would not be economically worthwhile, having a benefit to cost ratio of only 0.3. In addition to this, the shortlisted flood modification options would have minimum effects on flood levels in less frequent floods.

For these reasons, it is not recommended that flood modification be investigated further at this location.

10.2.5 Bloodwood Pl, Bradbury

Residential Hotspot ID number: 5

Selection Criteria Satisfied:

- Criterion 2 (risk to property) satisfied by two buildings
- Criteria 1, 3 and 4 (risk to people) satisfied by multiple buildings

This location is presented in detail in Map 36, Vol 2.

a) Flood Behaviour

There is a long overland flow route which starts nearly a kilometre south east of Bloodwood Pl and has a branch running along Guise Rd and another along the rear of the houses on the northern side of Guise Rd. It then flows into Karri Pl and through the walkway which connects to Bloodwood Pl, but also through the rear of properties in Bloodwood Pl to Ash Pl and Olympic Cct. From Olympic Cct, Ash Pl and Bloodwood Pl it discharges across The Parkway into Fishers Ghost Creek.

i) 20% AEP

Two buildings may experience above floor flooding in a 20% AEP flood which can be as deep as 0.5m in a few isolated puddles in Bloodwood Pl. Fifteen houses here are effectively isolated in this flood event

ii) 1% AEP

Six buildings may experience AFF between Karri Pl, Bloodwood Pl and Ash Pl.

iii) PMF

In a PMF event, 16 single-storey buildings may experience AFF depths exceeding 0.5m. Of these, seven are located within a low flood island. There are also six additional buildings that are in a low flood island, however these would experience AFF depths lower than 0.5m. The flood model suggests at least three buildings may experience structural instability in the PMF.

b) Flood Modification Options

i) Background Analysis

The model showed that five of these buildings may benefit from an increase in pipe capacity, including two which may experience above floor flooding in a 20% AEP event.

The closest location for a potential detention basin is Willow Court Park, where Alliot St becomes Guise Rd.

ii) Identification of Potential Flood Modification Options

The following combinations of flood modification options were tested for this hotpot:

- Blockage proofing of culverts under The Parkway, opposite Olympus Cct. This option looked at the potential benefit of reducing the blockage applied to The Parkway culvert on Fishers Ghost Creek. This was done in an attempt to allow the pipes which drain Bloodwood Pl to discharge to the creek more efficiently. The model showed some notable flood level reductions, however these were confined to open space areas (i.e. Bradbury Oval) and had negligible effect on buildings near Bloodwood Pl. For these reasons this option was not further investigated.
- Karri Place to Fishers Ghost Creek Drainage Upgrade. This option included a larger pit (same width as the roadway) and culvert conveying floodwaters from Bloodwood Pl under The Parkway to Fishers Ghost Creek. However this did not provide sufficient flood level reductions and was not further investigated.
- Willow Court Park Detention Basin. The basin could provide a storage of 5,000m^3, corresponding to a 1m storage depth (spillway elevation = 106m AHD). The basin alone was trialled in the model and showed insufficient capacity to attenuate flows during events equal to and greater than the 5% AEP.
- Willow Court Park Detention Basin, with pipe upgrades. The basin mentioned above was coupled with an upgraded pipe system running from the basin to Fishers Ghost Creek. This involved duplicating each of the downstream pipes for a length of 800m. This option produced greater reductions in flood levels (ranging between 5mm and 15mm reduction) along all downstream properties during both the 5% AEP and 1% AEP events. However pipe duplication through such a large number of properties was deemed impractical and this option was not further investigated.
- Karri Place to Fishers Ghost Creek drainage upgrade. This entailed regrading the walkway from Karri Pl to Bloodwood Pl, in an effort to direct flows to the alleyway. It also included the duplication of the drainage system from Karri Pl to Fishers Ghost Creek. However the model showed that this configuration did not provide sufficient flood level reductions.
- Karri Place to Fishers Ghost Creek drainage upgrade, with regrading on The Parkway. The previous configuration was modified by adding a regrading of the corner of The Parkway and Bloodwood Pl. However this configuration did not provide sufficient flood level reductions.

The model results showed that none of the previously listed options, or combination of options, could generate sufficient flood level reductions in this hotspot. Flood modification was therefore considered not worthwhile at this location.

c) Property Modification Options

All of the affected dwellings in this hotspot are in land zoned R2 low density residential. While Olympic Circuit is on the boundary of the Campbelltown precinct within the Glenfield to

Macarthur Urban Renewal Corridor, the adjacent land within the precinct is shown as low rise residential on the maps. This means that there are no town planning opportunities to replace the existing houses with dwellings which are more compatible with the flood risks.

d) Response Modification Options

Flooding in this area will occur with little warning and will be of short duration. Leaving premises after they are surrounded by high hazard floodwaters would be dangerous.

For more detail on flood response across the BBBC Creek catchment, please refer to Section 11.2.1.

e) Shortlisted Options

In light of the preceding discussion no flood risk reduction options were shortlisted for evaluation in detail:

10.2.6 Tigg Pl, Ambarvale

Residential Hotspot ID number: 9

Selection Criteria Satisfied:

- Criteria 1 and 3 (risk to people) satisfied by multiple buildings

This location is presented in detail in Map 37, Vol 2.

a) Flood Behaviour

Tigg Pl and the adjacent Miggs Pl are just to the east of Birunji Creek where it passes under Therry Rd. There is a complexity of overland flow paths from the east which flow towards Birunji Creek. One comes through Jaggers Pl which Tigg Pl and Miggs Pl run off, but more flow follows a drainage line along the southern side of Therry Rd which runs behind the houses in Tigg Pl and Miggs Pl. This drain passes through a pipe under an embankment which supports a footpath.

Water from Jaggers Pl flows down Tigg Pl and Miggs Pl and through properties and into the drain and the drain fills up behind the Therry Rd and footpath embankments until it reaches a level where all of the properties in Tigg Pl and Miggs Pl flood.

This location experiences overland flooding in events up to the 0.2% AEP and mainstream flooding from Birunji Creek in less frequent events.

i) 20% AEP

In the 20% AEP event there is only mild overland flooding, with the backyards of two properties in Tigg Pl being affected, in addition to floodwaters ponding in the cul de sac. The model does not show any buildings with AFF in this event.

ii) 1% AEP

In the 1% AEP event, the overland flow extent widens to surround two buildings in Tigg Pl, one of which experiences AFF depths up to 10mm. The cul de sac is affected by a larger flood extent, and access is cut to at least five buildings in Tigg Pl.

iii) PMF

In a PMF event, floodwaters from Birjunji Creek become highly hazardous throughout Tigg Pl and the western side of Migg Pl, resulting in 11 buildings experiencing AFF depths over 0.5m. Of these, the flood model shows that six may experience structural instability in the PMF. All these buildings are single-storey.

b) Flood Modification Options

Because there is no significant property affectation in frequent flood events (up to the 1% AEP) and risk to people is mainly driven by events bigger than the 0.2% AEP, flood modification is unlikely to reduce risk at this location. Analysis shows only one building may benefit from pipe capacity upgrades. For this reason, flood modification was deemed unsuitable for this hotspot.

c) Property Modification Options

These houses are within a R2 low density residential zone and just outside of the Macarthur Precinct in the Glenfield to Macarthur Urban Renewal Corridor (NSW Govt., 2015) so redevelopment with alternative housing is not a viable option.

d) Response Modification Options

Flooding in this area will occur with little warning and will be of short duration. Leaving premises after they are surrounded by high hazard floodwaters would be dangerous.

For more detail on flood response across the BBBC Creek catchment, please refer to Section 11.2.1.

e) Shortlisted Options

In light of the preceding discussion, no flood risk reduction options were shortlisted for evaluation in detail.

10.2.7 Gould Rd, Claymore

Residential Hotspot ID number: 10

Selection Criteria Satisfied:

- Criteria 1 and 3 (risk to people) satisfied by multiple buildings

This location is presented in detail in Map 38, Vol 2.

a) Flood Behaviour

There is a row of houses on the south eastern side of Gould Rd which back onto a creek before it passes under the Hume Motorway. There is an overland flow path along Gould Rd and at various places, even in a 20% AEP flood, it overflows between some of the houses into the creek.

i) 20% AEP

No houses are likely to experience above floor flooding in the 20% AEP event. The model results show one building with AFF from the 20% AEP but closer investigations concluded that this flooding has very low hazard level (i.e. H1) and is likely to be managed by the private stormwater system.

ii) 1% AEP

Only two houses experience above floor flooding in the 1% AEP event even though the water is ponding more than 2m deep behind the Motorway.

iii) PMF

Eighteen houses – all single storey - would experience above floor flooding more than 0.5m deep, the flood model suggests at least 15 of which may have their structural integrity affected.

b) Potential Flood Modification Options

Because there is no significant property affectation in frequent flood events (up to the 1% AEP) and risk to people is mainly driven by events bigger than the 0.2% AEP, flood modification is unlikely to reduce risk at this location. Analysis shows that only three buildings may benefit from pipe capacity upgrades. For this reason, flood modification was deemed unsuitable for this hotspot.

c) Property Modification Options

This area is zoned R2 low density residential and is outside of the Leumeah precinct in the Glenfield to Macarthur Urban Renewal Corridor (NSW Govt., 2015) so strategic planning options are not viable.

d) Response Modification Options

The houses are all lower than the street which will start flooding in the most frequent flood events and then overflow down the driveways. Leaving premises after they are surrounded by high hazard floodwaters would be dangerous.

For more detail on flood response across the BBBC Creek catchment, please refer to Section 11.2.1.

e) Shortlisted Options

In light of the preceding discussion, no flood risk reduction options were shortlisted for evaluation in detail:

10.2.8 Matra Pl, Raby

Residential Hotspot ID number: 12

Selection Criteria Satisfied:

- Criteria 1 and 3 (risk to people) satisfied by multiple buildings

This location is presented in detail in Map 39, Vol. 2.

a) Flood Behaviour

Houses in Matra Pl, Wessex Pl and Spitfire Dr back onto Bunbury Curran Creek before it passes under St Andrews Rd. These houses are flood free in frequent events but in the PMF 16 of them would experience above floor flooding deeper than 0.5m and the model shows that five of them may be at risk of structural instability because of the depth of flooding.

Floodwaters could be conveyed through the culvert under St Andrews Rd and then the motorway via flood modification measures, but this would only be effective in the PMF, because there is no significant risk in the 1% AEP event.

b) Flood Modification Options

Pipe capacity upgrades would not benefit any buildings at this location. The only flood modification option which might help in this location would be to increase the size of the opening under St Andrews Rd. This would increase flood levels downstream but it appears this area is currently used as agricultural land and while there are some buildings they do not appear to be inhabited.

However, given that this problem only occurs in events exceeding the 0.1% AEP event, it would be difficult to justify the expenditure required to reduce PMF flood levels which themselves have about a 1 in 10,000,000 chance of occurrence.

c) Property Modification Options

All of the affected dwellings in this hotspot are in land zoned R2 low density residential and are outside of the Glenfield to Macarthur Urban Renewal Corridor. This means that there are no town planning opportunities to replace the existing houses with dwellings which are more compatible with the flood risks.

d) Response Modification Options

Vehicular access to most houses in Matra Pl gets cut by hazardous floodwaters from the 0.2% AEP event. However flood modelling suggests that most of these homes have a low hazard overland (i.e. pedestrian) escape route along Thunderbolt Dr even in the 0.1% AEP event.

For this reason, consideration was given to installing a water level alert system in the creek and set an alert trigger providing sufficient time for safe evacuation.

The warning time available was deemed too short, as a result of quick rate of rise and the topography of the local area. As a result a warning system was deemed unsuitable for this location.

For more detail on flood response across the BBBC Creek catchment, please refer to Section 11.2.1.

e) Shortlisted Options

In light of the preceding discussion, no flood risk reduction options were shortlisted for evaluation in detail.

10.2.9 Appaloosa Cct, Blairmont

Residential Hotspot ID number: 13

Selection Criteria Satisfied:

- Criteria 1 and 3 (risk to people) satisfied by multiple buildings

This location is presented in detail in Map 40, Vol 2.

a) Flood Behaviour

Biriwiri Creek runs at the rear of houses in Appaloosa Cct and Clydesdale Dr before it flows under the Hume Motorway. Flows up to the 0.1% AEP event do not directly affect these properties but in a PMF, 15 of them could experience more than 0.5m depth of water across their floors, and the model shows that at least six of them are possibly at risk of structural instability. The cause of the problem is water backing up against the motorway embankment.

b) Flood Modification Options

Pipe capacity upgrades would not benefit any buildings at this location. Opening up the path under the motorway would reduce the flooding at these properties but there is a large industrial area downstream which would already be severely impacted by flooding so it would not be appropriate to send more water towards that area.

c) Property Modification Options

All of the affected dwellings in this hotspot are outside the boundary of the Campbelltown precinct within the Glenfield to Macarthur Urban Renewal Corridor. This means that there are no town planning opportunities to replace the existing houses with dwellings which are more compatible with the flood risks.

d) Response Modification Options

Flooding in this area will occur with little warning and will be of short duration. Leaving premises after they are surrounded by high hazard floodwaters would be dangerous.

For more detail on flood response across the BBBC Creek catchment, please refer to Section 11.2.1.

e) Shortlisted Options

In light of the preceding discussion, no flood risk reduction options were shortlisted for evaluation in detail:

10.2.10Macquarie Fields/Glenfield #1

Residential Hotspot ID number: 14

Selection Criteria Satisfied:

- Criteria 1, 3 and 4 (risk to people) satisfied by multiple buildings

This location is presented in detail in Map 41, Vol 2.

a) Flood Behaviour

Flooding at this location is caused by two overland flow paths, both of which form west of the crossroad between Newtown Rd and Fawcett St and run in opposite directions. One runs south towards Bunbury Curran Creek, where floodwaters build up against the river bank. The other one runs north-west and builds up when it encounters the embankment of Railway Pde. Flooding then expands eastward and affects residential properties along Newtown Rd and Fawcett St (in events greater than the 0.2% AEP).

The model shows that 98 buildings (that are single-storey) would experience a depth of AFF exceeding 0.5m in the PMF. Of these, the flood model suggests at least 52 may incur structural instability as a result of high hazard floodwaters. There are also 10 two storey buildings which may not be structurally stable in a PMF.

In the northern part of the hotspot there are buildings classified as being in a low flood island, however these are mostly confined by low hazard floodwaters.

b) Flood Modification Options

Pipe capacity upgrades would not benefit any buildings at this location. This hotspot is entirely driven by events less frequent than the 0.2% AEP. Even though properties on low flood islands get isolated from the 20% AEP, these are mostly confined by low hazard floodwaters. As such, flood modification was deemed unsuitable for this location.

c) Property Modification Option

The land included in this hotspot is part of the Glenfield precinct within the Glenfield to Macarthur Urban Renewal Corridor. Figure 37 shows that the area north of Fawcett St is zoned as medium rise residential (with the exception of some buildings north of Belmont Rd, which are zoned as mixed use), while the area south of Fawcett St as low rise residential. This means that at least for the buildings north of Fawcett Rd, there are town planning opportunities to replace the existing houses with dwellings which are more compatible with the flood risks.

d) Response Modification Options

Flooding in this area will occur with little warning and will be of short duration. Leaving premises after they are surrounded by high hazard floodwaters would be dangerous.

The rezoning and redevelopment of this area as part of the Glenfield to Macarthur Urban Renewal Corridor Strategy (NSW Govt., 2015) may provide options for improving flood response. .

For more detail on flood response across the BBBC Creek catchment, please refer to Section 11.2.1.

e) Shortlisted Options

In light of the preceding discussion, the following flood risk reduction options were evaluated in detail:

- As part of the Glenfield to Macarthur Urban Renewal Corridor Strategy (NSW Govt., 2015), encourage redevelopment which is more compatible with the flood risks
- Consider the adoption of locality-specific development controls to improve flood response outcomes.

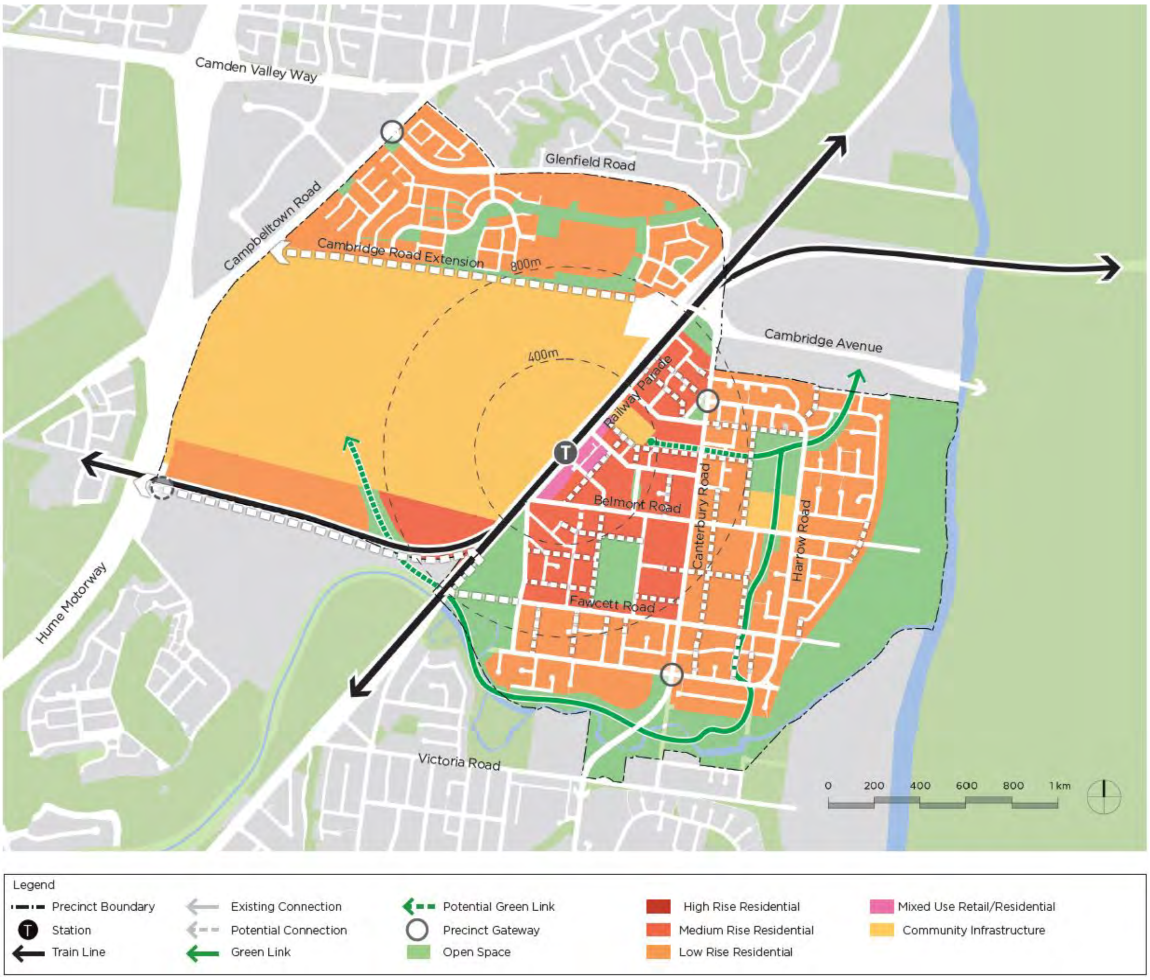

Figure 37. Glenfield To Macarthur Corridor: Glenfield Land Use and Infrastructure Plan

f) Evaluation of the Shortlisted Options

i) Property Modification

Although flooding at this location is driven by events rarer than the 0.2% AEP, the rezoning of part of the flood-affected buildings to medium rise residential planned under the Glenfield to Macarthur Urban Renewal Corridor Strategy (NSW Govt., 2015) provides a practical opportunity to address flood risk to people through locality-specific development controls.

The advantage of addressing flood risk with property modification as part of redevelopment to high rise buildings is that the associated costs are distributed across many property owners, making the benefit to cost ratio much greater than it would be in low rise dwellings.

As such, it is recommended that Council works with the NSW Department to Planning and

Environment to ensure that flood risk is acknowledged and addressed as part of the redevelopment.

ii) Response Modification

Redevelopment to multi-storey buildings as part of the Glenfield to Macarthur Urban Renewal Corridor Strategy (NSW Govt., 2015) should be used as an opportunity to adopt locality-specific development controls that improve flood response outcomes.

10.2.11 Macquarie Fields/Glenfield #2

Residential Hotspot ID number: 15

Selection Criteria Satisfied:

- Criteria 1, 3 and 4 (risk to people) satisfied by multiple buildings

This location is presented in detail in Map 42, Vol 2.

a) Flood Behaviour

None of the properties in this hotspot are flooded in any event other than the PMF. Most of the buildings in this hotspot are within a low flood island and some of them become isolated in frequent events. There is a low point just south of the cul de sac in Adrian St where overland flooding builds up from the 20% AEP event and cuts vehicular access to some of the buildings nearby. Adrian St also floods in the 20% AEP event at the corner with Fraser St, cutting access to most buildings in the eastern part of the hotspot.

In less frequent events the flood expands and starts running off Adrian St in all directions (north, south-west and east), isolating more buildings. In the PMF, the overland flow path inundates all buildings located in the western part of the hotpots. At the same time, Redfern Creek overtops its banks just upstream of the confluence with Bunbury Curran Creek and generates fast mainstream flooding running north-east between the creek and the railway, then veering south-east to follow the path of Bunbury Curran Creek. Part of this flow then runs south through some of the properties on the eastern side of the hotspot, along Adrian St. Here flood hazards are very high in the PMF, and the model shows that 11 buildings may experience structural instability.

Overall, the flood model shows that 104 buildings in this hotspot may experience AFF depths exceeding 0.5m in the PMF. Of these, 78 are on a low flood island from the 20% AEP, and 11 may become structurally unstable in the PMF.

b) Flood Modification Options

Even though properties on low flood islands get isolated from the 20% AEP, they do not flood in any event but in the PMF.

As such, flood modification was deemed unsuitable for this location.

c) Property Modification Options

The land included in this hotspot is part of the Macquarie Fields precinct within the Glenfield to Macarthur Urban Renewal Corridor. Figure 38 shows that the western part of the hotspot is rezoned as medium rise residential, while the eastern part remains zoned as low rise residential. This means that, at least in the western part of the hotspot, there are town planning opportunities to replace the existing flood-affected houses with multi-storey dwellings which are more compatible with the flood risks.

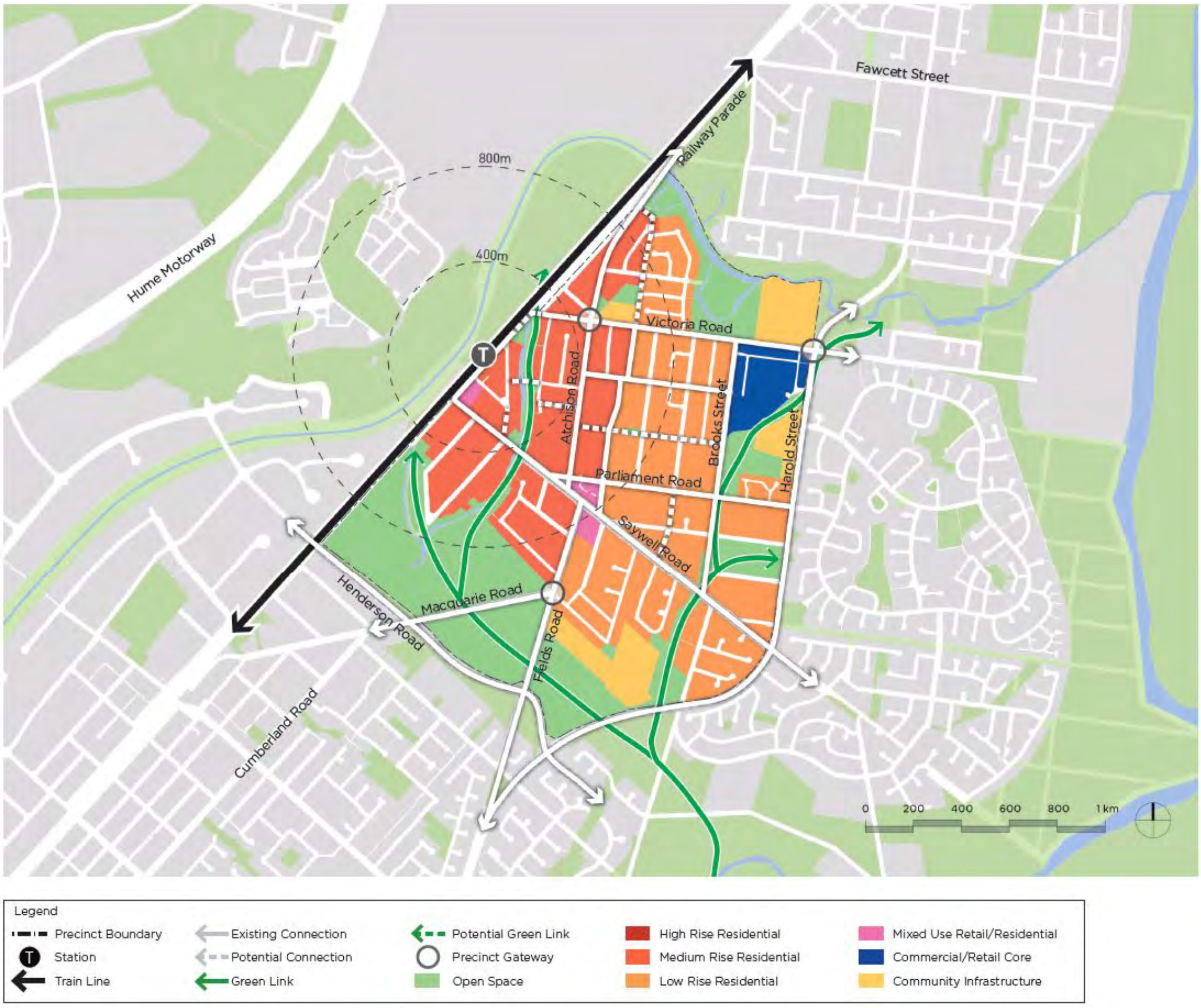

Figure 38. Glenfield To Macarthur Corridor: Macquarie Fields Land Use and Infrastructure Plan

d) Response Modification Options

The rezoning and redevelopment of this area as part of the Glenfield to Macarthur Urban Renewal Corridor Strategy (NSW Govt., 2015) may provide an opportunity to improve flood response. For more detail on flood response across the BBBC Creek catchment, please refer to Section 11.2.1.

e) Shortlisted Options

In light of the preceding discussion, the following flood risk mitigation options were evaluated in detail:

- As part of the Glenfield to Macarthur Urban Renewal Corridor Strategy (NSW Govt., 2015), encourage redevelopment which is more compatible with the flood risks.
- Consider the adoption of locality-specific development controls to improve flood response outcomes.

f) Evaluation of the Shortlisted Options

i) Property Modification

Although flooding at this location is driven by the PMF, the rezoning of part of the hotspot to medium rise planned under the Glenfield to Macarthur Urban Renewal Corridor Strategy (NSW Govt., 2015) provides a practical opportunity to address flood risk to people through locality-specific development controls.

The advantage of addressing flood risk with property modification as part of redevelopment to medium or high rise buildings is that the associated costs are distributed across many property owners, making the benefit to cost ratio much greater than it would be in low rise dwellings.

As such, it is recommended that Council works with the NSW Department to Planning and Environment to ensure that flood risk is acknowledged and addressed as part of the redevelopment of the western part of the hotspot.

ii) Response Modification

Redevelopment to multi-storey buildings as part of the Glenfield to Macarthur Urban Renewal Corridor should be explored as an opportunity to adopt locality-specific development controls which improve flood response opportunities.

10.2.12Victoria Rd, Macquarie Fields

Residential Hotspot ID number: 16

Selection Criteria Satisfied:

- Criterion 3 (risk to people) satisfied by most buildings. Some buildings also satisfy criteria 1 and 4 (risk to people) and 2 (risk to property).

This location is presented in detail in Map 43, Vol 2.

a) Flood Behaviour

No buildings here experience flooding in any events more frequent than the PMF. The U-shaped driveway running through the hotspot has a low point near its north-west corner which gets cut by local flooding from the 20% AEP event and isolates three houses. The model shows two buildings with AFF from the 20% AEP, but upon closer inspection it was observed that this is caused by local puddles which are likely to be managed by the buildings' private stormwater systems

In the PMF, mainstream flooding from Macquarie Creek reaches the site from the south, with high hazard floodwaters affecting the buildings on the western side of the hotspot.

Overall there are 24 single-storey buildings here with AFF depth exceeding 0.5m in the PMF. Of these, the model shows that nine are possibly at risk of structural instability in the PMF, and three are within a low flood island.

b) Flood Modification Options

This hotspot is entirely driven by the PMF. Even though three buildings on low flood islands get isolated from the 20% AEP, they do not flood in any event but in the PMF. As such, flood modification was deemed unsuitable for this location.

c) Property Modification Options

All of the affected dwellings in this hotspot are outside the Glenfield to Macarthur Urban Renewal Corridor. This means that there are no town planning opportunities to replace the existing houses with dwellings which are more compatible with the flood risks.

d) Response Modification Options

Flooding in this area will occur with little warning and will be of short duration. Leaving premises after they are surrounded by high hazard floodwaters would be dangerous. For more detail on flood response across the BBBC Creek catchment, please refer to Section 11.2.1.

e) Shortlisted Options

In light of the preceding discussion, no flood risk mitigation options were shortlisted for evaluation in detail.

-

10.2.13 Coronata Wy, Macquarie Fields

Residential Hotspot ID number: 17

Selection Criteria Satisfied:

- Criteria 1 and 3 (risk to people) satisfied by multiple buildings.

This location is presented in detail in Map 44, Vol 2.

a) Flood Behaviour

Flooding at this location is caused by the confluence of Macquarie Creek and an overland flow path running north from Bass

Reserve. This results in Coronata Wy being cut from the 20% AEP, and in high hazard floodwaters affecting multiple buildings in the PMF. However all buildings are flood free in events smaller than the PMF.

The model shows that overall at this location there are 23 single-storey buildings with AFF depth over 0.5m in the PMF, and 22 buildings the flood model suggests could experience structural instability in the PMF.

b) Flood Modification Options

This hotspot is entirely driven by the PMF.

Even though the buildings at the end of Coronata Wy are isolated from the 20% AEP event, they still have overland (i.e. pedestrian) escape routes to Harold St and they do not flood in any event but in the PMF. As such, flood modification was deemed unsuitable for this location.

c) Property Modification Options

All of these buildings are owned by Land and Housing Corporation. Any property modifications, including redevelopment of the area, is at the discretion of Land and Housing Corporation.

d) Response Modification Options

Flooding in this area will occur with little warning and will be of short duration. Leaving premises after they are surrounded by high hazard floodwaters would be dangerous. For more detail on flood response across the BBBC Creek catchment, please refer to Section 11.2.1.

e) Shortlisted Options

In light of the preceding discussion, no flood risk mitigation options were shortlisted for evaluation in detail

10.2.14 Macquarie Fields/Glenfield #3

Residential Hotspot ID number: 18

Selection Criteria Satisfied:

- Criteria 1 and 3 (risk to people) satisfied by multiple buildings.

This location is presented in detail in Map 45, Vol 2.

a) Flood Behaviour

This hotspot is affected by mainstream flooding caused by Redfern Creek overtopping its banks upstream of the culvert under the railway and, to a lesser extent, upstream of the culvert under Saywell Rd.

There is no flooding of any buildings in events more frequent than the 0.2% AEP, and most buildings are only affected in the PMF.

Overall, the model shows that 65 single-storey buildings would experience AFF depths exceeding 0.5m in the PMF, of which the flood model suggests that 15 may experience structural instability due to highly hazardous floodwaters. There are also three two-storey buildings which the flood model suggests may be at risk of structural instability in the PMF.

b) Flood Modification Options

This hotspot is entirely driven by the PMF. The only flood modification options that could reduce risk to people would be to increase the capacity of the culvert under the railway, or to build a levee along Redfern Creek. However, to be effective in a PMF, these options would have extremely high costs and would involve significant practical difficulties. These cannot be justified given that the probability of a PMF is 1 in 10,000,000 per year. As such, flood modification was deemed unsuitable for this location.

c) Property Modification Options

This hotspot is part of the Macquarie Fields precinct within the Glenfield to Macarthur Urban Renewal Corridor. Figure 38 shows that all the land within this hotspot, with the exception of Redfern Creek, is rezoned as medium rise residential. This means that there are town planning opportunities to replace the existing flood-affected houses with multi-storey dwellings which are more compatible with the flood risks.

d) Response Modification Options

The model shows that most of the affected existing buildings have vehicular or pedestrian evacuation routes that are flood free in all events but the PMF. For this reason, consideration was given to installing a water level alert system in the creek and set an alert trigger providing sufficient time for safe evacuation.

The warning time available was deemed too short, as a result of quick rate of rise and the topography of the local area. As a result a warning system was deemed unsuitable for this location.

However, the rezoning and redevelopment of this area as part of the Glenfield to Macarthur Urban Renewal Corridor Strategy (NSW Govt., 2015) will provide an opportunity to replace existing low rise houses with medium rise buildings, and use locality-specific development controls to improve flood response outcomes.

For more detail on flood response across the BBBC Creek catchment, please refer to Section 11.2.1.

e) Shortlisted Options

In light of the preceding discussion, the following flood risk mitigation options were evaluate in detail

- As part of the Glenfield to Macarthur Urban Renewal Corridor Strategy (NSW Govt., 2015) , encourage redevelopment which is more compatible with the flood risks;
- Consider the adoption of locality-specific development controls to improve flood response outcomes.

f) Evaluation of the Shortlisted Options

i) Property Modification

Although flooding at this location is driven by the PMF, the rezoning of the hotspot to medium rise residential planned under the Glenfield to Macarthur Urban Renewal Corridor Strategy (NSW Govt., 2015) provides a practical opportunity to address flood risk to people through locality-specific development controls.

The advantage of addressing flood risk with property modification as part of redevelopment to medium or high rise buildings is that the associated costs are distributed across many property owners, making the benefit to cost ratio much greater than it would be in low rise dwellings.

As such, it is recommended that Council works with the NSW Department to Planning and Environment to ensure that flood risk is acknowledged and addressed as part of the redevelopment of the western part of the hotspot.

ii) Response Modification

At this location floodwaters would rise quickly and without warning, and inundation would be of relatively short flood duration

It is recommended that locality-specific development controls be used to improve flood response outcomes.

10.2.15 Waratah Cres/Myee Rd, Macquarie Fields

Residential Hotspot ID number: 19

Selection Criteria Satisfied:

- Criteria 1 and 3 (risk to people) satisfied by multiple buildings.

This location is presented in detail in Map 46, Vol 2.

a) Flood Behaviour

The model shows that there is no building affectation in frequent events and no significant risk to property.

Flooding of buildings at this location is caused for the most part by a large overland flow path running south from the railway underpass and being conveyed into a natural channel towards Redfern Creek. Many of the buildings located along this channel are affected by highly hazardous floodwaters from the 0.2 % AEP event. There are also some buildings in the south-eastern part of the hotspot that are affected by Redfern Creek overtopping its banks from the 0.2% AEP.

In the PMF, 44 single storey buildings may experience AFF depths exceeding 0.5m. The flood model suggests twenty-seven of these, as well as eight additional two-storey buildings, may experience structural instability in the PMF due to impact from high-hazard floodwaters.

b) Flood Modification Options

This hotspot is entirely driven by events rarer than the 0.2% AEP.

Because risk is controlled by rare events, flood modification is likely to be either ineffective or extremely expensive and impractical, which would not be justifiable given that the PMF probability of occurrence is as low as 1 in 10,000,000 per year.

c) Property Modification Options

This hotspot is part of the Macquarie Fields precinct within the Glenfield to Macarthur Urban Renewal Corridor. Figure 38 shows that all the land within this hotspot is rezoned as medium rise residential. This means that there are town planning opportunities to replace the existing flood-affected houses with multi-storey dwellings which are more compatible with the flood risks.

d) Response Modification Options

In a PMF, the flood model suggests 35 buildings are possibly at risk of structural instability due to highly hazardous floodwaters. However the model shows that these buildings, as well as most of the affected buildings throughout the hotspot, have vehicular or pedestrian evacuation routes that are flood free in all events up to the 0.2% AEP. If enough warning lead time was available, residents of the affected buildings could reach higher grounds in Waratah Cres and Myee Rd and wait for the floodwaters to recede. For this reason, consideration was given to installing a water level alert system in the channel south of the railway underpass and set an alert trigger providing sufficient time for safe evacuation.

The warning time available was deemed too short, as a result of quick rate of rise and the topography of the local area. As a result a warning system was deemed unsuitable for this location.

However, the rezoning and redevelopment of this area as part of the Glenfield to Macarthur Urban Renewal Corridor Strategy (NSW Govt., 2015) will provide an opportunity to replace existing low rise houses with medium rise buildings, and use locality-specific development controls to improve flood response outcomes.

For more detail on flood response across the BBBC Creek catchment, please refer to Section 11.2.1.

e) Shortlisted Options

In light of the preceding discussion, the following flood risk mitigation options were evaluate in detail

- As part of the Glenfield to Macarthur Urban Renewal Corridor Strategy (NSW Govt., 2015) , encourage redevelopment of single storey houses to development which is more compatible with the flood risks;
- Consider the adoption of locality-specific development controls to achieve better flood response outcomes;

f) Evaluation of the Shortlisted Options

i) Property Modification

Although flooding at this location is driven by events rarer than the 0.2% AEP, the rezoning of the hotspot to medium rise residential planned under the Glenfield to Macarthur Urban Renewal Corridor Strategy (NSW Govt., 2015) provides a practical opportunity to address flood risk to people through locality-specific development controls.

The advantage of addressing flood risk with property modification as part of redevelopment to medium or high rise buildings is that the associated costs are distributed across many property owners, making the benefit to cost ratio much greater than it would be in low rise dwellings.

As such, it is recommended that Council works with the NSW Department to Planning and Environment to ensure that flood risk is acknowledged and addressed as part of the redevelopment of the western part of the hotspot.

ii) Response Modification

At this location floodwaters would rise quickly and without warning and flooding would be of relatively short duration.

Redevelopment as part of the Glenfield to Macarthur Urban Renewal Corridor may provide an opportunity to adopt locality-specific development controls to ensure that new buildings provide better flood response outcomes.

10.2.16Chester Rd, Ingleburn

Residential Hotspot ID number: 20

Selection Criteria Satisfied:

- Criteria 1, 3 and 4 (risk to people) satisfied by multiple buildings.

This location is presented in detail in Map 47, Vol 2.

a) Flood Behaviour

This hotspot is affected by overland flooding running from Cumberland Rd and Jacklyn St towards Ingleburn Rd and Chester Rd.

The model shows that there is no building affectation in frequent events and no significant risk to property. However in the PMF, seven single-storey buildings may experience AFF depths exceeding 0.5m. The model shows that two of these, as well as an additional two-storey building, may experience structural instability in the PMF due to impact from high-hazard floodwaters.

There are also eight buildings classified as being located within a low flood island which is isolated from the 20% AEP, however upon closer investigation it was observed that these are isolated by low hazard floodwaters in frequent events.

b) Flood Modification Options

This hotspot is entirely driven by the PMF and no flood modification measures would be effective, practical or economically worthwhile. As such, flood modification was deemed unsuitable for this location.

c) Property Modification Options

All of the land in this hotspot is currently zoned R2 low density residential. Being relatively close to the railway line, this hotspot does figure in the Glenfield to Macarthur Urban Renewal Corridor, but it is classified as “low rise residential”. This means that there are no town planning opportunities to replace the existing houses with dwellings which are more compatible with the flood risks.

d) Response Modification Options

Flooding in this area will occur with little warning and will be of short duration. Leaving premises after they are surrounded by high hazard floodwaters would be dangerous..

For more detail on flood response across the BBBC Creek catchment, please refer to Section 11.2.1.

e) Shortlisted Options

In light of the preceding discussion, no flood risk mitigation options were shortlisted for evaluation in detail:

10.2.17Harrow Rd, Glenfield

Residential Hotspot ID number: 23

Selection Criteria Satisfied:

- Criterion 2 (risk to property) is satisfied by three buildings.

This location is presented in detail in Map 48, Vol 2.

a) Flood Behaviour

An overland flow path forms in Calvados St and runs west to O’Malley Pl, then south to Harrow Rd, and then west again along the road to a low point at the crossroad with Bansbach Rd. From this point, floodwaters run south towards the Bunbury Curran Creek through a path between some residential properties.

i) 20% AEP

Three two-storey houses are likely to experience above floor flooding depth ranging between 150 and 250mm in the 20% AEP event.

ii) 1% AEP

No additional houses experience AFF in the 1% AEP event however the three houses with AFF from the 20% AEP event would experience greater AFF depths, ranging between 300 and 400mm.

iii) PMF

Even though the three houses mentioned above have AFF from frequent events, risk to people criteria are not satisfied because these are two storey buildings which the flood model suggest in a PMF would remain structurally stable.

b) Flood Modification Options

The model showed that a sufficient reduction of flood water levels could be achieved by appropriately regrading the terrain at the rear of the affected properties to relieve localised flooding and train flows towards the creek (Figure39).

Figure39. Layout and details of the shortlisted flood modification options in Harrow Rd, Glenfield.

c) Property Modification Options

It is noted that this hotspot figures in the Glenfield to Macarthur Urban Renewal Corridor (NSW Govt., 2015) (Figure 37) where it is classified as “low rise residential”. As such these buildings are unlikely to be redeveloped in the near future.

d) Response Modification Options

Flooding in this area will occur with little warning and will be of short duration. Leaving premises after they are surrounded by high hazard floodwaters would be dangerous. For more detail on flood response across the BBBC Creek catchment, please refer to Section 11.2.1.

e) Shortlisted Options

In light of the preceding discussion, the following flood risk mitigation options were evaluated in detail:

- The proposed flood modification option (i.e. regrading of terrain at the back of the affected properties);

f) Evaluation of the Shortlisted Options

i) Flood Modification

A cost-benefit analysis was undertaken for the shortlisted flood modification option to assess if it would be economically worthwhile. Table 26 shows a summary of the results for this hotspot (please refer to Appendix E and F for more details).

Table 26. Results of Cost Benefit Analysis for Flood Modification Options in Harrow Rd, Glenfield

Total Option Costs	$98k
Total Option Benefits	$284k
Benefit/Cost Ratio	2.90

The cost/benefit analysis showed that flood modification at this location would be economically worthwhile, having a benefit to cost ratio of 2.90.

However, the concept design identified some practical challenges with implementing this option including the location of underground services and private boundary fences which may either limit the amount of flow diversion which can be achieved or increase the cost of meeting the diversion modelled.

In terms of social costs, the shortlisted flood modification option would cause only minor inconvenience during construction operations, and these would be temporary.

The slopes along the regraded area would have to be properly stabilised to avoid any scouring caused by concentration of flows.

There are trees at the beginning and the end of the area which has been identified as requiring regrading. Many of these are introduced species but there are at least two eucalypts at the northern end that may need to be removed, or if this is not necessary, there would still be an impact on the trees' root zones. The tree at the southern end may also have its root zone disturbed.

The vegetation map (Map 3, Vol. 2) classifies the ecological community at this area as Cumberland Shale Plains Woodland, which is critically endangered under the Biodiversity Conservation Act (BC) NSW 2016 and the Commonwealth Environment Protection and Biodiversity Conservation Act (EPBC) 1999. As such, any potential impacts may require the preparation of Assessments of Significance under the BC Act and the EPBC Act although referral to the Commonwealth Government is unlikely for two or three trees.

In conclusion, social costs associated with the proposed flood modification options at this location are negligible and can be reduced if appropriate action is taken during design and construction. However there are potential physical constraints and environmental impacts which would have to be further investigated and which may require design modifications which will affect the economic worth of the option.

For these reasons, it is recommended that the shortlisted flood modification option is considered for detailed design in the Floodplain Risk Management Plan.

10.2.18Oxford Rd, Ingleburn

Residential Hotspot ID number: 24

Selection Criteria Satisfied:

- Criterion 2 (risk to property) is satisfied by three buildings;
- Criteria 3 and 4 (risk to people) satisfied by multiple buildings.

This location is presented in detail in Map 49, Vol 2.

a) Flood Behaviour

An overland flow path runs north-west along the alignment of Oxford Rd (both in pipes and overland) from approximately Wood Crest Ave to a local depression in line with Wonga Place. Water then flows perpendicular to Oxford Rd, along a local depression, through several properties between Oxford Rd and Kookaburra St and subsequently along Wonga Pl, toward Koala Walk Reserve. Here, it joins another overland flow path running north-west through Kola Walk Reserve to Cumberland Rd.

i) 20% AEP

Four houses in between Oxford Rd and Kookaburra St experience AFF from the 20% AEP event. Three of these have two storeys, and one is single storey.

ii) 1% AEP

In addition to the four houses mentioned above, two more houses between Wonga Pl and Jacana Pl experience AFF from the 5% AEP.

iii) PMF

Even though the six houses mentioned above have AFF in events as frequent as the 1% AEP, only two satisfied the risk to people criteria in the PMF because they are single storey, whereas the remaining four are two-storeys.

In addition to these, between Koala Walk Reserve and Cumberland Rd there are ten more buildings with risk to people, because they are located in a low flood island (isolated from the 20% AEP event) and have AFF in the PMF. Two of these have also AFF depths exceeding 0.5m (in the PMF) and are single storey.

It should be noted that three of the buildings classified as being within a low flood island (the ones closer to Cumberland Rd) are isolated in frequent events only by low-hazard floodwaters.

b) Flood Modification Options

The model showed that a sufficient reduction of flood levels could be achieved through the following configuration of flood modification options (Figure 40):

- Disconnect existing pipe connections along Oxford Rd between Pardalote St and a private driveway north west of 130 Oxford Rd;
- Redirect flow along Pardalote St, via new and upgraded stormwater pipes, to Koala Walk Reserve;
- Raise the western corner of Koala Walk Reserve to train flows into upgraded stormwater pits and pipes, which convey flows to a discharge location downstream of Aubrey St.

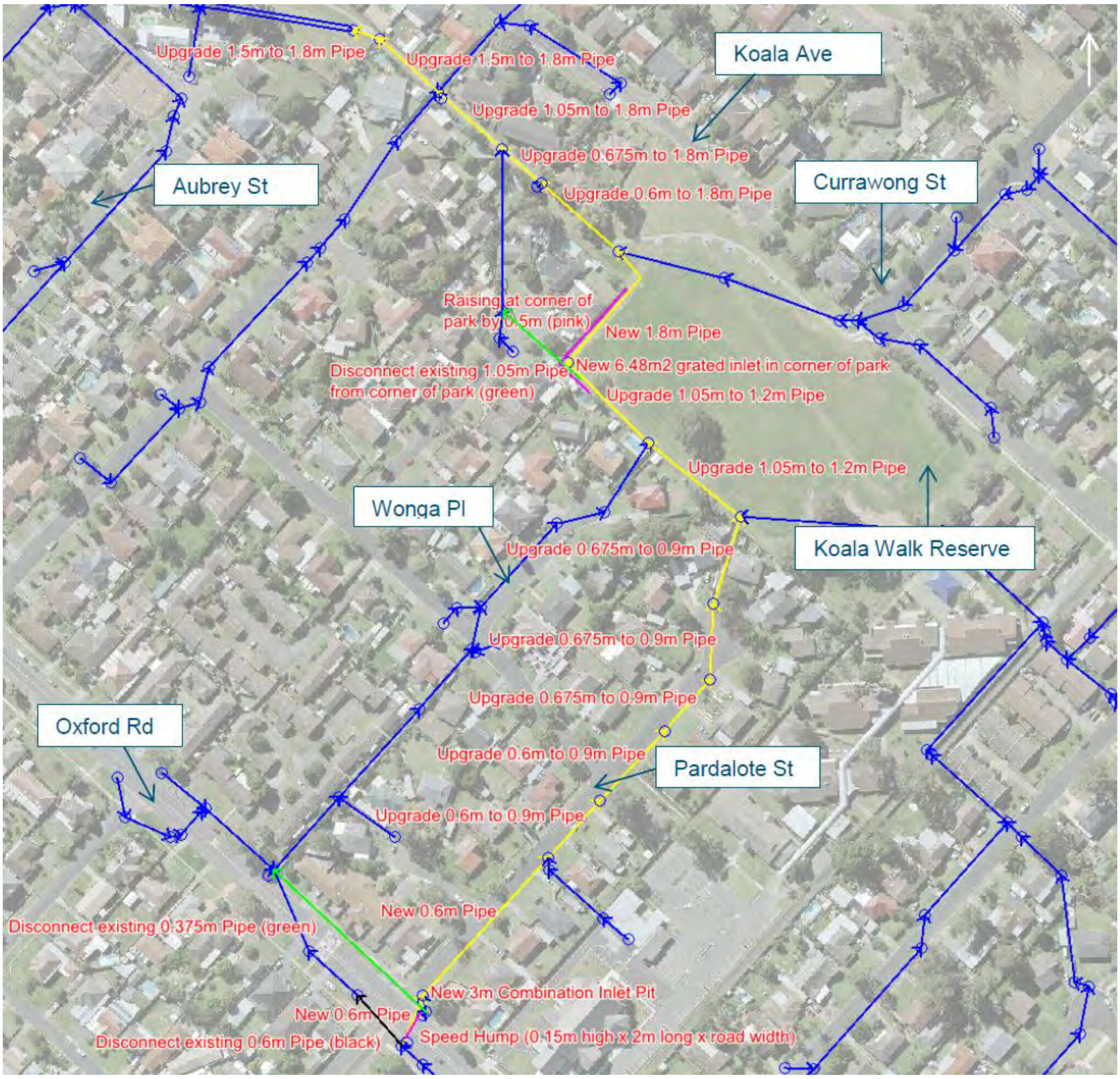

Figure 40. Layout and details of the shortlisted flood modification options in Oxford Rd and Koala Walk Reserve (Ingleburn)

c) Property Modification Options

This hotspot is part of the Ingleburn precinct within the Glenfield to Macarthur Urban Renewal Corridor. Figure 34 shows that all the land within this hotspot, with the exception of Koala Walk Reserve, would be rezoned as medium rise residential. This means that there are town planning opportunities to replace the existing flood-affected houses with multi-storey dwellings which are more compatible with the flood risks.

d) Response Modification Options

Rezoning and redevelopment of this area as part of the Glenfield to Macarthur Urban Renewal Corridor Strategy (NSW Govt., 2015) may provide an opportunity to use locality-specific development controls to deliver improved flood response outcomes.

For more detail on flood response across the BBBC Creek catchment, please refer to Section 11.2.1.

e) Shortlisted Options

In light of the preceding discussion, the following flood risk mitigation options were evaluated in detail

- The shortlisted flood modification options;
- As part of the Glenfield to Macarthur Urban Renewal Corridor Strategy (NSW Govt., 2015) , encourage redevelopment which is more compatible with the flood risks;
- Consider the adoption of locality-specific development controls to improve flood response opportunities.

f) Evaluation of the Shortlisted Options

i) Flood Modification

A cost-benefit analysis was undertaken for the shortlisted flood modification option to assess if it would be economically worthwhile. Table 26 shows a summary of the results for this hotspot (please refer to Appendix E and F for more details).

Table 27. Results of Cost Benefit Analysis for Flood Modification Options in Oxford Rd, Ingleburn

Total Option Costs	$1.453M
Total Option Benefits	$271k
Benefit/Cost Ratio	0.19

The cost/benefit analysis showed that flood modification at this location would not be economically worthwhile, having a benefit to cost ratio of only 0.19.

In addition to this, the shortlisted flood modification option would have minimum effects on flood levels in low-probability floods, which typically pose a risk to people.

For these reasons, we do not recommend investigating flood modification further at this location.

ii) Property Modification

The rezoning of the hotspot to medium rise residential planned under the Glenfield to Macarthur Urban Renewal Corridor Strategy (NSW Govt., 2015) provides a practical opportunity to address flood risk to people through locality-specific development controls.

The advantage of addressing flood risk with property modification as part of redevelopment to medium or high rise buildings is that the associated costs are distributed across many property owners, making the benefit to cost ratio much greater than it would be in low rise dwellings.

As such, it is recommended that Council works with the NSW Department to Planning and Environment to ensure that flood risk is acknowledged and addressed as part of the redevelopment of the hotspot.

iii) Response Modification

Redevelopment to multi-storey buildings as part of the Glenfield to Macarthur Urban Renewal Corridor may provide an opportunity to adopt locality-specific development controls to ensure that new buildings deliver improved flood response outcomes.

10.2.19 Brooks St, Macquarie Fields

Residential Hotspot ID number: 25

Selection Criteria Satisfied:

- Criterion 2 (risk to property) is satisfied by one building;
- Criterion 3 (risk to people) is satisfied by four buildings

This location is presented in detail in Map 50, Vol 2.

a) Flood Behaviour

Flooding at this location is caused by Macquarie Creek overtopping its banks past the culvert under Third Ave. Some building affectation is observed from the 20% AEP event, with the model showing one building with AFF. In less frequent events (from the 0.2% AEP), all properties on the left side of the creek between Third Ave and Parliament Rd are affected, however only four of these (including the one mentioned above) satisfy criterion 3 for risk to people (i.e. single storey buildings experiencing AFF depths over 0.5m in the PMF).

However, Council has indicated that the properties in question may be affected by more frequent events than the modelling suggests and this is possibly a result of property modification in the flow path.

b) Flood Modification Options

Only one building would benefit from an upgrade of pipe capacity of the local stormwater system. This is the building discussed above. In the remaining buildings, risk is driven by large events and as such it is likely any alteration of the pipe capacity or the local stormwater system would not bring any benefits.

Upgrading pipe capacity to reduce risk to a single building would have a disproportionate cost compared to the benefits. For this reason, flood modification at this location was not further investigated.

c) Property Modification Options

All of the land in this hotspot is currently zoned R2 low density residential. Being relatively close to the railway line, this hotspot does figure in the Glenfield to Macarthur Urban Renewal Corridor, but it is classified as "low rise residential". This means that there are no town planning opportunities to replace the existing houses with dwellings which are more compatible with the flood risks.

d) Response Modification Options

Floodwaters would rise very quickly and without warning in this location. Even if a water level alert was installed in the creek, this would not be able to provide enough evacuating lead time because most of the buildings could experience hazardous flooding within 15 minutes from when the creek water level began to rise in a rapidly rising flood.

For more detail on flood response across the BBBC Creek catchment, please refer to Section 11.2.1.

e) Shortlisted Options

In light of the preceding discussion, no flood risk mitigation options were shortlisted to be evaluated in detail.

10.2.20 Fisher's Ghost Creek, Bradbury

a) Flood Behaviour

Flow from Fishers Ghost Creek over tops the culverts underneath The Parkway in events as frequent as the 20% AEP. Flood waters pond in The Parkway and Olympus Ct and flood the Gordon Fetterplace Aquatic Centre. The flows then move through a series of culverts and open channels as they make their way to Hurley Street, where the flood waters pond. This is of particular concern as Hurley St provides access for a significant number of bus services to Campbelltown Station, including buses which service areas outside of the Campbelltown LGA.

Flood waters also pond in the rail corridor and impact the Airport and South Line, the Southern Highlands Line, Intercity XPT services and the Southern Sydney Freight Line as flood water moves towards the creek on the northern side of the rail. Flooding in the rail corridor has the potential to cause significant impacts on rail services due to depth and velocity.

i) 20% AEP Event

Flood depths exceed 1.4m in The Parkway and the front of the Gordon Fetterplace Aquatic Centre, before flowing into Bradbury Park. The ponding in Hurley St exceeds 0.5m. These flows also move into the rail corridor where ponding exceeding 1m is occurring.

ii) 1% AEP Event

Flood depths exceed 1.4m in The Parkway and the front of the Gordon Fetterplace Aquatic Centre, before flowing into Bradbury Park. The ponding in Hurley St exceeds 0.5m. These flows also move into the rail corridor where ponding exceeding 1m is occurring.

b) Flood Modification Options

i) Background Analysis

Analysis of the existing pipe capacities showed that the culverts under The Parkway are operating at capacity from the 20% AEP event and increasing the capacity of these culverts may significantly reduce flooding of The Parkway and Olympus Ct. This could be achieved through a combination of increases to the culvert size and blockage proofing structures upstream of the culvert.

ii) Identification of Potential Flood Modification Options

A series of flood modelling exercises were run for the area, looking at a series of small detention basins constructed along Fishers Ghost Creek. The following iterations were modelled:

- Initially three basins were modelled, while this provided some benefit it was deemed necessary to include an additional two basins. Two basins were modelled upstream of where Campbellfield Ave crosses the creek and three basins were included between Campbellfield Ave and The Parkway. Slight variations to basin locations and the basin outlets were also included to ensure the most effective flood mitigation was achieved.
- The next iteration of the model included the five detention basins as above in addition to applying no blockage to the culvert under The Parkway. This provided notable decrease to flood levels downstream of The Parkway.
- The culvert size was then increased and extended to the culverts to the south-west under Moore Oxley Bypass and an additional pipe was included in Bradbury Park to capture overland flows moving to the north of the park and passing under the Moore Oxley Bypass. This resulted in the following flood level reductions:

20% AEP

- Flood level reductions up to 1.1m at the intersection of The Parkway and Olympic Cct
- Flood level reductions up to 0.3m in numerous areas of Bradbury Park
- Flood level reductions up to 0.1m adjacent to Milby Road and in the property on Queen St, opposite Milby Road.
- Flood level reductions up to 0.08m at the Hurley St roundabout entrance to Campbelltown Mall
- Flood level reductions up to 0.2m in the rail corridor.

1% AEP

- Flood level reductions up to 1.3m at the intersection of The Parkway and Olympic Cct
- Flood level reductions up to 0.3m in numerous areas of Bradbury Park
- Flood level reductions ranging from 0.1-0.3m adjacent to Milby Road, and the property on Queen St, opposite Milby Road.
- Flood level reductions up to 0.2m through the floodway in Koshigaya Park
- Flood level reductions up to 0.15m at the Hurley St roundabout entrance to Campbelltown Mall
- Flood level reductions up to 0.3m in the rail corridor.

- The above iteration was then compared to an iteration which included all pipe and culvert upgrades as per the above iteration, but without the basins. This showed significantly lower reductions in flood levels than the iteration with the basins included, and as a result is not recommended for further investigation.

The final option configuration, including the basins and pipe and culvert upgrades through Bradbury Park, is shown in Figure 41.

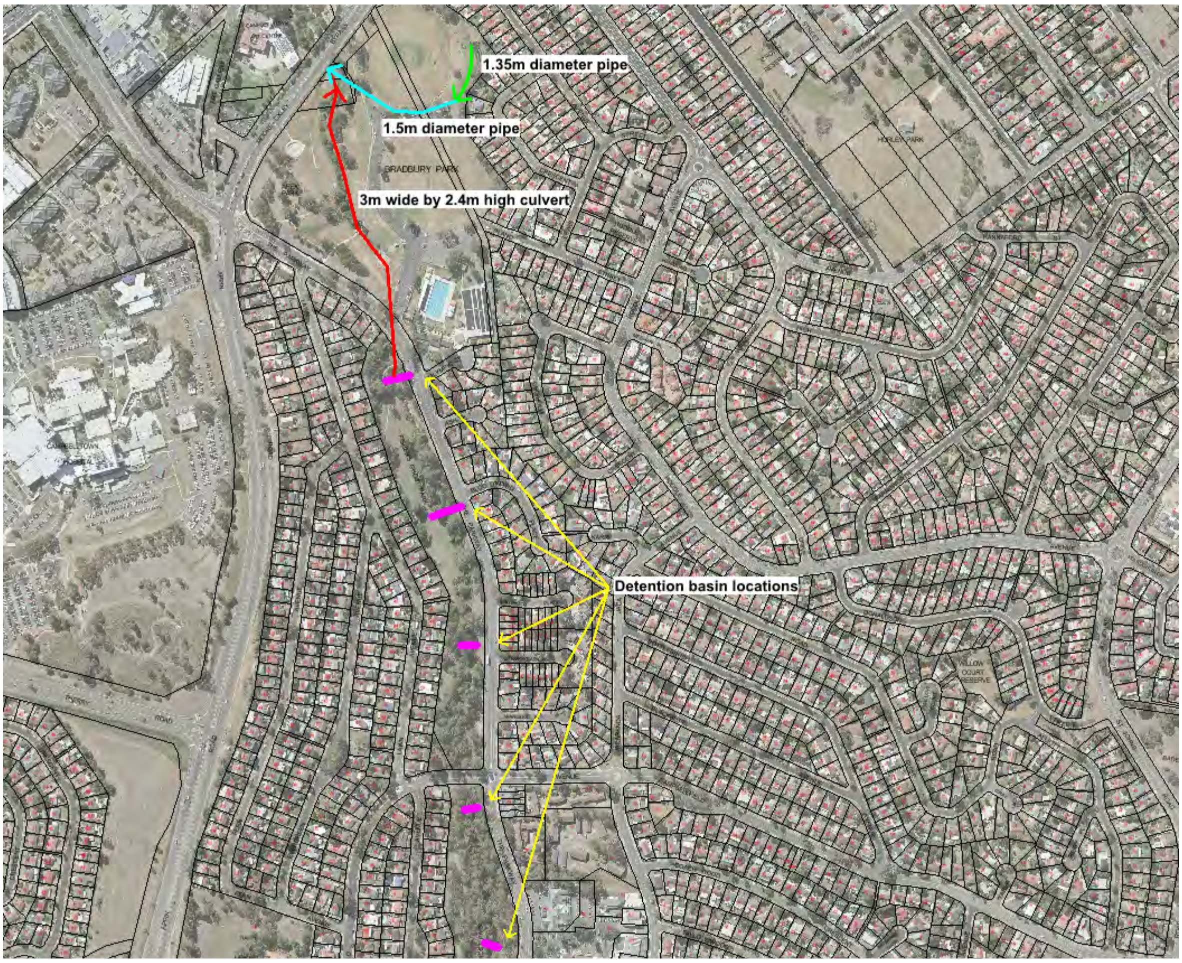

Figure 41. Flood modification for Hurley St (Bradbury)

c) Evaluation of short listed options

i) Flood Modification

A cost benefit analysis was not undertaken for this option, as benefits are dependent on future downstream land use. The buildings currently downstream of this option are not representative of future land use, the building in Milby Road and Queen St are zoned "Mixed Use". Once this area is developed, this would provide significantly higher benefit. It is recommended that once downstream land uses are finalised, a cost benefit analysis be completed.

Benefits of this option would include a significant reduction in the cost of repair to damages to rail infrastructure and reductions in delays to rail services while this occurs. There would be a significant reduction in hazard to any vehicle or person in Hurley St when a flood event occurs. This also applies to The Parkway, as this road provides linkage to the Campbelltown CBD from Bradbury and surrounding suburbs. The Gordon Fetterplace Aquatic Centre would also experience significantly lower flood levels.

For these reasons it is recommended that flood modification be investigated further at this location

10.3 COMMERCIAL AND INDUSTRIAL HOTSPOTS

10.3.1 Louise Ave, Ingleburn

Commercial and Industrial Hotspot ID number: 1

Selection Criteria Satisfied:

- Five industrial buildings between Louise Ave and Aero Rd show with AFF from the %5 or 20% AEP.

This location is presented in detail in Map 51, Vol 2.

a) Flood Behaviour

An overland flow path runs northeast along Stanley Rd and continues north-west in Louise Ave and Aero Rd. In Louise Ave, floodwaters build up at a low point half-way between Stanley Rd and Memorial Oval. From here, another flow path heads north-east towards Aero Rd, causing AFF in five industrial properties (in four from the 20% AEP). Although some of these are former residential houses currently used as businesses, and as such have a floor level higher than what was assumed in the model, the remainder are known to Council to experience relatively frequent AFF.

b) Flood Modification Options

The model shows that pipes between Louise Ave and Aero Rd run at capacity from the 20% AEP event. It was also noted that the pipe between Louise Ave and Aero Rd is misaligned, which may limit its hydraulic performance. The following flood modification options, to be undertaken as part of any future development of these properties, were proposed by Council:

- Easements should be dedicated to Council in 4 Aero Rd;
- The pipe between Louise Ave and Aero Rd should be realigned through the properties at 4 and 7 Aero Rd;
- A larger pipe should be used if required.

These would need to be tested using the hydraulic model to assess their effectiveness.

c) Property Modification Options

This land is currently zoned light industrial but is mapped as potential high rise and medium rise residential in the Glenfield to Macarthur Urban Renewal Corridor Strategy (NSW Govt, 2015). Rezoning and redevelopment at this location may provide an opportunity to address flood risks through locality-specific development controls. Redevelopment may also provide an opportunity to implement the shortlisted flood modification options.

For further details on how flood risk reduction could be achieved at this location as part of the redevelopment process, please refer to the description of property modification options for Ingleburn CBD (Section 10.2.2.c).

d) Response Modification

The proposed catchment-wide response modification options discussed in Section 11 were considered sufficient to address risk to people in commercial and industrial properties throughout the study area in current conditions.

Once the area is redeveloped to medium and high rise residential, it is recommended that flood risk to people is acknowledged and appropriately addressed using locality-specific development controls.

e) Shortlisted Options

In light of the preceding discussion, the following flood risk mitigation options were taken forward for evaluation:

- Upgraded stormwater system between Louise Ave and Aero Rd as part of the redevelopment of the area under the Glenfield to Macarthur Urban Renewal Corridor;
- As part of the rezoning and redevelopment of Ingleburn CBD:
  - Relocate development outside high hazard zones;
  - Redevelop the flood-affected properties with medium and high rise residential buildings which are less vulnerable to floodwaters.

- Use locality-specific development controls throughout the area to reduce risk to people and property.

f) Evaluation of the Shortlisted Options

i) Flood Modification

The proposed flood modification works are relatively minor, however they could easily be evaluated in detail the context of the future rezoning and redevelopment of the area from light industrial to high rise residential.

ii) Property Modification

As this hotspot is expected to be rezoned and redeveloped to medium and high rise residential as part of the Glenfield to Macarthur Urban Renewal Corridor Strategy (NSW Govt., 2015) , the section about evaluation of property modification options for Ingleburn CBD (Section 10.2.2.c) applies to this location too.

iii) Response Modification

If the area is redeveloped to medium and high rise residential, risk to people might increase and it was suggested that this should be managed by implementing location-specific development controls.

10.3.2 Blaxland and Badgally Rd, Campbelltown

Commercial and Industrial Hotspot ID number: 2

Selection Criteria Satisfied:

- Two commercial buildings in Blaxland Rd show AFF from the 20% AEP;
- A commercial building in Badgally Rd shows AFF from the 5% AEP.

This location is presented in detail in Map 52, Vol 2.

a) Flood Behaviour

Flooding at his hotspot is caused by Biriwiri Creek surcharging into Blaxland Rd and then Blaxland Rd overflowing into the surrounding commercial properties.

b) Flood Modification Options

The model shows that all local pipes are at capacity from the 20% AEP event. However flooding here is controlled by Biriwiri Creek and as such upgrading the local stormwater system is unlikely to reduce risk.

Council suggested that a sufficiently high cross fall at the driveways of the affected properties in Blaxland Rd may prevent floodwaters from entering the buildings in frequent events and that this be investigated as a development control for the affected properties in the future.

c) Property Modification Options

This land within this hotspot is currently zoned as industrial, however it is marked to undergo rezoning and redevelopment to a use of employment under the Glenfield to Macarthur Urban Renewal Corridor Strategy (NSW Govt., 2015). As such, the affected industrial buildings at this location may be redeveloped to high rise offices in the near future. This will provide an opportunity to acknowledge and address flood risks, which could be achieved as part of the redevelopment process through various building modification measures, such as:

- Car parking at ground level through which overland flows could pass;
- Buildings with elevated ground floor slabs under which overland flows would pass;
- Buildings with sealable ground floors to prevent entry of floodwaters;
- Buildings with ground floor uses and materials which are compatible with occasional flooding.

Redevelopment will also offer an opportunity to address flood risk to property and life via location-specific development controls.

d) Response Modification

At this location, as with most locations throughout the catchment, floodwaters would rise quickly and without warning. Many local and regional roads would be cut by hazardous floodwaters before most buildings experience any flooding. The proposed Catchment-wide response modification options discussed in Section 11 were considered sufficient to address risk to people in commercial and industrial properties throughout the study area in current conditions.

Once the area is redeveloped to employment use, it is recommended that flood risk to people is acknowledged and appropriately addressed using locality-specific development controls.

e) Shortlisted Options

In light of the preceding discussion, the following flood risk mitigation options were shortlisted:

- Increased cross fall at the driveways to the affected buildings in Blaxland Rd. These flood modification measures are to be further evaluated as part of the redevelopment of the area under the Glenfield to Macarthur Urban Renewal Corridor;
- A range of building modification measures to be considered as part of the redevelopment, with the aim to replace existing buildings with less vulnerable ones.
- Use of locality-specific development controls throughout the area to reduce risk to people and property.

f) Evaluation of the Shortlisted Options

i) Flood Modification

The proposed flood modification works are relatively minor, however they are to be evaluated in detail in the context of the future rezoning and redevelopment of the area from light industrial to employment use.

ii) Property Modification

The rezoning of the hotspot to employment use under the Glenfield to Macarthur Urban Renewal Corridor Strategy (NSW Govt., 2015) will provide a practical opportunity to address flood risk through a range of property modification measures, including locality-specific development controls.

The advantage of addressing flood risk with property modification as part of the redevelopment to employment (which may entail the construction of multi-storey office buildings) is that the associated costs are distributed across more square metres of lettable space, making the benefit to cost ratio much greater than it would be in low rise commercial or industrial development.

As such, it is recommended that Council works with the NSW Department to Planning and Environment to ensure that flood risk is acknowledged and addressed as part of the redevelopment of the hotspot.

iii) Response Modification

When the area will be redeveloped to employment use, risk to people might increase due to greater building occupancy numbers and it was suggested that this should be managed by implementing location-specific development controls to facilitate improved flood response outcomes.

10.3.3 Farrow Rd and Dumaresq St, Campbelltown

Commercial and Industrial Hotspot ID number: 3

Selection Criteria Satisfied:

- Two large commercial buildings on Farrow Rd with AFF from the 5% AEP;
- Three commercial buildings in Dumaresq St with AFF from the 20% AEP.

This location is presented in detail in Map 53, Vol 2.

a) Flood Behaviour

The model shows that there is an overland flow path running north along Dumaresq St. The resulting overland flooding affects one building at the corner with Queen St, and two buildings at the northern end of Dumaresq St. These show AFF from the 20% AEP event.

Further downstream, In Farrow Rd, flooding in frequent events is caused by the open channel running north from the culvert under the railway to the culvert under the car park west of Farrow Rd and south of Bow Bowing Creek. The channel overtops it banks north of Farrow Rd from the 20% AEP. The resulting flooding affects two large commercial buildings south-west of Farrow Rd.

Overall at this hotspot it was estimated that about 50 commercial tenancies may be flood affected.

b) Flood Modification Options

In current conditions the pipe that runs along Dumaresq St, under the railway and further downstream, parallel to Farrow Rd is at capacity from the 20% AEP event. This suggests that all the commercial and industrial buildings fulfilling the hotspot selection criteria would benefit from a pipe capacity upgrade.

As such, flood modification was investigated further at this location. The model showed that the following configuration of options would provide sufficient local reductions of flood levels:

- The equivalent of an inlet area of 8m x 6m at the Oxley St intersection.
- A new higher capacity culvert from Oxley St to Queen St
- A new grated inlet at the Queen St intersection
- 2.7 wide by 1.5m high reinforced concrete box culvert from Queen St to Hurley St
- A new grated inlet at the Hurley St intersection
- A new culvert under the railway, from 2. Hurley St to the northern side of railway
- Two new culverts from the northern side of railway to Bow Bowing Creek.

This arrangement is illustrated in Figure 42.

c) Property Modification Options

This land within this hotspot that is north of the railway, including the affected buildings in Farrow Rd, is marked to undergo rezoning and redevelopment to a use of high rise residential under the Glenfield to Macarthur Urban Renewal Corridor Strategy. On the other hand, the part of the hotspot along Dumaresq St is currently classified as commercial core, and will not be rezoned (with the exception of the lot opposite Coogan Pl, to be rezoned as community infrastructure).

As such, the affected industrial buildings in Farrow Rd may be redeveloped to high rise apartments in the near future. This will provide an opportunity to acknowledge and address flood risks, which could be achieved as part of the redevelopment process through a variety of building modification measures, such as:

- Car parking at ground level through which overland flows could pass;
- Buildings with elevated ground floor slabs under which overland flows would pass;
- Buildings with sealable ground floors to prevent entry of floodwaters;
- Buildings with ground floor uses and materials which are compatible with occasional flooding.

Redevelopment will also offer an opportunity to address flood risk to property and life via location-specific development controls.

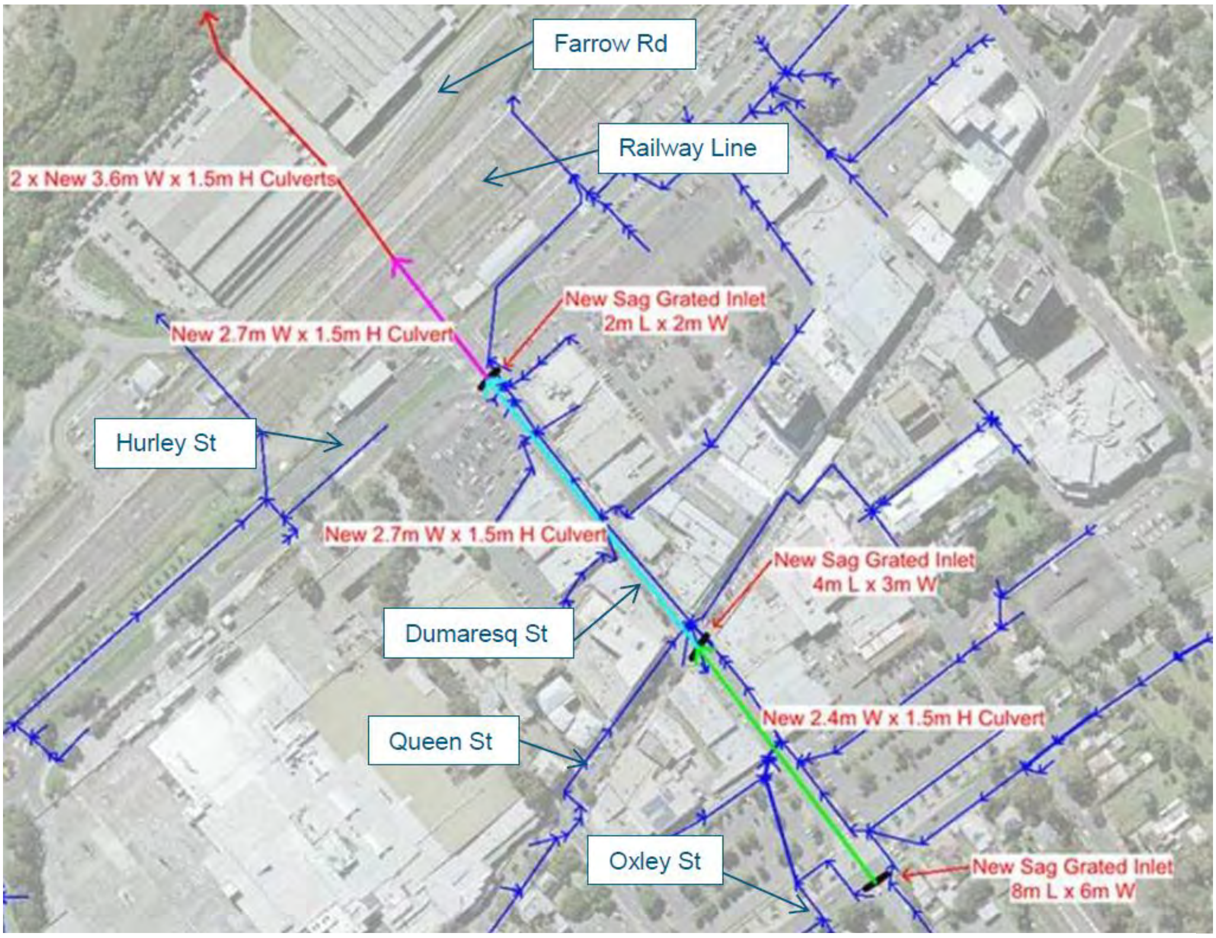

Figure 42. Layout and details of the shortlisted flood modification options in Farrow Rd and Dumaresq St (Campbelltown)

d) Response Modification

The proposed Catchment-wide response modification options discussed in Section 11 were considered sufficient to address risk to people in commercial and industrial properties throughout the study area in current conditions.

Once the area north of the railway is redeveloped to high rise residential use, it is recommended that flood risk to people is acknowledged and appropriately addressed using locality-specific development controls.

e) Shortlisted Options

In light of the preceding discussion, the following flood risk mitigation options were shortlisted:

- The identified set of flood modification works;
- A range of building modification measures to be considered as part of the redevelopment of the part of the hotspot north of the railway, with the aim to replace existing buildings with less vulnerable ones.
- Use of locality-specific development controls throughout the area to reduce risk to people and property.

f) Evaluation of the Shortlisted Options

i) Flood Modification

A cost-benefit analysis was undertaken for the shortlisted flood modification options to assess if these would be economically worthwhile. Table 28 shows a summary of the results for this hotspot (please refer to Appendix E and F for more details).

Table 28. Results of Cost Benefit Analysis for Flood Modification Options in Farrow Rd and Dumaresq St, Campbelltown

Total Option Costs	$7.280M
Total Option Benefits	$10.244M
Benefit/Cost Ratio	1.41

The cost/benefit analysis showed that flood modification at this location would be economically worthwhile, having a benefit to cost ratio of 1.41.

In terms of social or environmental costs, the shortlisted flood modification options would cause only minor inconvenience during construction and maintenance operations, and these would be temporary. No significant environmental costs were identified.

However, there would be significant feasibility issues to be addressed before the necessary works can be undertaken. These include:

- Significant clashes with existing services are likely to encountered during implementation of the options, especially considering the elements to be installed are large-medium sized box culverts;
- Of particular concern are potable water and sewer mains along the length of Dumaresq Street ranging in size from 150mm to 300mm in diameter;
- Furthermore a number of services bisect Dumaresq Street including gas, and telecommunications assets.

It is therefore recommended that the shortlisted flood modification option, as well as the above mentioned feasibility issues, are investigated in more detail as part of the Floodplain Risk Management Plan.

ii) Property Modification

The rezoning of part of this hotspot to high rise residential use under the Glenfield to Macarthur Urban Renewal Corridor Strategy will provide a practical opportunity to address flood risk through a range of property modification measures, including locality-specific development controls.

The advantage of addressing flood risk with property modification as part of the redevelopment to high rise residential is that the associated costs are distributed across many property owners, making the benefit to cost ratio much greater than it would be in low rise dwellings. As such, it is recommended that Council works with the NSW Department to Planning and Environment to ensure that flood risk is acknowledged and addressed as part of the redevelopment of the western part of the hotspot.

Given that there is extensive flooding from the 20% AEP event, with high hazard floodwaters from the 0.2% AEP, it would not be appropriate to rely upon property modification alone (which would rely on the 1% AEP event) and some flood modification should be implemented.

iii) Response Modification

When the area north of the railway will be redeveloped to high rise residential use, risk to people might increase due to higher building occupancy rates and it is suggested that this should be managed by implementing location-specific development controls.

10.3.4 Ingleburn CBD

Commercial and Industrial Hotspot ID number: 3.Selection Criteria Satisfied:

- Six large commercial buildings with AFF from the 20% AEP. It was estimated that these buildings host about 71 commercial tenancies.

This location is presented in detail in Map 54, Vol 2.

a) Flood Behaviour

Flood behaviour in Ingleburn CBD is described in detail in Section 10.2.2.a. The model shows that here most pipes would be at capacity from the 20% AEP, and all the non-residential buildings affected by AFF would benefit from an increase of pipe capacity.

b) Flood Risk Reduction Options

The hotspot in Ingleburn CBD includes both commercial and residential buildings. As these are exposed to the same flooding mechanism, they would benefit from the same flood risk reduction measures. These are described in detail and evaluated in Section 10.2.2.a.

10.4 ROAD HOTSPOTS

10.4.1 Shortlisted Hotspots

As explained in Section 9.3.3, six road hot spots were identified for further investigation:

- Menangle Rd (Glen Alpine);
- Tindall St (Campbelltown);
- Appin Rd (between Bradbury and Campbelltown);
- Oxley St (Campbelltown);
- Collins Prom (Ingleburn);
- Pembroke Rd (Minto).

10.4.2 Menangle Road

This road hotspot is shown in Map 55, Vol. 2. The road is cut from the 20% AEP at three locations:

- North and south bound, between Glen Alpine Dr and Gilchrist Dr;
- South bound at a location north of Glenlee Rd;
- North bound, at a different location north of Glenlee Rd.

Preliminary investigations suggest that flooding in the southern most location north of Glenlee Rd occurs when flows exceed the capacity of the roadside drainage swale on the western side of the road and water spreads out over the road. There is a wide roadside verge in this area and there may be scope to increase the size of the drainage swale to alleviate this problem. It is recommended that this is investigated further.

At the location further north it would appear that flooding of the road is occurring where a culvert passes water from east of the road to west of the road. Increasing the culvert capacity at this location should be investigated as a means of alleviating flooding at this location. The flood impacts of such a measure on rural residential properties west of Menangle Rd would need to be assessed.

Finally, at the northern most location it would appear that Menangle Rd is flooded due to the small capacity of the culvert under the railway line to its west. This may be a modelling issue as Campbelltown Council was able to validate the size of many of the culverts under the rail line. Alternatively, the model is correct and the culvert is undersized.

It is recommended that this be investigated further and, if the culvert is undersized, the costs and benefits of increasing its capacity be investigated.

Passing additional flows under the rail line is not likely to have a significant downstream impact as they would flow directly into the detention basins between the railway and the Western Sydney University.

10.4.3 Tindall Street

This road hotspot is shown in Map 56, Vol. 2. Tindall St is cut north and south bound in the 20% AEP event near the crossroad with Menangle Rd by overland flows. Modelling shows that in this location the pipe network is running at capacity in this area during the 20% AEP but further downstream it would appear to be operating below capacity in the same event. It is therefore recommended that increasing the pipe network capacity in this location be investigated as a mitigation option.

10.4.4 Appin Road

This road hotspot is shown in Map 57, Vol. 2. Overland flows run north along the south-bound lanes of Appin Rd south of Narellan Rd. There is a pipe running under the road at this location which modelling shows is flowing at capacity in the 20% AEP event. The benefits of providing additional drainage capacity along this length of the network should be investigated. It may be more cost effective to provide an additional pipe within the wide verge along the eastern side of the road rather than increase the capacity of the pipe which is directly below the road.

10.4.5 Oxley Street

This road hotspot is shown in Map 58, Vol. 2. Oxley St is cut south bound, south of Dumaresq St by overland flows in the 20% AEP event. This section of road is up the hill from the non-residential hotspot described in Section 10.3.3 and would not benefit from the flood modification options recommended for that hotspot.

It is noted, however, that the pipe network in this location is operating at capacity in the 20% AEP. If the pipe capacity in Dumaresq St is increased downstream to deal with flooding in the identified non-residential hotspot, this may provide sufficient downstream capacity for an increase in pipe capacity at Oxley St to alleviate the flooding at this road hot spot. It is recommended that this option be investigated further.

10.4.6 Collins Promenade

This road hotspot is shown in Map 59, Vol. 2. Collins Prom is cut north bound, south of Eagleview Rd by overland flows in the 20% AEP event. There is a culvert under the road at this location and it would appear that it is surcharging on the upstream side in the 20% AEP event. Increasing the culvert size may alleviate this problem but there are houses immediately downstream which may be adversely impacted by the increased flows.

An alternative would be to provide flow detention in the extensive open space which is upstream of the road. Immediately adjacent to the road the area is densely vegetated with remnant bushland which has been mapped as Cumberland Plain Woodland and should not be cleared to create a detention basin. However, about 200m further upstream the vegetation is mapped as urban exotic/native and there may be more opportunity to create a detention basin here.

It is recommended that the costs and benefits of a detention basin about 200m upstream of Collins Prom be investigated to alleviate the road flooding in this location.

10.4.7 Pembroke Road

This road hotspot is shown in Map 60, Vol. 2. Pembroke Rd is cut from the 20% AEP at three locations:

- North and south bound, south of Westmoreland Rd;
- South bound, north of Ben Lomond Dr;
- North bound, north of Derby St.

In the location south of Westmoreland Rd the problem appears to be caused by a lack of capacity in the culvert under the road. Increasing the culvert capacity may alleviate the problem at the road without significantly increasing flood impacts in the industrial area downstream. It is recommended that this be investigated further.

North of Ben Lomond Dr the underground pipe network appears to be operating at capacity in the 20% AEP event and the excess flows are running along the road. It may be that an increase in pipe capacity underneath the road with it discharging into the large detention basin west of the road may be the method of alleviating this problem. It is recommended that this option be investigated further.

North of Derby St the pipe network is operating at capacity in the 20% AEP event and overland flows are flowing across the road. The challenge at this location is that there is an extensive catchment upstream of the road and a number of overland flow paths converging at this location. There is a wide verge where it might be possible to create a detention basin upstream of the road and put a culvert under the road to connect into the drainage swale downstream. It is recommended that this be investigated further.

10.5 CATCHMENT SPECIFIC FRMSP

This FRMSP has addressed residential, commercial and industrial properties based on criteria using extreme flooding scenarios. The need to complete further investigation at a smaller scale is apparent. This will allow the identification of individual properties and assets with flooding issues and potential measures to address these issues.

It is recommended that FRMSP be completed for each of the sub-catchments making up the BBBC Catchment.

11 BBBC CATCHMENT-WIDE MITIGATION OPTIONS

This section describes the proposed flood risk mitigation options that apply to the whole BBBC Catchment, as opposed to being location-specific as those discussed in Section 10.

These include the following categories of risk mitigation options:

- BBBC Catchment Wide Property Modification;
- BBBC Catchment Wide Response Modification.

Flood modification options were excluded from this section because these do not typically apply to areas as large as a catchment.

11.1 BBBC CATCHMENT WIDE PROPERTY MODIFICATION

11.1.1 Strategic Planning and Potential Redevelopment

The Glenfield to Macarthur Urban Renewal Corridor strategy provides an opportunity to reduce flood risks through urban renewal. Figure 43 shows the extent of the corridor.

a) Glenfield and Macquarie Fields

There is not a large number of residential or non-residential buildings in Glenfield or Macquarie Fields which are likely to experience frequent above floor flooding so there are no real strategic planning solutions for these areas.

b) Ingleburn

Ingleburn on the other hand has considerable flood risks for both residential and non-residential buildings and, as discussed in Section 10, urban renewal provides a real opportunity to provide significant flood mitigation benefits.

c) Minto

In Minto there are few residential properties which are currently at risk from flooding.

The proximity of the Minto industrial area to Bow Bowing Creek means that flood depths in this area are considerable in more extreme floods and there is a risk to people (particularly as many buildings are single storey).

The strategic vision for Minto includes a renewal of the industrial area and the creation of a business park in the northern part of the existing industrial area (Figure 44)

The flood risks in this area can be considered as part of the redevelopment of this area including the requirement for flood-free refuges in buildings where there is a significant risk to people who may be trapped.

d) Leumeah

Leumeah is very similar to Minto in that there are few existing residential properties with significant flood risk but quite a few commercial and industrial buildings which can be isolated and flooded in frequent floods. However, there are fewer buildings affected in this way in Leumeah.

As in Minto, these risks may be overestimated due to the inability to incorporate any private stormwater pipes in the model. The vision for a renewed industrial estate and business park will provide an opportunity to reduce some of these risks (Figure 45.).

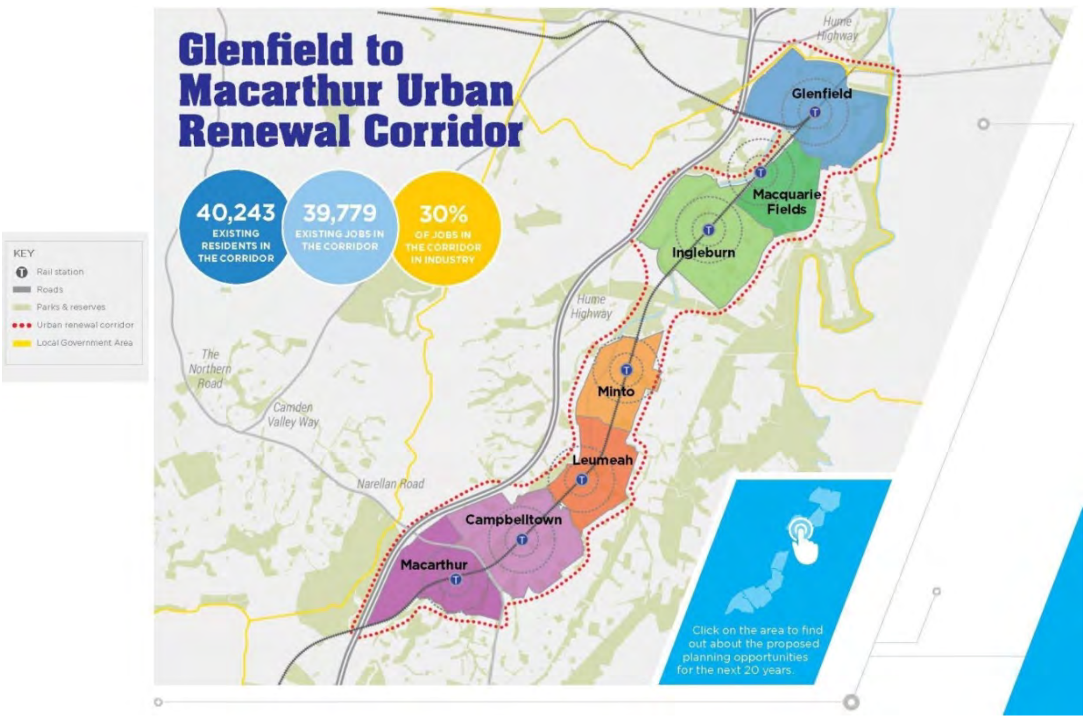

Figure 43. Glenfield to Macarthur - Extent of Urban Renewal Corridor

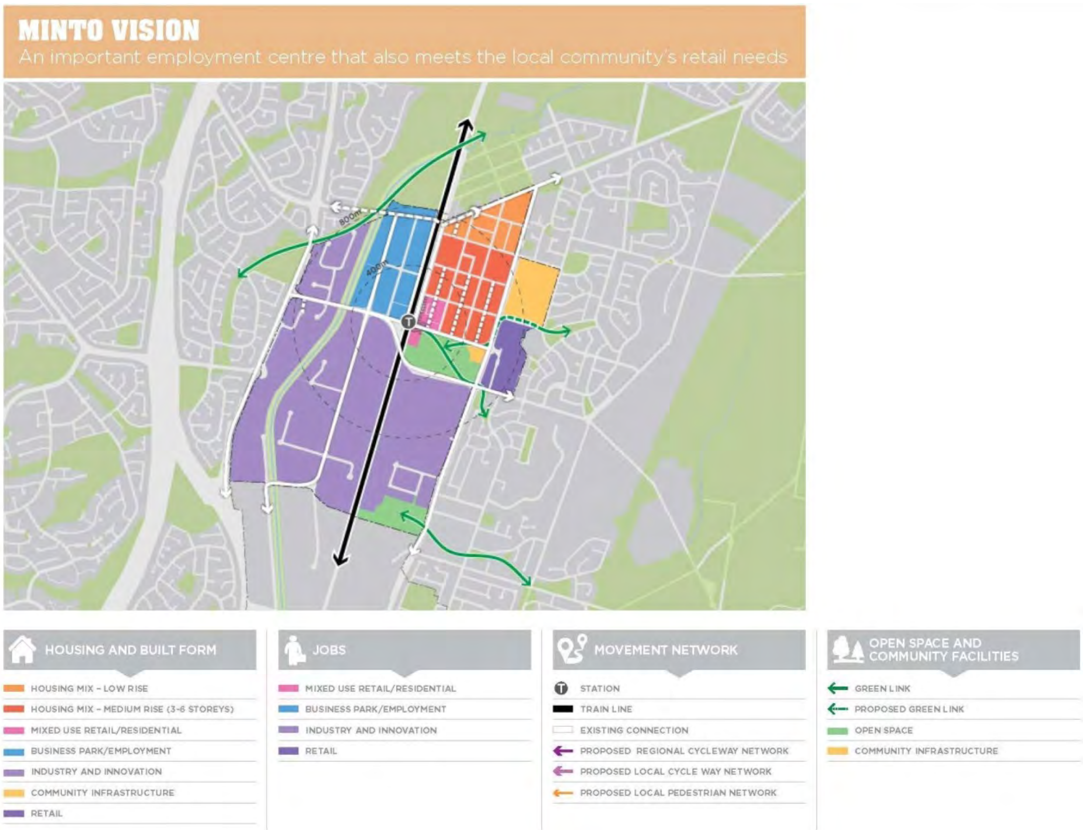

Figure 44. Minto Precinct from Glenfield to Macarthur Urban Renewal Strategy

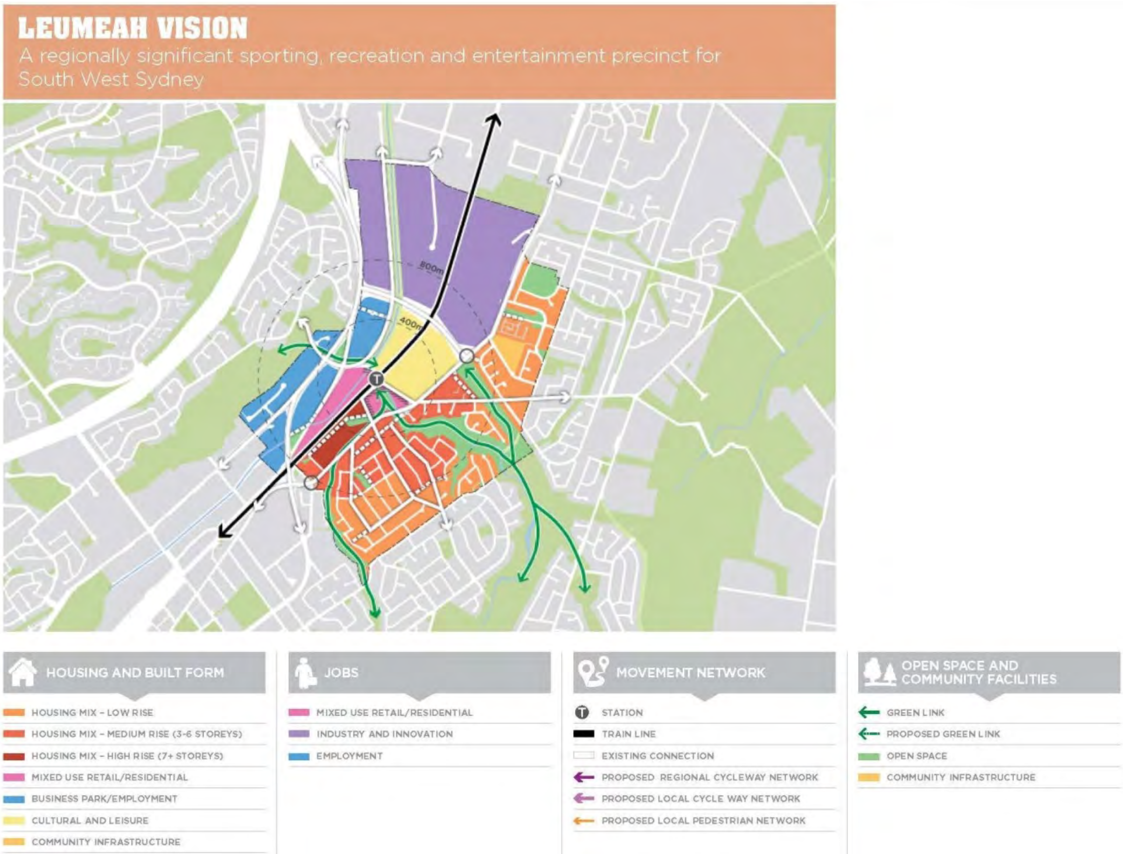

Figure 45. Leumeah Precinct from Glenfield to Macarthur Urban Renewal Strategy

The vision includes mixed use retail/residential to the west of the railway, either side of Bow Bowing Creek in an area which is currently industrial. While the 1% AEP flood is within the lined channel in this area, the PMF hazard can pose a danger to building stability. This needs to be given careful consideration before zoning this area to include residential buildings.

To the east of the railway line there is an area of high rise residential development envisioned, but this is currently zoned infrastructure which acknowledges flood affectation in the area. Parts of this area appear to reach flood depths of up to 1.5m in a 1% flood, possibly due to undersized culverts under the rail embankment. This could also be due to a limitation of the model which does not include some the existing culverts at this location, because the relevant data was not made available to Council. A couple of existing dwellings in this area may experience above floor flooding in frequent floods. Urban renewal in this area is an opportunity to ensure that new development is located and designed to be compatible with the flood risk. This principle also needs to be applied in delineating the proposed medium rise and low rise development further east from the open space corridors which traverse them, generally following the drainage paths.

e) Campbelltown

The industrial area north of the railway line at Campbelltown appears to have similar flood risks to Leumeah. Parts of this are proposed to be redeveloped as a business park which should be an opportunity to deal with some of these flood risks (Figure 46).

There are also several commercial buildings along Queen Street, west of Moore St which would appear to be at risk of frequent above floor flooding and isolation. The vision for this area and beyond is for high rise residential apartments. This may be an opportunity to reduce these flood risks.

f) Macarthur

There are few existing buildings within the Macarthur precinct which are identified in the modelling as having a serious flood risk, probably because they are all part of newly constructed estates which took overland flows and flooding into consideration. It is recommended this continues with future development in this precinct.

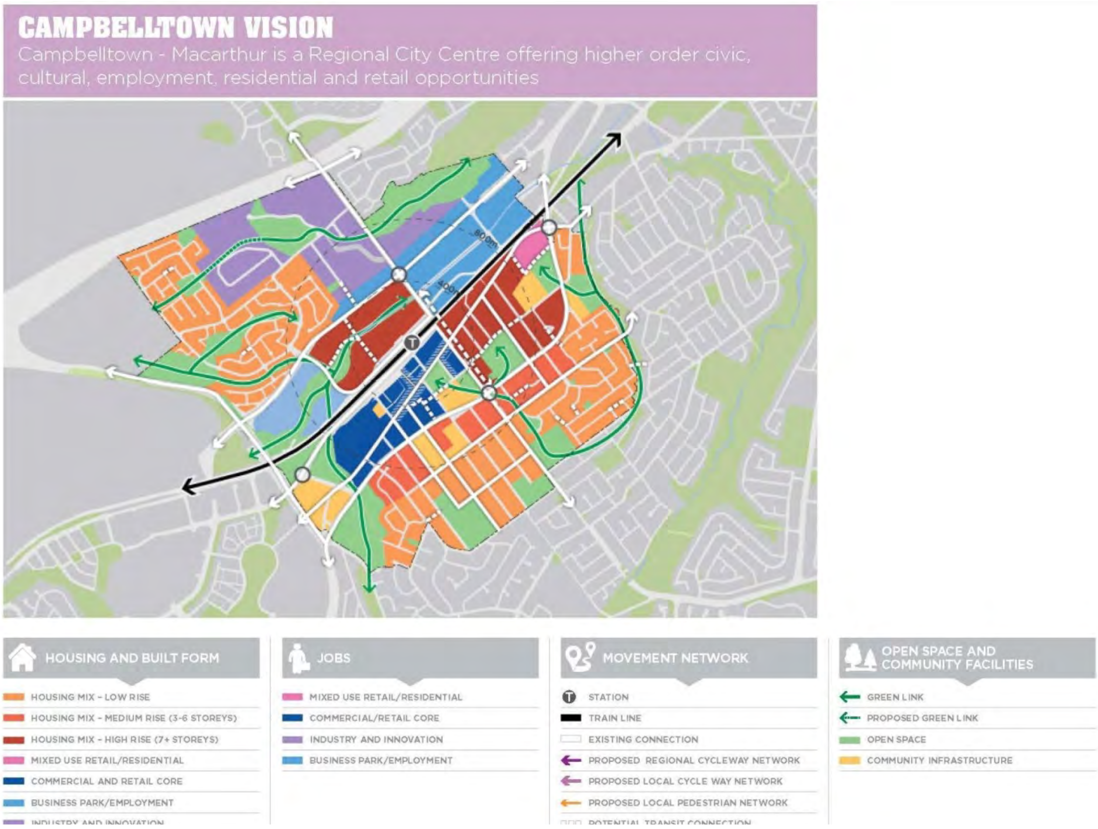

Figure 46. Campbelltown Precinct from Glenfield to Macarthur Urban Renewal Strategy

g) Land and Housing Corporation

Land and Housing Corporation (LAHC) is a State owned corporation which provides low cost housing to people who are socially disadvantaged. This includes many people who are aged, frail or have a disability.

It owns hundreds of dwellings throughout the Campbelltown LGA, many of which are flood affected to varying degrees.

LAHC is currently reviewing its portfolio to determine which of its properties need to be redeveloped. As part of this review it is considering flood risk to determine whether:

- they need to dispose of properties where the risks would be too high for their tenants
- they need to dispose of properties where satisfying minimum floor level criteria would provide access challenges for their tenant
- there are locations where the redevelopment needs to be responsive to the flood risks.

It is recommended that Campbelltown Council work closely with LAHC to find opportunities to reduce flood risks through redevelopment, particularly for vulnerable residents.

h) Critical Infrastructure

Council officers have met with Endeavour Energy and Campbelltown Hospital and are actively working towards a better understanding of flooding issues on these sites and working with the stakeholders to manage these issues. With the exception of the M5

Hume Motorway, all state roads in the LGA are under the care, control and management of Council. Council will work with RMS with respect to issues on the relevant roads.

Council is also seeking to obtain information from City Rail regarding any stormwater infrastructure in the corridor which may affect flood affectation of the rail network and adjacent areas.

11.1.2 Development Controls

Development controls provide the opportunity to reduce flood risks when buildings are being built, renovated or extended.

Campbelltown's planning provisions with regards to flooding can be found in three related documents:

- Campbelltown Local Environmental Plan 2015 (CLEP 2015);
- Campbelltown (Sustainable City) Development Control Plan 2015 (CDCP 2015)
- Engineering Design for Development (An addendum to the DCP

A review of the existing flood risk management clauses of CDCP 2015, with comments and proposed amendments in provided in Table 29.

A technical addendum to the DCP called Engineering Design for Development is used in close conjunction with the DCP and is reviewed and commented in Table 30.

Some broader comments and suggested improvements are described below:

A discussion of various planning controls which are in these documents follows with recommendations of how they can be improved to better manage flood risks.

a) Flood Planning Level

Flood planning is addressed in Clause 7.2 of CLEP 2015, which is reproduced in Figure 47. This clause is based on a non-mandatory model clause which accompanied the NSW standard instrument for a Local Environment Plan. It relates to land at or below the flood planning level (FPL), which is defined as land below the level of the 100 year ARI flood plus 0.5m freeboard.

In NSW the State Government recommends that the FPL be set at 0.5m above the 1% AEP flood level for standard residential dwellings (DIPNR, 2005 and S117 Direction 4.3). In this regard CLEP 2015 is consistent with the State Government policy. However, the NSW Floodplain Development Manual (DIPNR, 2005) encourages consideration of alternative flood planning levels for other developments. Furthermore, S117 Direction 4.3 permits the adoption of a higher or lower flood planning level for residential development if it can be demonstrated that there are "exceptional circumstances".

7.2 Flood planning

(1) The objectives of this clause are as follows:

(a) to minimise the flood risk to life and property associated with the use of land,

(b) to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change,

(c) to avoid significant adverse impacts on flood behaviour and the environment.

(2) This clause applies to land at or below the flood planning level.

(3) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

(a) is compatible with the flood hazard of the land, and

(b) will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and

(c) incorporates appropriate measures to manage risk to life from flood, and

(d) will not significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and

(e) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

(4) A word or expression used in this clause has the same meaning as it has in the *Floodplain Development Manual (*ISBN 0 7347 5476 0*)* published by the NSW Government in April 2005, unless it is otherwise defined in this clause.

(5) In this clause:

land at or below the flood planning level means land at or below the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metre freeboard.

Figure 47. Flood planning clause from Campbelltown LEP 2015 (as of 20 February 2017)

However, CDCP 2015 has the following definition "Flood Planning Level is the 100 year Average Recurrence Interval flood level plus freeboard in accordance with Table 4.1 of Council's Engineering Design for Development." That table has a range of flood planning levels which vary from between 0.1m and 0.5m above the 1% flood level with the smaller freeboard applied in situations with shallow flooding or insignificant consequences. The same FPL is applied to residential, commercial and industrial developments including sensitive land uses and critical infrastructure.

A more detailed discussion on the justification of this approach can be found in Section 3.4.1. There is no compelling reason to change the CDCP 2015 approach in Campbelltown with regards to standard residential, commercial and industrial development and, as explained in Section 3.4.1, it is not inconsistent with the requirement to manage flood risks up to 0.5m above the 100 year ARI flood level.

Where the challenges lie are:

- The current CLEP 2015 FPL definition means that, technically, S10.7 Certificates must be issued with a flood notation for any properties which are at or below this defined FPL which is not current practice by Council;
- Changing the FPL definition in CLEP 2015, for example to refer to a variable FPL set out in the DCP, would require preparation of a draft LEP amendment which would need to go through consultation and exhibition before being adopted;
- As CDCP 2015 was created after S117 Direction 4.3 was issued in 2007, to apply any FPL to standard residential development which is higher or lower than 0.5m above the 1% AEP flood level requires an application for exceptional circumstance to the Department of Planning and Environment and the Office of Environment and Heritage.

While Council's current practice both in terms of S10.7 certificates and application of the FPL is not consistent with legislation and state government directives, it has no negative practical implications as Council is apply less strict controls where flood consequences do not warrant having a freeboard of up to 0.5m above the 1% AEP flood level.

Nevertheless, it is recommended that Council modify its LEP and also an application for exceptional circumstances.

b) Campbelltown (Sustainable City) Development Control Plan 2015

Campbelltown (Sustainable City) Development Control Plan 2015 (CDCP 2015) sets the design and construction standards that apply when carrying out development within the LGA. It supports CLEP 2015, which regulates the uses that are permissible on the land.

i) Organisation

Most flood risk management controls are located in 'Part 2 - Requirements applying to all types of development' of CDCP 2015. This contains some material that is also found – typically in more detail – in the *Engineering Design for Development* technical addendum to the DCP. It is not straightforward to locate the flood risk management objectives and controls because they are not consolidated in a single chapter or section as they are in other DCPs. Rather, relevant controls are contained in sections including 'Cut, fill and floor levels' and 'Stormwater management'. Also, there is considerable duplication, such as description of controls for underground carparks, which are found in Section 2.8.2(g) of CDCP 2015 and Sections 4.5 and 4.13.8 of *Engineering Design for Development*.

Consolidation of flood risk management controls into a single chapter in a single document would be advantageous. The argument for focussing this work on the *Engineering Design for Development* addendum is that when changes are made there, the DCP need not be updated. But *Engineering Design for Development* is considered to be a dense engineering document that is not the most appropriate 'home' for a consolidated flood risk management chapter, which would better sit in the DCP proper. Further, Council may wish to consider whether having controls in its DCP adds more weight than if they were listed only in a technical addendum, in the event of a contentious development proposal being taken to the Land and Environment Court for adjudication.

A flood risk management chapter in the DCP should include some preamble that locates the DCP in relation to the Floodplain Development Manual and sets forth high level objectives.

Where flooding needs to be addressed in the site specific development control plans it would be appropriate for these to cross reference to Volume 1 (Development Controls for all Types of Development) which would have a suite of controls suitable for the various situations which need to be managed at particular sites.

ii) Degree of prescription

The impression is that the flood/overland flow risk management provisions of CDCP 2015 are generally less prescriptive than equivalent policies from other LGAs, placing more demand on Council officers to interpret particular site characteristics and to apply particular conditions of consent. There is a requirement for minimum freeboards above the 100 year ARI level. But the comments relating to critical infrastructure in *Engineering Design for Development* (Section 4.5) imply that the assessment of individual development applications according to their own 'merit' is Council's standard method. This could potentially result in inconsistent approaches to development (since there is more room for individual interpretation) and create a higher burden on Council's development engineers.

Council has indicated that the existence of drainage systems from the time of construction means that only relatively infrequently are Council officers called upon to provide input on, for example, flood-proofing requirements (which aren't spelt out in the DCP). It is considered that a more systematic approach to applying conditions for consent is fitting.

iii) Definition of flooding/overland flow classes

In contrast to some other DCPs that adopt three or more categories to describe the severity and/or frequency of flooding, CDCP 2015 by and large adopts a single category for land below the 1% AEP flood plus freeboard. The DCP does require *consideration* of the effect of floods rarer than the design flood, notably near the start of Section 4 'Stormwater design' in *Engineering Design for Development*, and especially for some sensitive land uses such as hospitals. But there may be advantage in more explicitly defining categories of inundation hazards, which would then allow for more targeted controls according to the degree to which land uses are judged to tolerate flooding. For example:

- Floodway in 1% AEP event;
- High hazard or flood storage in 1% AEP event;
- Low hazard and flood fringe in 1% AEP event;
- PMF inundation.

iv) Categorisation of land uses

Different land uses present different risks for the same level of flooding. The current DCP and *Engineering Design for Development* recognise this to some degree by indicating greater scrutiny would be applied for some vulnerable uses such as hospitals, seniors living, educational establishments, evacuation centres and nursing homes. Consideration should be given to formalising a list of critical infrastructure and sensitive uses for which there is negligible or zero tolerance of inundation even in the PMF. To the list above could be added electricity substations, communications facilities, correctional centres, child care centres and liquid fuel depots. Specific controls could be prepared for this land use category.

Commercial and industrial developments may not present precisely the same flood risk as residential developments, though care is required not to overexpose these uses to flood hazards given the impacts flooding of the extensive areas near Bow Bowing Creek zoned for business would have on people's livelihoods.

Buildings for recreation or rural uses (e.g. farm building, toilet block) might be able to tolerate more flood hazard.

Engineering Design for Development (Section 4.5) does allow for minor additions – what some other DCPs call 'concessional development'. Some DCPs also consider a change of use in a commercial or industrial building to be 'concessional development', which triggers a requirement for a flood emergency response plan.

Explicit definition of the various land uses in a schedule would make more systematic the application of the DCP.

v) Scope of controls

Another question to consider is whether the scope of development controls in CDCP 2015 is sufficient to manage flood risk across the LGA.

The focus of the current controls is on floor levels (Table 4), though the *Engineering Design for Development* addendum does at one point (Section 4.5) indicate that Council may require flood-proofing measures such as the use of flood compatible materials and location of electrical infrastructure. There is also some attention to ensuring development does not have adverse flood effects on neighbouring lots (CDCP 2015 Section 2.10.2(d); *Engineering Design for Development* Section 4.14.3), though the wording could be more explicit to convey the intention.

The current focus on ensuring that all building platforms are filled to at least the level of the 100 year ARI flood level, and the required freeboards for dwelling floors, could, if perfectly implemented, obviate the need for some other controls such as for flood-compatible building components below the 1% AEP flood. But as noted in Table 29 and Table 30, there are some concerns with this narrow focus:

- Filling land may involve a loss of flood conveyance or storage and so be unacceptable given other controls;
- In the case of a 'knock-down-and-rebuild' in an older area where pipes do not convey the 100 year ARI flows, filling one residential lot to meet this requirement could have adverse effects on drainage and flood levels at neighbouring lots.
- The adoption of this standard may be unduly risk-averse for some land uses (e.g. sportsground toilet blocks).
- The requirement for ground levels to meet this standard, rather than floor levels, is also quite inflexible.

It is considered advantageous to include a suite of categories of development controls in the DCP, including:

- minimum floor levels
- building components

- structural soundness
- flood effects (i.e. to ensure development doesn't increase flooding elsewhere)
- car parking and driveway access
- evacuation/shelter-in-place
- management and design (e.g. provision of flood emergency response plan; storage of hazardous goods)

This does not mean that every type of control would be applied, or that the same level of control would be applied, for every combination of flood hazard and land use. But it does serve to show the full 'armoury' at the flood risk manager's disposal.

vi) Matrix

Many Councils adopt less of a text-based DCP, preferring to use a matrix that lists development controls for different degrees of flood/overland flow hazard and different land uses. This can aid clarity and reduce duplication. A matrix can also more systematically list the various types of development controls that may be employed to manage risk to people and property. The shape of a sample matrix is shown in Table 31**.**

c) Campbelltown S10.7 Certificates

The review of S10.7 Certificates did not identify any items that would benefit from substantial amendments. However, the following comment was made regarding S10.7(5): "*When the current FRMS&P is finalised, there will be opportunity to amend the 'FLOODS1' wording. For example, plain language describing the hydraulic hazard in a 1% AEP event and the PMF could be included*".

Table 29. Comments on flood risk management aspects of CDCP 2015

Extract from CDCP 2015	Comment	Proposed Changes
1.4 Definitions Flood Planning Level is the 100 year Average Recurrence Interval flood level plus freeboard in accordance with Table 4.1 of Council's Engineering Design for Development	This is Council's preferred definition, but is currently inconsistent with the definition in CLEP 2015.	CLEP 2015 be amended to permit variable freeboard where Council has assessed the risks to be acceptable as per the table which currently appears in the CDCP 2015. Council to apply for "exceptional circumstances to permit variable freeboard"
2.8 Cut, Fill and Floor Levels 2.8.2 Surface Water and Floor Levels	It is not ideal to have core flood risk management controls located in a section called 'Cut, fill and floor levels'.	It is suggested that a new section called 'Risk Management – Flood and Overland Flow' be developed (akin to the sections for bushfire risk, etc.)
2.8.2 Design requirements a) Development shall not occur on land that is affected by the 100-year ARI event unless the development is consistent with the NSW Floodplain Development Manual.	It is unrealistic to expect either developers or Council's development assessment officers to be so familiar with the Floodplain Development Manual that they can assess a development's consistency with it. Rather, a DCP or supporting document should embody the principles of the Floodplain Development Manual.	This clause could remain as is but refer to the Engineering Design Guide to provide greater clarity as to what Council considers to be consistent.
c) All development shall have a ground surface level, at or above a minimum, equal to the 100-year 'average recurrence interval' (ARI) flood level.	At face value, this clause excludes all development within the extent of the 100 year ARI flood, unless that land is filled to raise it to the 100 year ARI level. This raises the following considerations: Filling land may involve a loss of flood conveyance or storage and so be unachievable given other controls. In the case of a 'knock-down-and-rebuild' in an older area where pipes do not convey the 100 year ARI flows, filling one residential lot to meet this	The clause needs to be reworded to ensure it only targets development types which need this level of protection and it needs to be less prescriptive and include the option of meeting a performance based objective.

Extract from CDCP 2015	Comment	Proposed Changes
	requirement could have adverse effects on drainage and flood levels at neighbouring lots. The adoption of this standard may be unduly risk-averse for some land uses (e.g. sportsground toilet blocks). The requirement for *ground* levels to meet this standard, rather than *floor* levels, is also quite inflexible. Taken at face value, this clause might also proscribe the use of basement carparks with floors below the 100 year ARI level (even if the driveway crest excludes inundation to the standard), which may not be the intention.	
d) For development on land not affected by an overland flow path the minimum height of the slab above finished ground level shall be 150 mm, except in sandy, well-drained areas where the minimum height shall be 100mm. These heights can be reduced locally to 50mm near adjoining paved areas that slope away from the building in accordance with AS 2870 (Residential Slabs and Footings Construction).	This clause could reference the minimum slab heights required under the BCA rather than spell out these heights, obviating the need to update the DCP should the BCA change.	Cross reference BCA
e) Buildings involving basements, hospitals, seniors living dwellings and educational establishment with more than 50 students shall comply with the provisions of Council's Engineering Design Guide for Development.	It is not clear what particular provisions in the Guide need to be complied with. This list includes some 'sensitive uses' as defined in other DCPs, and could be extended. Also, the vulnerability of an educational establishment should not be defined so as to depend on the number of students enrolled.	Include a clearer list of vulnerable and sensitive uses

Extract from CDCP 2015	Comment	Proposed Changes
f) Any solid fence constructed across an overland flow path shall be a minimum 100mm above the finished surface level of the overland flow path.	This clearance would be difficult to achieve for a masonry fence. Further guidance could be provided about types of flood compatible fences..	The engineering guideline needs to have examples of acceptable solutions for various fence designs.
g) Where underground car parking is proposed, measures shall be taken in design and construction to ensure escape routes, pump out drainage systems (which include backup systems) and location of service utilities (including power, phone, lifts) are appropriately located in relation to the 100 year ARI event, in accordance with Section 4.13.8 of Council's Engineering Design Guide for Development.	Section 4.5 of the *Engineering Design for Development* guide explicitly requires that the risk in a PMF (not just the 100 year ARI event) be managed, which is appropriate.	This section should be amended for consistency with Section 4.5. If there is potential for rapid ingress of water to underground carparks, it is recommended that on-site alarm systems also be required to manage the risk to people. The details of requirements may be placed in the Engineering Design Guide.
Table 2.8.1 Floor level requirements A 'dwelling room' is any room within or attached to a dwelling excluding a garage or shed	Consideration is given to whether a 'dwelling' room may be better described as a 'habitable' room, which is defined in Part 1.4 of the DCP. However, there, oddly, a habitable room is defined so as to exclude a pantry and walk-in-wardrobe, which, if flooded, could be rooms where considerable damage is sustained. Accordingly, a 'dwelling' room as currently defined, while somewhat conservative, is not inappropriate.	No change
Table 2.8.1 Floor level requirements Floor Level in relation to any creek or major stormwater line including detention basins for any dwelling room# including all commercial or industrial areas	It is understood that inundation from creeks and major stormwater lines is not spatially differentiated from overland flow, which makes it difficult for an applicant to determine which floor level requirement applies to their development. Mapping inundation into these categories is required if this clause is to be implementable. It also needs to be clearer that this	Needs editing to make it clearer what happens on sites which are affected by both mainstream flooding and overland flows.

Extract from CDCP 2015	Comment	Proposed Changes
	second criterion in Table 2.8.1 based on location (requiring a 500mm freeboard) trumps the first criterion in Table 2.8.1 based on flow depth (potentially requiring a lesser 300mm freeboard).	
2.10 Water Cycle Management 2.10.2 Stormwater Design Requirements d) Development shall not impact on adjoining sites by way of overland flow of stormwater unless an easement is provided. All overland flow shall be directed to designated overland flow paths such as roads.	Depending on how it is applied, this control could guard against adverse flood effects caused by the loss of conveyance or storage, though the design event (100 year ARI?) to which it relates is not stated.	This issue could be addressed in a new 'Risk Management – Flood and Overland Flow' section, where it is commonly found in many equivalent DCPs.
e) Safe passage of the Probable Maximum Flood (PMF) shall be demonstrated for major systems.	The language of 'safe passage' is ambiguous, being unclear whether this refers to conveyance (and unclear as to what degree of obstruction to conveyance or loss of storage is tolerable) or risk to people or both. If it is conveyance then this is significantly more onerous than the requirement in most other DCPs.	Safe passage needs to be better defined.

Table 30. Comments on flood risk management aspects of Engineering Design for Development

Extract from Engineering Design for Development	Comment
Glossary	The glossary requires updating. Council should consider revising its terminology for flood frequency (in both the glossary and guideline) in keeping with AR&R revisions, which advocate AEP over ARI (or EY for events more frequent than 50% AEP). The names of Government departments also require revision.
4. Stormwater Design 4.5 Fill and floor levels	It is not ideal to have core flood risk management controls located in a section called 'Stormwater design'. It is suggested that a new section called 'Risk Management – Flood and Overland Flow' be developed.
Critical infrastructure including hospitals and evacuation centres may require fill and floor level controls higher than those set out in Table 4.1. Special consideration will also be given to evacuation routes and vulnerable development (like nursing homes) in areas above the 100 year ARI flood.	This clause rightly recognises the greater consequences of inundation for critical infrastructure and sensitive uses. There would be benefit in preparing an annex that lists all such uses (not just hospitals, evacuation centres and nursing homes). There would also be benefit in specifying more explicit standards in relation to floor levels and provision for shelter-in-place for land uses with vulnerable residents, such as nursing homes, where research has shown that a proportion of residents do not survive evacuations.
The minimum fill level for a property is the level of the 100 year ARI flood level.	Given its importance, this statement should be included in the DCP too. It raises the following considerations: Filling land may involve a loss of flood conveyance or storage and so be unachievable given other controls. In the case of a 'knock-down-and-rebuild' in an older area where pipes do not convey the 100 year ARI flows, filling one residential lot to meet this requirement could have adverse effects on drainage and flood levels at neighbouring lots. The adoption of this standard may be unduly risk-averse for some land uses (e.g. sportsground toilet blocks). The requirement for *ground* levels to meet this standard, rather than *floor* levels, is also quite inflexible.
Table 4.1 Floor Level and Freeboard Requirements	This table is also shown in the DCP, and the same comments apply.
Where underground carparks are proposed,	It is appropriate that the risk of inundation of

Extract from Engineering Design for Development	Comment
consideration must be given to escape routes, pumpout drainage systems (which must include backup pumpout systems), location of service utilities (including power, phone, lifts) for the flood planning level, as well as the PMF. Additional requirements are detailed in Section 4.13.8.	underground carparks in a PMF be managed, as required by this clause (but not by equivalent clauses in the DCP and in Section 4.13.8 of this guideline). If there is potential for rapid ingress of water to underground carparks, it is recommended that on-site alarm systems also be required to manage the risk to people.
Where an application is lodged for additions to a property which is currently flood affected, it will be assessed on the merit of the individual circumstances, however, as a general rule; if the additions constitute 10% or less of the existing floor area, the additions will be approved at the current level. Where the additions constitute more than 10% of the existing floor area, the additions will be required to be constructed at the levels determined by the above controls. Council reserves the right to impose flood-proofing requirements on additions located in flood-affected areas (Through the use of flood compatible materials, location of electrical infrastructure, etc).	This clause allows for what in equivalent DCPs is often called 'concessional development'. The final sentence suggests that Council may invest considerable resources in assessing the merits of individual development applications and considering conditions for development approval. It is considered that a more prescriptive approach may result in a more consistent and efficient processing of development applications.
4.13 Major System Flood warning signs are required in all locations where floodwaters may pond or flow and special consideration will need to be given to car parks used as floodways, detention basins and channels.	It is not ideal to have core flood risk management controls located in a section called 'Major system'. It is suggested that a new section called 'Risk Management – Flood and Overland Flow' be developed. What is meant by 'special consideration' is not clear. Does this mean that consideration will be given to allowing them or that particular controls may be applied if they are allowed? This needs to be clarified in the document
Council requirements are aimed at ensuring that all properties are protected against the 100 year ARI flood. Properties are to be free from inundation from floods of up to 100-year average ARI recurrence interval. No buildings or other structures are permitted within areas inundated by such flows.	The adoption of this standard may be unduly risk-averse for some land uses (e.g. sportsground toilet blocks). The requirement for no *buildings* within areas inundated by the 100 year ARI flood – even if floor levels are raised – is also quite inflexible.
4.13.1 PMF Requirements Safe passage of the PMF must be demonstrated on major systems. Where there is risk to property and/or life it will be necessary to check the results for the	The language of 'safe passage' of the PMF is also included in the DCP. Here it is clearer that risk to people is to be considered, especially for major release areas and major public infrastructure such as hospitals. What actually constitutes 'safe passage', however, is not clear. Does this mean that

Extract from Engineering Design for Development	Comment
Probable Maximum Flood (PMF).	conveyance of the PMF cannot be obstructed in any way or that the development cannot increase the level of the PMF? This is more onerous than most other DCPs. If risk to people it the principal consideration then perhaps it could require that that the development does not change the hazard category in a PMF; that way marginal increases in depth or velocity would be tolerable as long as they are not increasing risk to people.
All developments must consider the impact of storms greater than the 100 year ARI event in terms of evacuation routes. No properties should be isolated or become islands in events greater than the 100 year ARI event. Flooding risks should increase incrementally, i.e. no small increase in runoff should generate major increases in affectation.	The *Engineering Design for Development* guide *encourages* the location of overland flow paths on roads (Section 4.3). The short catchment response times and lack of formal flood warning will also make evacuation problematic. It is therefore unrealistic to expect that properties will not become isolated, and that evacuation up a rising grade will be possible everywhere. While for new urban releases, the design of subdivisions should *ideally* include rising road access or overland escape route (without having to cross fences), providing shelter-in-place above the PMF in buildings able to withstand the forces of a PMF is an acceptable solution – arguably a preferred solution considering hazards on roads – given the short duration of flooding. And in the case of 'knock-down-and-rebuild' residential developments, it will often be impractical to provide evacuation routes, so there the priority should be for the replacement dwelling to provide for safe shelter-in-place. Council could consider having shelter requirements which are commensurate with the duration and hazard category of isolating floodwaters. The inclusion of this provision would require application for "exceptional circumstances".
4.13.8 Underground Car Parks Special consideration must be given to underground carparks and services adjoining roadways carrying major flows. These facilities must demonstrate that access and entry points are not affected by the 100 yr ARI flood. This includes ventilation openings, windows and access points. The following considerations will be evaluated for any proposal for underground car parking: Provision for safe and clearly sign posted flood free pedestrian escape routes for events in excess of the 100 yr ARI must be demonstrated separate to the vehicular	Section 4.5 of the *Engineering Design for Development* guide explicitly requires that the risk in a PMF (not just the 100 year ARI event) be managed, which is appropriate. This section should be amended for consistency with Section 4.5. If there is potential for rapid ingress of water to underground carparks, it is recommended that on-site alarm systems also be required to manage the risk to people. The evacuation of disabled persons from an underground carpark would likely require a lift with an uninterruptable power supply. But lifts also need to be configured so as not to descend into a basement that is being inundated.

Extract from Engineering Design for Development	Comment
access ramps; Consideration must also be given to evacuation of disabled persons; Pumpout systems must have at least 2 independent pumps each sized to satisfy the pumpout volumes individually; The two (2) pumps are to be designed to work in tandem to ensure that both pumps receive equal usage and neither pump remains continuously idle; The lip of the driveway must be located at or above the 100 yr ARI flood level; Any ramp down to an underground carpark must be covered to minimise rainwater intrusion; The basement parking area must be graded to fall to the sump; The pump-out system must be independent of any gravity stormwater lines except at the site boundary where a grated surface inlet pit is to be constructed providing connection to Council's road drainage system; and Engineering details and manufacturers specifications for the pumps, switching system and sump are to be submitted for approval prior to issue of the Construction Certificate.	Some areas of the flood prone land have a considerable flood height range between the PMF and 100 year ARI flood, which suggests that setting a driveway crest at a minimum of 100 year ARI (without freeboard) may provide inadequate protection of basement carparks located in such areas.
4.14.3 Sites Affected by Overland Flow Development sites that are impacted by overland flows from upstream catchments need to account for the following: The proposed development is not to have an adverse impact on adjoining properties through the diversion, concentration or damming of such flows; The proposed development is to accommodate the passage of overland flow through the site and where applicable is to be designed to withstand damage due to scour, debris or buoyancy forces so that the risk of incidental damage is minimised; The proposed development is not to be sited where flows will create a hazardous situation for future occupants in terms of depth and velocity of flows through the property;	It appears that this clause is aimed at ensuring development does not redirect overland flows into adjacent properties or is located where flows could be hazardous. It is not clear how this can be achieved if the land is below the level of the 1% AEP event and must be filled to the 1% level to satisfy Clause 4.5. Perhaps 'hazardous situation' needs to be defined. How a development applicant is meant to know about 'any future mitigation strategies' that the development needs to be compatible with is not clear.

Extract from Engineering Design for Development	Comment
Floor levels within the development are to be set to comply with the freeboard requirements as set out in Section 4.5; and The proposed development is compatible with any future mitigation strategies to be implemented by Council in terms of such overland flows.	

Table 31. Shape of possible flood/overland flow risk management matrix

Dev. controls	PMF inundation					Flood Planning Area excluding high hazard, flood storage and floodway					High hazard or flood storage in 1% AEP					Floodway in 1% AEP				
Land uses	CRI/ SEN	RES	COM / IND	REC	CON	CRI/ SEN	RES	COM / IND	REC	CON	CRI/ SEN	RES	COM / IND	REC	CON	CRI/ SEN	RES	COM / IND	REC	CON
Floor level							As per Codes SEPP and BCA (incl. for safe shelter-in-place)				Unsuitable for development					Unsuitable for development	Unsuitable for development	Unsuitable for development		
Building components																				
Structural soundness																				
Flood effects																				
Car parking/ driveway access																				
Evacuation/ shelter-in-place																				
Management and design																				

Land uses: CRI/SEN = critical infrastructure and sensitive uses; RES = residential; COM/IND = commercial/industrial; REC = recreation and rural; CON = concessional development

The preceding discussion highlights that there are opportunities to make flood risk management through planning controls more robust, consistent, unambiguous and easier to follow. This would require a significant reworking of both the CDCP 2015 and its accompanying engineering guide. It is recommended that Council undertake such a review and rewrite, taking into account the recommendations in the preceding section.

11.1.3 Voluntary House Raising

House raising involves placing jacks under an existing house and raising the floor to a higher level, usually at or above the FPL. This is only economically worthwhile if the avoided damage exceeds the cost of the house raising although the intangible benefits of reduced frequency of above floor flooding may also be another factor that is considered.

There is not a lot of data publically available on the costs of house raising in Australia. Data from OEH provides the level of subsidy which local government schemes provide for house raising but this is a reflection of what government is willing to pay rather than the true cost of house raising. Generally a payment of about $80,000 is made but inquiries indicate this may be based on actual costs of house raising in Fairfield LGA in the late 1990s.

Using this figure and inflating it by the rise in average weekly earnings between 1998 and 2016, it is estimated that house raising today would cost in the order of $154,000 today. If it is assumed that the building's life is 50 years, this equates to an annual payment of $11,130 per year at a discount rate of 7% (as per NSW Treasury Guidelines). In other words, the reduction in annual average damage (AAD) would have to exceed $11,130 for house raising to be economically worthwhile.

The OEH standard method for AAD calculation includes a cost of damage to items outside the home when the property begins to flood but above floor flooding has not commenced. House raising would not reduce this cost, and arguable could increase it if people use the additional space created below the house for storage. This has an AAD of about $2,332 when a property experiences above floor flooding in a 20% AEP flood.

When this is taken into account, only those properties which currently have average annual damages exceeding $13,468 would be worth raising. Analysis of the flood damages database for Campbelltown revealed there are no houses which satisfy this criterion. It is recommended that Campbelltown Council does not investigate a voluntary house raising scheme further.

11.1.4 Voluntary Purchase

The NSW Office of Environment and Heritage has provided guidelines for voluntary house raising schemes. It states:

"Assessing the viability of a VP scheme or an individual property for VP is part of a collective assessment of floodplain risk management options for the community when an FRMP is developed. The FRMP will be adopted by the council and should have considered:

- *flood hazard classification and associated risk to life*
- *hydraulic classification in relation to location in a floodway*
- *the benefits of floodway clearance to the flood-affected areas*
- *economic, social and environmental costs and benefits*
- *viability of the scope and scale of the scheme and how the scheme will be prioritised generally on the basis of degree of flood hazard exposure*
- *identification of each affected property and the buildings on them*
- *the support of the affected community for VP as determined through consultation with affected owners*
- *an implementation plan for the scheme."*

According to realestate.com.au the current median house price in Campbelltown is $651,000 (June 2018). A land valuation search was conducted on the Valuer General website (www.valuergeneral.nsw.gov.au) for one of the properties with frequent above floor flooding in Raby. The gross land value on 1 July 2016 (latest data available) was $332,000.

If it is assumed that the land would be worth that much to Council as open space (which it would not be) then the cost of the purchase would be a minimum of $319,000. For this to be recovered over 50 years, AAD would have to exceed $23,116. There are no properties in the study area with damages this high so it is unlikely that voluntary purchase could be economically justified as a means of reducing flood damages.

Furthermore, no properties have been identified by the modelling where there is a significant risk to life in events more frequent than the PMF.

Finally, no buildings have been identified which are in floodways or causing a significant blockage to floodways.

For these reasons it is recommended that voluntary purchase not be considered as an option within the BBBC catchment.

11.2 CATCHMENT-WIDE RESPONSE MODIFICATION OPTIONS

Flood response is contingent on three things:

- Knowing what flooding one is responding to;
- Knowing how to respond appropriately;
- Being capable of responding appropriately.

11.2.1 Flood Warning

The flood modelling and mapping undertaken by Council provides information about the possible extent and impacts of flooding. It is preferable for people to have specific information about the flood they are actually responding to. This is only possible with a flood forecasting system.

The Bureau of Meteorology is responsible for flood forecasting in Australia but does not provide a flood forecasting service where flood warning times are less than six hours. Even at the junction of Bunbury Curran Creek with the Georges River it is unlikely that there would be more than six hours warning of flooding coming from the top of the catchment. For this reason the Bureau of Meteorology will not provide flood forecasts.

The Bureau will provide severe weather warnings for the area generally and may warn of the chance of flash flooding. This, followed by the commencement of heavy rain is the only warnings which the area would currently get that flooding may be about to occur and there would be no indication as to how severe it might get.

Council could choose to install its own flash flood warning system in the catchment and the Bureau provides councils with guidance to do that. The long narrow shape of the catchment means that outside of the main channel of Bow Bowing/ Bunbury Curran Creek there would be less than 30 minutes between the commencement of rainfall and the commencement of flooding in the streets or along the side creeks. At the northern end of Bunbury Curran Creek it may be possible to get a few hours warning. However, the northern end of the floodplain is not where most of the risk to property and risk to people occurs. A council operated catchment wide flood warning system is not seen as a practical response modification option.

11.2.2 Emergency Response Plans

The NSW SES is the lead agency for response to flood events and accordingly has a local flood emergency response plan for Campbelltown LGA. At the time this Floodplain Risk Management Study was being prepared, the NSW SES had issued Volume 1 of the Campbelltown LGA Local Flood Plan (LFP) (NSW SES, 2015), while Volume 2, including a description of flood behaviour and possible impacts on communities, had not been completed.

The information in this study provides the NSW SES to complete Volume 2 with the most up to date flood information and make any necessary amendments to Volume 1 in light of that information and changes to their response strategies.

Businesses and households can also develop their own flood emergency response plans which are specific to their own circumstances to reduce the direct and indirect impacts of flooding on them. The NSW SES has produced templates to assist with this task and the information in this floodplain risk management study can also assist in the regard. Some property owners and occupiers may need to obtain more specific local flood data from Council.

11.2.3 Community Education

Most flood fatalities in Australia are caused by people voluntarily entering flood waters either by driving on flooded roads, walking through floodwaters or recreating in floodwaters. Some fatalities have been caused by people being caught unexpectedly by fast flowing and quickly rising floodwaters entering the buildings which they occupy.

While flooding will come up quickly in the study area, the flood depths and velocities in most residential areas are such that they do not pose a significant risk to people who stay indoors even in events exceeding the 1% AEP flood. There are some areas where risks are higher and these are highlighted in the hotspots in Section 3 and Section 10.

The NSW SES has flood education initiatives throughout NSW including campaigns advising people not to drive, walk or ride through floodwaters. The NSW SES stance is also to prefer evacuation in advance of a flood to get people out of the floodplain. However, it does acknowledge that where it is unsafe to evacuate it is better for people to remain in buildings. In most areas in the BBBC Creek catchment flooding is more hazardous in the streets than it is where buildings are situated across the full range of floods.

Because of short warning times and more hazardous flooding in streets it is neither safe nor practical to try and evacuate people from buildings in the BBBC Creek catchment during a flood. The short duration of the flooding, which varies between about two hours in the upper catchment and 5 hours in the lower catchment, also means that people will not be isolated in buildings for long.

It is recommended that the appropriate flood response throughout the BBBC Creek catchment is for people to shelter within buildings, preferably above the reach of floodwaters.

It is recommended that Council work with the NSW SES to reach consensus on that approach and develop and implement a community education strategy to encourage that response.

a) Equipping People

There are several ways in which Council can assist people to respond appropriately:

- Strategic planning and development controls which minimises the chance of above floor flooding in buildings will make people safer within buildings and discourage them to exit the building during a flood;
- Encouraging people with single storey homes which have a significant risk from above floor flooding to add a second storey would also give people a place to take refuge and discourage leaving buildings;
- Working with the NSW SES to encourage the preparation of household and business flood emergency response plans using NSW SES tools and templates;
- Provide information in community languages and through existing community networks to maximise the number of people reached.

It is recommended that all of the above be investigated in consultation with the NSW SES as part of an ongoing community flood response and education strategy.

PART D: DRAFT FLOODPLAIN RISK MANAGEMENT PLAN

12 Draft Floodplain Risk Management Plan

12.1 OBJECTIVE

The overall objective of the Bow Bowing Bunbury Curran (BBBC) Creek (FRMP) is to develop a long-term approach to flood and floodplain management in the BBBC catchment that addresses the existing and future flood risks in accordance with the general desires of the community and in line with the principles and guidelines laid out in the NSW *Floodplain Development Manual*.

This will ensure that the following broad needs are met:

- Reduce the flood hazard and risk to people and property, now and in the future; and
- Ensure floodplain risk management decisions integrate economic, environmental and social considerations.

12.2 RECOMMENDED MEASURES

The recommended measures for the FRMP have been selected from the suite of flood risk options introduced, discussed and evaluated in Section 10 (i.e. options applying to specific risk hotspots) and Section 11 (i.e. options applying to the whole catchment area). These options were shortlisted for detailed investigation in the FRMP after an assessment of their impact on flood risk, as well as consideration of economic, environmental and social factors. The recommended measures are summarised in Table 32 with flood modification measure locations shown in Map 61 (Vol. 2).

12.3 PLAN IMPLEMENTATION

12.3.1 Costs

The total capital cost of implementing the Plan to reduce risk to residential and commercial property is about $21M, comprised mainly of the stormwater upgrades in Ingleburn CBD ($13.5M) and in Campbelltown CBD (Farrow Rd and Dumaresq St) (~$7M). This would yield damage savings of at least $34M, resulting in an overall benefit-cost ratio of about 1.6. It would reduce the number of houses that the models shows as flooded above floor in the 100 year ARI flood by 15, and where there would still be AFF, the depth would be significantly reduced.

Also, there would be significant intangible benefits associated with the recommended flood modification options, as well as with the proposed amendments to planning instruments and development controls, emergency management planning and community flood awareness and readiness.

The redevelopment of most areas located along the railway line, planned under the Glenfield to Macarthur Urban Renewal Strategy (NSW Govt, 2015) will provide a further opportunity to acknowledge and address flood risk to future development.

It should be noted that even when the benefit to cost ratio analysis suggests that an option is economically viable, there may be significant practical difficulties in its implementation. These may include social or environmental impacts that are not considered in the benefit to cost ratio, because of their intangible nature. Table 32 lists the social and environmental impacts and implications for each option.

12.3.2 Resourcing

Plan implementation will be dependent on adequate resourcing of its implementation and maintenance. Resources may include financial and human resource and come from a number of sources. Potential contributors of resources include:

- Campbelltown City Council – financial resources from capital and operating budgets, staff time;
- NSW State Government – financial grants for investigations, mitigations works and programs, DPE and NSW SES staff time;
- Commonwealth Government – financial grants for investigations, mitigations works and programs;

- Developers – Building construction, Section 7.11 contributions for open space and drainage works;
- Property owners – building modifications
- Community – volunteer time.

12.4 PLAN MAINTENANCE

A FRMP plan is never truly finished. The BBBC Creek FRMP should be regarded as a dynamic instrument requiring review and modification over time. Catalysts for change could include flood events, revised flood modelling, better information about potential climate change flood impacts, social changes, legislative and planning changes or variations to the availability of funding. In any event, a thorough review every five years is warranted to ensure the ongoing relevance of the Plan.

It is envisaged that the Plan will be implemented progressively over a 5 to 10 year timeframe. The timing of the proposed works and measures will depend on the overall budgetary commitments of Council and the availability of funds from other sources.

Table 32. Summary of recommended flood risk reduction measures

Report Section	Floodplain Management Measures	Location	Responsibility	Initial Cost	Whole of Life Cost	Benefit to Cost Ratio	Resourcing	Feasibility	Social and Environmental Implications
	DETAILED INVESTIGATION FLOODPLAIN RISK MANAGEMENT STUDIES AND PLANS								
10.5	Detailed Investigation FRMSP - Campbelltown Locality	Campbelltown Locality	Council	-	-	-	A combination of Council funds with State and Federal Government Grants	Required to address any property with risk from flooding.	
10.5	Detailed Investigation FRMSP – Ingleburn Locality	Ingleburn Locality	Council	-	-	-	A combination of Council funds with State and Federal Government Grants	Required to address any property with risk from flooding.	
10.5	Detailed Investigation FRMSP – Glenfield/ Macquarie Fields	Glenfield/ Macquarie Fields Localities	Council	-	-	-	A combination of Council funds with State and Federal Government Grants	Required to address any property with risk from flooding.	
10.5	Detailed Investigation FRMSP – Minto McBarron Creek	Minto McBarron Creek Catchment	Council	-	-	-	A combination of Council funds with State and Federal Government Grants	Required to address any property with risk from flooding.	
10.5	Detailed Investigation FRMSP – Smiths Creek	Smiths Creek Catchment	Council	-	-	-	A combination of Council funds with State and Federal Government Grants	Required to address any property with risk from flooding.	
10.5	Detailed Investigation FRMSP – Birunji Creek	Birunji Creek Catchment	Council	-	-	-	A combination of Council funds with State and Federal Government Grants	Required to address any property with risk from flooding.	
10.5	Detailed Investigation FRMSP – Thompsons Creek	Thompsons Creek Catchment	Council	-	-	-	A combination of Council funds with State and Federal Government Grants	Required to address any property with risk from flooding.	
10.5	Detailed Investigation FRMSP – Upper Bow Bowing Creek	Upper Bow Bowing Creek Catchment	Council	-	-	-	A combination of Council funds with State and Federal Government Grants	Required to address any property with risk from flooding.	
10.5	Detailed Investigation FRMSP – Upper Bunbury Curran Creek	Upper Bunbury Curran Creek Catchment	Council	-	-	-	A combination of Council funds with State and Federal Government Grants	Required to address any property with risk from flooding.	
10.5	Detailed Investigation FRMSP – Claymore Locality	Claymore Locality	Council	-	-	-	A combination of Council funds with State and Federal Government Grants	Required to address any property with risk from flooding.	
10.5	Detailed Investigation FRMSP – Blairmount	Blairmount Locality	Council	-	-	-	A combination of Council funds with State and Federal Government Grants	Required to address any property with risk from flooding.	

Report Section	Floodplain Management Measures	Location	Responsibility	Initial Cost	Whole of Life Cost	Benefit to Cost Ratio	Resourcing	Feasibility	Social and Environmental Implications
	FLOOD MODIFICATION MEASURES								
10.2.2.b	Ingleburn CBD stormwater system upgrades	Ingleburn CBD (residential hotspot ID no. 2 and commercial hotspot 13)	Council	$13.4M	$50,000	1.74	Potentially a combination of Council funds, State and Federal Government grants, or developer S7.11 Contribution Plans	Subject to detailed engineering investigations and costings Location of underground services may affect feasibility and/or costs	In terms of social and environmental costs, the shortlisted flood modification option would cause some inconvenience during construction and maintenance operations. For instance, closing Norfolk St and Ingleburn Rd would have significant impact on the local traffic flows during construction. However, these impacts would be temporary and would be further reduced if the construction works were undertaken as part of the CBD redevelopment
10.2.3.b	Pipe capacity upgrades along the walkway between number 36 and 38 Epping Forest Dr, regrading of the walkway, speed hump on Epping Forest Dr	Epping Forest Dr, Kearns (residential hotspot ID no. 3)	Council	$117,500	$0	6.23	Potentially a combination of Council funds and State and Federal Government grants	Subject to detailed engineering investigations and costings	These options would cause only minor inconvenience during construction and maintenance operations, and these would be temporary. The proposed speed hump would have to be adequately designed to avoid or minimise any traffic disruptions. Social costs associated with the proposed flood modification options at this location are negligible and can be reduced if appropriate action is taken during design and construction. No environmental costs were identified.
10.2.17.b	Regrading terrain at rear of affected properties to relieve localised flooding and train flows towards the creek	Harrow Rd, Glenfield (residential hotspot ID no. 23)	Council	$98,000	$0	2.90	Potentially a combination of Council funds and State and Federal Government grants,	Subject to detailed engineering investigations and costings Location of underground services and private boundary fences may either limit the amount of achievable flow diversion or increase the cost of meeting the diversion modelled.	In terms of social costs, the shortlisted flood modification option would cause only minor inconvenience during construction operations, and these would be temporary. There are trees in area which has been identified as requiring regrading. Many of these are introduced species, but there are at least two eucalypts which are part of an ecological community classified as Cumberland Shale Plains Woodland. This is critically endangered under the Biodiversity Conservation Act (BC) NSW 2016 and the Commonwealth Environment Protection and Biodiversity Conservation Act (EPBC) 1999.
10.2.20	Fisher's Ghost Creek Mitigation	Campbelltown Locality	Council	n.a.	n.a.	n.a.	A combination of Council funds with State and Federal Government Grants	Fisher's Ghost Creek Mitigation	Campbelltown Locality

Report Section	Floodplain Management Measures	Location	Responsibility	Initial Cost	Whole of Life Cost	Benefit to Cost Ratio	Resourcing	Feasibility	Social and Environmental Implications
10.3.1.a	Assess the merits of upgraded stormwater system between Louise Ave and Aero Rd as part of the redevelopment of Glenfield to Macarthur Urban Renewal Corridor Strategy	Louise Ave, Ingleburn (commercial hotspot ID no. 1)	Council	Cost included in urban design investigations of precinct	included in costs of precinct redevelopment	n.a.	Potentially a combination of Council funds and developer S7.11 Contribution Plans		
10.3.2.a	Assess the merits of an increased cross fall at the driveways to the affected buildings in Blaxland Rd as part of the redevelopment of the area under the Glenfield to Macarthur Urban Renewal Corridor Strategy	Blaxland and Badgally Ave, Campbelltown (commercial hotspot ID no. 2)	Council	Cost included in urban design investigations of precinct	included in costs of precinct redevelopment	n.a.	Paid for by developers		
10.3.3.a	Upgraded stormwater system along Dumaresq St with new culvert under railway line and two new culverts discharging to Bow Bowing Creek	Farrow Rd & Dumaresq St, Campbelltown CBD (commercial hotspot ID no. 3)	Council	$7.3M	$21,900	1.33	Potentially a combination of Council funds and developer S7.11 Contribution Plans	Subject to detailed engineering investigations and costings Location of underground services may affect feasibility and/or costs	Only minor inconvenience during construction and maintenance operations, and these would be temporary. No significant environmental costs were identified.
10.4.2	Assess the merits of increasing capacity of culverts under the road and under the railway line	Menangle Rd	Council	$10,000	$0	n.a.	Council		When traffic data available need to compare costs of disruption with costs of solution
10.4.3	Assess the merits of increasing pipe capacity	Tindall St	Council	$10,000	$0	n.a.	Council		When traffic data available compare costs of disruption with costs of solution
10.4.4	Assess the merits of increasing pipe capacity	Appin Rd	Council	$10,000	$0	n.a.	Council		When traffic data available compare costs of disruption with costs of solution
10.4.5	Assess effects of recommended flood modification measures in Dumaresq St (commercial hotspot ID no. 2) on cut-off point in Oxley St. If insufficient, consider local pipe capacity upgrade.	Oxley St	Council	$10,000	$0	n.a.	Council		When traffic data available compare costs of disruption with costs of solution

Report Section	Floodplain Management Measures	Location	Responsibility	Initial Cost	Whole of Life Cost	Benefit to Cost Ratio	Resourcing	Feasibility	Social and Environmental Implications
10.4.6	Assess the merits of increasing local pipe capacity and/or an upstream detention basin	Collins Prom	Council	$10,000	$0	n.a.	Council		When traffic data available compare costs of disruption with costs of solution
10.4.7	Assess the merits of increasing pipe capacity	Pembroke Rd, south west of Westmoreland Rd	Council	$10,000	$0	n.a.	Council		When traffic data available compare costs of disruption with costs of solution
10.4.7	Assess the merits of increasing pipe capacity	Pembroke Rd, north of Ben Lomond Dr	Council	$10,000	$0	n.a.	Council		When traffic data available compare costs of disruption with costs of solution
10.4.7	Assess the merits of an upstream detention basin	Pembroke Rd, north of Derby St	Council	$10,000	$0	n.a.	Council		When traffic data available compare costs of disruption with costs of solution
	PROPERTY MODIFICATION MEASURES								
10	Acknowledge and address flood risk through redevelopment and development outside of high hazard zones where possible as part of Glenfield to Macarthur Urban Renewal Corridor Strategy	Residential Hotspots ID no. 2, 14, 15, 18, 19, 24. All Commercial Hotspots.	Council, Department of Planning and Environment	included in costs of precinct redevelop ment	$0	n.a.	Developers		The advantage of addressing flood risk with property modification as part of redevelopment to high rise buildings is that the associated costs are distributed across many property owners, making the benefit to cost ratio much greater than it would be in low rise dwellings.
10	Use locality specific development controls to reduce risk to life and property	Residential Hotspots ID no. 2, 14, 15, 18, 19, 24. All Commercial Hotspots.	Council	included in costs of precinct redevelop ment	$0	n.a.	Developers		
11.1.1.g	Find opportunities to reduce flood risks through redeveloping public housing, particularly for vulnerable residents.	Whole Catchment	Council, Land and Housing Corporation	included in costs of redevelop ment	$0	n.a.	Land and Housing Corporation		
11.1.c	Council undertakes a comprehensive review of the DCP (CDCP 2015) and the Engineering Design for Development	Whole Catchment	Council	$10,000	$0	n.a.	Council		

Report Section	Floodplain Management Measures	Location	Responsibility	Initial Cost	Whole of Life Cost	Benefit to Cost Ratio	Resourcing	Feasibility	Social and Environmental Implications
	with respect to flooding, as recommended in Section 11.								
11.1.2.a	Development Controls. Consider amending the LEP so that it makes provision for variable a FPLs as Defined in CDCP 2015. Apply for "exceptional circumstances" to ensure variable FPL is consistent with S117 Direction 4.3	Whole Catchment	Council	Included in cost of comprehen sive DCP review	$0	n.a.	Council	The DCP make reference to the use of variable freeboard in locations where Council has assessed the risk of lesser freeboard to be acceptable below the FPL	
	RESPONSE MODIFICATION MEASURES								
11.2.3	Council to work with the NSW SES to develop and implement a community education strategy to encourage appropriate responses.	Whole Catchment	Council and NSW SES	$50,000	$5,000 p.a.	n.a.	Council and NSW SES		
11.2.2	Council to work with the NSW SES to encourage the preparation of Emergency Response Plans for businesses and households where appropriate	Whole Catchment	Council and NSW SES	Included in cost of education strategy	$0	n.a.	Council and NSW SES		

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APPENDIX A - GLOSSARY AND ABBREVIATIONS

This Floodplain Risk Management Study utilises the terminology used in the NSW *Floodplain Development Manual* (2005). The following Glossary is drawn from that Manual.

Terminology	Meaning
Above Floor Flooding (AFF)	Refers to the flooding of properties above the floor level
acid sulphate soils	These are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid.
annual exceedance probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (i.e., a one-in-20 chance) of a 500 m^3/s or larger events occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
average annual damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
average recurrence interval (ARI)	The long-term average number of years between the occurrence of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
Average Weekly Earnings (AWE)	Average weekly earnings statistics represent average gross (before tax) earnings of employees and do not relate to average award rates nor to the earnings of the 'average person'. Estimates of average weekly earnings are derived by dividing estimates of weekly total earnings by estimates of number of employees.
BoM	Bureau of Meteorology
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
Consent authority	The council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the council, however legislation or an EPI may specify a Minister or public authority (other than a council), or the Director General of DPI, as having the function to determine an application.
Defined Flood Event (DFE)	The flood event selected for the management of flood

	hazard as determined by the appropriate authority. The DFE is typically the 1% AEP flood.
Development	Defined in Part 4 of the EP&A Act: Infill development: refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development New development: refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve re-zoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. Redevelopment: refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either re-zoning or major extensions to urban services.
Disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
Discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
EP&A Act	The Environmental Planning & Assessment Act, the principal planning legislation in NSW.
EPI	Environmental Planning Instrument – a generic term for the suite of planning documents specified under the Environmental Planning & Assessment ACT and includes State Environmental Planning Policies (SEPP), Local Environmental Plans (LEP) and Development Control Plans (DCP).
Ecologically Sustainable Development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act, 1993.
Effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective

	warning time is typically used to raise furniture, evacuate people and their possessions.
Emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
Flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
Flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
Flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves and their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
Flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
Flood hazard level (FHL)	The Flood Hazard Level (FHL) is defined as the DFE plus freeboard
Flood liable land	Is synonymous with flood prone land, i.e., land susceptible to flooding by the PMF event. Note that the term flood liable land covers the whole floodplain, not just that part below the FPL (see flood planning area).
Flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
Floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
Floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
Floodplain risk management plan	A management plan developed in accordance with the

	principles and guidelines in this manual. Usually includes both written and 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 by the SES.
Flood planning area (FPA)	The area of land below the FPL and thus subject to flood related development controls.
Flood planning levels (FPLs)	Are the combinations of flood levels and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans.
Flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
Flood prone land	Land susceptible to flooding by the PMF event. Flood prone land is synonymous with flood liable land.
Flood readiness	Readiness is an ability to react within the effective warning time. (see flood awareness)
Flood refuge	In an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks: Existing flood risk: the risk a community is exposed to as a result of its location on the floodplain. Future flood risk: the risk a community may be exposed to as a result of new development on the floodplain. Continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented.
Flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
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 a significant increase in flood levels.

Freeboard	It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc.
Habitable room	In a residential situation: a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom.
Hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Two levels of hazard are usually adopted in floodplain risk management planning: High hazard: possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty in wading to safety; potential for significant structural damage to buildings. Low hazard: should it be necessary, truck could evacuate people and their possessions; able-bodied adults would have little difficulty in wading to safety.
Hydraulics	The study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
Hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
Hydrology	The study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
Local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
Local drainage	Smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
Major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purposes of this study, major drainage involves: the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or water depths generally in excess of 0.3m (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 flowpaths through developed areas outside of defined drainage reserves; and/or the potential to affect a number of buildings along the major flow path.
Minor, moderate and major flooding	Both the SES and the BoM use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood: Minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. Moderate flooding: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered. Major flooding: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
Modification measures	Measures that modify either the flood or the property or the response to flooding. There are three generally recognised ways of managing floodplains to minimise the risk to people and to reduce flood losses: By modifying the response of the population at risk to better cope with a flood event (Response Modification); by modifying the behaviour of the flood itself (Flood Modification); and by modifying or removing existing properties and/or by imposing controls on property and infrastructure development (Property Modification).
Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically viable to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable maximum precipitation	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year,

	with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
Probability	A statistical measure of the expected chance of flooding (see AEP).
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In this context, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
SES	State Emergency Service
Stage	Equivalent to water level (both measured with reference to a specified datum).
Stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
Survey plan	A plan prepared by a registered surveyor.
Water surface profile	A graph showing the flood stage along a watercourse at a particular time.

APPENDIX B – FLOOD MODEL UPDATES

Catchment Simulation Solutions updated each of the eleven (11) TUFLOW models that were developed as part of the original flood studies for the Bow Bowing Bunbury Curran (BBBC) Creek catchment. The model updates were completed to better reflect contemporary catchment conditions.

The TUFLOW model updates included:

- **Topography**: The original TUFLOW models were developed from a range of topographic datasets dating as far back as 2003. Therefore, the TUFLOW models were updated to include more recent 2011 and 2013 LiDAR datasets to ensure a consistent and more contemporary topographic representation is provided across the catchment. However, it was necessary to "splice in" some older ALS information across areas where the newer data was not determined to be reliable (e.g., areas covered by shade cloth near Minto and Ingleburn). Design topography was also incorporated across some areas where significant topographic changes have occurred since 2011/2013 or will occur in the very near future (e.g., Minto and Claymore renewal areas).

- **Stormwater System**: The stormwater system across the full extent of the BBBC Creek catchment was updated based upon Council's most recent stormwater asset GIS layer (comprising approximately 20,000 stormwater pits and pipes).

- **Land Use**: To ensure the models were providing a reliable description of contemporary conditions it was necessary to update the land use information in the model (which informs Manning 's "n" roughness coefficients) to reflect changes that have occurred since the models were originally prepared. The updated land use information was prepared based upon 2015 aerial imagery provided by Council.

- **Bridge/Culvert Representation**: The original TUFLOW models used a 1-dimensional representation for bridges and culverts as well as weir flow across the roadways. However, this approach made it difficult to determine when and where roadways were overtopped during each design flood. Therefore, the representation of bridges and culverts were updated so that flow across each roadway could be represented in two-dimensions. This allows a better description of water depths across roadways when the capacity of the bridge/culvert is exceeded which, in turn, should provide better insight into evacuation/emergency response as part of the floodplain risk management study.

- **1D Channel Updates**: It was noted that there were some discontinuities in results along the boundary between the one-dimensional channels and the two-dimensional domain. Therefore, the one-dimensional channels were updated to include water level line points to ensure a more reliable description of topography was provided along the edge of one-dimensional channels. Some 1D channels were completely updated where extensive changes have occurred (e.g., realignment of the Bow Bowing Creek channel near freight rail line) or removed in areas where the new LiDAR information allowed the channels to be reliably defined in 2D (e.g., swale adjacent to Campbelltown Mall).

- **Flow Application**: It was noted that water was not being applied sufficiently high up each catchment to fully define overland flow behaviour in some areas. Therefore, the points at which flow hydrographs were applied to the model were updated across some areas. In addition, the models were modified to allow water from upstream models to be "fed" into the downstream models. This should help to ensure consistency in results near model boundaries and will better represent the cumulative storage across the BBBC Creek catchment (e.g., behind roadway embankments) that cannot be easily represented in the XP-RAFTS models.

- **Representation of Dams/Storage**: The terrain representation for some dams/water storage was also updated to provide a better description of the terrain below the water surface. The initial water levels within each storage were also updated in some instances so that all storages were "full" at the start of each simulation.

- **Miscellaneous Modifications**: Numerous other minor modifications were made to the models to improve model stability and minimise mass balance errors. A number of new hydraulic structures were included in the model (e.g., Farrow Road bridge) and blockage factors for all bridges and culverts were reviewed and updated, as necessary.

Each of the eleven updated TUFLOW models were subsequently used to re-simulate the 5 year, 20 year, 50 year, 100 year, 500 year and 1000 year ARI floods as well as the PMF for a range of storm durations. A range of sensitivity simulations were also completed to assess the impact of future runoff, future runoff with future filling as well as no blockage and complete blockage of pits, culverts and bridges.

Once each of the design storms was run through each of the 11 TUFLOW models, it was necessary to "assemble" the results into a single continuous results surface covering the full extent of the BBBC Creek catchment. As discussed above, flows from upstream TUFLOW models were "fed" into downstream models to ensure relatively consist results across common model areas (i.e., each of the models were setup to include overlapping model areas to provide an opportunity for upstream boundary conditions to stabilise before entering the study areas proper. As a result, some sections of the BBBC Ck catchment were represented in more than one of the models). The results across common model areas were reviewed and the individual results surfaces were "clipped" where model results were consistent (to ensure there were no discontinuities in the final results surfaces). The clipped results surfaces were subsequently combined to form a final combined results surface for each design flood.

APPENDIX C – DAMAGES ASSESSMENT

Available Data

The building database was created from a GIS layer containing building footprints within the PMF extent. In this layer, buildings were represented as polygons. Although for the purpose of assessing flood damages buildings can also be represented by points, the use of polygons was preferred for the following reasons:

- An initial polygon GIS layer was already available from the flood modelling;
- Potential for overland flows on sloping blocks, in which the up-hill side of the building could be exposed to a higher flood level than the down-hill side. This issue could only be represented accurately using polygons (Figure B1).

In addition to the initial GIS buildings layer, the following sources of information were used to generate the building database:

- A set of high resolution aerial images (2014) (https://maps.six.nsw.gov.au);
- Street level photography of specific buildings accessed via Google Street View;
- The 2011 and 2013 LiDAR surveys of the study area;
- GIS cadastral mapping;
- Local Environmental Plan (LEP) zoning maps;
- A GIS layer containing point features of certain 'vulnerable' land uses (e.g. schools, hospitals, aged care facilities);
- The Council's Development Application database, containing data from the year 1980 onwards.

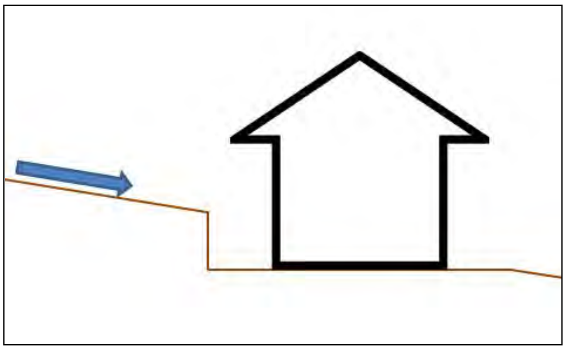

Figure B1. Overland flow affecting buildings on sloping blocks

When the initial GIS layer of building polygons was audited and compared with the cadastre data, the aerial images, and Google Street View, the following issues were identified:

- Some buildings were represented by duplicate polygons;
- Some polygons contained more than one dwelling (e.g. townhouses);
- Some of the most recently constructed buildings were not included;
- Some buildings had been demolished and rebuilt with a different shape/design;
- Some polygons were slightly inaccurate in shape and size;
- Apartment blocks were identified by a single polygon, but contained multiple units (i.e. dwellings) on different storeys;
- The GIS layer did not contain data on the number of storeys, building floor heights and building use, which are necessary to run the damage assessment calculations.

Amendments to the GIS Building Layer

The initial GIS building layer was edited to address the issues identified in the audit and obtain a dataset suitable for the damage assessment calculations. The following amendments were made:

- An assumption was made that polygons having an area smaller than 30 m^2 were not dwellings, but sheds and garages. The assumption was generally supported by visual inspection using Google Street View. All polygons having an area smaller than 30 m^2 were deleted.
- Duplicates of building polygons which were copies of the same building were identified and removed;
- Where the aerial photograph showed the proportions of the polygon were significantly inaccurate existing polygons were replaced with new polygons. It should be noted that the orthorectified aerial images may

contain localised inaccuracies exceeding 1m;

- Single building polygons which encompassed multiple dwellings were split into multiple polygons, so that each polygon corresponds to only one dwelling;
- Additional polygons were included with different floor levels and OEH floor level categories to represent units/apartments in multistorey buildings.

Creating the Building Database

To be able to undertake flood damage calculations, additional attributes needed to be assigned to each building. A list of additional attributes recorded for each building, together with an explanation of the derivation or source of those attributes, is provided in Table B1.

Building use

The building use (i.e. residential, industrial, commercial) was estimated initially from the LEP zoning. Aerial photography and Google Street View were then used to adjust the land use assigned to each building where building use differed from the zoning.

Council also provided a list of 'vulnerable' land uses including schools, hospitals and aged care facilities. A search was also made for emergency services facilities and police stations. These sources were used to fine-tune the nominated building use.

For non-residential land uses, the type of activity was split into one of six codes for the application of six different stage-damage curves:

- Commercial (CM) ;
- Industrial (I) ;
- Education Facilities (ED) ;
- Health Care (HC) ;
- Emergency Services Facilities (ES) ;
- Police Stations (PS).

The database included 25,114 buildings of which 21,151 are touched by floodwaters in the modelled Probable Maximum Flood (PMF), and as such are potentially directly affected by flooding. Of these, 19,697 are residential and 1,454 are non-residential.

It should be noted that buildings "touched" by the water were identified using the GIS to overlay the flood extents (obtained from the Flood Studies) and the building polygons. However, as a result of one of the assumptions made in the flood modelling exercise (Campbelltown City Council, 2009a), the flood extents layer contained no flood data where each building polygon was located. For this reason, each building polygon was buffered around its footprint by 0.5m so that the buffered area would overlap with the flood extent. If, even after buffering each building, no overlap with the flood extent was observed, the building was considered not affected by flooding.

Ground level

Ground levels vary across a site and it is important when undertaking flood damage assessments that the appropriate ground level is used. Because this study area involves significant areas of overland flow, flood levels around a building will vary depending on the underlying ground level.

For this study area, two ground levels were extracted from the LiDAR dataset for each building: a median ground level and a maximum ground level.

The median ground level within a building footprint was used when estimating the number of storeys while the maximum ground level was used when estimating the building floor levels. In part of the buildings, the estimate of the floor level was confirmed with field surveys.

Number of storeys

The number of storeys was estimated through an analysis of the raw LiDAR dataset, which contains the roof levels of each building. Following sampling, all buildings whose median roof level was less than 5m above the median ground level were assumed to have only one storey, while buildings higher than 5m were assumed to be multi-storey.

For dwellings that post-dated the LiDAR dataset, the number of storeys was populated using a database of Council's Development Applications (DA).

A sample of dwellings was inspected using Google Street View, supporting this approach.

Table B1 – Attributes recorded in building database

Attribute	Source/Comment
Unique Identifier	Attributed arbitrarily
Address	Council
Zoning	Council
Building use (residential, commercial, industrial, health care, education, emergency services)	LEP, Council's vulnerable uses dataset, aerial imagery, Google Street View
Number of storeys	LiDAR, Council's Development Application database
Ground level (m AHD)	1m Digital Elevation Model (DEM) used for the TUFLOW flood modelling
Floor level (m AHD)	Residential: floor heights based on average age of subdivision (supplied by Council) Industrial: floor level assumed to be at ground level Commercial, education, health care, emergency services, police stations : Google Street View survey
Floor area (m^2)	Calculated within GIS
Design flood levels (AEP = 20%, 5%, 2%, 1%, 0.2%, 0.1%, PMF)	Flood Study, extracting the maximum flood level within each building polygon buffered by 0.5m

Floor levels

Building floor levels were estimated by adding an estimated height above ground level to the maximum ground level within the building footprint. The maximum ground level was used because in most instances the ground floor would be built at or above this height. The exception would be where a building has been cut into the landscape and its walls retain soil or rock. Such instances would be rare in the BBBC Creek catchment.

Building floor heights were estimated as follows:

- **Residential buildings**. Heights were estimated based on the age of subdivision. For subdivisions from the 1970s or earlier, estimated floor heights were 0.3m above ground level based on the assumption that these buildings would in most cases be built on pier and beam. For more recent subdivisions (post-1970s), the estimated floor heights were 0.15m (assuming these would be built on a slab on ground, and in accordance with the requirements of the Building Code of Australia). Council supplied a GIS layer showing the age of subdivisions. Some older areas undergoing urban renewal or intensification are known to have a mix of building styles. In some such streets, individual floor heights were inspected and adjusted from the global assumptions using Google Street View;
- **Industrial buildings**. Floor heights were assumed to be 0.0m based on the observation that many industrial buildings are built to enable vehicles to drive into the building for loading and unloading, which is compliant with the Building Code of Australia;
- **Commercial buildings**. Floor heights were assumed to be 0.1m based on a sample from Google Street View and the knowledge that most shops are built so that it is not necessary to step up more than one step from the footpath into the shop;
- **Education buildings**. Floor heights were assumed to be 0.3m based on a sample from Google Street View;
- **Health care buildings**. Floor heights were assumed to be 0.1m based on a sample from Google Street View.

Disclaimer: It is important to note that a floor survey was undertaken only for part of the buildings. The assumptions made are reasonable and rational. However, there will be instances where floor height assumptions are incorrect and the findings of this study with respect to these individual dwellings may not be correct. For instance, errors in overlaying buildings and flood extent may have arisen from inherent inaccuracies in the orthorectified aerial images.

Dwelling categories

NSW OEH's method for assessing residential flood damages requires houses to be split into three categories for the application of three different stage-damage curves:

- Single story high-set (coded '1' in the building database) these have floor levels more than 1.5m above ground level;
- Single storey low-set/slab-on-ground (coded '2') ;
- Two storey (coded '3').

Using the assumed floor heights above, no residential buildings in the BBBC Creek catchment would be classified as being high set. However, it was recognised that residential apartments need to be counted as individual dwellings in the damage assessment, recognising those above the ground floor need to be treated differently to those on the ground floor.

For this damage assessment residential dwellings in apartment blocks located at the first floor (above the ground floor) and above were classified as single storey high set (coded '1'). The first floor units were assumed to have a floor level 2.6m above the ground floor level and each subsequent floor was assumed to be 2.6m higher again.

Multistorey buildings were identified using the method outlined in Section 2.3.3 and Category 1 buildings were distinguished from category 3 buildings using aerial photography and using Google Street View focussing particularly on unit blocks.

Floor areas

Floor areas for each building were calculated using a dedicated GIS function applied to the building polygons.

For residential damage calculations an average floor area of 153m^2 was used based on the average across the entire data set of residential dwellings. This is a required input to the NSW OEH residential damages spreadsheet.

For the non-residential buildings the actual floor area of each building was calculated and assigned to each building within the database because the assessment of non-residential damages multiplies damages per square metre by the ground floor building area.

Input Parameters for Damages Calculations

This section provides a rationale for the selection of in the input parameters required by the NSW OEH residential damages spreadsheet. The selected parameters are summarised in Table B2.

Buildings

- **Regional cost variation factor**. The BBBC Creek catchment was assumed to be part of the Sydney metropolitan area and therefore a value of 1 was adopted;
- **Post late 2001 Adjustment.** This value was calculated as the May 2016 AWE of 1160.2 (all employees average weekly total earnings) divided by the November 2001 AWE of 673.6 (both of which were taken from the ABS website in 2017). The value obtained is 1.72. (We note that the OEH spreadsheet has a November 2001 value of 676.4. If this value were used it would have given an adjustment factor of 1.71, which is not significantly different to the value adopted). More recent AWE estimates were not available in March 2017 when the damage calculations were undertaken;
- **Post Flood Inflation Factor.** This factor results from the cost of house repairs (not contents) being significantly higher than predicted by insurance assessors (DECC, 2007a). We selected the factor value recommended by OEH for medium scale impacts in a regional city, given the depths of inundation are unlikely to cause significant structural damage;
- **Typical duration of immersion.** This value would vary based on the size of the flood and the location of the dwelling in the landscape, however in the worst case scenario the duration is unlikely to exceed 3 hours, and would be generally shorter. We note that this value does not affect directly the calculations, but is used as a reference to determine building and contents damage repair limitation factors;
- **Building damage repair limitation factor.** OEH's suggested range is 0.85 (for short immersion time) to 1.00 (for long immersion time). Based on the assumption that duration is unlikely to exceed 3 hours, the lower range limit was adopted;
- **Typical House Size.** The average house size was obtained as an average value of all the dwellings within the extent of flood prone area.

Contents

- **Average Contents Relevant to Site.** The recommended average contents value from the spreadsheet was adopted. While it is acknowledged that the standard contents stage-damage curves may under-report damage to contents given an increasing use of technology in houses, they were adopted in this study without modification because no better estimates were available;
- **Contents Damage Repair Limitation Factor.** The OEH suggested range is 0.75 (for short immersion time) to 1.00 (for long immersion time). Based on the assumption that duration is unlikely to exceed 3 hours, the lower range limit was adopted;
- **Level of flood awareness.** A low flood awareness is assumed as per the OEH guideline;
- **Effective warning time.** Given the flashiness of inundation in the catchment, zero effective warning time is assumed;

- **Typical table bench heights.** 0.9 metres is the adopted typical table bench height.

Table B2 - OEH input values used for all flood ranges and dwelling sizes

Input Field	Input values	Source
Regional cost variation factor	1.00	DECC, 2007a
Post late 2001 adjustments	1.72	Calculated using data from ABS (accessed in 2017)
Post-flood inflation factor	1.20	DECC, 2007a
Typical duration of immersion	< 3 hours	Estimated based on Flood Studies
Building damage repair limitation factor	0.85	DECC, 2007a
Typical House Size	153 sq.m.	Calculated
Average Contents Relevant to Site	$38,250	DECC, 2007a
Contents damage repair limitation factor	0.75	DECC, 2007a
Level of flood awareness	Low	DECC, 2007a
Effective warning time	0 hours	Estimated based on Flood Studies
Typical table bench height	0.90	DECC, 2007a
External damage	$6,700 in 2001 $, equivalent to $11,540 in 2016 $	DECC, 2007a
Clean Up Costs	$4,000 in 2001 $, equivalent to $6,890 in 2016 $	DECC, 2007a
Likely time in alternative accommodation	2 weeks	Estimated based upon the immersion, clean up and recovery times
Additional accommodation costs	$220/week in 2001 $, equivalent to $379 in 2016$	DECC, 2007a
Up to second floor level	2.6m	NSW Department of Planning and Infrastructure (2013)
From second storey up	2.6m	NSW Department of Planning and Infrastructure (2013)
Flood depth adjustment factor (up to second storey)	70% for two storey house where second storey not flooded	DECC, 2007a
Flood depth adjustment factor(from second storey up)	115% for two storey house where second storey flooded	DECC, 2007a

Additional Factors

- **External damage.** The guideline value of $6,700 (2001 value) was used. The spreadsheet inflates this to 2016 dollars ($11,540) based on changes in AWE;
- **Clean-up costs.** The guideline value of $4,000 was used (2001 value). The spreadsheet inflates this to 2016 dollars ($6,890) based on changes in AWE;
- **Likely time in alternative accommodation.** Given typically shallow inundation, dwellings are unlikely to be uninhabitable for a prolonged period following the flood. A period of two weeks has been adopted;
- **Additional accommodation costs /loss of Rent.** The guideline value of $220 per week was used (2001 value). The spreadsheet inflates this to 2016 dollars ($379 per week) based on changes in AWE.

Two Storey House Building & Contents Factors

- **Second storey floor level.** The standard floor level of a second storey was assumed to be 2.6 metres. For additional storeys we have assumed 2.6m;
- **Flood depth adjustment factors.** The OEH guideline and spreadsheet recommend different factors to be applied to two storey houses, depending upon whether or not the water overtops the second storey. It recommends that 70% be used if the water is below the first floor level and 115% if it is above. Alternative values cannot be justified, so the recommended values are used.

APPENDIX D- VULNERABLE BUILDINGS WITH POSSIBLE ABOVE FLOOR FLOODING

MSID1	Land Use Type	Facility Name	Facility Address	Suburb	Depth of Flooding Above Floor (m)						
					20%	5%	2%	1%	0.5%	0.2%	PMF
ELECTRICTY SUBSTATION											
5975	CM	Lot 12	Victoria Road	MINTO 2566	N.A.	N.A.	N.A.	N.A.	0.2	0.4	4.0
5976	CM	Lot 12	Victoria Road	MINTO 2566	N.A.	N.A.	N.A.	N.A.	0.1	0.3	3.9
EDUCATIONAL INSTITUTIONS											
18794	ED	Amber Cottage Child Care Centre	55 Crispsparkle Drive	AMBARVALE 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.2
19112	ED	Amber Cottage Child Care Centre	55 Crispsparkle Drive	AMBARVALE 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.4
15237	ED	Approved - not constructed	58 Chamberlain Street	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	<0.1
17380	ED	Beverley Park Special School	98 Beverley Road	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.2
17376	ED	Beverley Park Special School	98 Beverley Road	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	<0.1
17377	ED	Beverley Park Special School	98 Beverley Road	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	<0.1
17378	ED	Beverley Park Special School	98 Beverley Road	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	<0.1
16204	ED	Bradbury Public School	Jacaranda Avenue	BRADBURY 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.7
17257	ED	Broughton Street Early Learning Centre	70 Broughton Street	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.3
14479	ED	Campbelltown Performing Arts High School	90 Beverley Rd	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.1
15498	ED	Campbelltown Performing Arts High School	90 Beverley Rd	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.4

17935	ED	Campbelltown Public School	31 Lithgow Street	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.2
17936	ED	Campbelltown Public School	31 Lithgow Street	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.2
17934	ED	Campbelltown Public School	31 Lithgow Street	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.3
17941	ED	Campbelltown Public School	31 Lithgow Street	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.5
13919	ED	Claymore Public School	25 Dobell Road	CLAYMORE 2559	N.A.	N.A.	<0.1	<0.1	0.3	0.3	1.1
13780	ED	Claymore Youth Centre	17 Dobell Road	CLAYMORE 2559	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.6
15060	ED	Community Kids Leumeah Early Education Centre	6 Hughes Street	LEUMEAH 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.5
3447	ED	Eschol Park Public School	Eschol Park Drive	ESCHOL PARK 2558	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	<0.1
19489	ED	Eschol Park Public School	Eschol Park Drive	ESCHOL PARK 2558	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	<0.1
6307	ED	Kabbarli Early Learning Centre	32 Guernsey Avenue	MINTO 2566	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	<0.1
18234	ED	Kids Tech Campbelltown College of TAFE	181 Narellan Road	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.1
2539	ED	KU Coomaling Mobile Preschool	St Andrews Community Centre, 74 Stranraer Drive	ST ANDREWS 2566	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.3
2540	ED	KU Coomaling Mobile Preschool	St Andrews Community Centre, 74 Stranraer Drive	ST ANDREWS 2566	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.4
7117	ED	Leumeah Public School	4 Burrendong Road	LEUMEAH 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.2
7115	ED	Leumeah Public School	4 Burrendong Road	LEUMEAH 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	<0.1
16893	ED	Little Leaders Early Learning Centre	19 Hoddle Avenue	BRADBURY 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	<0.1

17947	ED	Namut Occassional Child Care Centre	5 Hurley Street	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.2
6173	ED	Passfield Park Special School	53 Guernsey Avenue	MINTO 2566	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.1
6165	ED	Passfield Park Special School	53 Guernsey Avenue	MINTO 2566	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	<0.1
6166	ED	Passfield Park Special School	53 Guernsey Avenue	MINTO 2566	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	<0.1
6172	ED	Passfield Park Special School	53 Guernsey Avenue	MINTO 2566	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	<0.1
1056	ED	Pt Lot	63 Narellan Road	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.6
5027	ED	Rainbow Family Centre for Children	34-36 Cudgegong Road	RUSE 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.1
19467	ED	Robert Townson Public School	15 Shuttleworth Avenue	RABY 2566	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.2
2553	ED	St Andrews Childrens Neighbourhood Centre	87 Ballantrae Drive	ST ANDREWS 2566	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.3
2629	ED	St Andrews Public School	89 Ballantrae Drive	ST ANDREWS 2566	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.1
2640	ED	St Andrews Public School	89 Ballantrae Drive	ST ANDREWS 2566	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.2
2633	ED	St Andrews Public School	89 Ballantrae Drive	ST ANDREWS 2566	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.2
2628	ED	St Andrews Public School	89 Ballantrae Drive	ST ANDREWS 2566	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.3
2634	ED	St Andrews Public School	89 Ballantrae Drive	ST ANDREWS 2566	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.3
2478	ED	St Andrews Public School	89 Ballantrae Drive	ST ANDREWS 2566	N.A.	N.A.	N.A.	N.A.	<0.1	<0.1	0.4
2636	ED	St Andrews Public School	89 Ballantrae Drive	ST ANDREWS 2566	N.A.	N.A.	N.A.	N.A.	<0.1	<0.1	0.4
2632	ED	St Andrews Public School	89 Ballantrae Drive	ST ANDREWS 2566	<0.1	0.1	0.2	0.2	0.2	0.3	0.6
2635	ED	St Andrews Public School	89 Ballantrae Drive	ST ANDREWS 2566	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	<0.1
2637	ED	St Andrews Public School	89 Ballantrae Drive	ST ANDREWS 2566	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	<0.1

2638	ED	St Andrews Public School	89 Ballantrae Drive	ST ANDREWS 2566	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	<0.1
19228	ED	St Peter's Anglican Primary School	5 Howe Street	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	<0.1
5394	ED	St Thomas More Catholic Primary School	6 St Johns Road	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.1
5665	ED	St Thomas More Catholic Primary School	6 St Johns Road	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.2
5396	ED	St Thomas More Catholic Primary School	6 St Johns Road	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	<0.1
17594	ED	The Cottage Family care Centre	Oxley Street	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.8
19150	ED	Thomas Reddall High School	Woodhouse Drive	AMBARVALE 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.2
19153	ED	Thomas Reddall High School	Woodhouse Drive	AMBARVALE 2560	N.A.	N.A.	N.A.	N.A.	<0.1	<0.1	0.3
19151	ED	Thomas Reddall High School	Woodhouse Drive	AMBARVALE 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.4
18201	ED	Thomas Reddall High School	Woodhouse Drive	AMBARVALE 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.5
18199	ED	Thomas Reddall High School	Woodhouse Drive	AMBARVALE 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	<0.1
1054	ED	Unique Kids Early Childhood Centre	38 Goldsmith Avenue	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	1.0
EMERGENCY SERVICES											
15724	ES	Campbelltown Fire Station	66 Broughton Street	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	<0.1
18370	ES	Campbelltown Hospital	Therry Road	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.4
20715	ES	NSW SES Campbelltown Unit	18 Alderney Street	MINTO 2566	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	<0.1
HEALTH CARE FACILITIES											
18363	HC	Campbelltown Hospital*	Therry Road	CAMPBELLTOWN 2560	N.A.	<0.1	<0.1	<0.1	<0.1	<0.1	0.2

18361	HC	Campbelltown Hospital*	Therry Road	CAMPBELLTOWN 2560	<0.1	<0.1	<0.1	<0.1	0.1	0.1	0.2
18368	HC	Campbelltown Hospital*	Therry Road	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.3
18362	HC	Campbelltown Hospital*	Therry Road	CAMPBELLTOWN 2560	N.A.	0.1	0.1	0.1	0.2	0.2	0.4
18365	HC	Campbelltown Hospital*	Therry Road	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	<0.1	<0.1	0.4
18364	HC	Campbelltown Hospital*	Therry Road	CAMPBELLTOWN 2560	0.1	0.1	0.2	0.2	0.2	0.3	0.6
18371	HC	Campbelltown Hospital*	Therry Road	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	1.0
18358	HC	Campbelltown Hospital*	Therry Road	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	<0.1	<0.1	<0.1	<0.1
18042	HC	Campbelltown Private Hospital	42 Parkside Crescent	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.1
10915	HC	Frank Whiddon Masonic Homes	81 Belmont Road	GLENFIELD 2167	0.1	0.1	0.1	0.1	0.1	0.1	0.1
POLICE STATIONS											
15566	PS	Campbelltown Police Station	65 Queen St	CAMPBELLTOWN 2560	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.3
3417	PS	Eagle Vale Police Station	Gould and Feldspar Road	EAGLE VALE 2558	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.2
11855	PS	Macquarie Fields Police Station	10 Brooks Street	MACQUARIE FIELDS 2564	N.A.	N.A.	N.A.	0.1	0.1	0.1	0.1

* Only a part of Campbelltown Hospital's private drainage system was included in the flood model. As such, results may overestimate flood risk at this location.

APPENDIX E - FLOOD MODIFICATION OPTIONS

Note / Memo

Haskoning Australia PTY Ltd.
Maritime & Aviation

To:	Dr Filippo Dall'Osso (Molino Stewart)
From:	Caleb Dykman
Date:	23 May 2018
Reviewed	Nick Lewis & Ben Patterson
Copy:	Steven Molino (Molino Stewart); Ben Patterson (RHDHV); Nick Lewis (RHDHV)
Our reference:	PA1707
Classification:	Project related

Subject: **Campbelltown Floodplain Risk Management Study and Plan Preparation**

1 Introduction

1.1 Overview

Molino Stewart engaged Royal HaskoningDHV (RHDHV) to provide engineering input, for seven (7) flood mitigation options identified within the Campbelltown Local Government Area (LGA), as part of the Campbelltown Floodplain Risk Management Study and Plan (FRMS&P), currently being prepared by Molino Stewart. This memo should be read in conjunction with the FRMS&P.

A summary table of the contents of this memo is provided in **Table 15** on page 56.

1.2 Background

Campbelltown City Council (Council) commissioned Molino Stewart to undertake the preparation of a Floodplain Risk Management Study and Plan (FRMS&P) of the Campbelltown Local Government Area (LGA) and requires RHDHV to develop concept designs for options identified to mitigate flooding 'hot spots'. It is understood that Catchment Simulation Solutions were engaged to undertake the Hydrologic and Hydraulic modelling of the catchment.

The seven (7) proposed flood mitigation options incorporate a number of different components including stormwater pits and pipes upgrades, detention basins, regrading and flow diversions. An outline of each of the proposed options is presented below in **Table 1** and their respective locations in **Figure 1**.

Table 1: Flood Mitigation Options Overview

Option	Description
Option 1 - Oxford Road Upgrade	Upgrades to the stormwater system from Oxford Road, down Pardalote St, through Koala Walk Reserve to a discharge location downstream of Aubrey Street, Ingleburn.
Option 2 – Ingleburn Stormwater Upgrades	Filling in of an existing open channel between Cumberland Road and Palmer Street and replacing with box culverts that connect into the existing trunk drainage line. Further box culverts are proposed along Ingleburn Road between Suffolk Street and Norfolk Street, and Norfolk Street and the Macquarie Road intersection respectively.
Option 3 – Manooka Reserve Basin	Formalising of a detention basin at Manooka Reserve and increasing of pipe capacities upstream. Speed humps are proposed along The Parkway

	to divert flows to the basin. Additional pipe upgrades are proposed downstream on Campbellfield Avenue and Greenoaks Avenue to relieve flooding in local sag locations.
Option 4 – Epping Forest Drive	Introduction of a speed hump along Epping Forest Drive and regrading of the road surface and a nearby walkway to divert flows into Vale Brooke Reserve.
Option 5 – Harrow Road	Regrading at the rear of properties backing onto the Bunbury Curran Creek to Relieve localised flooding.
Option 6 – Sopwith Avenue & Spitfire Drive	Introduction of a new pipe between Kittyhawk Crescent and Harrier Avenue and duplication of an existing pipe downstream to Kittyhawk Crescent. A surcharge pit is to be added to the Raby Shopping Centre carpark. A detention basin is to be formalised at Sopwith Park with additional pits and pumps inserted into the basin and a new outlet pipe.
Option 7 – Dumaresq Street Drainage	Box culverts are proposed along the alignment of Dumaresq Street from Oxley Street to Hurley Street and continuing under the Railway embankment where they discharge into the Bow Bowing Creek Channel.

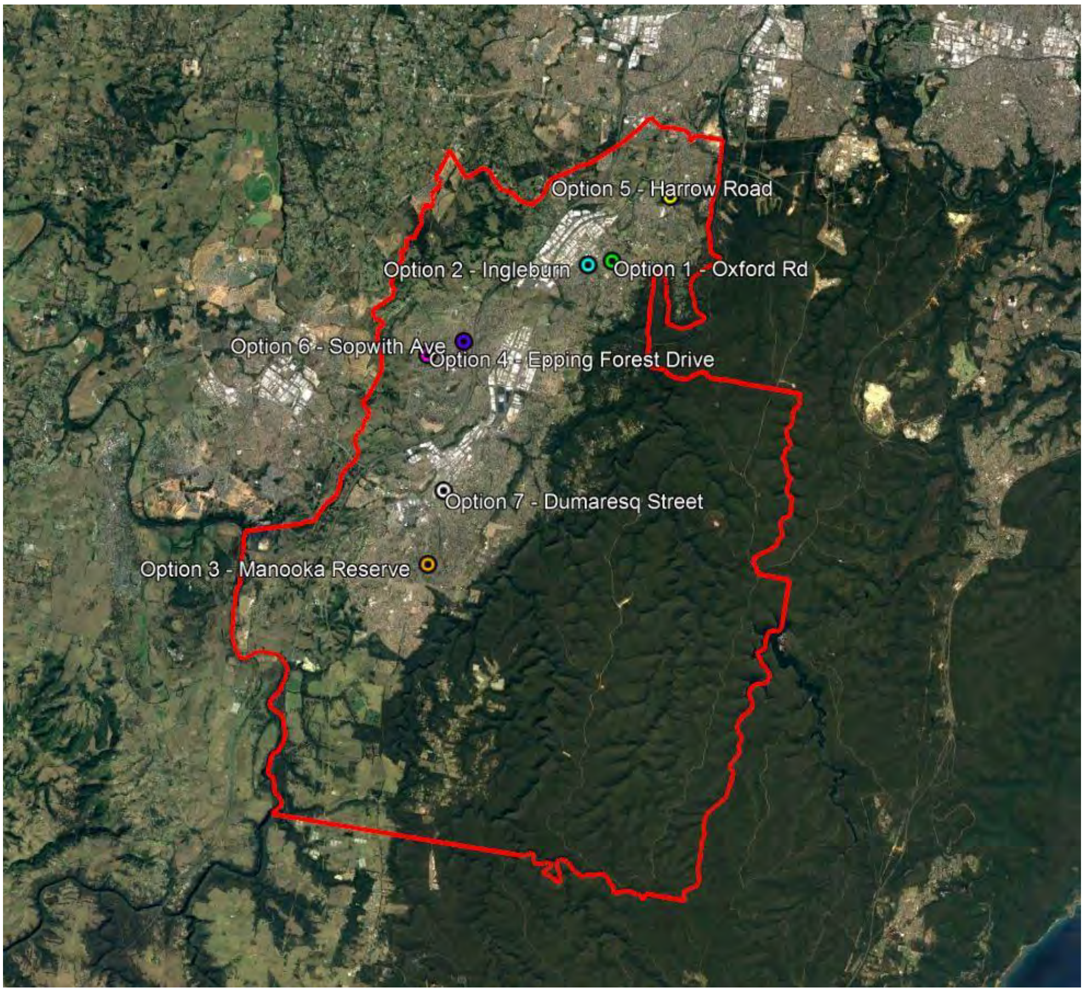

Figure 1: Overview of Option Locations; Campbelltown LGA Boundary Shown in Red (Aerial Source: Google Earth 2016)

1.3 Methodology

In preparing the engineering input documented in this memo the methodology outlined below in **Table 2** has been employed.

Table 2: Methodology

Section	Methodology
Services	Existing services assets relevant to the proposed flood mitigation options were determined by obtaining and reviewing Dial Before You Dig plans and confirming locations where possible during site inspection. An outline of the services likely to be present is detailed and excerpts of the DBYD for gas and water/sewer mains, which represent the service assets that are most commonly difficult to relocate are provided.
Concept Design	Concept level designs were developed based on the provided model input files and detailed further based on RHDHV's engineering judgement, professional experience and best practice engineering design. Concept designs were developed to a high level to assess feasibility and develop preliminary costings and should not be taken further without undertaking further investigations .For concept design sketches of each of the proposed options please refer to **Appendix A**.
Health & Safety	Health & safety considerations associated with the implementation of the proposed options were highlighted based on what RHDHV believed to be potential impacts that could pose a risk to the public and environment.
Operation & Maintenance	Operation & maintenance considerations were determined with regard to the elements of the proposed options and what RHDHV believed to be necessary actions required for standard operation.
Cost	Estimated costs for the implementation of proposed flood mitigation options are based on the application of RHDHV's engineering judgement and professional experience, in conjunction with resources such as Rawlinson's Australian Construction Handbook (2018). Reflecting the stage of development (concept), a 30% contingency has been applied to the final value of all cost estimates .For detailed cost estimates of each of the proposed options please refer to **Appendix B.** Whole of life costs are estimated based on the assumed operation and maintenance requirements of each option applied over a 50 year design. Present value figures were calculated using a rate of inflation of 7% and assumed that the provided rates would be paid at the end of each period.
Feasibility	Potential issues regarding the overall feasibility of the proposed options were flagged by RHDHV where they were considered to pose a risk to any further development of an option or where conflicts with engineering guidelines and standards were apparent. Issues that were deemed irreconcilable were highlighted as 'red flags'.
Data Gaps	Data gaps were highlighted based on experience gained by RHDHV in undertaking a multitude of detailed design projects.

2 Flood Mitigation Options

2.1 Option 1 – Oxford Road Upgrade

2.1.1 Description & Intended Hydraulic Performance

The aim of this option is to relieve flooding at properties between Oxford Road and Kookaburra Street and along Wonga Place, as well as properties downstream of Koala Walk Reserve. Currently, water flows North West along the alignment of Oxford Road (both in pipes and overland) from approximately Wood Crest Avenue to a local depression in line with Wonga Place. Water then flows perpendicular to Oxford Road, along a local depression, through several properties between Oxford Road and Kookaburra Street and subsequently along Wonga Place, toward Koala Walk Reserve.

The objective of this option is to disconnect existing pipe connections along Oxford Road between Pardalote Street and a private driveway north west of no. 130 Oxford Road and redirect flow along Pardalote Street, via new and upgraded stormwater pipes, to Koala Walk Reserve (refer **Figure 2**).

Once at Koala Walk Reserve, flood waters currently inundate properties along the North West boundary of the reserve. As such the reserve is to be raised in the Western corner to train flows into upgraded stormwater pits and pipes, which convey flows to a discharge location downstream of Aubrey Street.

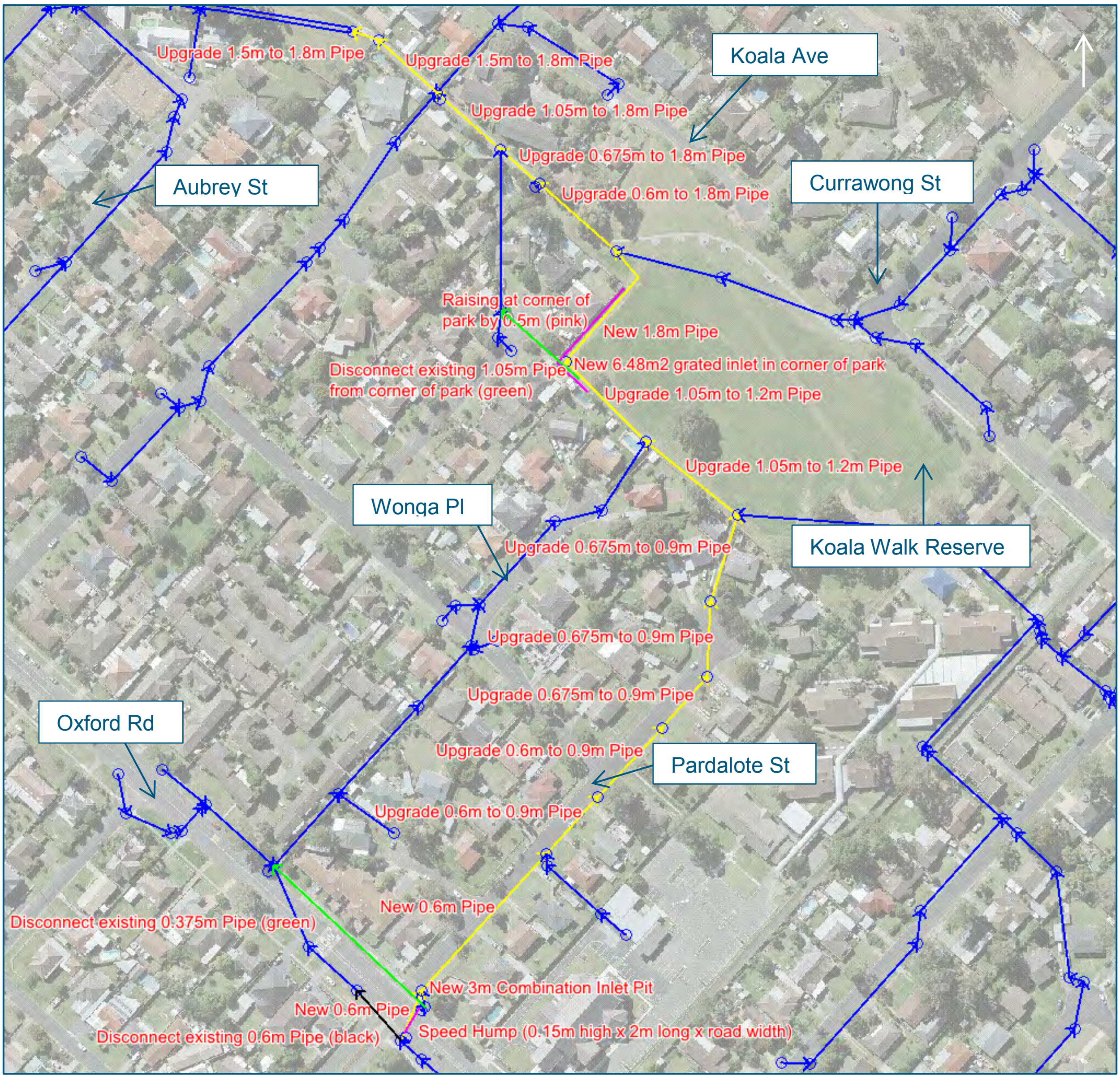

Figure 2: Schematised Overview of Option 1

2.1.2 Existing Services Locations

Several services exist along the alignment of the proposed upgrade works, particularly along Pardalote Street. Noteworthy services present include:

- Underground Endeavour Energy assets exist along the southern side of Pardalote Street continuing to the footpath at the end of the street, which leads to Koala Walk Reserve. There are also several street lights present along the alignment of this asset.
- A Ø110mm, 210 kPa Jemena gas network main exists along the northern side of Oxford Road, approximately 1m from the boundary lines at the entry to Pardalote Street (refer **Figure 4**).
- NBN assets exist along the entire length of Pardalote Street and continue to Koala Walk Reserve. Another asset travels from the western corner of Currawong Street through Koala Walk Reserve and along the alignment of the footpath behind Koala Avenue.

- A Ø100mm cast iron cement lined (CICL) Sydney Water Corporation main exists along the length of Pardalote Street, travelling along the southern side of the road and terminating at no.12 Pardalote Street (refer **Figure 4**).
- A Ø150mm vitrified clay (VC) Sydney Water Corporation sewer main follows an alignment similar to the existing stormwater network to be upgraded. (i.e. along Pardalote Street, then the southern boundary of Koala Walk reserve, across Jacana Place, and along the footpath; refer **Figure 4**).
- A PIPE networks duct, containing Telecommunications assets, exists along the southern side of Pardalote Street, fronting property no.'s 1-13, wherein it travel along the footpath between no.'s 13 and 15 Pardalote Street.

Given that stormwater pipes already exist along the alignment of Pardalote Street and are being replaced rather than a new network branch being installed, and that for the most part the increases in pipe sizes are not major (i.e. ≤ 300mm), it is not expected that existing services would pose a major problem for the upgrade of the pipe network along Pardalote Street. This is further grounded in the fact that the other existing services are for the most part relatively minor (i.e. ≤ Ø150mm).

The upgrade of the pipe network along the footpath leading from Koala Walk Reserve (refer **Figure 3**) has the potential to pose a significant constraint to the upgrades as they are much larger than the existing pipes; with pipes being increased by up to 1.2m to Ø1800mm within a relatively small corridor approximately 5m wide. There are also several other services which exist along this corridor including a sewer main and NBN assets.

Figure 3: Walkway Leading from Koala Walk Reserve Where Stormwater Upgrades are Proposed.

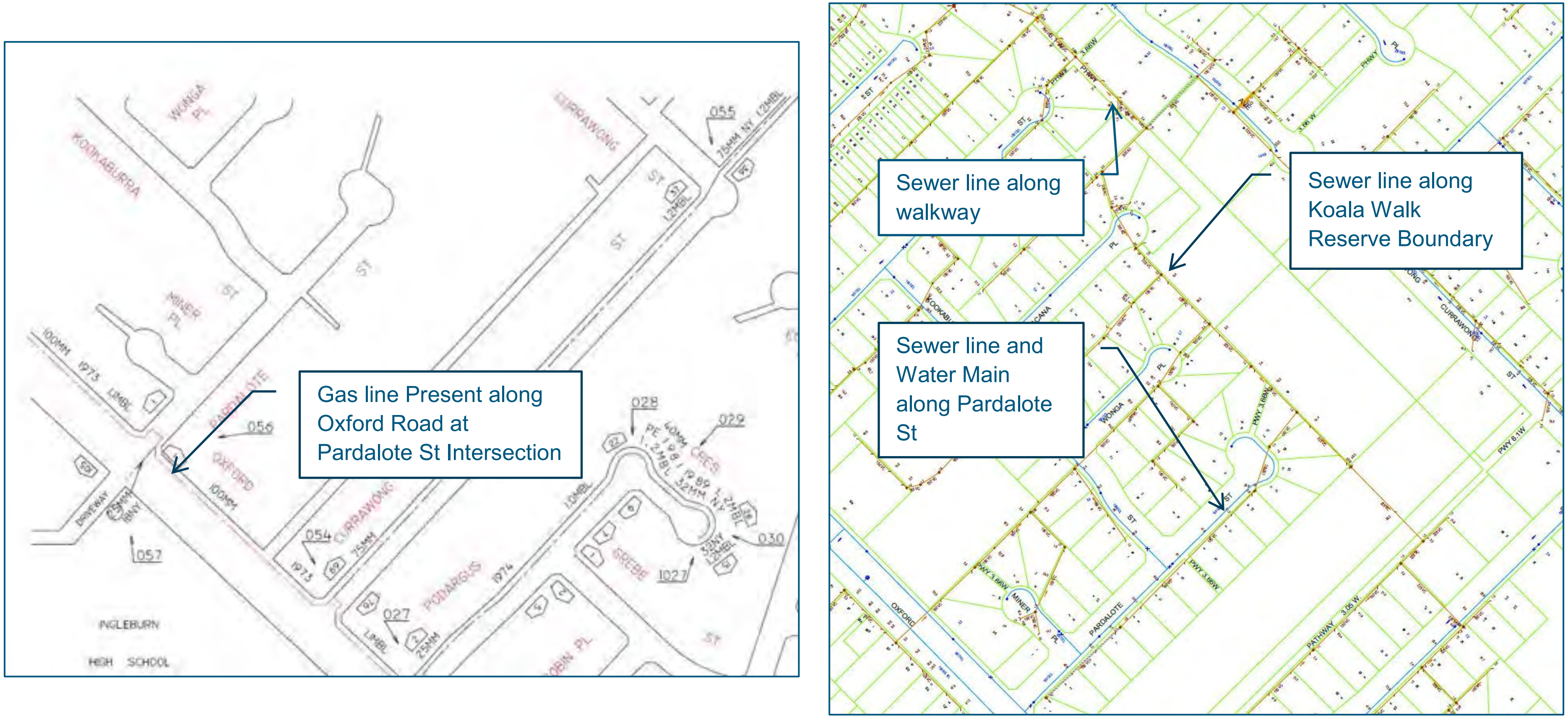

Figure 4: Jemena and Sydney Water Corporation Assets at Oxford Road

2.1.3 Concept Design

There are two principal components to the design of Option 1, being subsurface pipe works and above ground earthworks.

The earthworks component of Option 1 comprises the raising of the western corner of Koala Walk Reserve. The area would presumably be raised by constructing a 0.5m high earth embankment with assumed battered slopes of 1 (V): 3 (H) with vegetation cover or 1 (V):4(H) with turf cover, a top of embankment crest width of 2m and a total length of embankment would of 5m (refer **Figure 5**) The area is to be raised would cover a surface area of approximately 325m^2 (refer **Figure 6**).

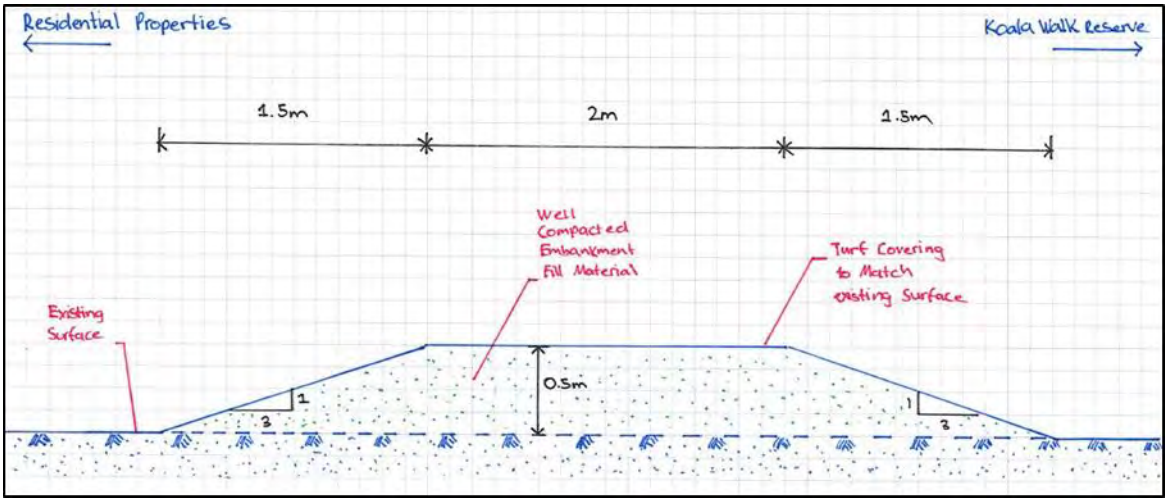

Figure 5: 0.5m embankment in western corner of Koala Walk Reserve.

It is understood, that council wishes to keep all embankment and excavation slopes to 1 (V):6(H) for maintenance purposes (i.e. to be turfed and mown), however during this level of design battered slopes of 1 (V):3(H) have been adopted, representing the steepest, generally acceptable slope for earth structures, to assess the feasibility of the options as accurately as possible whilst remaining as close as possible the physical profile of the modelled options. However, the use of 1(V):6(H) embankment and excavation slopes should be explored and adopted where necessary during later stages of design.

Figure 6: Left: Approximate Footprint of Proposed Embankment (Aerial Image Source: Nearmap 2018); Right: Ground Level Photo of Proposed Embankment Location

The pipe works component of Option 1 comprises the upgrade of a stormwater line from Oxford Road along Pardalote Street and through Koala Walk Reserve. A new Ø600mm pipe is to be constructed connecting Oxford Road to Pardalote Street and along Pardalote Street the existing pipes are to be upgraded to Ø900mm pipes. Through Koala Walk Reserve the existing pipes are to be upgraded to Ø1200mm pipes and a new Ø1800mm pipe is to be constructed along western boundary of the reserve. Along a public footpath leading from Koala Walk Reserve the existing drainage pipes are to be upgraded to Ø1800mm pipes.

All proposed pipes would be assumed to be class 2 reinforced concrete drainage pipes installed with HS2 type supports in accordance with AS3725-2007. A typical pipe section is presented in **Figure 7**.

The assumed construction method would be open trench including trench shoring where appropriate.

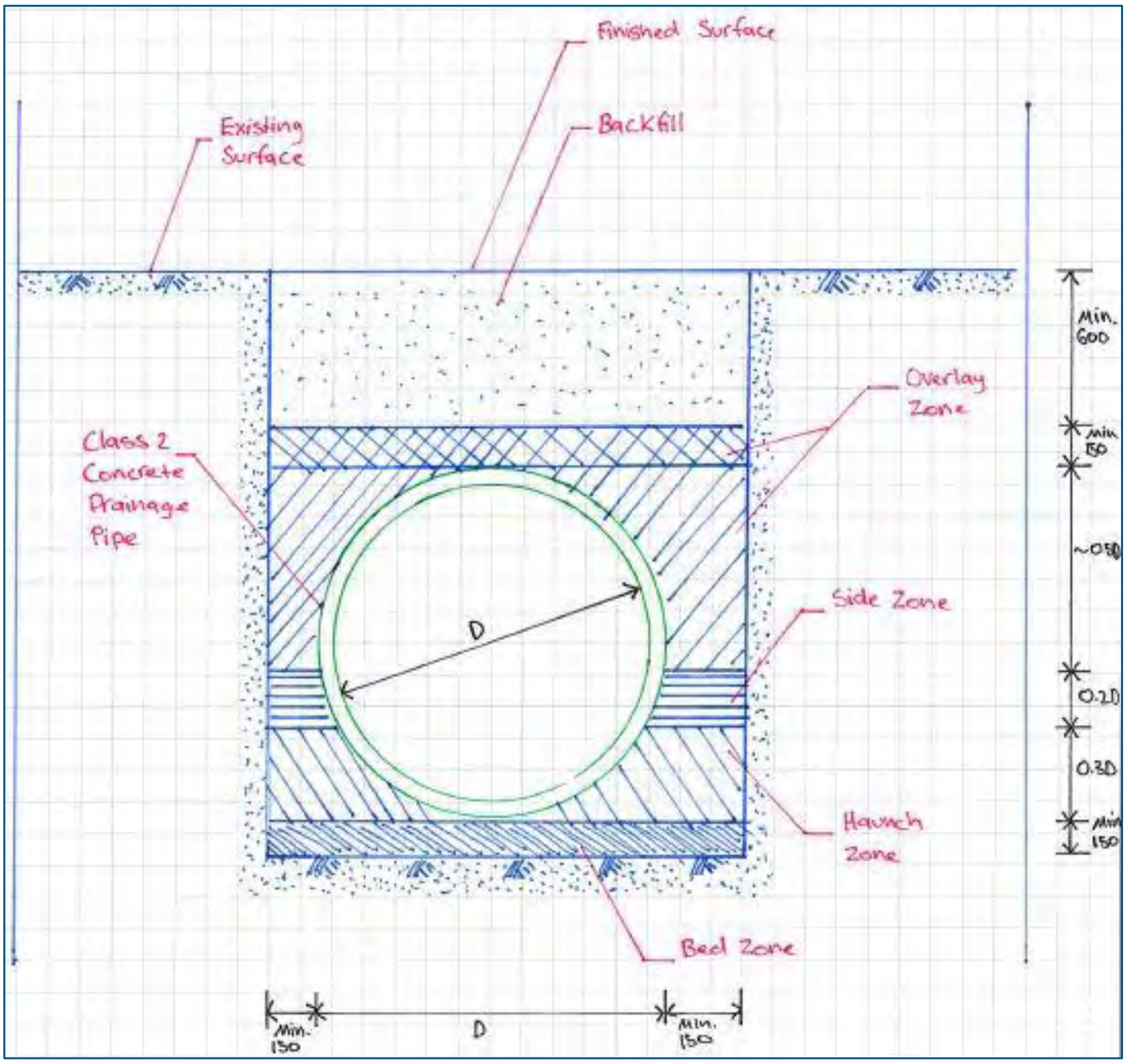

Figure 7: Typical Pipe Section with HS2 Support

For concept design sketches of Option 1 please refer to **Appendix A**

2.1.4 Health & Safety Considerations

The following health and safety considerations have been identified for Option 1:

- As the capacity of the local stormwater network has been appreciably increased, increased discharge velocities at the pipe outlet downstream of Aubrey Street will likely be experienced.
- The proposed 150mm speed hump along Oxford Road must be adequately designed to suit local traffic conditions including the type and speed of vehicles.

2.1.5 Operation & Maintenance Consideration

The following operation and maintenance considerations have been identified for Option 1:

- New inlet pits including a new 3m combination pit on the corner of Oxford Road and Pardalote Street and a 6.48m2 grated inlet pit in the western corner of Koala Walk Reserve will require routine maintenance to remove collected debris and reduce the risk of blockages.

2.1.6 Cost

The estimated costs for the implementation of Option 1 are presented below in **Table 3**.

Table 3: Option 1 Estimated Capital Costs

Items	Costs
Preliminaries	$286,500
Clearing & Demolition	$33,105
Earthworks	$279,888
Stormwater Drainage	$653,104
Road Pavements	$3,424
Concrete Works	$30,808
Landscaping	$10,888
Subtotal	**$1,017,228**
Contingency and Administration	$423,126
TOTAL	**$1,440,354**

Table 4: Option 1 Estimated Whole of Life Costs

Items	Rate ($/Period)	Total Present Value (at Rate of 7%)
Routine Cleaning of grated Inlet Pits (i.e. once every 5 years)	$1,000 every 5 years	$2,399.56
Routine Inspection and Cleaning of stormwater pipes (i.e. once every 5 years)	$3,000 every 5 years	$7,198.69
	Subtotal	**$9598**
	Contingency (30%)	$2879
	TOTAL	**$12,738**

Assumptions

In preparing the above cost estimate the following key assumptions have been made:

- No excavation into rock;
- Embankment slopes of 1(V):3(H) are acceptable;
- No services relocation; and
- Class 2 reinforced concrete stormwater pipes are sufficient;.

2.1.7 Overall Feasibility

No significant 'red flags' have been encountered during concept design & assessment however the following potential issues are highlighted:

- There is possible risk of clashes with existing services present along the alignment of proposed stormwater upgrades.
- The proposed speed hump along Oxford Road is approximately 150mm above road surface. Maximum height of speed hump recommended by Austroads along a bus route (bus stops present along Oxford Road in the vicinity of Pardalote Street) is 75mm (refer **Appendix C**).

2.1.8 Alternative Approaches

No alternative approaches are deemed necessary at this stage for consideration with respect to Option 1.

2.1.9 Data Gaps

The following further investigations/data is considered to be required prior to any further design development:

- Detailed services survey with the location and invert of all relevant services assets along the alignment of the proposed stormwater network upgrades.
- Detailed topographic survey along the alignment of the proposed stormwater network upgrades (i.e. Pardalote Street and Koala Walk Reserve).
- Geotechnical Investigations to determine the soil characteristics where new stormwater lines are proposed.

2.2 Option 2 – Ingleburn Stormwater Upgrades

2.2.1 Description & Intended Hydraulic Performance

The Ingleburn CBD is understood to be one of the worst affected areas in the Campbelltown LGA with respect to overland flows. Flows from the upper catchment, near Wood Park, transverse an overland flow path towards Cumberland Road at Norfolk Street. Flows then follow Norfolk St overland to Ingleburn Road where they inundate the Ingleburn CBD area.

Option two seeks to upgrade the capacity of a number of existing stormwater system elements and construct new stormwater elements to convey flows within the subsurface pipe network as much as possible, before discharging back into an existing open concrete channel near Macquarie Road (refer **Figure 8**).

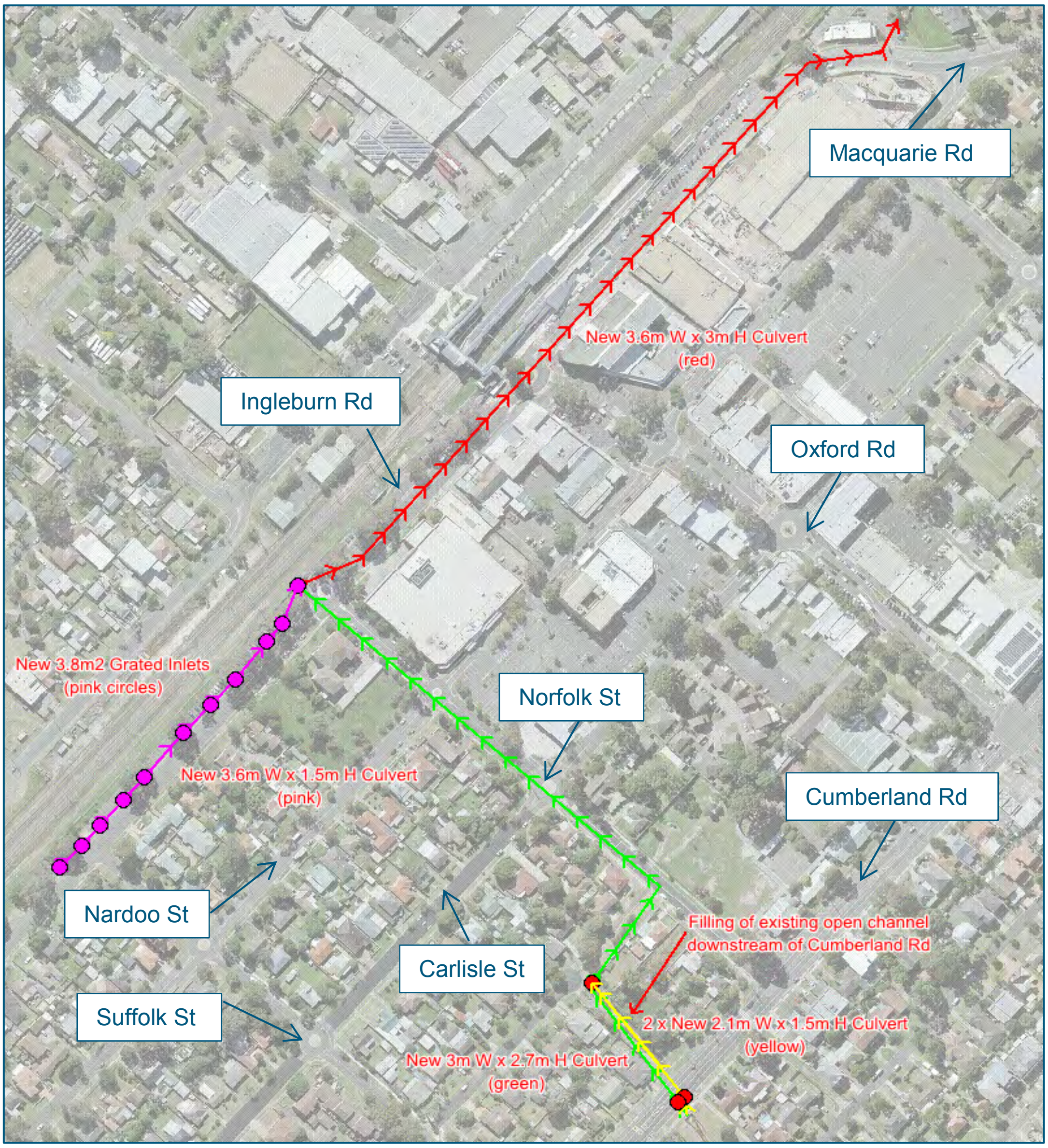

Figure 8: Option 2 Schematised Overview

2.2.2 Existing Services Locations

Major services assets exist along the alignment of Ingleburn Road in the vicinity of the proposed stormwater upgrades. Noteworthy services present include:

- A telecommunications services duct is present parallel to Ingleburn Road at the Macquarie Road intersection.
- A Jemena Gas Ø150mm, 1050kPa secondary main runs along Ingleburn Road between Norfolk Street and Oxford Road. A further Ø50mm 210 kPa network main runs along Norfolk Street between Cumberland Road and Ingleburn Road (refer **Figure 9**).
- NBN assets exist along Ingleburn Road between Norfolk Street and Oxford Road and between Suffolk Street and Norfolk Street. NBN assets also exist along Norfolk Street between Ingleburn Road and Cumberland Road. NBN assets generally follow a similar alignment to the proposed stormwater upgrades.
- A Nextgen services duct cuts across Norfolk Street at Nardoo Street and then continues along to Ingleburn Road after Oxford Road.
- An Optus fibre optic asset exists along the same alignment as the Nextgen services duct.
- A Ø100mm CICL Sydney Water Corporation main exists along Ingleburn Road between Norfolk Street, becoming a Ø150mm CICL between Norfolk Street and Oxford Road. A Ø100mm Ductile Iron Cement (mortar) Lined (DICL) water main exists along Norfolk Street between Nardoo Street and Cumberland Road (refer **Figure 9**).
- A Ø450mm VC Sydney water sewer main traverse across Norfolk Street at Palmer Street. Ø225mm and Ø300mm VC sewer mains exist on Norfolk Street between Carlisle Street and Nardoo St and Nardoo St and Ingleburn Road respectively. A further Ø225mm VC sewer main exists on Ingleburn Road between Oxford Road and Macquarie Road (refer **Figure 9**).
- Multiple Endeavour Energy assets exist along the proposed alignment of stormwater upgrades for Ingleburn.

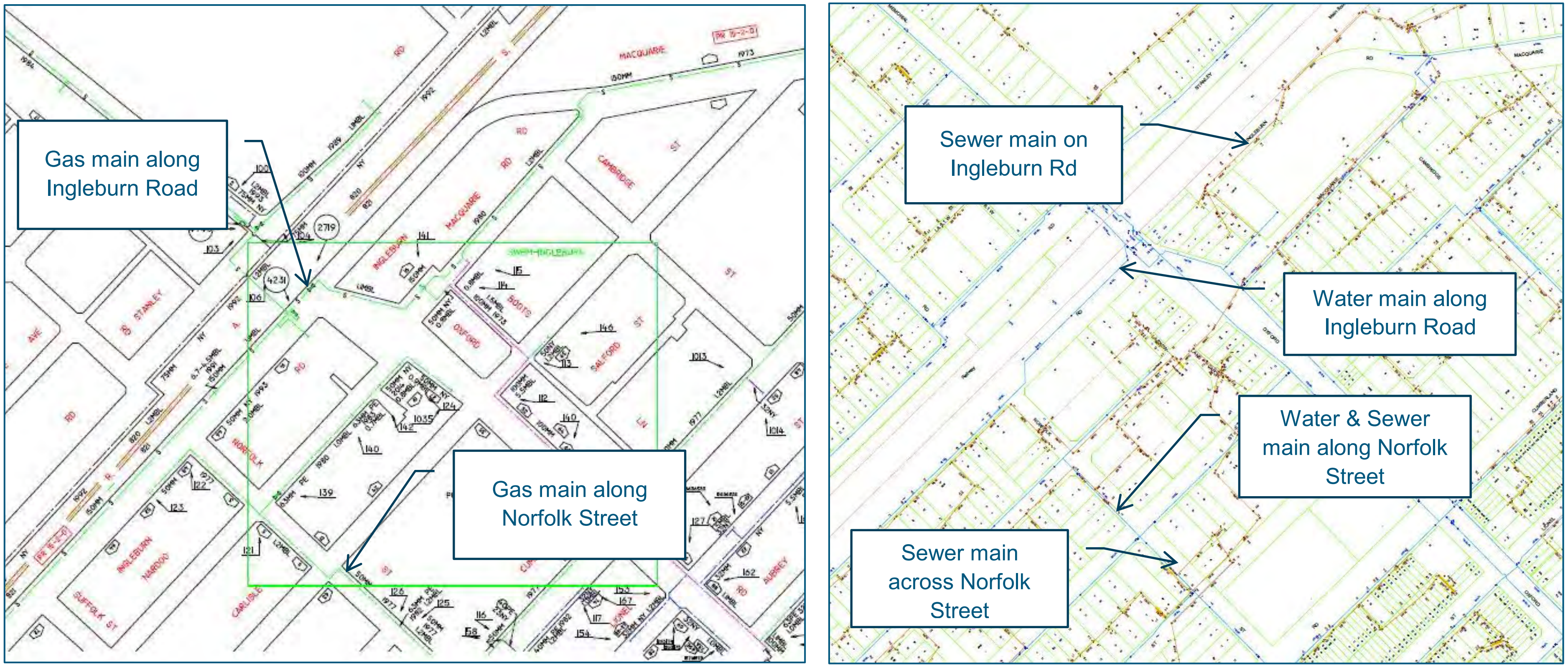

Figure 9: Jemena (Left) and Sydney Water Corporation (Right) Assets at Ingleburn CBD

2.2.3 Concept Design

Option 2 predominantly involves two main tasks, demolition of the existing open concrete channel and replacement with culverts, and installation of proposed new culvert lines.

The open channel north of Cumberland Road near Norfolk Street (refer **Figure 10**) is to be demolished, replaced with 3 new reinforced concrete box culverts and backfilled to match the surrounding surface levels. Two of the proposed culverts will be 2.1m (W) x 1.5m (H) with the third being 3m (W) x 2.7m (H). Demolition of the existing open concrete channel would require breaking out of the concrete and ground excavations of over 2m to adequately fit the proposed box culvert sizes. A typical section of the proposed box culverts replacing the existing open concrete channel is presented in **Figure 11**. Upstream of the open concrete channel Cumberland Road would be saw cut and excavated, and the existing culverts underneath demolished and replaced.

Figure 10: Existing Open Concrete Stormwater Channel Between Cumberland Road and Palmer Street (to be Culverted)

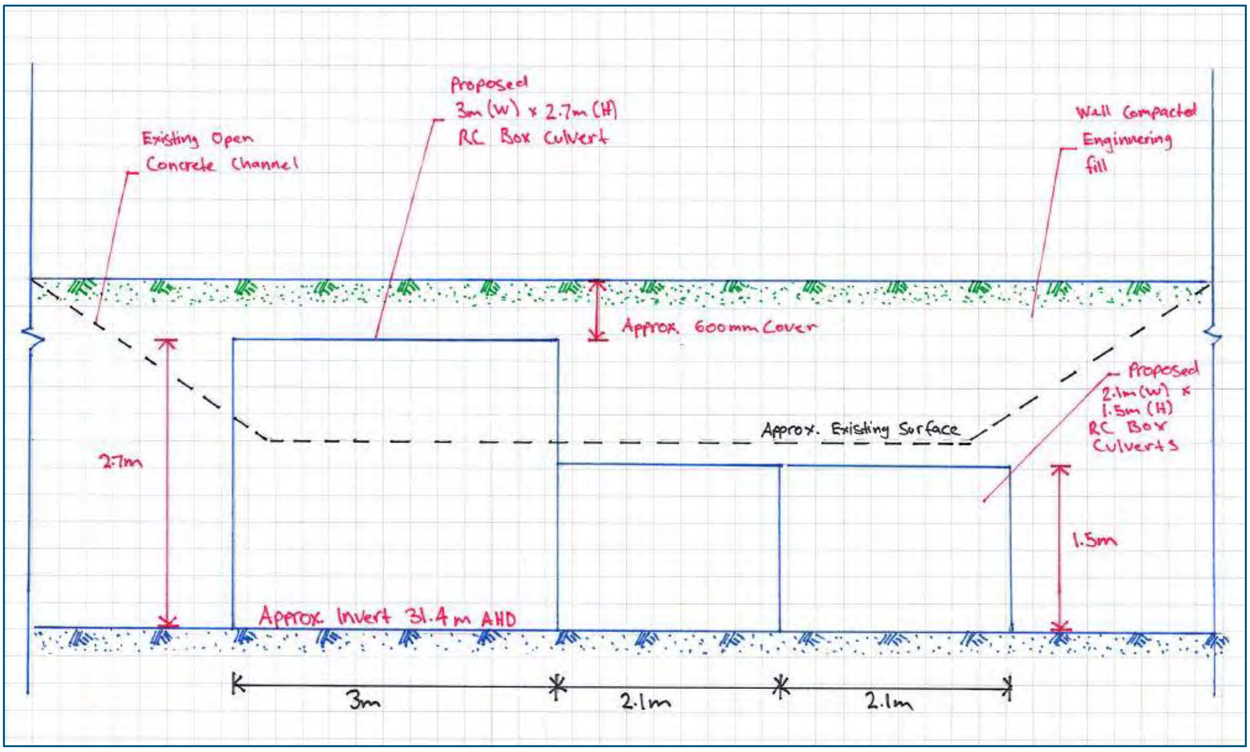

Figure 11: Cross Section of Proposed Culverts Replacing Concrete Channel (Looking Downstream)

The 3m (W) x 2.7m (H) culvert is to continue downstream along Norfolk Street to the intersection with Ingleburn Road where it would connect to a new 3.6m (W) x 3m (H) culvert. This culvert will continue north east along Ingleburn Road to the intersection with Macquarie Road where it will discharge to an open concrete channel. A new 3.6m (W) x 1.5m (H) culvert will also be construction along Ingleburn Road from Suffolk Street to Norfolk Street along with eleven (11) 3.8m^2 grated inlet pits.

All Culverts would be assumed to be Class 2A reinforced concrete box culverts capable of being subject to loads associated with up to 2m of fill above the culvert unit, link or base slab (depending on the orientation and configuration) and road vehicle loadings in accordance with AS5100.2. Culverts would require excavation of a trench with a width having a minimum of 150mm between the culvert walls and trench walls (including any shoring equipment). Installation of the culverts would require a bedding layer of a minimum depth of 150mm, side zones of a minimum width of 150mm and an overlay zone of a minimum depth of 150mm. All bedding zone, side zone and overlay zone material would be select engineering fill in accordance with AS1597.2-2013. For a typical culvert section refer **Figure 33** in **Section 2.7.3.**

For concept design sketches of Option 2 please refer to **Appendix A**.

2.2.4 Health & Safety Considerations

The following health and safety considerations have been identified for Option 2:

- The existing open concrete channel is to be demolished, excavated deeper to maintain long profile grade, replaced with several culverts and backfilled to match the surrounding ground levels. As a result there will be a local increase in surface levels (when compared to the existing open channel) by up to approximately 1.5m. Without installation of proper drainage infrastructure (i.e. pits) this has the potential to result in a localised increase in flood levels to the adjacent properties, due to water ponding.

2.2.5 Operation & Maintenance Consideration

The following operation and maintenance considerations have been identified for Option 2:

- The construction of eleven (11) 3.8m^2 grated inlets along the proposed new 3.6m (W) x 1.5m (H) on Ingleburn Road would require routine maintenance to remove collected debris and reduce the risk of blockages.
- New culverts would increase effort to inspect.

2.2.6 Cost

The estimated costs for the implementation of Option 2 are presented below in **Table 5**.

Table 5: Option 2 Estimated Capital Costs

Items	Costs
Preliminaries	$420,000
Clearing & Demolition	$175,140
Earthworks	$2,044,352
Stormwater Drainage	$6,756,386
Road Pavements	$368,437
Concrete Works	$19,076
Landscaping	$16,505
Subtotal	**$9,799,896**
Contingency and Administration	$3,636,762
TOTAL	**$13,436,659**

Table 6: Option 2 Estimated Whole of Life Costs

Items	Rate ($/Period)	Total Present Value (at Rate of 7%)
Routine Cleaning of grated Inlet Pits (i.e. once every 5 years)	$11,000 every 5 years	$26,395
Routine Inspection and Cleaning of stormwater culverts (i.e. once every 5 years)	$5,000 every 5 years	$11,998
	Subtotal	**$38,393**
	Contingency (30%)	$11,518
	TOTAL	**$49,911**

Assumptions
In preparing the above cost estimate the following key assumptions have been made:

- No excavation into rock;
- No services relocation; and
- Class 2A reinforced concrete box culverts are sufficient.

2.2.7 Overall Feasibility

The following potential issues regarding the feasibility of Option 4 were identified during concept design:

- Owing to the size of the proposed box culverts and their alignments, large excavations along busy roads will be required, resulting in lane closures and traffic diversions necessitating extensive traffic management.
- As the proposed culverts are relatively large and are proposed along the alignment of a number of existing services assets it is likely that construction of the culverts will require the realigning of some existing services. It is not possible at this stage to determine which services and at which locations this may be the case, without further detailed services survey.

2.2.8 Alternative Approaches

No alternative approaches are deemed necessary at this stage for consideration with respect to Option 2.

2.2.9 Data Gaps

The following further investigations/data are considered to be required prior to any further design development:

- Detailed services survey with the location and invert of all relevant services assets along the alignment of the proposed stormwater network upgrades.
- Detailed topographic survey of the existing open concrete channel from just upstream of Cumberland Road, through to Palmer Street.
- Geotechnical investigations below the existing concrete channel to determine the soil characteristics beneath the proposed new box culverts. Further geotechnical investigations to determine the soil characteristics where new stormwater lines are proposed.

2.3 Option 3 – Manooka Reserve Basin

2.3.1 Description & Intended Hydraulic Performance

A formalised detention basin at Manooka Reserve, Bradbury is proposed to collect and detain flows coming from the relatively steeper upper catchment areas. In particular, overland flows that travel north along the Parkway and overland flows in the adjacent residential area along Manooka Crescent are to be diverted into the detention basin to relieve local flooding (refer **Figure 12**).

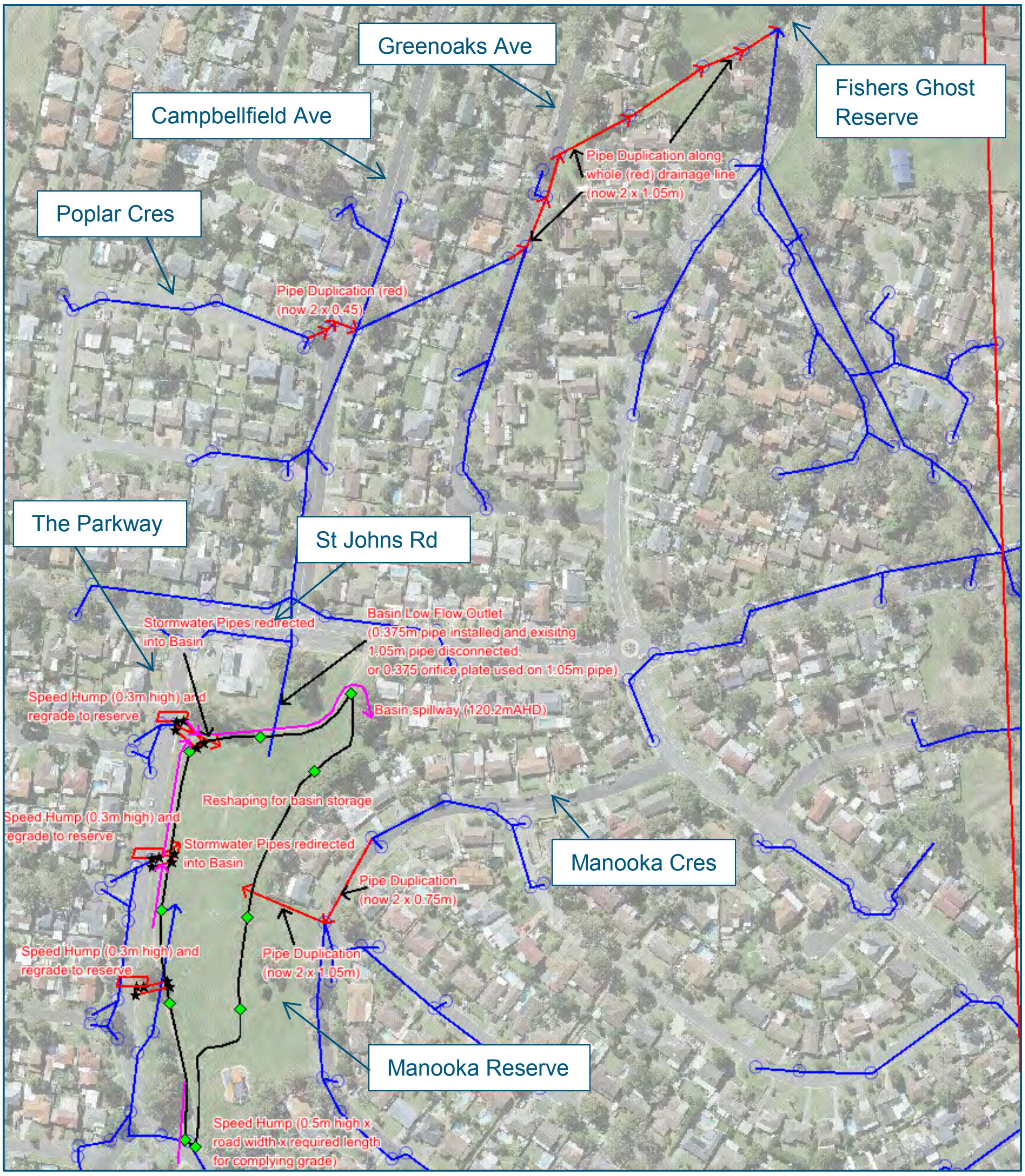

Figure 12: Option 3 Schematised Overview

2.3.2 Existing Services Locations

Services are not expected to pose major obstructions to the implementation of Option 3. An outline of the services likely to be present is detailed below and excerpts of the DBYD for gas and water/sewer mains are presented in **Figure 13**:

- A Ø110mm, 210 kPa Jemena Gas network main runs along Campbellfield Avenue approximately 2.6m from the adjacent property boundary line and a Ø50mm, 210 kPa network main exists along Greenoaks Avenue approximately 1.2m from the adjacent property boundary line. The pipe duplication across Campbellfield Avenue and Greenoaks Avenue are bisected by the respective gas mains (Refer **Figure 13**).
- NBN assets exist along the length of both Campbellfield Avenue and Greenoaks Avenue.
- Several Sydney Water Corporation assets (Refer **Figure 13**) including both potable water and sewer mains, such as:
    - A Ø150mm VC Sewer main across Campbellfield Avenue at Poplar Crescent;
    - A Ø250mm CICL water main along the eastern side of Campbellfield Avenue;
    - A Ø300VC sewer main along both sides of Greenoaks Avenue and through to Fishers Ghost Reserve; and
    - A Ø100mm CICL water main along the western side of Green Oaks Avenue:
- Several underground Endeavour Energy assets exist along St Johns Road adjacent to Manooka Reserve and along Greenoaks Road adjacent to Fishers Ghost Reserve, in the vicinity of the proposed pipe duplications.

There is not expected to be any services bisecting Manooka Reserve that would be disturbed by earthworks associated with excavation of the basin.

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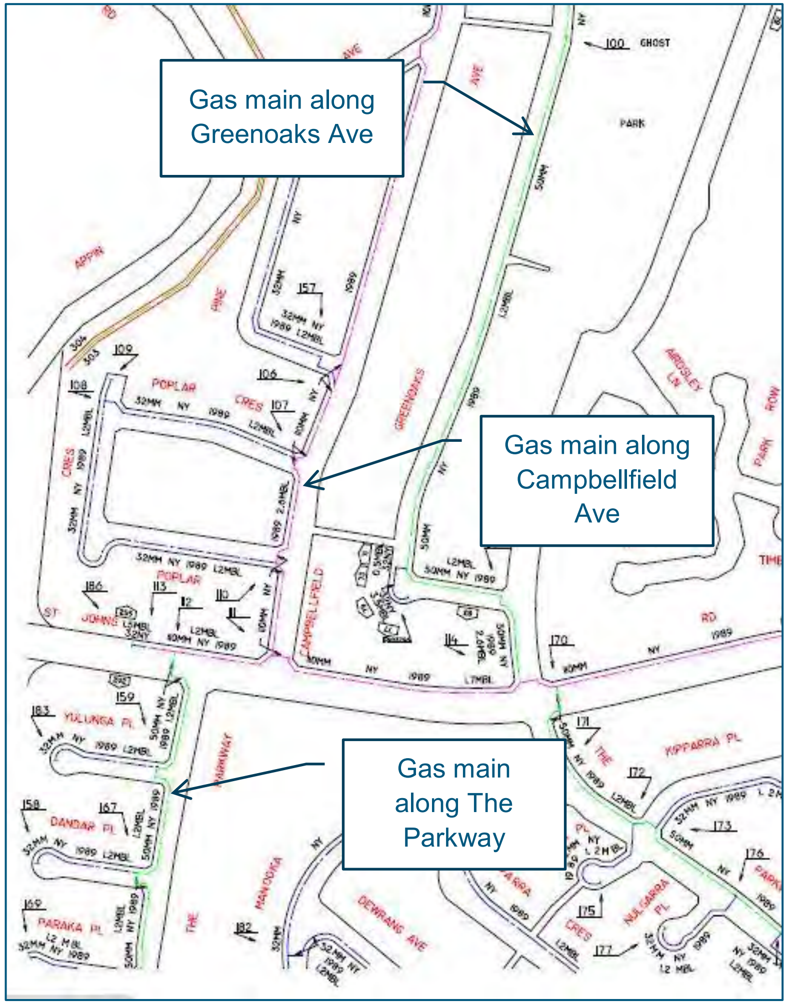


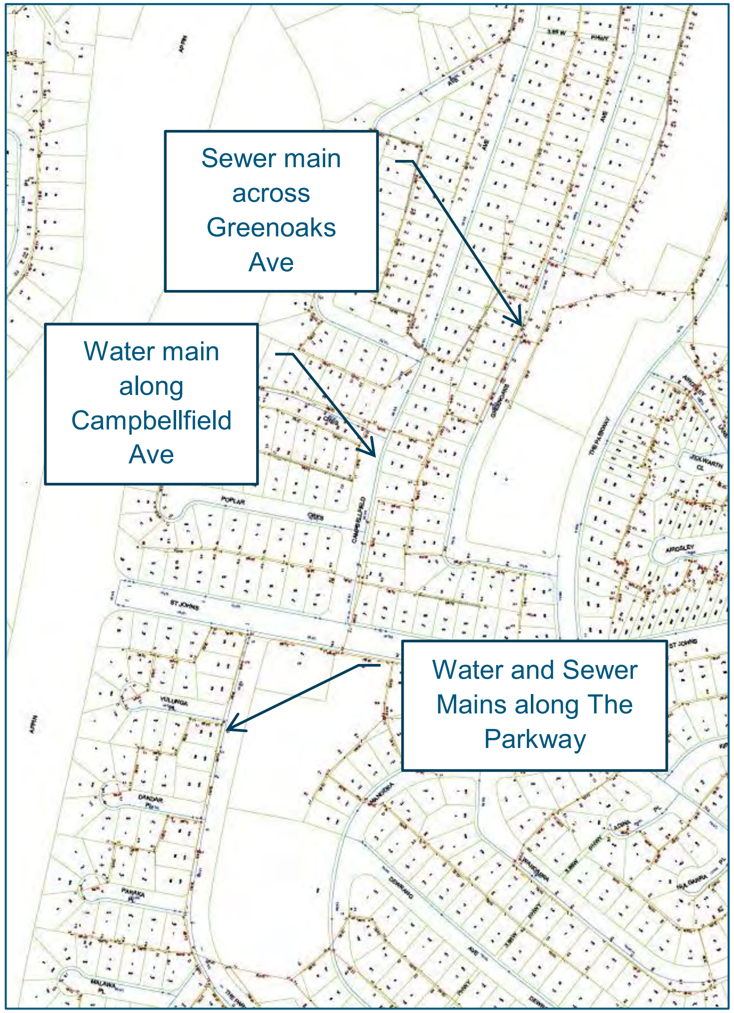


Figure 13: Jemena and Sydney Water Corporation Assets at Manooka Reserve

2.3.3 Concept Design

Manooka Reserve is proposed to be reshaped into a formalised detention basin, with a storage surface area of approximately 8,250m^2 and a storage volume of approximately 32,950m^3, requiring a net excavation of approximately 38,900 m^3 (refer **Figure 14** and **Figure 15**).

Due to space constraints associated with maintaining the required (i.e. modelled) storage volume and public amenity, as well providing the most cost effective design, a slope of 1(V):3(H) batters has been included in preliminary designs for assessment purposes. To maintain a stable basin embankment, it is considered that slopes would need to be battered to a slope not in excess of 1 (V):3(H) to a basin floor level of 117.5mAHD. Embankment slopes would ideally be battered at a slope of 1 (V): 6 (H) to allow for maintained (i.e. mown) grass coverage, however, such a configuration would significantly impact on the available storage volume.

An approximately 100m long 'dam' at 120.2mAHD is to be formalised along the northern and western boundary of the basin following the alignment of the existing footpath, with a reinforced grass spillway to be formalised in the north eastern corner of the Reserve (refer **Figure 15**). A typical cross section of the proposed basin and approximate longitudinal section are presented in **Figure 16** and **Figure 17** respectively.

Figure 14: Manooka Reserve

Figure 15: Manooka Reserve Basin; Areas in blue to be cut and areas in yellow - red to be filled

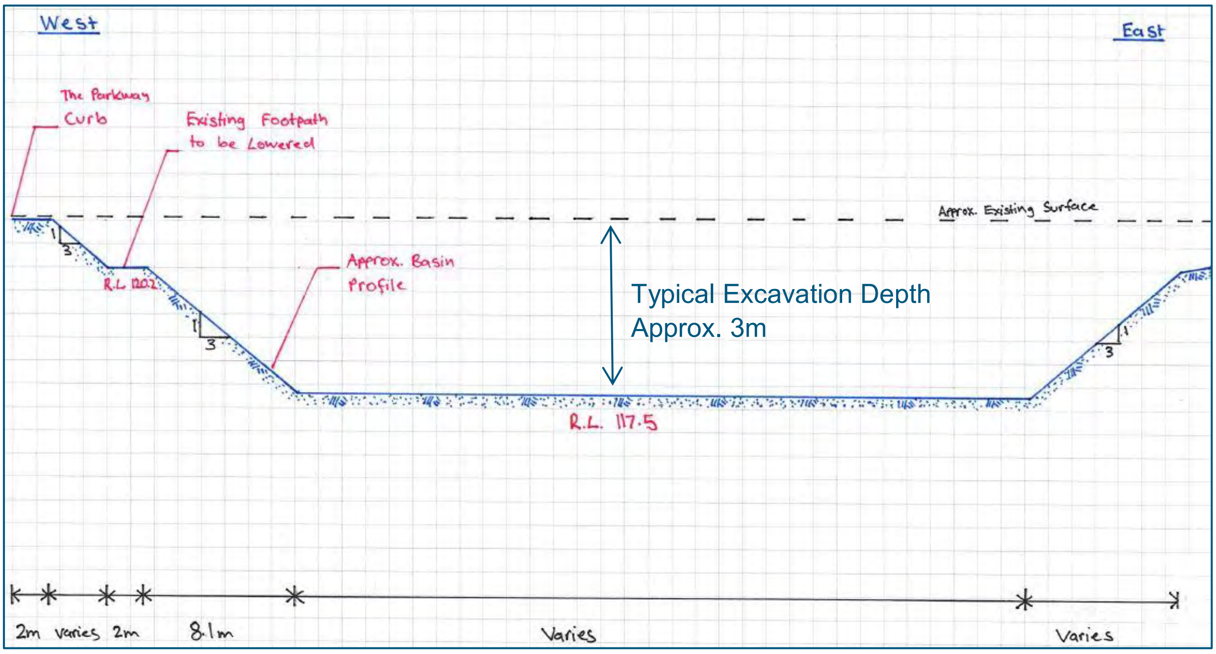


Figure 16: Manooka Reserve Basin Cross Section

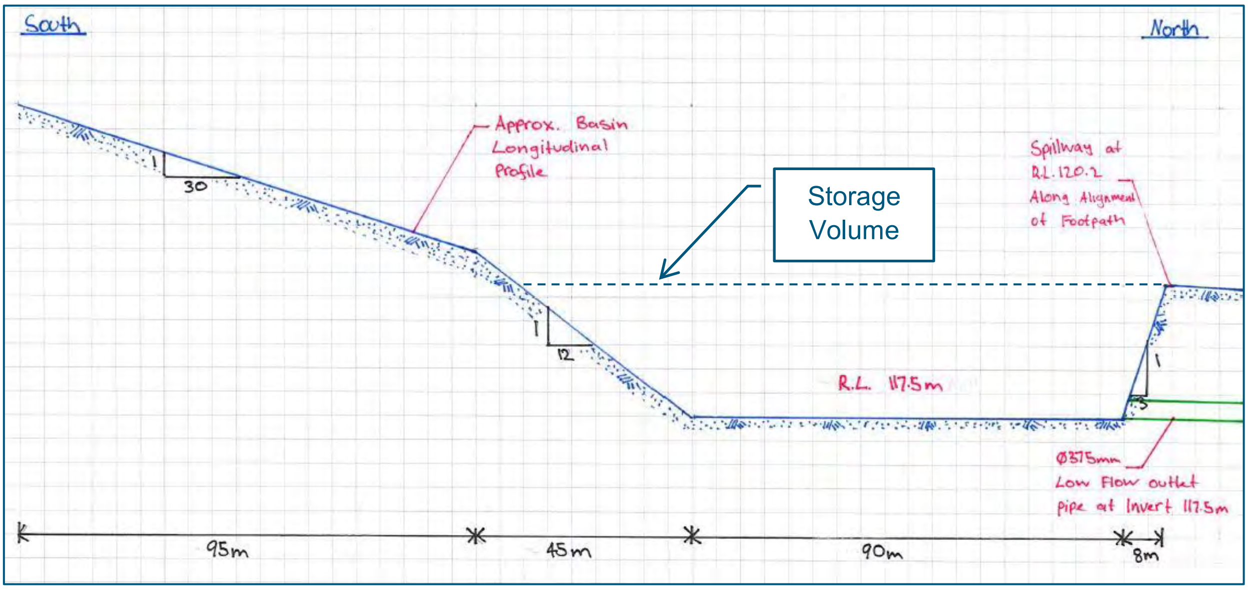


Figure 17: Manooka Reserve Longitudinal Section

Additionally, three speed humps are to be constructed (or installed) along the Parkway to divert flows along regraded areas into the detention basin (approximately grade of 1:14). Two sections of pipe connecting Manooka Crescent to the detention basin are to be duplicated to allow for increased diversion of flows to the detention basin. The detention basin's low flow outlet is to be restricted to a Ø375mm pipe from the existing Ø1050mm pipe.

Furthermore, approximately 30m of Ø450mm pipeline at Campbell field Avenue and 220m of Ø1050mm pipeline at Greenoaks Avenue are to be duplicated to assist in reliving flooding at localised sag areas. All pipes would be class 2 reinforced concrete pipes with a HS2 type support. For a typical pipe cross section refer **Figure 7**.

For concept design sketches of Option 3 please refer to **Appendix A**.

2.3.4 Health & Safety Considerations

The following health and safety considerations have been identified for Option 3:

- In formalising a detention basin at Manooka Reserve there a number of risks associated with overtopping and potential failure of the embankments; however these risks cannot be formally quantified without further investigations.
- Manooka Reserve is a public playing field; therefore formalising of a detention basin poses a risk to the public if they are not aware that the Reserve will become flooded by deep water during large rainfall events. As such appropriate signage should be installed.
- It is likely that water will not be completely drained following a large rainfall event and water will pond. It is also likely that the basin will be regularly water logged and therefore temporarily unsuitable for use by the public.
- A residential property is located immediately adjacent to the northeast-corner of the spillway which is estimated to overtop in the 500 year ARI event. This may lead to a concentration of flow and a higher flood hazard at this location.
- A petrol station is located immediately downstream of the proposed northern spillway, which is estimated to overtop between the 1000 year ARI and PMF event. This may lead to a

concentration of flow and a higher flood hazard at this location. More residential properties are located further downstream of the spillway on the northern side of St Johns Road.

- The proposed three (3)150mm speed humps along The Parkway must be adequately designed to suit local traffic conditions including the type and speed of vehicles.

2.3.5 Operation & Maintenance Consideration

The following operation and maintenance considerations have been identified for Option 3:

- The proposed basin at Manooka Reserve has a Ø375mm low flow pipe at an Invert of 117.5m AHD. Given that the basin floor has a relatively shallow grade it is likely that water will pond in the basin and not completely drain after filling.
- New inlet pits including a new 1.8m combination pit on the corner of Campbellfield Avenue and Poplar Crescent and a 0.54m^2 grated inlet pit in Fishers Ghost Reserve will require routine maintenance to remove collected debris and reduce the risk of blockages.

2.3.6 Cost

The estimated costs for the implementation of Option 3 are presented below in **Table 7**.

Table 7: Option 3 Estimated Capital Costs

Items	Costs
Preliminaries	$286,500
Clearing & Demolition	$118,487
Earthworks	$1,926,686
Stormwater Drainage	$358,408
Road Pavements	$22,628
Concrete Works	$25,234
Landscaping	$163,554
Ancillary Works	$25,284
Subtotal	**$2,926,781**
Contingency and Administration	$1,121,202
TOTAL	**$4,047,983**

Table 8: Option 3 Estimated Whole of Life Costs

Items	Rate ($/Period)	Total Present Value (at Rate of 7%)
Routine Cleaning of grated Inlet Pits (i.e. once every 5 years)	$500 every 5 years	$1,200
Routine Inspection and Cleaning of stormwater pipes (i.e. once every 5 years)	$500 every 5 years	$1,200
	Subtotal	**$2,400**
	Contingency (30%)	$7,20
	TOTAL	**$3,120**

Assumptions

In preparing the above cost estimate the following key assumptions have been made:

- No excavation into rock;
- Excavation slopes of 1(V):3(H) are acceptable;
- No contaminated material;
- Price Includes allowance to haul and dispose virgin excavated natural materials to offsite surplus spoil location;
- No services relocation; and
- Class 2 reinforced concrete stormwater pipes are sufficient.

2.3.7 Overall Feasibility

The following potential issues regarding the feasibility of Option 4 were identified during concept design:

- The Proposed speed humps along The Parkway are approximately 300mm above road surface. The Maximum height of a speed hump recommended by Austroads along a bus route (a bus stop is present along the parkway adjacent Manooka Reserve) is 75mm (refer **Appendix C**);
- Formalising of a basin at Manooka Reserve, as modelled, requires excavation depths of up to 6m in some areas, with a typical excavation depth of approximately 3m. The local geology over the basin area is as yet unknown and as such excavation depths may be constrained by the prevailing ground conditions (e.g. the presence of shallow rock), which would likely be costly to excavate.
- If the area to be excavated is found to be comprised of contaminated materials then formalising of the basin will become unfeasible.
- Formal spillway sizing has not yet been undertaken for the basin and as such it is not yet clear whether the proposed embankment height / spillway size is sufficient. As such further excavations and/or increases to the spillway height may be required. This is necessary as despite being a ‘cut’ basin, due to the local ground levels which decrease steeply to the north, an embankment is formed, therefore ‘failure’ of the embankment is a possibility and a natural spillway is created downstream, which must be properly designed and reinforced.
- The modelled storage volume, as mentioned previously, is approximately 32,950m^3 with side slopes battered at approximately 1 (H):1(V) However in reality a stable earth batter requires a slope not greater than 1(H):3(V) .Therefore, due to the need for shallower excavation slopes the

basin storage volume would be reduced to approximately 29,950m^3; representing a decrease of over 3000m^3 or close to 10%..

2.3.8 Alternative Approaches

As mentioned previously, the modelled storage volume is currently not feasible within the proposed basin profile due to the need for shallower, battered excavation slopes. However, with this being said, it is likely that the modelled storage volume could be achieved in reality if the storage area of the basin is extended further south or retaining structures are implemented to allow for steeper excavation slopes.

Should it be desired that the footprint of the proposed basin not be altered and the embankment slopes decreased beyond 1 (V):3(H) then it is recommended that the basin be remodelled with a smaller storage volume to represent the physical constraints present at the Reserve.

2.3.9 Data Gaps

The following further investigations/data is required to prior to any further design development:

- Detailed services survey with the location and invert of all relevant services assets along the alignment of the proposed stormwater network upgrades (i.e. at Campbellfield Avenue. and Greenoaks Avenue.)
- Detailed topographic survey of the existing Manooka Reserve along the alignment of the proposed stormwater network upgrades (i.e. at Campbellfield Avenue. and Greenoaks Avenue).
- Geotechnical Investigations of the materials making up the existing reserve and of the materials likely to be encountered during excavation; including if contaminated materials are present.
- A formal dam break analysis needs to be undertake, determining the flood consequence category and an appropriate spillway height and basin design that would subsequently need to be approved by the NSW Dam safety committee.

2.4 Option 4 – Epping Forest Drive

2.4.1 Description & Intended Hydraulic Performance

Adjacent to Epping Forest Drive, flood water flows along an open channel through Vale Brooke Reserve downstream to Eschol Park. To divert overland flows from Epping Forest Drive into Vale Brooke Reserve and to minimise the flooding of surrounding residential properties, regrading of the road surface and construction of a speed hump are proposed. In addition, regrading of a walkway between no. 38 and no. 36 Epping Forest Drive is also proposed to direct flows from Epping Forest Drive through to Vale Brooke Reserve.

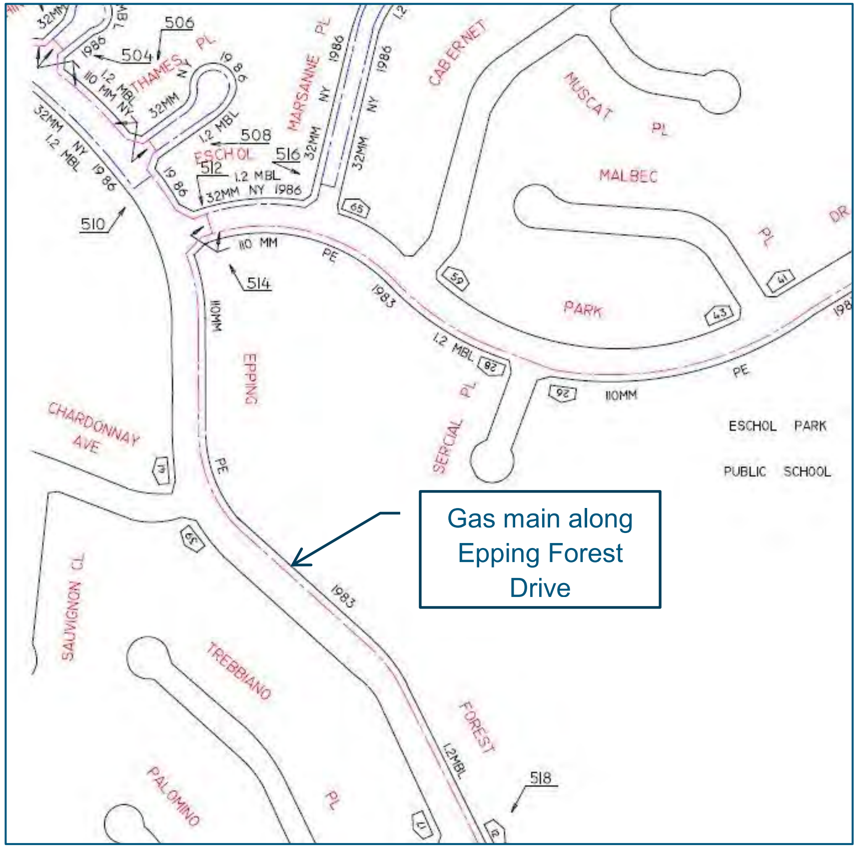
Figure 18: Option 4 Schematised Overview

2.4.2 Existing Services Locations

Due to the limited nature of regrading along Epping Forest Drive it not expected that services will be disturbed by the proposed works. No Services are expected along the existing footpath alignment between no. 38 and no. 36 Epping Forest Drive.

Noteworthy services assets present include:

- A Ø110mm PE, 210 kPa Jemena Gas network main is present along the eastern edge of Epping Forest Drive approximately 1.2m from the boundary line (refer **Figure 19**) .
- A Sydney Water Ø150mm VC Sewer Main bisects Epping Forest Drive just south of 60 Eschol Park Drive. A 450 DICL Potable water main runs along the western side of Epping Forest Drive. A further Ø150mm VC sewer main crosses the eastern end of the walkway between no. 38 and no. 36 Epping Forest Drive (refer **Figure 19**).



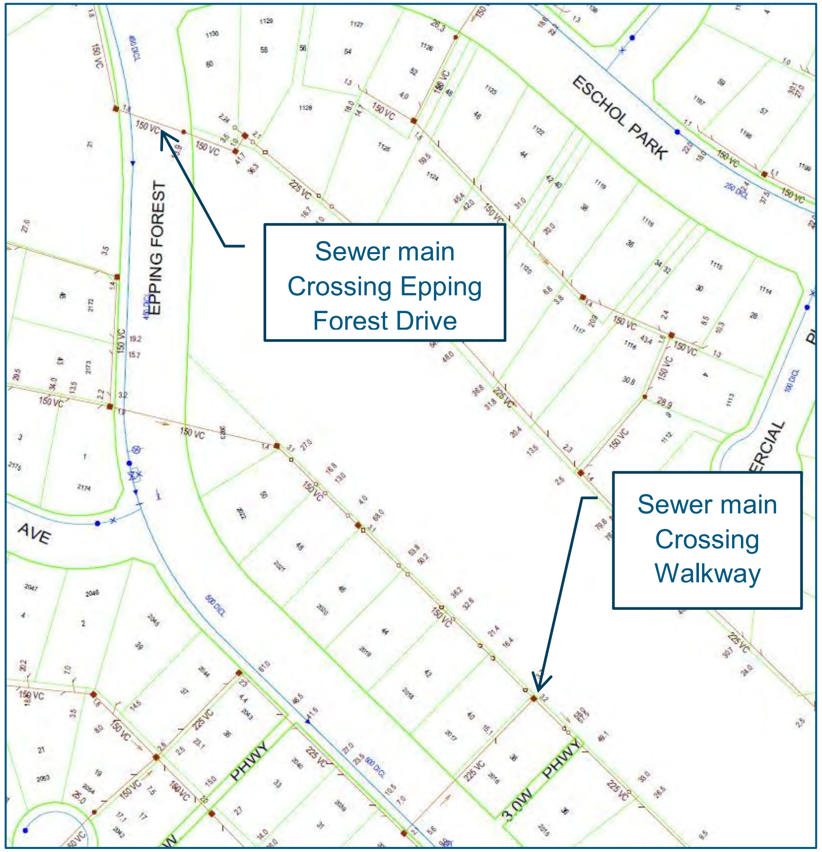


Figure 19: Jemena and Sydney Water Corporation Assets at Epping Forest Drive

2.4.3 Concept Design

The proposed speed hump along Epping Forest Drive would have a maximum vertical deflection of approximately 0.15m and a crest height of 79mAHD. North of the speed hump the road surface would be regraded to a single grade of approximately 1:100 from North to South and a single cross fall grade from west to east of approximately 2% to divert flows into Vale Brooke Reserve.

The walkway between no. 38 and no. 36 Epping Forest Drive (refer **Figure 20**) would be excavated by as much as 0.6m and regraded to a slope of approximately 1:100; requiring a net excavation of approximately 55m^3 and construction of retaining walls. A typical cross section of the proposed walkway is presented in **Figure 21**.The kerb along Epping Forest Drive at the walkway would need to be replaced with a concrete dish crossing to allow flows from the road to be diverted along the footpath.

Figure 20: Existing Walkway off Epping Forest Drive, Looking Towards Vale Brooke Reserve

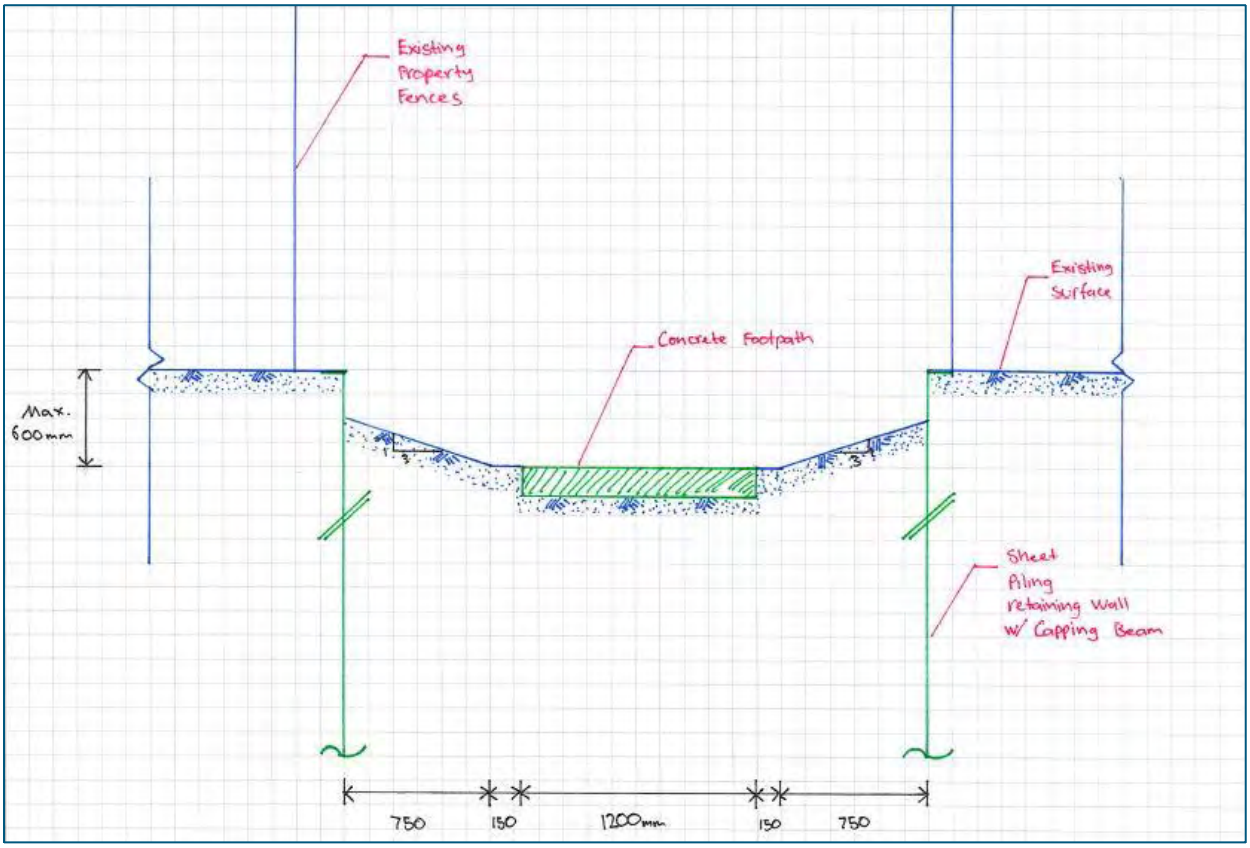


Figure 21: Walkway Cross Section

For concept design sketches of Option 4 please refer to **Appendix A.**

2.4.4 Health & Safety Considerations

The following health and safety considerations have been identified for Option 4:

- The proposed 150mm speed hump along Oxford Road must be adequately designed to suit local traffic conditions including the type and speed of vehicles.
- The concentration of flows along the regraded walkway has the potential to create issues relating to scour of the soft grassed areas on either side of the concrete pathway which may undermine the integrity of the pathway and adjacent property fences and potentially encroach into the adjacent residential properties if the excavated slopes are not properly stabilised.

2.4.5 Operation & Maintenance Consideration

- No significant operation and maintenance considerations are considered to arise from implementation of Option 4.

2.4.6 Cost

The Estimated costs for the implementation of Option 2 are presented below in **Table 9**.

Table 9: Option 4 Estimated Capital Costs

Items	Costs
Preliminaries	$33,000
Clearing & Demolition	$3,428
Earthworks	$6,516
Road Pavements	$27,741
Concrete Works	$5,848
Ancillary Works	$6,027
Subtotal	**$82,380**
Contingency and Administration	$35,151
TOTAL	**$117,530**

Assumptions

In preparing the above cost estimate the following key assumptions have been made:

- No services relocation;
- Excavation slopes of (1V):3(H) are acceptable; and
- Construction of a retaining wall along the edges of the walkway corridor will be required given the excavation depths and space constraints.

2.4.7 Overall Feasibility

The following potential issues regarding the feasibility of Option 4 were identified during concept design:

- The Proposed speed hump on Epping Forest Drive is approximately 150mm above the road surface. The maximum height of a speed hump recommended by Austroads along a bus route (Epping Forest Drive has a number of bus stops in the vicinity of the proposed speed hump) is 75mm (refer **Appendix C**);
- The existing footpath is approximately 1200mm wide within a corridor less than 3m wide and the typical reduction in height of the footpath at the Epping Forest Drive end (eastern end) is approximately 0.5m. As such, batter slopes for excavation are confined to approximately 1:1.2 which is considered too steep to maintain a stable earth batter especially when considering the potential for high flows through the corridor. Therefore some form of retaining wall would be required so as to not impact on the foundations of the adjacent property fences and to a lesser extent the residential buildings.

2.4.8 Alternative Approaches

To allow for the proposed excavation depths within the narrow walkway corridor, alternative retaining structures, such as a blockwork wall, may also be utilised.

2.4.9 Data Gaps

The following further investigations/data is required prior to any further design development:

- Detailed topographic survey of where the road surface area that is to be regraded and speed hump constructed and detailed topographic survey of the walkway corridor between no.36 and no.38 Epping Forest Drive.

2.5 Option 5 – Harrow Road

2.5.1 Description & Intended Hydraulic Performance

An overland flow path from Canterbury Road continuing South West to Harrow Road comes in close proximity to a number of residential properties which back onto the main channel of Bunbury Curran Creek. Regrading of an area behind a number of residential properties is proposed to relieve localised flooding and train flows away from the residential properties towards the creek (refer **Figure 22**).

Figure 22: Option 5 Schematised Overview

2.5.2 Existing Services Locations

The area to be regraded directly overlies an existing Ø900mm stormwater pipe that discharges water from Harrow Road into Bunbury Curran Creek. A pit representing the connection of two Ø375mm pipes from the east and west respectively into the main Ø900mm pipe also exists below the subject area.

The only other services asset, other than stormwater, expected to be in the vicinity of the work is a Ø225mm VC Sydney Water Corporation Sewer Main running from the southern end of Bensbach Road across Harrow Road and through to Bunbury Curran Creek (refer **Figure -23**).

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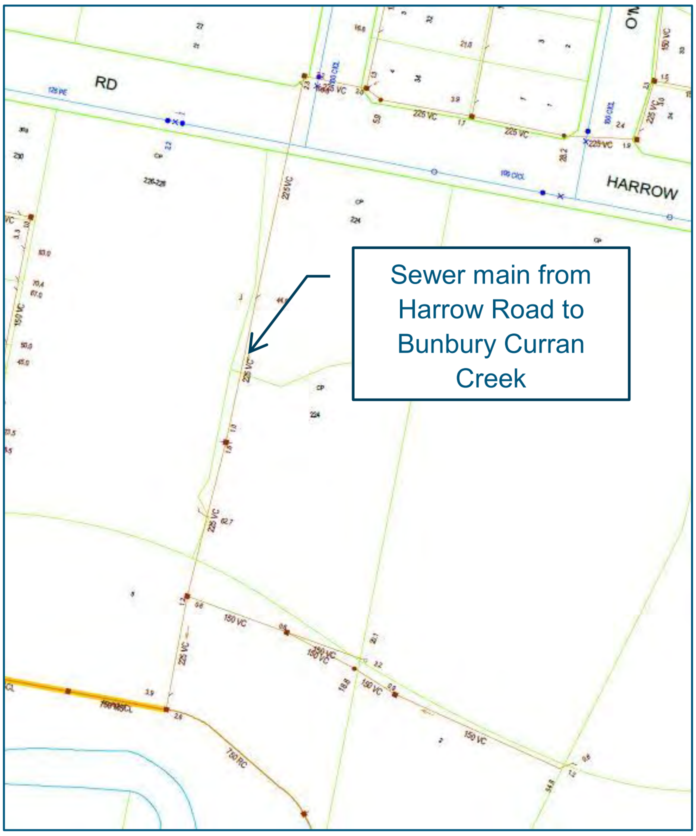


Figure -23: Sydney Water Corporation Assets at Harrow Road

Regrading of the area will likely be limited by the depth of the above mentioned services. The proposed depth of the area to be regraded (~19mAHD) is below the obvert (~19.6mAHD) of the stormwater services at the junction pit even with the proposed reductions in inverts. Further to this, the invert of the sewer main present is approximately 1.6m below the surface and the area to be regraded is to be excavated by approximately 1.7m in the vicinity of the pipe.

This issue is further exacerbated by the relatively narrow corridor in which the regrading is proposed to take place.

2.5.3 Concept Design

The area to be regraded is approximately 230m^2 and 45m long by 5m wide, and would be regraded to a uniform slope of approximately 1:11. To achieve this, approximately 300m^3 of material would need to be excavated. The proposed cross sectional area of the channel would be approximately 6m^2.

Two stormwater pits (ID: 67357 & 67355) below the area to be regarded are also proposed to be altered, with their inverts, and those of the connecting pipes, lowered from 19.98m AHD and 19.35m AHD to 18.8mAHD and 18.7mAHD Respectively. A cross section of the proposed regraded area in the vicinity of the existing stormwater pit is presented in **Figure 24**.

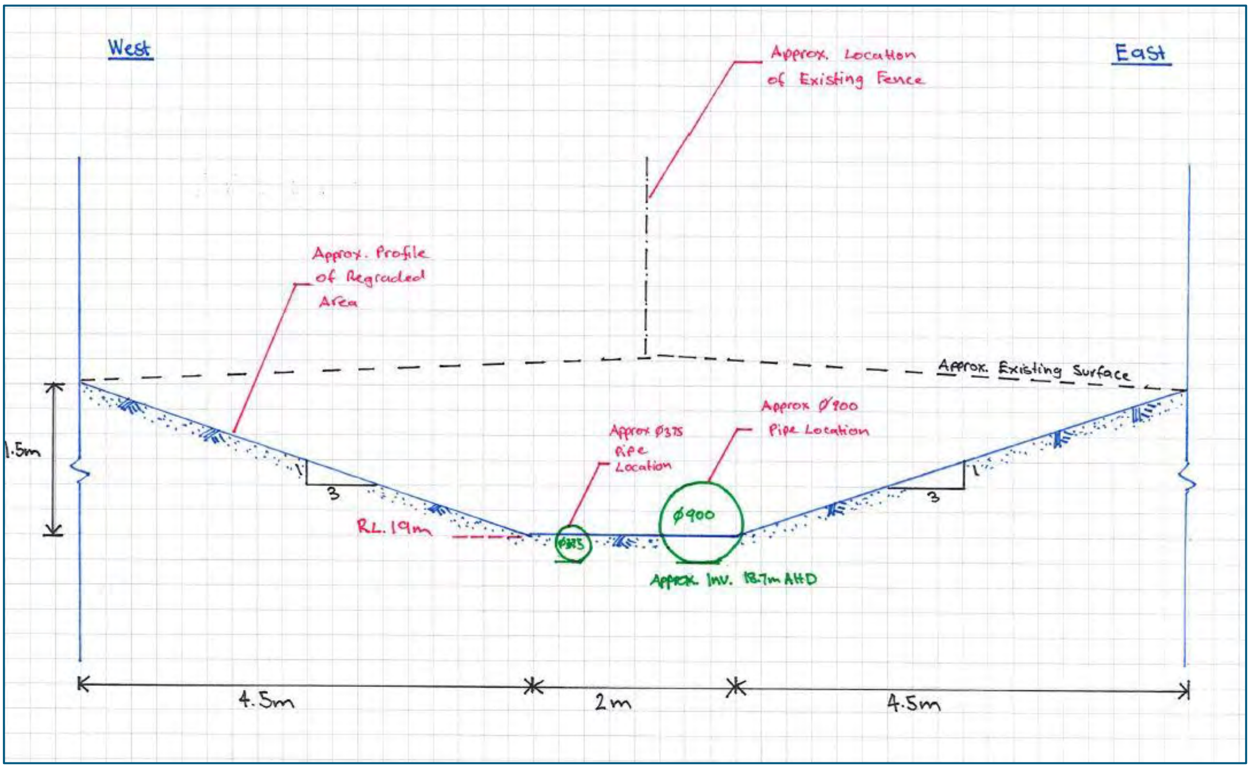


Figure 24: Cross Section of Proposed Regraded Area showing The Potential Conflict with Existing Services

For concept design sketches of Option 5 please refer to **Appendix A.**

2.5.4 Health & Safety Considerations

The following health and safety considerations have been identified for Option 5:

- Depending on the magnitude of velocities, the concentration of flows along the regraded area off Harrow Road has the potential to create issues relating to scour. Given how narrow the corridor is, scour of the bed and banks may extend and undermine the adjacent property fences and in the worst case nearby residential buildings.
- Similarly, more concentrated flows along the subject corridor may create potential, hazardous overland flow paths.

2.5.5 Operation & Maintenance Consideration

No significant additional operation and maintenance considerations are likely to arise from implementation of Option 5.

2.5.6 Cost

The Estimated costs for the implementation of Option 2 are presented below in **Table 10**.

Table 10: Option 5 Estimated Capital Cost

Items	Costs
Preliminaries	$27,000
Clearing & Demolition	$2,169
Earthworks	$31,770
Stormwater Drainage	$3,900
Landscaping	$3,204
Subtotal	**$68,043**
Contingency and Administration	$29,904
TOTAL	**$97,946**

Assumptions

In preparing the above cost estimate the following key assumptions have been made:

- No excavation into rock; and
- Excavation slopes of 1(V):3(H) are acceptable.

2.5.7 Overall Feasibility

The following potential issues regarding the feasibility of Option 4 were identified during concept design:

- The principal issue regarding the feasibility of Option 5 is concerning the space constraints of grading an open channel with a specified cross-sectional area within such a narrow corridor. Issues regarding space constraints are outlined in the following points:
    - Width of the regrading area has to be less than approximately 3m wide to avoid demolishing any structures such as property fences (refer **Figure 25**). The currently proposed regraded area is approximately 5m wide.
    - The modelled cross sectional area cannot be physically achieved without encroachment into residential properties and relocation of fencing. The area to be regarded currently encroaches over three (3) metres into the back yard of a residential property. Furthermore the modelled cross section of the regraded area has bank slopes of approximately 1:1.5 which would generally be considered too steep for stable earth embankments. As a minimum, stable bank slopes should be at least 1:3 and preferably 1:6, which would further exacerbate space constraint issues.

- Regrading at the designated area is restricted to a maximum depth of excavation of 0.8m, given the pipe invert of 18.7m AHD, a diameter of 0.9m and minimum cover to the pipe of approximately 300mm.

Figure 25: Narrow Corridor between Properties Where Regrading is proposed

2.5.8 Alternative Approaches

Given that existing stormwater pits and pipes are to have their inverts lowered to accommodate for the area of regrading, it is recommended that the capacity of these pipes, in particular the centrally located Ø900mm pipe, be increased so as to reduce the size of, or otherwise eliminate, the need for the regraded area. A further large grated inlet pit is also suggested upstream of the area to be regraded to charge the enlarged subsurface stormwater pipe.

Additional options that may be considered include construction of a rock lined chute or open concrete channel to allow for steeper bank angles whilst maintaining bank stability.

2.5.9 Data Gaps

The following further investigations/data is required prior to any further design development:

- Detailed topographic survey of the area designated for regrading.
- Detailed services survey of the relevant services within the area to be regraded
- Minor geotechnical investigations to ascertain the ground conditions along the area to be excavated and regraded and where stormwater pits are to be relocated.

2.6 Option 6 – Sopwith Avenue & Spitfire Drive

2.6.1 Description & Intended Hydraulic Performance

Flows from the upper reaches of the catchment travel from higher elevations between Raby Road and Hurricane Drive along a flow path that roughly follows the alignment of Spitfire Drive. To enhance the ability of the sub-surface stormwater network to convey flows north towards Bunbury Curren Creek, near Sunderland Park, a number of new and duplications of existing pipelines are proposed. In addition to this, to prevent flooding of residential properties due to overland flows a formalised detention basin is proposed at Sopwith Park (refer **Figure 26**).

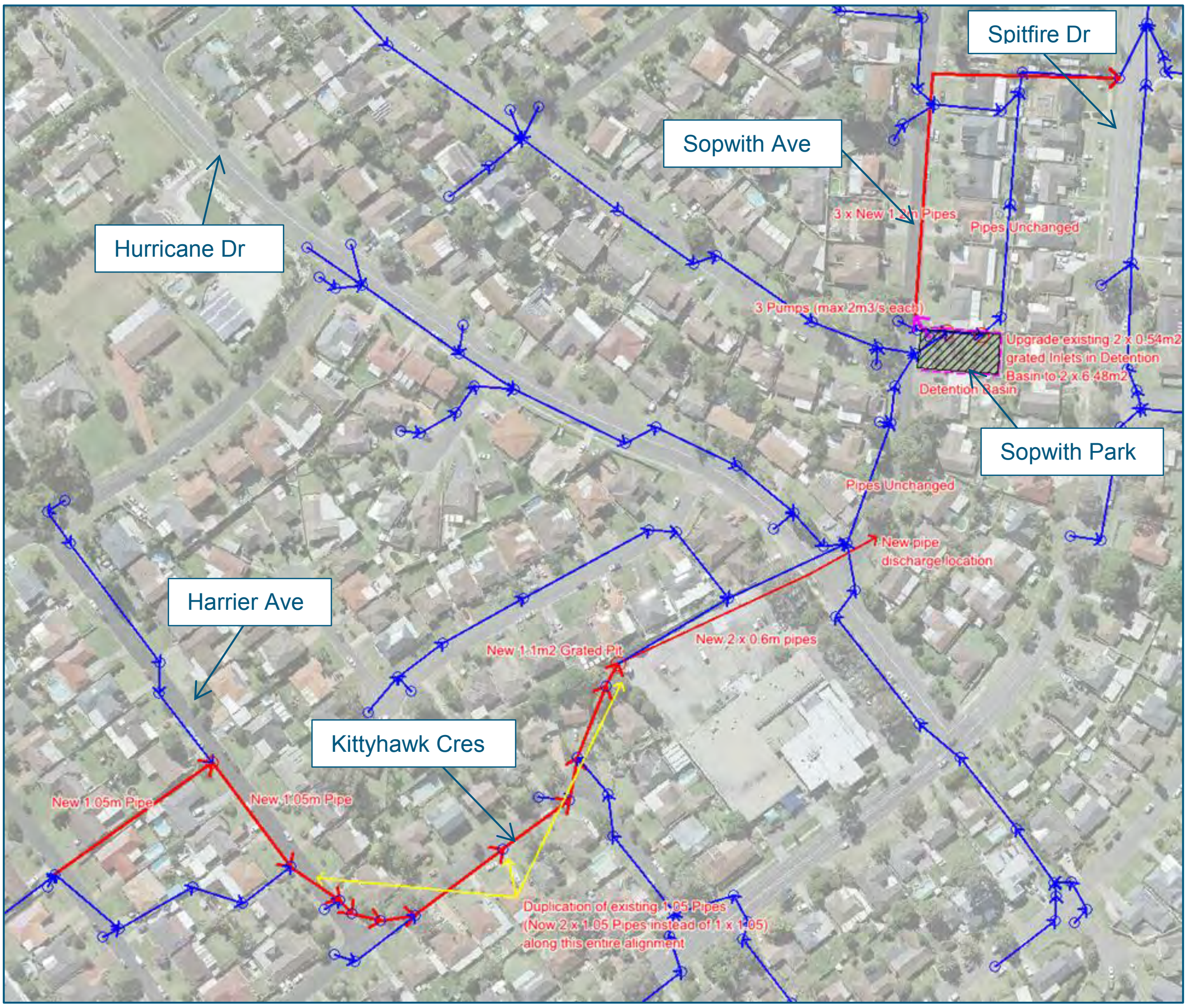
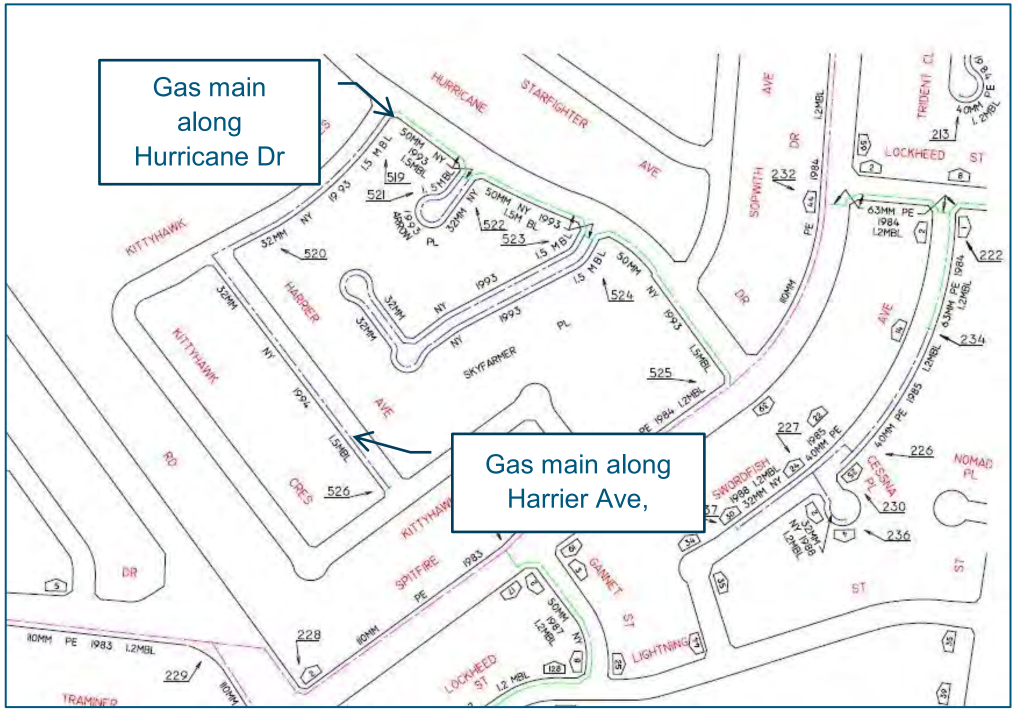


Figure 26: Option 6 Schematised Overview

2.6.2 Existing Services Locations

An outline of the services likely to be present is detailed below and excerpts of the DBYD for gas and water/sewer mains are presented in **Figure 27**:

- A Ø32mm, 210kPa Jemena Gas network main exists along the southern edge of Harrier Avenue. A Ø50mm 210kPa gas network main also exists along the southern edge Hurricane Drive opposite Sopwith Avenue (refer **Figure 27**).
- Endeavour energy assets exist along Harrier Avenue, Kittyhawk Crescent and Sopwith Avenue along the general alignment of the proposed stormwater network upgrades.
- An Optus services duct exists along the western edge of Spitfire Drive.
- A Ø150mm DICL Sydney Water potable water main exists along Harrier Avenue and Kittyhawk Crescent along a similar alignment to those of the proposed new Ø1050 stormwater pipes.
- A Ø150mm VC sewer main is present between Kittyhawk Crescent and Harrier Avenue. A Ø225mm VC Sewer main exists along similar alignment to the proposed new stormwater pipes off Kittyhawk Crescent along the northern boundary of the Raby Shopping Centre. A further Ø150mm VC sewer main crosses Sopwith Avenue between no.s'12 and 15 through the alignment of the proposed 3 x Ø1200mm stormwater pipes. A Ø300mm VC sewer main exists parallel to both Sopwith Avenue and Spitfire Drive, running behind the residential properties though the alignment of the proposed stormwater pipes running between Sopwith Avenue and Spitfire Drive (refer **Figure 27**).



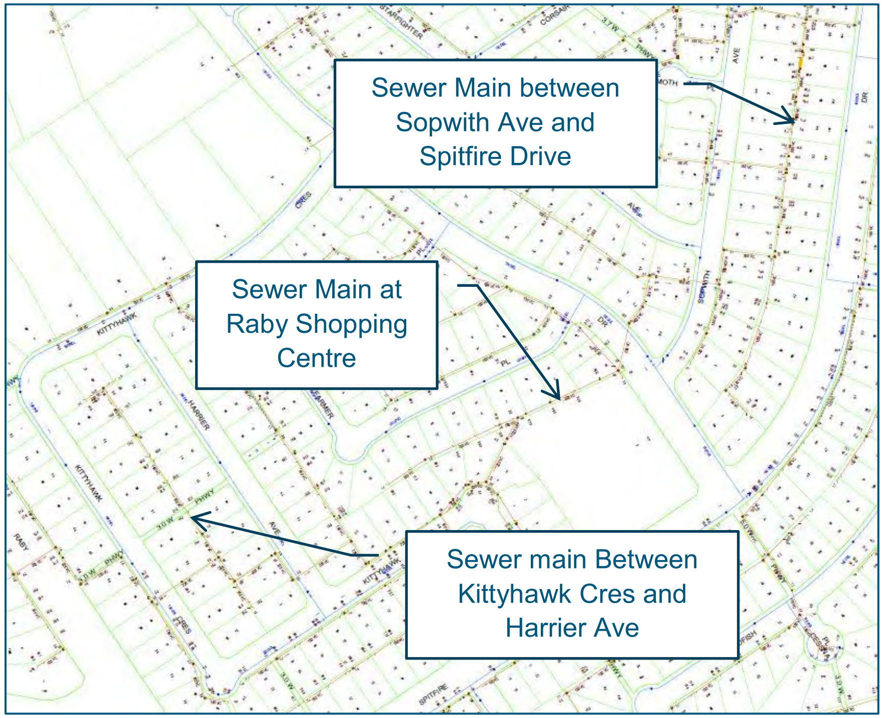


Figure 27: Jemena and Sydney Water Corporation Assets at Sopwith Avenue

2.6.3 Concept Design

Approximately 80m of new Ø1050mm pipeline along an existing walkway between no.37 and no. 35 Kittyhawk Crescent is proposed connecting to an additional approximately 55m of Ø1050mm pipeline parallel to Harrier Avenue and subsequently connecting back into the existing network at 6 Harrier Avenue, to supplement the existing stormwater network.

Furthermore, duplication of approximately 200m of pipeline from Harrier Avenue to the Raby Shopping Centre is proposed with a further additional 120m of 2 x Ø600mm pipes from the north west corner of the Shopping centre to a discharge location at the corner of Hurricane Drive and Sopwith Avenue.

At Sopwith Park (refer **Figure 28**), a detention basin is to be formalised and the existing two 0.54m^2 inlets are to both be replaced with 6.48m^2 grated inlets. The net excavation required to achieve the desired basin levels would be approximately 600m^3. An overview of Sopwith Park is presented in **Figure 29** and a typical cross section of the proposed basin is presented in **Figure 30**.

Furthermore, Three pumps of 2m^3/s capacity are also to be installed within the basin and connected to approximately 180m of new 3 x Ø1200mm pipes which travel north down Sopwith Avenue and then east between no. 25 and no. 23 Sopwith Avenue where they connecting into the existing network on Spitfire Drive. All proposed pipes would be class 2 reinforced concrete pipes with a HS2 type support. For a typical pipe cross section refer **Figure 7**

Figure 28: Sopwith Park Street View

Figure 29: Sopwith Park Overview: Areas in blue to be cut and areas in yellow - red to be filled (Aerial Source: Nearmap, 2018)

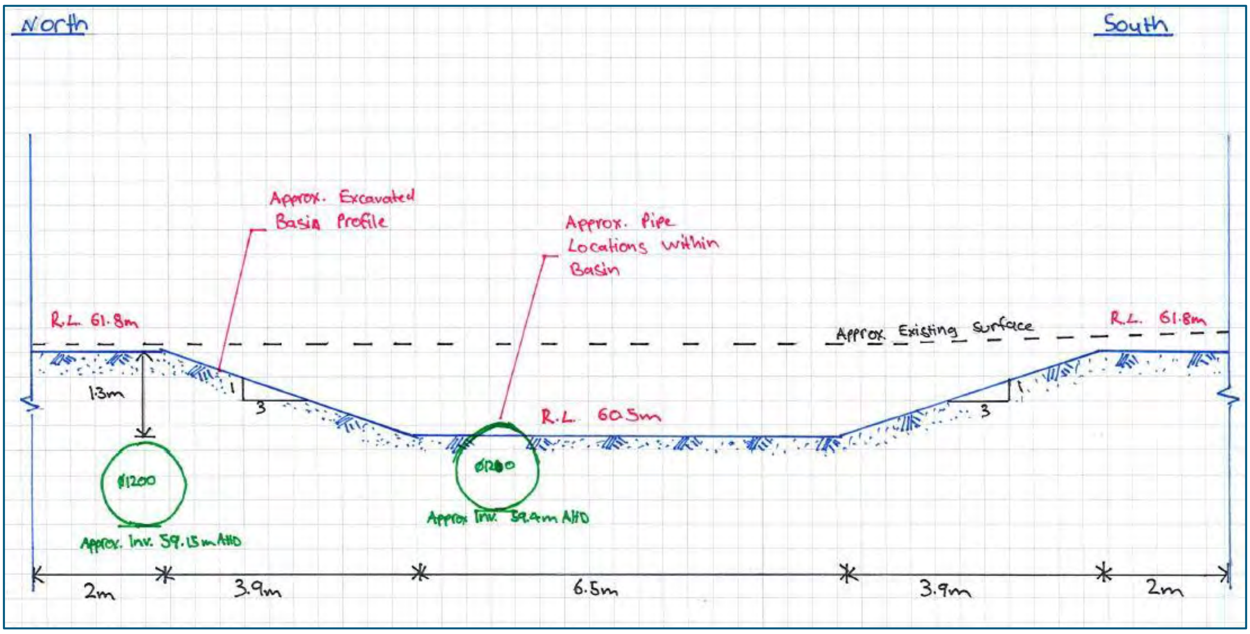


Figure 30: Cross Section of Proposed Sopwith Park Basin

For concept design sketches of Option 6 please refer to **Appendix A.**

2.6.4 Health & Safety Considerations

The following health and safety considerations have been identified for Option 6:

- The health and safety considerations for Option 6 are principally concerning the detention basin at Sopwith Park. Considerations include:
  - The basin spillway (chiefly the northern park embankment) is abutting a residential property and is within 1m of the residential buildings. Despite being a small basin, should the basin overtop (which it currently does from the 20yr ARI event onwards) it is likely to cause a localised increase in flood hazard to those properties immediately downstream (i.e. to the north) due to a concentration of flows across the spillway.
  - The operation of such large pumps in close vicinity to a number of residential properties poses a potential risk to the public.
  - In the event that the proposed pumps fail to operate properly due to mechanical faults or power failure during a major storm, there is again likely to be a localised increase in flood hazard to the those properties downstream given the concentrated volume of water that would flow across the spillway.

2.6.5 Operation & Maintenance Consideration

The following operation and maintenance considerations have been identified for Option 6:

- The proposed pumps and supporting infrastructure (e.g. power supply, transformers etc.) will require specialist routine maintenance to maintain optimal performance ;
- The pumps will also require routine cleaning to remove collected debris and reduce the risk of blockages
- New inlet pits including two new 6.48m2 grated inlet pits within Sopwith Park will require routine maintenance to remove collected debris and reduce the risk of blockages.

2.6.6 Cost

The Estimated costs for the implementation of Option 2 are presented below in **Table 11**.

Table 11: Option 6 Estimated Capital Cost

Items	Costs
Preliminaries	$286,500
Clearing & Demolition	$26,693
Earthworks	$223,194
Stormwater Drainage	$510,619
Outlet Pumps	*$3,000,000**
Road Pavements	$26,834
Concrete Works	$6,259
Landscaping	$14,952
Subtotal	**$4,095,050**
Contingency and Administration	$1,548,788
TOTAL	**$5,643,839**

**Nominal Fee of $1M per 2m^3/s pump.*

Table 12: Option 6 Estimated Whole of Life Costs

Items	Rate ($/Period)	Total Present Value (at Rate of 7%)
Routine maintenance of Pump (i.e. once every 2 years)	$4,000 every 2 years	$26,668
Routine cleaning of pumps (i.e. once every year)	$1,000 every year	$13,801
Routine cleaning of grated inlet pits (i.e. once every year)	$2,000 every year	$27,601
Routine Inspection and Cleaning of stormwater pipes (i.e. once every 5 years)	$3,000 every 5 years	$7,199
	Subtotal	**$75,269**
	Contingency (30%)	$22,581
	TOTAL	**$97,850**

Assumptions

In preparing the above cost estimate the following key assumptions have been made:

- No excavation into rock;
- Excavation slopes of 1(V):3(H) are acceptable;
- No services relocation;
- No contaminated materials; and
- Class 2 reinforced concrete stormwater pipes are sufficient.

2.6.7 Overall Feasibility

The following potential issues regarding the feasibility of Option 4 were identified during concept design:

- The capacity of basin at Sopwith Park would be significantly reduced due to required battering of embankment slopes. The approximate length of each embankment would be 6m and would reduce the width of the basin floor from the modelled approximately 12.5m to approximately 6.5m; representing a loss in volume of approximately 100m^3
- The size of Sopwith Park is such that it would not operate as a detention basin, however would rather operate as a sump for the proposed three 2m^3/s pumps.
- The proposed three 2m^3/s pumps would occupy almost the entire basin surface area.
- Employing pumps at the reserve would require significant supporting infrastructure (i.e. pumping station power requirements, transformers etc.).
- Construction of new pipes along Sopwith Avenue (3 x Ø1200mm) and through to Spitfire Drive would require excavation and shoring of an approximately 5m wide trench that crosses directly through two residential properties.
- Duplication of the Ø1050mm pipes between Kittyhawk Cres and the Raby Shopping Centre would require excavation of an approximately 2.5m trench that crosses directly through a residential property.
- A Ø1200mm stormwater pipe crosses through the north west corner of Sopwith Park and post excavation would be above basin floor level without relocation.

2.6.8 Alternative Approaches

Owing to the relatively small size of the proposed detention basin at Sopwith Park and the requirements for large pumping infrastructure it is suggested that an alternative approach utilising underground storage be considered should a storage basin on Sopwith Avenue be deemed necessary. If the storage of the detention basin is relocated underground a more efficient use of space can be achieved by installing the pumping infrastructure within the Park and having a sump below the park. It is acknowledged that this would be an expensive alternative however given the space restraints and the already significant capital investment required to install the proposed pumps it should be recognised as a potentially feasible alternative. Furthermore, if the detention basin storage was relocated underground a greater storage volume may be achieved, depending on the prevailing ground conditions and services, and hence the need for three 2 m^3/s pumps may be reduced. It is also acknowledged that this option would require increased inspection and maintenance requirements.

2.6.9 Data Gaps

The following further investigations/data is required to prior to any further design development:

- Detailed topographic survey of Sopwith Park along the alignment of the proposed stormwater network upgrades (i.e. along Kittyhawk Crescent, Harrier Avenue and Sopwith Avenue).
- Detailed services survey with the location and invert of all relevant services assets along the alignment of the proposed stormwater network upgrades (i.e. along Kittyhawk Crescent, Harrier Avenue and Sopwith Avenue).
- Geotechnical Investigations of the materials making up the existing reserve and of the materials likely to be encountered during excavation. Additional geotechnical Investigations to determine the soil characteristics where new stormwater lines are proposed.
- Further investigations into the requirements of employing pumps at the reserve and the required supporting infrastructure (i.e. pumping station power requirements, transformers etc).

2.7 Option 7 – Dumaresq Street Drainage

2.7.1 Description & Intended Hydraulic Performance

To divert overland flows from the Campbelltown CBD and surrounding residential areas back into Bow Bowing Creek, increased stormwater pits and pipes network capacity is proposed along Dumaresq Street and under Queen St and subsequently under Hurley Street and the Railway Embankment, back into the creek at Farrow Road.

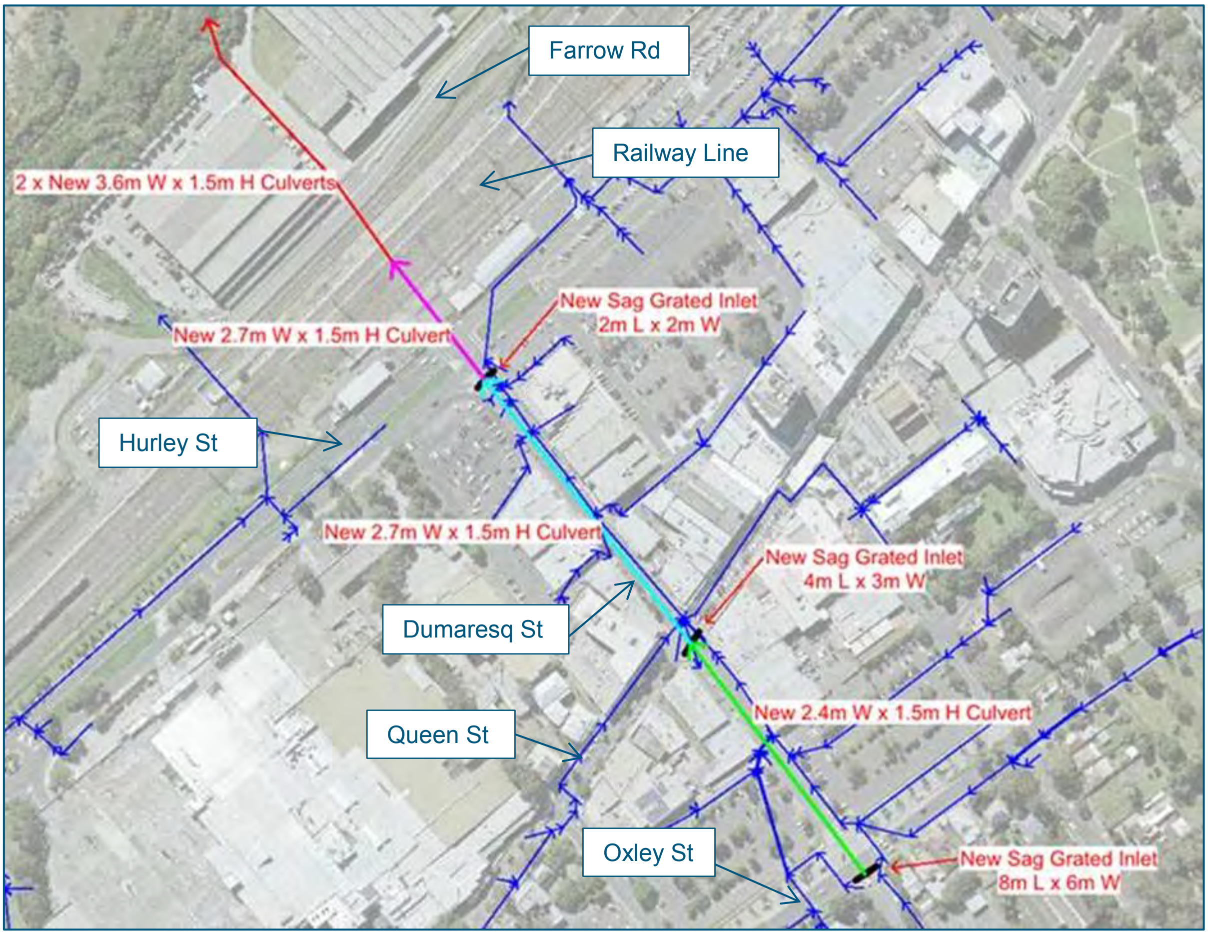


Figure 31: Option 7 Schematised Overview

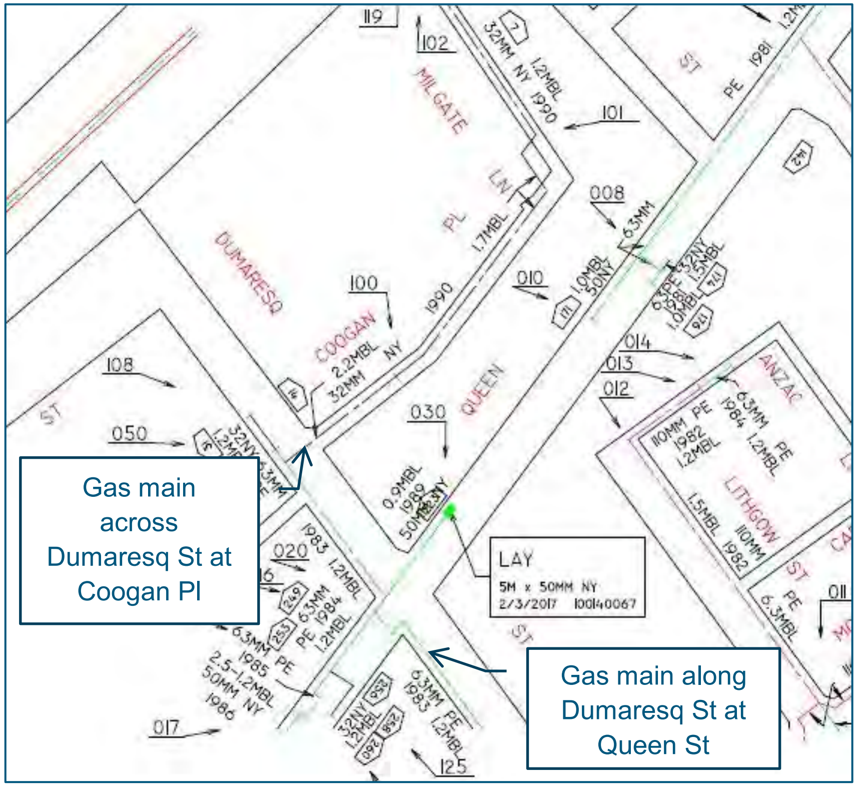
2.7.2 Existing Services Locations

The proposed alignment of new stormwater network elements which comprise Option 7 are likely to encounter significant clashes with existing services, especially considering the elements to be installed are relatively large box culverts. An outline of the services likely to obstruct the alignment of the proposed stormwater network upgrades is detailed below and excerpts of the DBYD for gas and water/sewer mains are presented in **Figure 32**:

- A Telecommunications services duct is present along Queen Street at the Dumaresq Street Intersection;
- Several Endeavour Energy assets exist along the proposed culvert alignment including at the Hurley Street Intersection and along the western side of Dumaresq Street between Oxley Street

and Coogan Place. Endeavour Energy assets also cross Dumaresq Street between Queen Street and Coogan Place and at the Coogan Place Intersection.

- A Ø63mm, 210 kPa Jemena Gas Network main is present along the western side of Dumaresq Street, between Oxley Street and Coogan Place, approximately 1.2 metres from the boundary line. Additional Ø50mm and Ø32mm 210kPa network mains cross Dumaresq Street at Queen Street and Coogan Place respectively (refer **Figure 32**).
- NBN assets are present along both the eastern and western side of Dumaresq Street between Oxley Street and Hurley Street.
- A Nextgen services duct bisects Dumaresq Street at Queen Street;
- Optus assets are present along the western side of Dumaresq Street between Queen Street and Hurley Street and continue through to the railway. Optus Assets also bisect Dumaresq Street at Queen Street.
- RMS traffic signal assets exist at Dumaresq Street at both the Queen Street and Hurley Street Intersections.
- Numerous Sydney Water Assets, both potable water and sewer mains, exist along the alignment of the proposed stormwater upgrades (refer **Figure 32**) including:
    - A Ø180mm PE water main along eastern side of Dumaresq Street Between Oxley Street and Queen Street;
    - A Ø150mm CICL water main along western side of Dumaresq Street Between Queen Street an Hurley Street;
    - A Ø150mm VC Sewer main along western side of Dumaresq Street from Oxley Street halfway to Queen Street;
    - Two Ø225 VC sewer mains along the centre of Dumaresq Street from Queen Street to the Railway line.
    - A Ø300mm EW to Ø450 PP (Concrete encased) underneath the railway line along the alignment of the proposed box culvert.



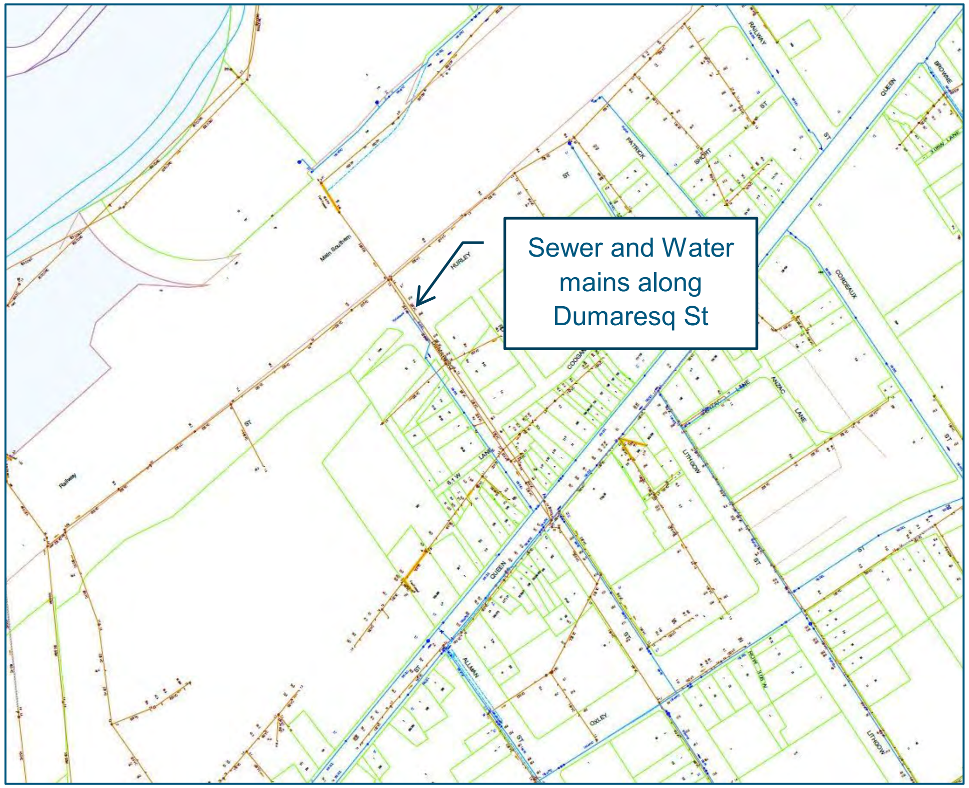


Figure 32: Jemena and Sydney Water Corporation Assets at Dumaresq Street

2.7.3 Concept Design

The proposed new stormwater elements along Dumaresq Street are to include:

- A 8m x 6m grated inlet at the Oxley Street intersection;
- An approximately 170m, 2.4m (W) x 1.5m (H) box culvert from Oxley Street to Queen Street along Dumaresq Street;
- A 4m x 3m grated inlet at the Queen Street Intersection;
- An approximately 200m, 2.7m (W) x 1.5m (H) box culvert from Queen Street to Hurley Street along Dumaresq Street;
- A 2m x 2m sag grated inlet at the Hurley Street intersection;
- An approximately 90m, 2.7m (W) x 1.5m (H) box culvert from Hurley Street to the eastern side of the railway line; and
- Approximately 180m of twin 3.6m (W) x 1.5m (H) box culverts from middle of the railway corridor to the Bow Bowing Creek Channel.

All culverts would be assumed to be Class 2A reinforced concrete box culverts capable of being subject to loads associated with up 2m of fill above the culvert unit, link or base slab and road vehicle loadings in accordance with AS5100.2. Culverts would require excavation of a trench with a width having a minimum of 150mm between the culvert walls and trench walls (or any shoring equipment). Installation of the culverts would require a bedding layer of a minimum depth of 150mm, side zones of a minimum width of 150mm and an overlay zone of a minimum 150mm depth. All bedding zone, side zone and overlay zone material would be engineering fill in accordance with AS1597.2-2013. For a typical culvert section within the road, refer **Figure 33**.

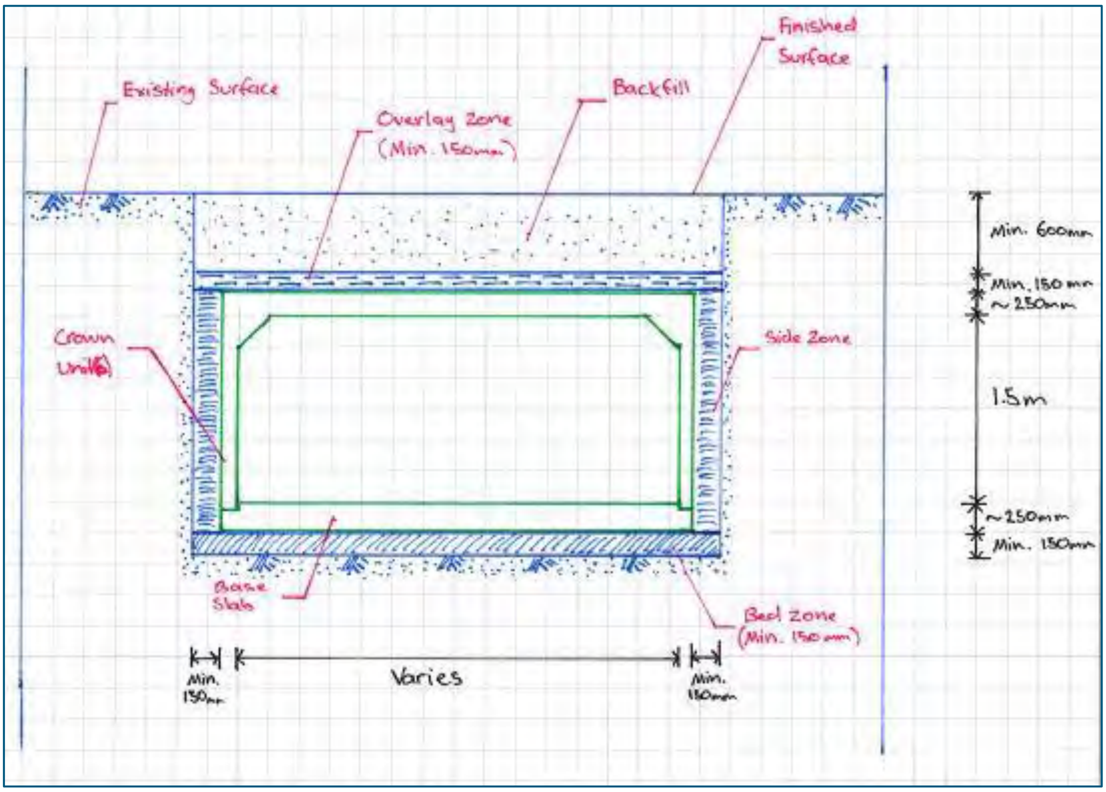


Figure 33: Typical Culvert Section

For concept design sketches of Option 7 please refer to **Appendix A.**

2.7.4 Health & Safety Considerations

No significant, additional health and safety considerations are likely to arise from implementation of Option 7.

2.7.5 Operation & Maintenance Consideration

The following operation and maintenance considerations have been identified for Option 7:

- New inlet pits including a new 8m x 6m sag grated inlet at the Oxley Street intersection, a new 4m x 3m sag grated inlet at the Queen Street intersection and a new 2m x 2m sag grated inlet at the Hurley Street intersection will require routine maintenance to remove collected debris and reduce the risk of blockages.

2.7.6 Cost

The estimated costs for the implementation of Option 2 are presented below in.

Table 13: Option 7 Estimated Capital Cost

Items	Costs
Preliminaries^	$536,500
Clearing & Demolition	$58,945
Earthworks*	*$2,594,433*
Stormwater Drainage	$1,954,636
Road Pavements	$132,213
Subtotal	**$5,276,737**
Contingency and Administration	$1,981,286
TOTAL	**$7,258,023**

^Including $200,000 allowance for railway 'possession'
**Nominal Fee of $2M for construction of culverts under railway*

Table 14: Option 7 Estimated Whole of Life Costs

Items	Rate ($/Period)	Total Present Value
Routine Cleaning of grated Inlet Pits (i.e. Once every 5 years)	$3,000 every 5 years	$7,199
Routine Inspection and Cleaning of stormwater culverts (i.e. once every 5 years)	$4,000 every 5 years	$9,598
	Subtotal	**$16,797**
	Contingency (30%)	$5,039
	TOTAL	**$21,836**

Royal HaskoningDHV

Assumptions

In preparing the above cost estimate the following key assumptions have been made:

- 'Possession'[1] of a local extent of railway will be required for construction of stormwater infrastructure under the railway. Possession of the rail line is considered to be required regardless of construction methodology (i.e. open cut trenches or directional drilling);
- No excavation into rock;
- No services relocation; and
- Class 2A reinforced concrete box culverts are sufficient.

2.7.7 Overall Feasibility

The following potential issues regarding the feasibility of Option 4 were identified during concept design:

- The principal concern regarding the feasibility of Option 7 is constructing the proposed 70m of culverts underneath the railway corridor. This may require either directional drilling or excavation and partial, temporary disconnection of the railway. Regardless, of the final construction methodology, it is likely that railway 'possession' will be required for this component of the works.
- The proposed design changes from a 2.7m (W) x 1.5m (H) box culvert to twin 3.6m (W) x 1.5m (H) box culverts midway along the railway. It is unlikely that the excavations needed for twin 3.6m (W) x 1.5m (H) box culverts can be achieved without some disruption to the operation of trains along the railway line.
- Due to the large size of the proposed stormwater elements and the location of existing services it is likely that conflicts with services will be encountered and that either the alignment of the stormwater line will have be altered or the affected services assets will have to be relocated where possible, however it is not possible to determine with certainty which services and at which locations this may be required without further services survey.
- Large disruptions to traffic will likely result due to the size of excavations required along Dumaresq Street and Hurley St. As such lanes will likely have to be temporarily closed and traffic diverted.

2.7.8 Alternative Approaches

Should it be deemed necessary for a stormwater line to cross under the railway embankment to discharge into the Bow Bowing Creek channel, it is suggested to replace the proposed 2.7m (W) x 1.5m (H) box culvert with two (2) Ø1800mm pipe culverts (or more) which maintains a similar cross sectional area and if directionally drilled would likely cause minimal if any disruption to railway activities.

2.7.9 Data Gaps

- Detailed topographic survey along the alignment of the proposed stormwater network upgrades (i.e. along Dumaresq Street).
- Detailed services survey with the location and invert of all relevant services assets along the alignment of the proposed stormwater network upgrades (i.e. along Dumaresq Street).
- Geotechnical Investigations to determine the soil characteristics where new stormwater lines are proposed and the characteristics of materials likely to be encountered during excavation.

[1] Railway 'possession' refers to a period of time where one or more tracks are closed to allow for the undertaking of major works. For the duration of the works a nominated person is granted control of the line and once the works are completed possession is relinquished back to the rail authority.

Geotechnical investigations are considered particularly important along the alignment of the proposed stormwater line under the railway.

- Further investigations into the feasibility of constructing a stormwater line under the railway corridor whether by directional drilling or open cut trenches and partial temporary disconnecting of the railway during railway ‘possession’.

3 Options Overview

Table 15: Options Overview

OPTIONS	Services	Health & Safety	Operation & Maintenance	Capital Costs	Whole of Life Costs (NPV)	Feasibility	Data Gaps
OPTION 1	• Several services assets exist along the alignment of the proposed upgrade works along Pardalote Street including energy, gas, telecommunications, potable water, and sewer. • Services unlikely to conflict with upgrades on Pardalote Street given scale of upgrades and existing alignment. • Conflicts with services maybe present along narrow walkway leading from Koala Walk Reserve, although unlikely (refer **Figure 3**).	• Increased discharge velocities at outlet downstream of Aubrey Street. • Proposed speed hump along Oxford Road must be suitable for traffic conditions.	• Routine maintenance of new grated inlet pits to prevent debris build up and blockage.	**$1.45M**	**$13K**	• No significant 'red flags'. • Potential, though unlikely, conflicts with services. • Maximum vertical deflection of proposed speed hump exceeds Austroads recommendations.	• Detailed services survey along proposed stormwater upgrades alignment. • Detailed topographic survey in Koala Walk Reserve. • Geotechnical investigations where new stormwater lines are proposed.
OPTION 2	• Major Service's assets exist along the alignment of Ingleburn Road in the vicinity of stormwater upgrades. • Of particular note are sewer mains present along Norfolk Street and Ingleburn Road ranging in size from Ø225mm to Ø450mm. • Given the relatively large size of the proposed culverts it is likely that conflicts with existing services will arise.	• Increased localised flooding of properties near existing open concrete channel as ground levels are increased if adequate surface drainage measures not installed..	• Routine maintenance of eleven (11) new grated inlet pits to prevent debris build up and blockages.	**$13.44M**	**$50K**	• Large excavations along busy suburban road will require lane closures and traffic diversions. • Owing to the size and alignment of the proposed culverts it is likely that realignment of some existing services will be required.	• Detailed services survey along Norfolk Street and Ingleburn Road. • Detailed topographic survey of existing open concrete channel. • Geotechnical investigations at locations of proposed new box culverts.
OPTION 3	• No major services conflicts are expected to be encountered during implementation of Option 3. • Duplication of existing stormwater pipes Greenoaks Avenue will need to be mindful of a Ø300mm sewer main along Greenoaks Avenue through to Fishers Ghost Reserve. • No services are expected to bisect Manooka Reserve other than stormwater.	• Overtopping of basin embankments and inundation of downstream properties. • Activation of spillway discharges water in close proximity to residential properties. • Ponding of water in Manooka Reserve. • Proposed speed humps along The Parkway must be suitable for traffic conditions.	• Routine maintenance of new grated inlet pits to prevent debris build up and blockage.	**$4.05M**	**$3K**	• Modelled storage volume will be decreased due to need for shallower excavation slopes. • Sufficiency of Spillway height has not been yet been determined. • Excavation depths may be limited by prevailing ground conditions. • Maximum vertical deflection of proposed speed hump exceeds Austroads recommendations	• Detailed services survey at relevant locations along Campbellfield Avenue and Greenoaks Avenue. • Detailed topographic survey of Manooka Reserve. • Geotechnical investigation at Manooka Reserve to ascertain local geology and soils. • Formal dam break assessment is required to determine adequacy of spillway.
OPTION 4	• Due to the limited nature of regrading along Epping Forest Drive no services are expected to be disturbed. • No services are expected along the extent of footpath regrading.	• Proposed speed hump along Oxford Road. must be suitable for traffic conditions • Concentration of flows along regraded walkway may scour and undermine existing property fences.	• No expected operation and maintenance requirements.	**$118K**	**N/A**	• Excavation and regrading of walkway will require some form of batter stabilisation (e.g. retaining wall or sheet piling). • Maximum vertical deflection of proposed speed hump exceeds Austroads recommendations.	• Detailed topographic survey of road surface and walkway to be regraded.

OPTIONS	Services	Health & Safety	Operation & Maintenance	Capital Costs	Whole of Life Costs (NPV)	Feasibility	Data Gaps
OPTION 5	• The area to be regraded overlies an existing Ø900mm stormwater pipe and Ø225mm sewer main. • The depth of the regraded area will be limited by the presences of these services which under the modelled design have obverts above the regraded ground surface.	• Concentration of flows along the regraded area may scour and undermine adjacent residential property fences.	• No expected operation and maintenance requirements.	**$98K**	**N/A**	• The modelled cross sectional area of the regraded area cannot be physical achieved without either: ○ Encroachment into residential properties; ○ Exposing subsurface services; or ○ Creating unstable bank slopes.	• Detailed services survey along the regraded area. • Detailed topographic survey of the area to be regraded. • Minor geotechnical investigations to ascertain local soil properties at area to be regraded and where pipe inverts are to be lowered.
OPTION 6	• Several services assets either exist along or bisect the alignment of the proposed stormwater upgrade works along Kittyhawk Crescent and Sopwith Avenue. • Of particular note is a Ø150mm sewer main between Kittyhawk Crescent and Harrier Avenue, a Ø225mm sewer main along Kittyhawk Crescent through to the Raby Shopping Centre and a Ø300mm sewer main between Sopwith Avenue and Spitfire Drive.	• The basin at Sopwith Park is immediately adjacent to residential properties and should it overtop would increase flood hazard at these properties. • The operation of large industrial pumps in close proximity to residential properties poses a risk to the public.	• Routine maintenance of pumps and supporting infrastructure. • Routine cleaning of pumps to prevent build of debris. • Routine maintenance of new grated inlet pits to prevent debris build up and blockage.	**$5.64M**	**$98K**	• The modelled basin storage area would be appreciably reduced by the need for shallower excavation slopes. • The three (3) $2m^3/s$ pumps and supporting infrastructure would likely occupy more than the entire surface area of the basin. • Existing services within the basin would become exposed with the proposed excavation s. • Construction of new Ø1200mm pipes between Sopwith Avenue and Spitfire Drive and duplication of Ø1050mm pipes between Kittyhawk Crescent and Harrier Avenue would require large excavations through multiple residential properties.	• Detailed topographic survey of Sopwith Park. • Detailed services survey along proposed stormwater upgrades alignment. • Geotechnical investigations of soil characteristics at Sopwith Park. • Further investigations into requirements and costs of installing pumping infrastructure at Sopwith Park.
OPTION 7	• Significant clashes with existing services are likely to encountered during implementation of Option 7, especially considering the elements to be installed are large-medium sized box culverts. • Of particular concern are potable water and sewer mains along the length of Dumaresq Street ranging in size from Ø150mm to Ø300mm. • Furthermore a number of services bisect Dumaresq Street including gas, and telecommunications assets.	• No significant health and safety issues are expected to arise as a result of implementation of Option 7.	Routine maintenance of new grated inlet pits to prevent debris build up and blockage.	**$7.26M**	**$22K**	• Directional drilling underneath the railway corridor may not be feasible for such large box culvert units in particular twin 3.6m (W) x 1.5m (H) culverts. • Construction of approximately 70m of large stormwater elements underneath the railway corridor may require temporary disconnection of the railway lines. • Owing to the size and alignment of the proposed culverts it is likely that realignment of some existing services will be required • Large excavations along busy suburban road will require lane closures and traffic diversions.	• Detailed services survey along Dumaresq Street. • Geotechnical Investigations at locations of proposed new box culverts in particular at the railway. • Further investigations into the feasibility and cost of constructing large stormwater lines under the railway corridor.

APPENDIX A – Concept Design Sketches

Calc Ref

Project Bow Bowing - Option 1

Oxford Rd. Embankment

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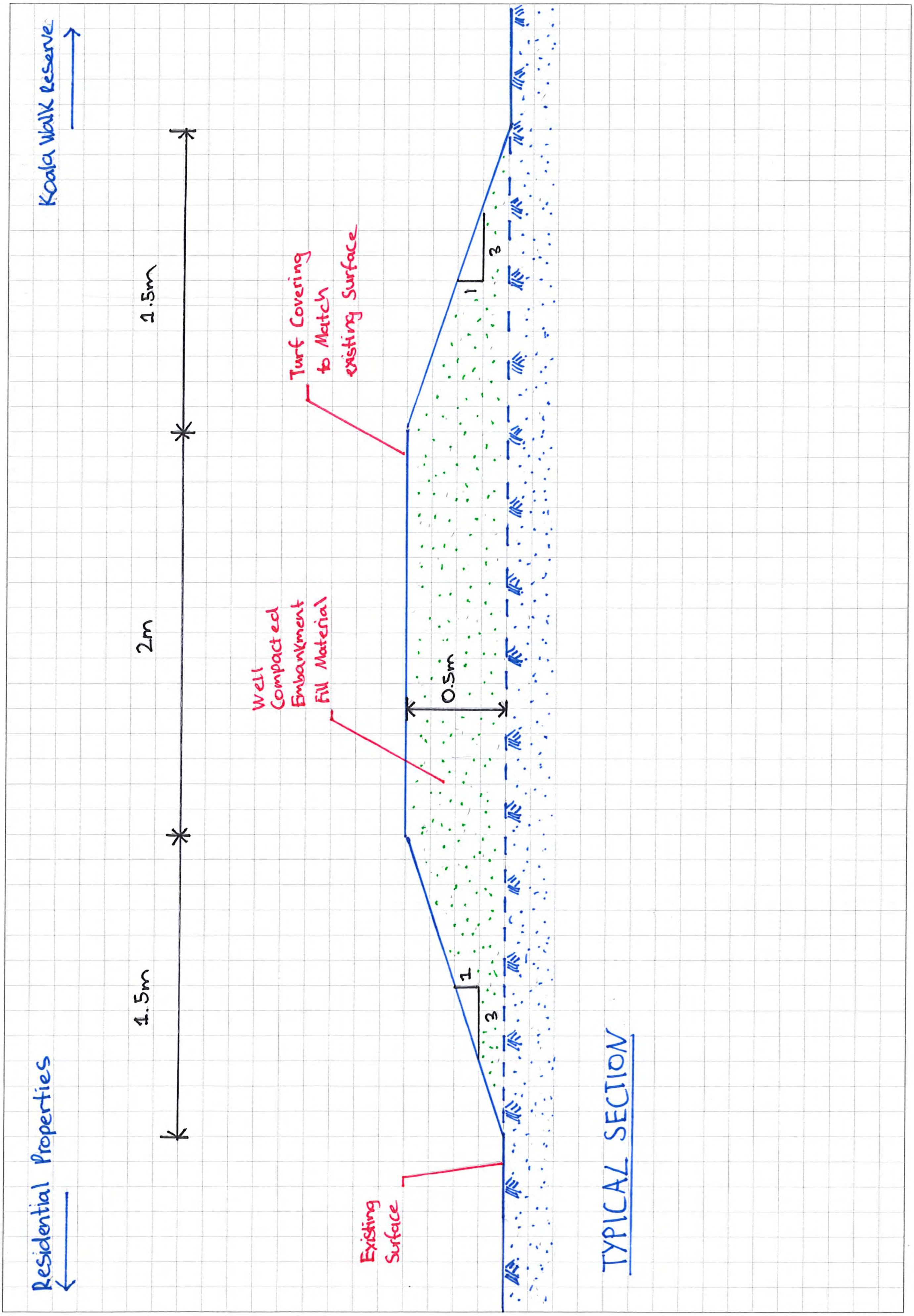

Calc Ref

Project Bow Bowing - Option 2
Open Channel - Typical Section

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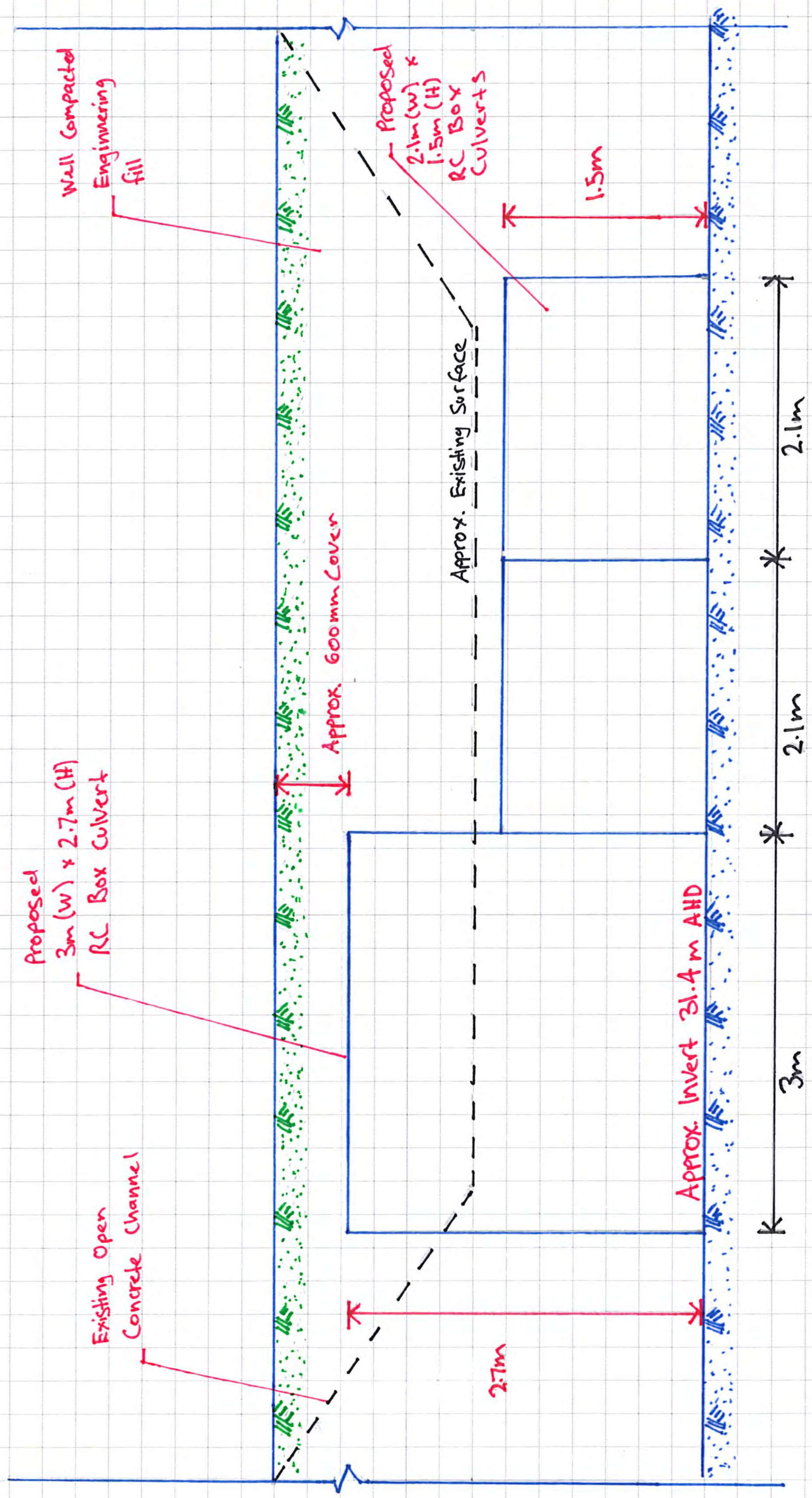

Calc Ref

Project Bow Bowing - Option 3

Manooka Reserve - Typical Section

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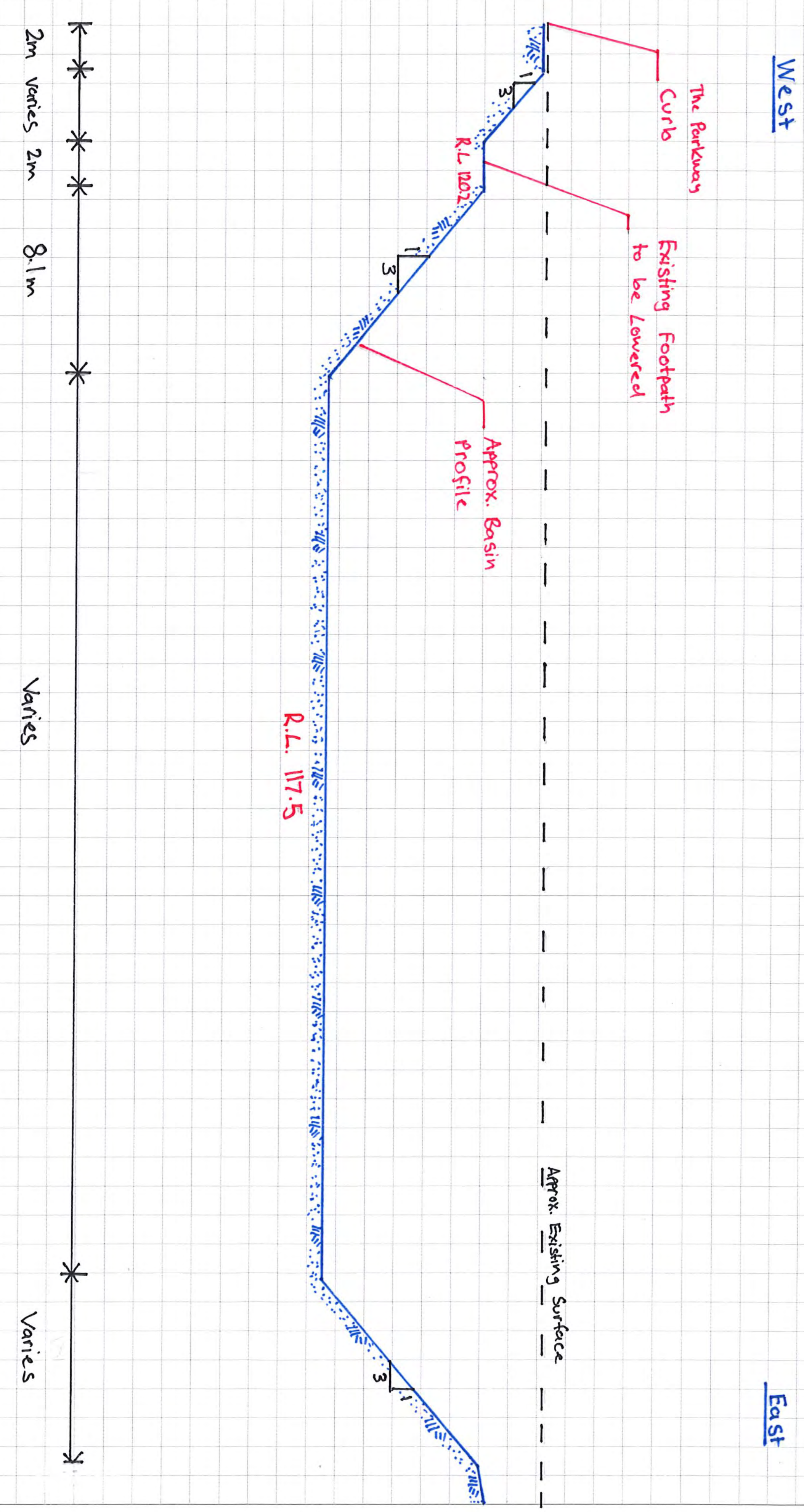

Calc Ref

Project Bow-Bowing Option 3

Mon Dok Reserve Longitudinal Section

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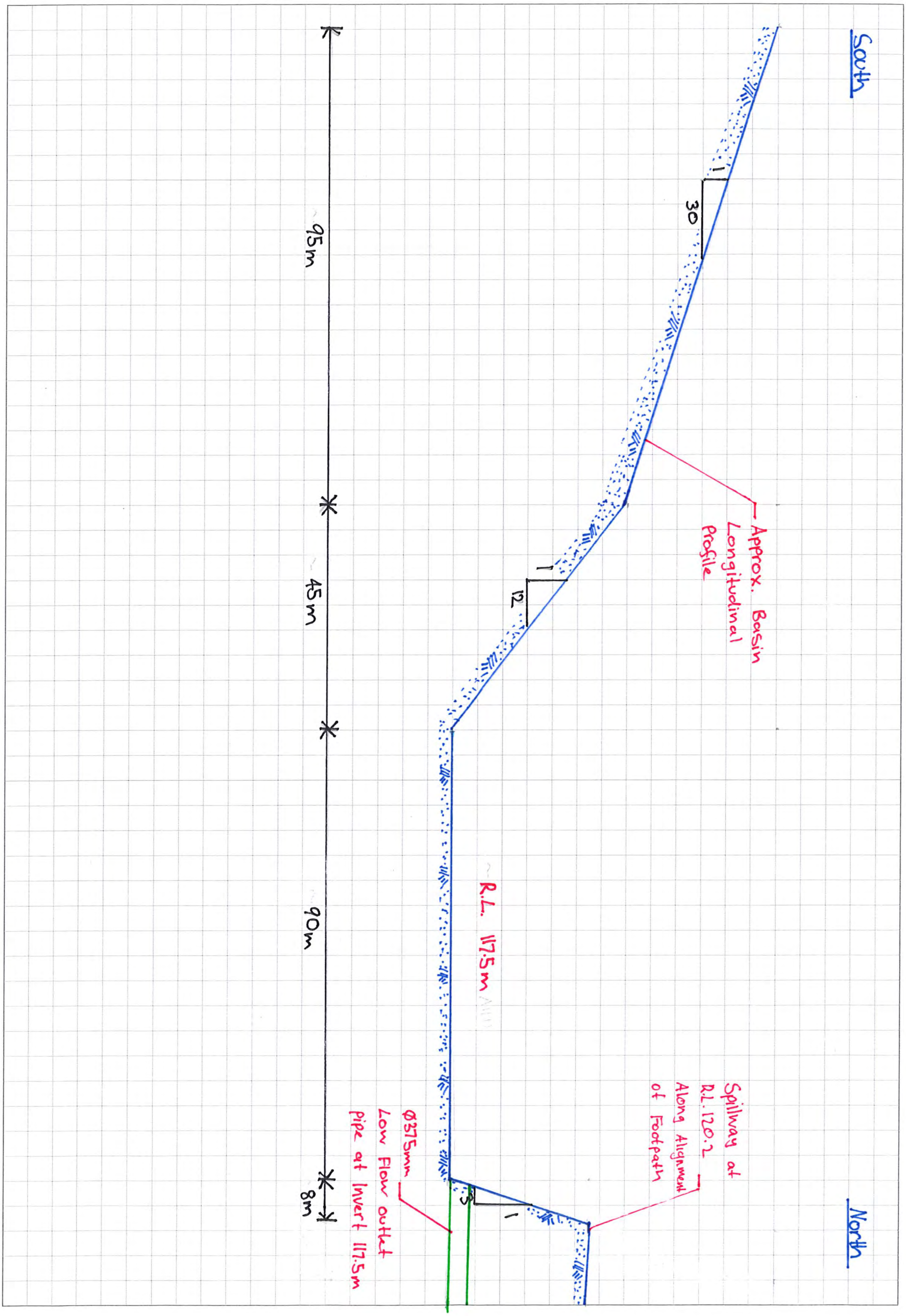

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Project Bow Rowing

Option 4 - Walkway X-Section

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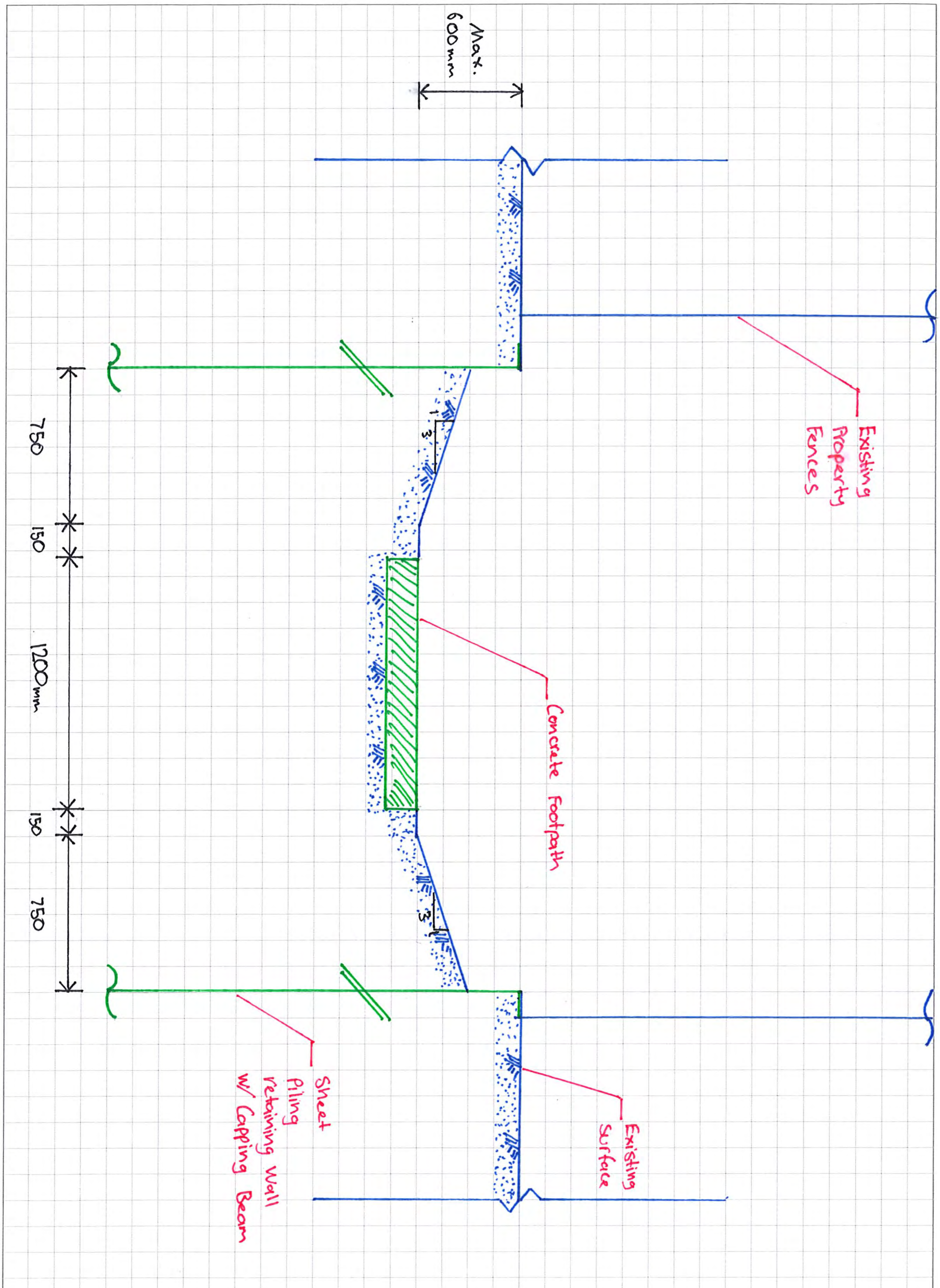

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Project Bow Bowing - Option 5

Cross Section Above Pit

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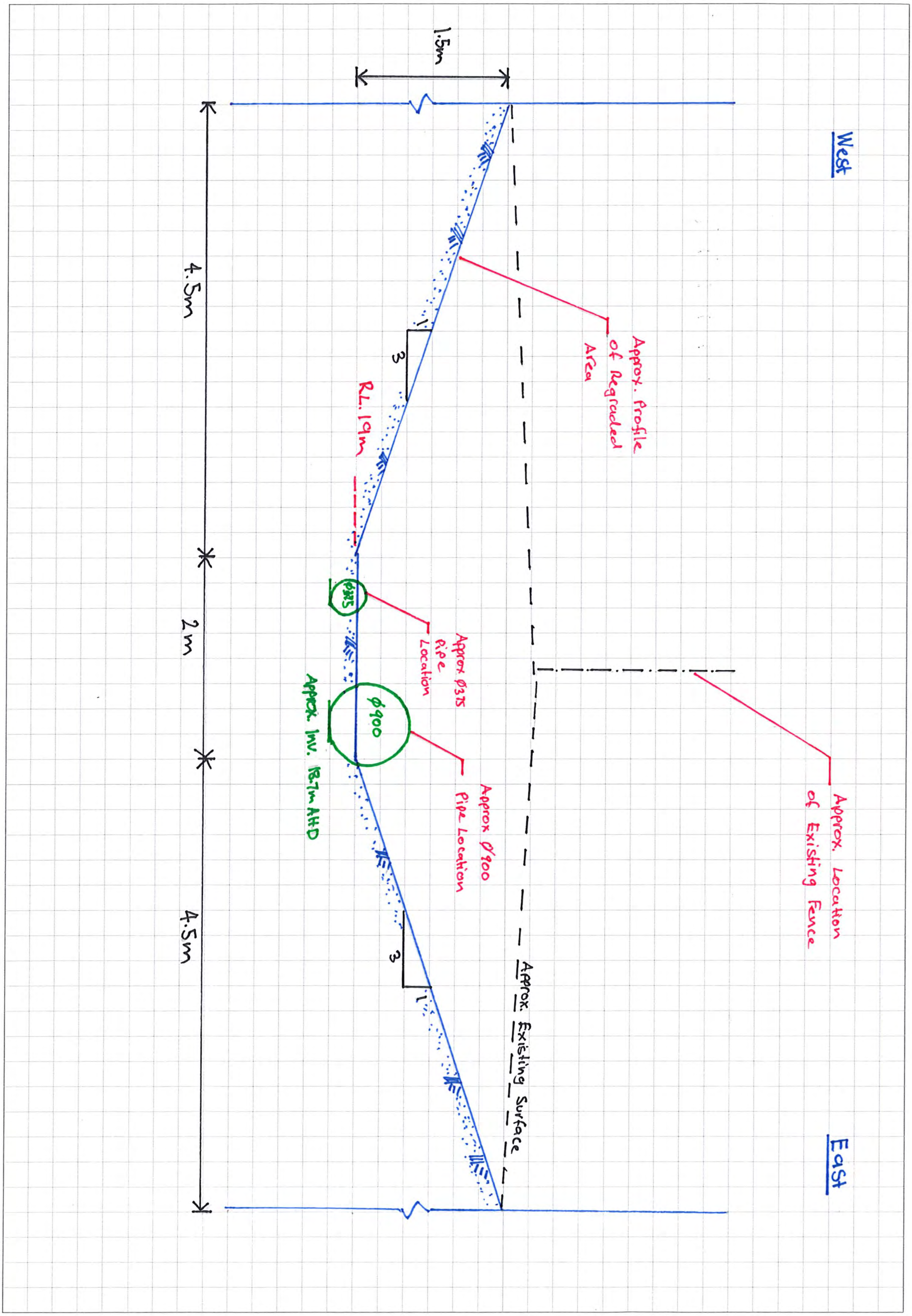

Calc Ref

Project Bow Bowing - Option 6 Sopwith Park Section

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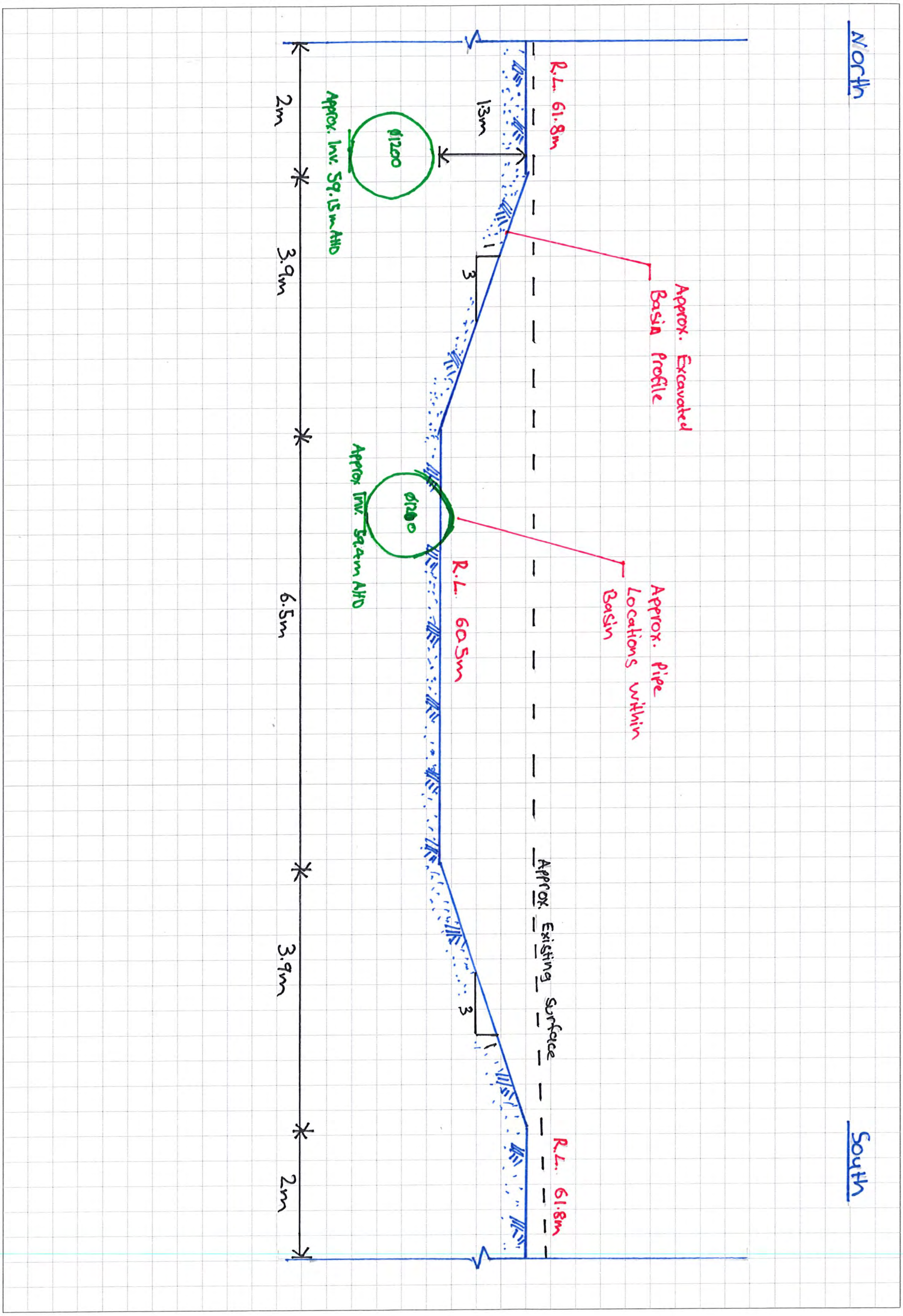

Calc Ref

Project Bow Bowing

Typical Culvert Section

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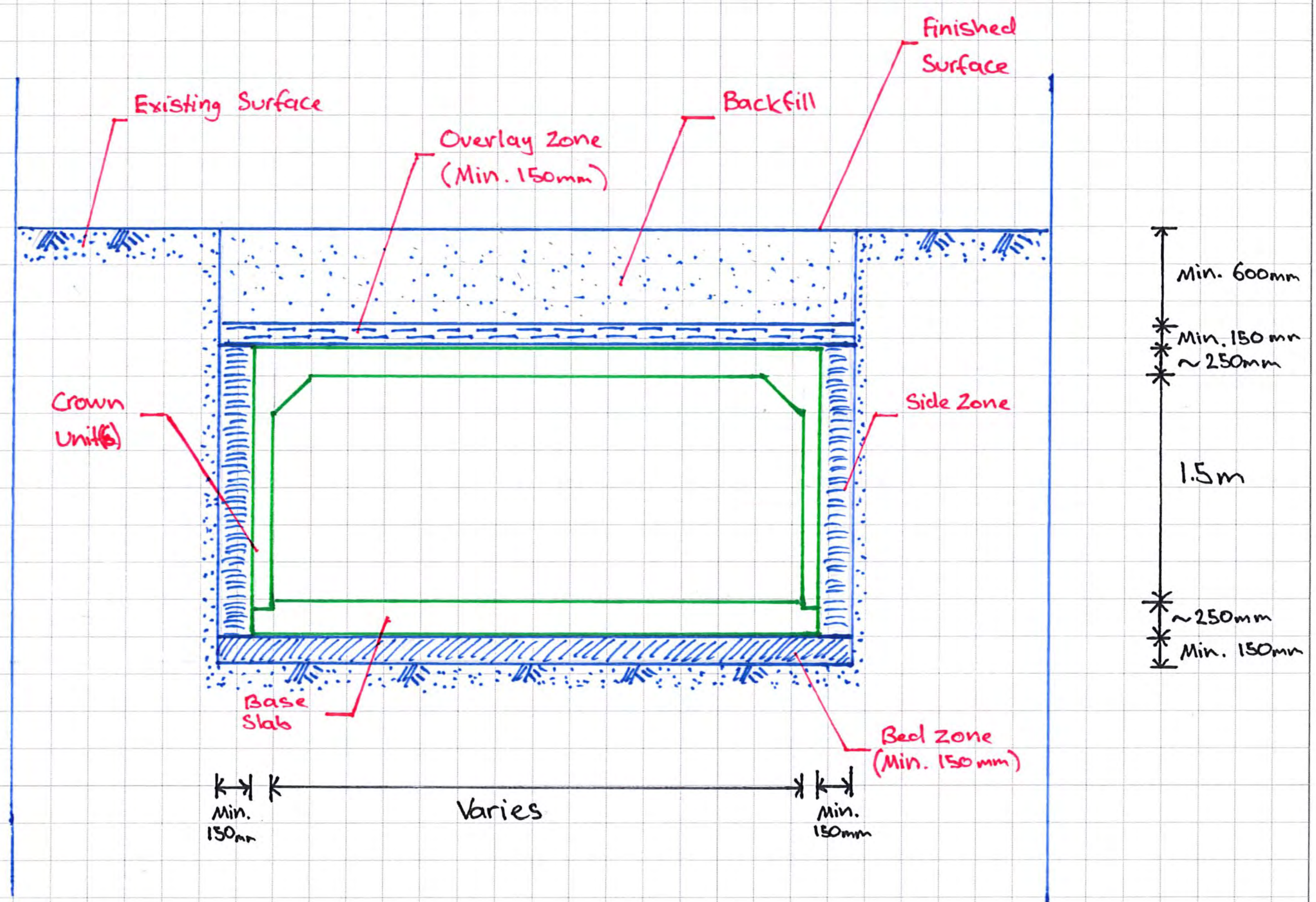

Calc Ref

Project Row Rowing

Typical Pipe Section

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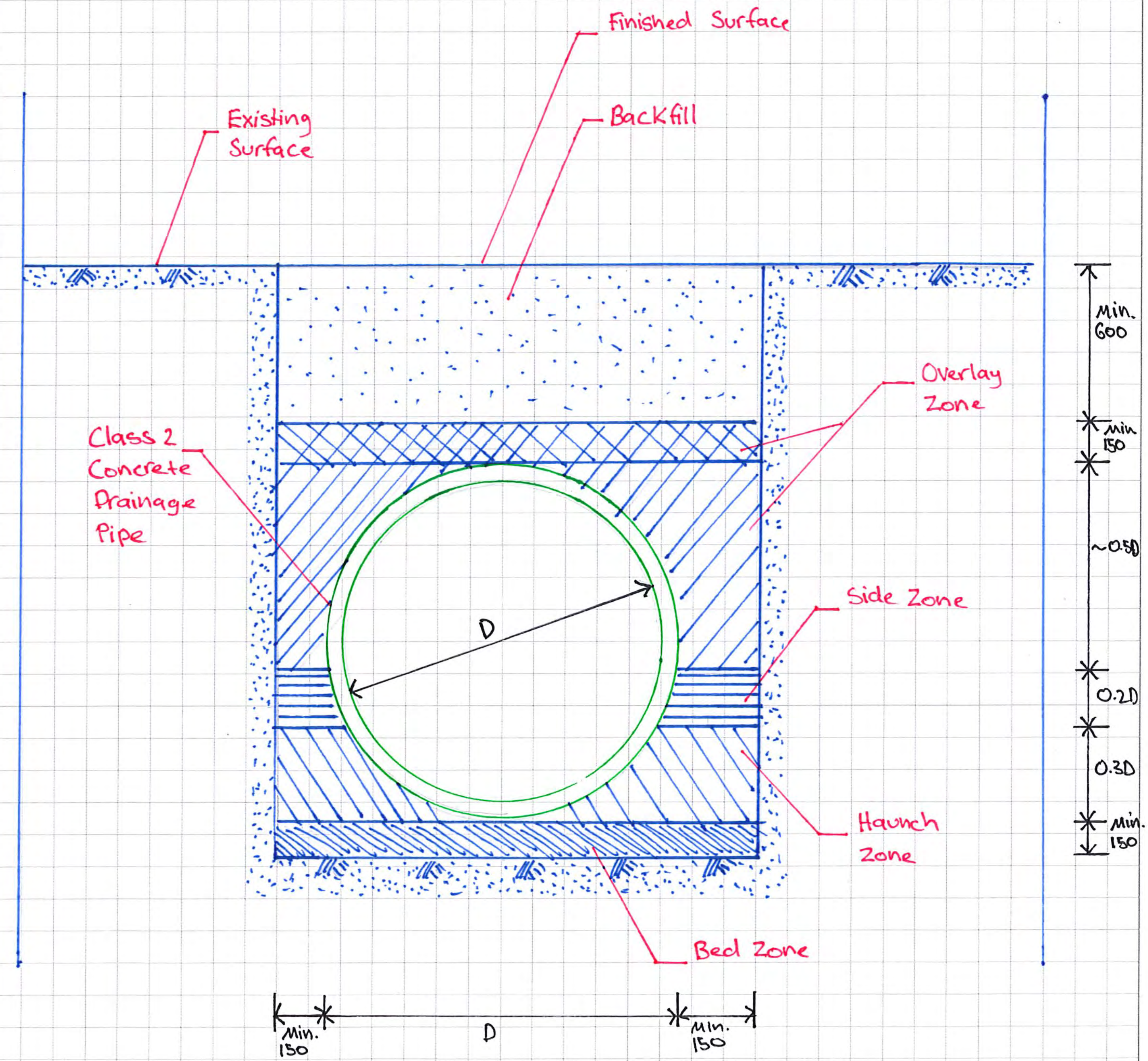

APPENDIX B – Detailed Cost Estimate

Budget Cost Estimate

Haskoning Australia Pty Ltd

Date: 9-May-18

Client: Molino Stewart
RHDHV Job No. PA1707
Project Name: Campbelltown FRMS&P Flood Mitigation Options
Item: **Option 1 - Oxford Road**

Item #	Description	Unit	Qty	Rate	Total
1	**Preliminaries**				
1.1	Project management & supervision	Item	1	$ 90,000.00	$ 90,000
1.2	Site compound	Item	1	$ 25,000.00	$ 25,000
1.3	Mobilisation	Item	1	$ 35,000.00	$ 35,000
1.4	Demobilisation	Item	1	$ 30,000.00	$ 30,000
1.5	OH&S allowances	Item	1	$ 15,000.00	$ 15,000
1.6	Site survey	Item	1	$ 15,000.00	$ 15,000
1.7	Works as executed	Item	1	$ 1,500.00	$ 1,500
1.8	Services location	Item	1	$ 5,000.00	$ 5,000
1.9	Erosion sediment and control	Item	1	$ 40,000.00	$ 40,000
1.10	Traffic management	Item	1	$ 15,000.00	$ 15,000
1.11	Engineering inspection and testing	Item	1	$ 10,000.00	$ 10,000
1.12	Insurances and security	Item	1	$ 5,000.00	$ 5,000
				Subtotal	**$ 286,500**
2	**Clearing & Demolition**				
2.1	Clear vegetation (Inc Turf) Where required	sq.m	785	$ 8.85	$ 6,947
2.2	Strip Topsoil	cu.m	79	$ 5.40	$ 424
2.3	Demolish and remove existing footpath <150thk	sq.m	495	$ 30.00	$ 14,850
2.4	Sawcaut existing roadway and kerb	m	70	$ 10.00	$ 700
2.5	Break up of existing pavement	sqm	53	$ 3.50	$ 184
2.6	Remove existing pipes offsite	item	4	$ 2,500.00	$ 10,000
				Subtotal	**$ 33,105**
3	**Earthworks**				
3.2	Trim and compact embankment subgrade	sq.m	325	$ 2.29	$ 744
3.3	Contruction of earth embankment	cu.m	114	$ 60.00	$ 6,825
3.4	Excavate Trench for Ø600mm Pipe & Backfill	cu.m	282	$ 60.40	$ 17,012
3.5	Excavate Trench for Ø900mm Pipe & Backfill	cu.m	557	$ 60.40	$ 33,642
3.6	Excavate Trench for Ø1200mm Pipe & Backfill	cu.m	406	$ 60.40	$ 24,494
3.7	Excavate Trench for Ø1800mm Pipe & Backfill	cu.m	1156	$ 60.40	$ 69,850
3.8	Excavate Trenches for Stormwater Pits	cu.m	13	$ 60.40	$ 783
3.9	Trench Shoring (where required)	sq.m	2414	$ 30.60	$ 73,855
3.10	Trim and compact trench subgrade	sq.m	965	$ 2.29	$ 2,211
3.11	Place and compact bedding layer (150mm thk)	cu.m	145	$ 55.00	$ 7,965
3.12	Allowance to haul and dispose off site surplus spoil (to Council site)	cu.m	850	$ 50.00	$ 42,508
				Subtotal	**$ 279,888**
4	**Stomrwater Drainage**				
	Pipes				
4.1	Supply and Place ø600mm Class 2 RCP	m	113	$ 310.00	$ 34,925
4.2	Supply and Place ø900mm Class 2 RCP	m	149	$ 570.00	$ 84,662
4.3	Supply and Place ø1200mm Class 2 RCP	m	108	$ 915.00	$ 98,948
4.4	Supply and Place ø1800mm Class 2 RCP	m	231	$ 1,550.00	$ 358,500
				Subtotal	*$ 577,034*
	Pits				
4.7	Supply and Place Stormwater drainage pit w/ 2.4m Lintel	No.	2	$ 3,400.00	$ 6,800
4.8	Supply and Place Stormwater drainage pit w/ 3m Lintel	No.	4	$ 3,800.00	$ 15,200
4.9	Supply and Place 0.45 x 0.45m grated Inlet Pit	No.	2	$ 1,800.00	$ 3,600
4.10	Supply and Place 1.5 x 1.5 Junction Pit w/Lid	No.	4	$ 4,500.00	$ 18,000
4.11	Supply and Place 1.5 x1.5m grated Inlet Pit	No.	1	$ 4,500.00	$ 4,500
4.12	Supply and Place 3.8m2 Grated Inlet Pit	No.	1	$ 8,600.00	$ 8,600
4.13	Supply and Place 6.48m2 Grated Inlet Pit	No.	1	$ 13,000.00	$ 13,000
				Subtotal	*$ 69,700*
				Subtotal	**$ 646,734**
5	**Outlet Headwall**				
5.1	RC Concrete Headwall foundation	cu.m	1	$ 526.00	$ 526
5.2	RC Concrete Headwall (200mm thick)	sq.m	2	$ 456.00	$ 684
5.3	Construct reinforced concrete wingwalls	sqm.	10.0	$ 450.00	$ 4,500
5.4	Construct reinforced concrete apron	cum.	2.0	$ 330.00	$ 660
				Subtotal	**$ 6,370**
5	**Road Pavements**				
5.1	Trim & compact subgrade	sq.m	53	$ 2.87	$ 151
5.2	200 DGS40 Subbase - supply, place & compact	sq.m	53	$ 21.64	$ 1,136
5.3	120 DGB20 Basecourse - supply, place & compact	sq.m	53	$ 15.21	$ 799
5.4	7mm primer seal	sq.m	53	$ 5.69	$ 299
5.5	30mm AC10 wearing course	sq.m	53	$ 19.80	$ 1,040

Budget Cost Estimate

Haskoning Australia Pty Ltd

Date: 9-May-18

Client: Molino Stewart
RHDHV Job No. PA1707
Project Name: Campbelltown FRMS&P Flood Mitigation Options
Item: **Option 1 - Oxford Road**

Item #	Description	Unit	Qty	Rate	Total
				Subtotal	**$ 3,424**
6	**Concrete Works**				
6.2	Trim and compact footpath subgrade	sq.m	492	$ 2.29	$ 1,127
6.3	1200mm wide reinforced concrete footpath	m	35	$ 76.60	$ 2,681
6.4	3000mm wide reinforced concrete footpath	m	150	$ 180.00	$ 27,000
				Subtotal	**$ 30,808**
7	**Landscaping**				
7.1	Trim & compact subgrade	sq.m	785	$ 2.87	$ 2,253
7.1	Replace topsoil 100 thk	sq.m	785	$ 5.00	$ 3,925
7.2	Replace Turf	sq.m	785	$ 6.00	$ 4,710
				Subtotal	**$ 10,888**
				SUBTOTAL (excl. GST)	**$ 1,017,828**
				Engineering Design (4%)	$ 40,713.13
				Environmental Assessment and Approvals	$ 50,000
				Tender Preparation (0.6%)	$ 6,107
				Supervision and Contract Administration (2%)	$ 20,356.57
				Contingency (30%)	$ 305,349
				TOTAL (excl. GST)	**$ 1,440,354**

This cost estimate is indicative being based on our experience from a number of projects at a range of sites and conditions. This estimate is provided for broad guidance only and is NOT guaranteed by Royal HaskoningDHV as we have no control over contractor's prices, market forces and competitive bids from tenderers. Any construction cost estimates provided may exclude items which should be considered in a cost plan. Examples of such items are design fees, project management fees, authority approval fees, contractors risk, preliminaries and project contingencies (e.g. to account for construction and site conditions, weather conditions, ground conditions and unknown services). If a reliable cost estimate is required, an appropriately qualified Quantity Surveyor should be engaged and market feedback sought.

Budget Cost Estimate

Haskoning Australia Pty Ltd

Date: 9-May-18

Client: Molino Stewart

RHDHV Job No. PA1707

Project Name: Campbelltown FRMS&P Flood Mitigation Options

Item: **Option 2 - Ingleburn Stormwater Upgrades**

Item #	Description	Unit	Qty	Rate	Total
1	**Preliminaries**				
1.1	Project management & supervision	Item	1	$ 100,000.00	$ 100,000
1.2	Site compound	Item	1	$ 30,000.00	$ 30,000
1.3	Mobilisation	Item	1	$ 40,000.00	$ 40,000
1.4	Demobilisation	Item	1	$ 30,000.00	$ 30,000
1.5	OH&S allowances	Item	1	$ 20,000.00	$ 20,000
1.6	Site survey	Item	1	$ 20,000.00	$ 20,000
1.7	Works as executed	Item	1	$ 10,000.00	$ 10,000
1.8	Services location	Item	1	$ 20,000.00	$ 20,000
1.9	Erosion sediment and control	Item	1	$ 50,000.00	$ 50,000
1.10	Traffic management	Item	1	$ 60,000.00	$ 60,000
1.11	Engineering inspection and testing	Item	1	$ 20,000.00	$ 20,000
1.12	Insurances and security	Item	1	$ 20,000.00	$ 20,000
				Subtotal	**$ 420,000**
2	**Clearing & Demolition**				
2.1	Clear vegetation (Inc Turf) Where required	sq.m	375	$ 8.85	$ 3,319
2.2	Strip Topsoil (100mm)	cu.m	38	$ 5.40	$ 203
2.3	Sawcut concrete footpath	m	12.0	$ 10.00	$ 120
2.4	Demolish and remove existing footpath <150thk	sq.m	160	$ 30.00	$ 4,800
2.5	Sawcaut existing roadway and kerb	m	2255	$ 10.00	$ 22,550
2.6	Break up of existing pavement	sqm	5650	$ 3.50	$ 19,775
2.7	Break up existing open concrete channel base	sqm	430	$ 72.90	$ 31,347
2.8	Break up existing open concrete channel walls	cum	56	$ 547.00	$ 30,632
2.9	Demolish esisting culvert suspended slabs	sqm	220	$ 158.50	$ 34,870
2.10	Demolish existing culvert slabs	sqm	220	$ 72.90	$ 16,038
2.11	Demolish existing culvert centre wall	cum	21	$ 547.00	$ 11,487
				Subtotal	**$ 175,140**
3	**Earthworks**				
3.4	Excavate Trench for 3m(W) x 2.7m(H) Culvert & Backfill	cu.m	7600	$ 60.40	$ 459,040
3.5	Excavate Trench for 3.6m(W) x 1.5m(H) Culvert & Backfill	cu.m	3600	$ 60.40	$ 217,440
3.6	Excavate Trench for 3.6m(W) x 3m(H) Culvert & Backfill	cu.m	10800	$ 60.40	$ 652,320
3.9	Trench Shoring (where required)	sq.m	4400	$ 30.60	$ 134,640
3.10	Trim and compact trench subgrade	sq.m	5800	$ 2.29	$ 13,282
3.11	Place and compact bedding layer (150mm thk)	cu.m	870	$ 55.00	$ 47,850
3.12	Allowance to haul and dispose off site surplus spoil (to Council site)	cu.m	10368	$ 50.00	$ 518,400
3.13	Backfill Culverts replacing open Channel	cu.m	23	$ 60.00	$ 1,380
				Subtotal	**$ 2,044,352**
4	**Stomrwater Drainage**				
	Pipes				
4.1	Supply and Place 3m(W) x 2.7m(H) Culvert	m	484	$ 4,900.00	$ 2,371,600
4.2	Supply and Place 3.6m(W) x 1.5m(H) Culvert	m	240	$ 3,500.00	$ 840,000
4.3	Supply and Place 3.6m(W) x 3m(H) Culvert	m	540	$ 5,900.00	$ 3,186,000
4.4	Supply and Place 2.1m (W) x 1.5m (H) Culvert	m	107	$ 2,300.00	$ 246,100
				Subtotal	*$ 6,643,700*
	Pits				
4.12	Supply and Place 3.8m2 Grated Inlet Pit		11	$ 8,600.00	$ 94,600
4.13	Supply and Place 6.48m2 Grated Inlet Pit	No.	1	$ 13,000.00	$ 13,000
				Subtotal	*$ 107,600*
	Outlets				
4.15	RC Concrete Headwall foundation	cu.m	1	$ 526.00	$ 526
4.16	RC Concrete Headwall (200mm thick)	sq.m	10	$ 456.00	$ 4,560
				Subtotal	**$ 6,756,386**
5	**Road Pavements**				
5.1	Trim & compact subgrade	sq.m	5650	$ 2.87	$ 16,216
5.2	200 DGS40 Subbase - supply, place & compact	sq.m	5650	$ 21.64	$ 122,266
5.3	120 DGB20 Basecourse - supply, place & compact	sq.m	5650	$ 15.21	$ 85,937
5.4	7mm primer seal	sq.m	5650	$ 5.69	$ 32,149
5.5	30mm AC10 wearing course	sq.m	5650	$ 19.80	$ 111,870
				Subtotal	**$ 368,437**
6	**Concrete Works**				
6.1	Kerb & gutter	m	130	$ 65.00	$ 8,450
6.2	Trim and compact footpath subgrade	sq.m	160	$ 2.29	$ 366
6.3	1200mm wide reinforced concrete footpath	m	100	$ 76.60	$ 7,660
6.4	2000mm wide reinforced concrete footpath	m	20	$ 130.00	$ 2,600
				Subtotal	**$ 19,076**
7	**Landscaping**				

Budget Cost Estimate

Haskoning Australia Pty Ltd

Date: 9-May-18

Client: Molino Stewart

RHDHV Job No. PA1707

Project Name: Campbelltown FRMS&P Flood Mitigation Options

Item: **Option 2 - Ingleburn Stormwater Upgrades**

Item #	Description	Unit	Qty	Rate	Total
7.1	Trim & compact subgrade	sq.m	1190	$ 2.87	$ 3,415
7.2	Replace topsoil 100 thk	sq.m	1190	$ 5.00	$ 5,950
7.3	Replace Turf	sq.m	1190	$ 6.00	$ 7,140
				Subtotal	**$ 16,505**
				SUBTOTAL (excl. GST)	**$ 9,799,896**
				Engineering Design (4%)	$ 391,995.86
				Environmental Assessment and Approvals	$ 50,000
				Tender Preparation (0.6%)	$ 58,799
				Supervision and Contract Administration (2%)	$ 195,997.93
				Contingency (30%)	$ 2,939,969
				TOTAL (excl. GST)	**$ 13,436,659**

This cost estimate is indicative being based on our experience from a number of projects at a range of sites and conditions. This estimate is provided for broad guidance only and is NOT guaranteed by Royal HaskoningDHV as we have no control over contractor's prices, market forces and competitive bids from tenderers. Any construction cost estimates provided may exclude items which should be considered in a cost plan. Examples of such items are design fees, project management fees, authority approval fees, contractors risk, preliminaries and project contingencies (e.g. to account for construction and site conditions, weather conditions, ground conditions and unknown services). If a reliable cost estimate is required, an appropriately qualified Quantity Surveyor should be engaged and market feedback sought.

Budget Cost Estimate

Haskoning Australia Pty Ltd

Date: 9-May-18

Client: Molino Stewart
RHDHV Job No. PA1707
Project Name: Campbelltown FRMS&P Flood Mitigation Options
Item: **Option 3 - Manooka Reserve Basin**

Item #	Description	Unit	Qty	Rate	Total
1	**Preliminaries**				
1.1	Project management & supervision	Item	1	$ 90,000.00	$ 90,000
1.2	Site compound	Item	1	$ 25,000.00	$ 25,000
1.3	Mobilisation	Item	1	$ 35,000.00	$ 35,000
1.4	Demobilisation	Item	1	$ 30,000.00	$ 30,000
1.5	OH&S allowances	Item	1	$ 15,000.00	$ 15,000
1.6	Site survey	Item	1	$ 15,000.00	$ 15,000
1.7	Works as executed	Item	1	$ 1,500.00	$ 1,500
1.8	Services location	Item	1	$ 5,000.00	$ 5,000
1.9	Erosion sediment and control	Item	1	$ 40,000.00	$ 40,000
1.10	Traffic management	Item	1	$ 15,000.00	$ 15,000
1.11	Engineering inspection and testing	Item	1	$ 10,000.00	$ 10,000
1.12	Insurances and security	Item	1	$ 5,000.00	$ 5,000
				Subtotal	**$ 286,500**
2	**Clearing & Demolition**				
2.1	Clear vegetation (Inc Turf) Where required	sq.m	10956	$ 8.85	$ 96,962
2.2	Strip Topsoil	cu.m	1096	$ 5.40	$ 5,916
2.3	Sawcut concrete footpath	m	4.5	$ 10.00	$ 45
2.3	Demolish and remove existing footpath <150thk	sq.m	375	$ 30.00	$ 11,250
2.4	Sawcaut existing roadway and kerb	m	60	$ 10.00	$ 600
2.5	Break up of existing pavement	sqm	347	$ 3.50	$ 1,215
2.6	Remove existing pipes offsite	item	1	$ 2,500.00	$ 2,500
				Subtotal	**$ 118,487**
3	**Earthworks**				
3.1	Excavation of Basin	cu.m	30600	$ 8.70	$ 266,220
3.3	Excavate Trench for Ø375mm Pipe & Backfill	cu.m	170	$ 60.40	$ 10,268
3.4	Excavate Trench for Ø450mm Pipe & Backfill	cu.m	80	$ 60.40	$ 4,832
3.5	Excavate Trench for Ø750mm Pipe & Backfill	cu.m	353	$ 60.40	$ 21,291
3.7	Excavate Trench for Ø1050mm Pipe & Backfill	cu.m	678	$ 60.40	$ 40,921
3.9	Trench Shoring (where required)	sq.m	1054	$ 30.60	$ 32,258
3.10	Trim and compact trench subgrade	sq.m	512	$ 2.29	$ 1,172
3.11	Place and compact bedding layer (150mm thk)	cu.m	77	$ 55.00	$ 4,224
3.12	Allowance to haul and dispose off site surplus spoil (to Council site)	cu.m	30910	$ 50.00	$ 1,545,500
				Subtotal	**$ 1,926,686**
4	**Stomrwater Drainage**				
	Pipes				
4.1	Supply and Place Ø375mm Class 2 RCP	m	68	$ 185.00	$ 12,580
4.2	Supply and Place Ø450mm Class 2 RCP	m	32	$ 235.00	$ 7,520
4.3	Supply and Place Ø750mm Class 2 RCP	m	141	$ 430.00	$ 60,630
5.3	Supply and Place Ø900mm Class 2 RCP	m	48	$ 570.00	$ 27,360
4.4	Supply and Place Ø1050mm Class 2 RCP	m	271	$ 742.50	$ 201,218
				Subtotal	*$ 309,308*
	Pits				
4.5	Supply and Place Stormwater drainage pit w/ 1.8m Lintel	No.	9	$ 3,000.00	$ 27,000
4.6	Supply and Place Stormwater drainage pit w/ 2.4m Lintel	No.	2	$ 3,400.00	$ 6,800
4.7	Supply and Place 0.45 x 0.45m grated Inlet Pit	No.	1	$ 1,800.00	$ 1,800
4.8	Supply and Place 1.5 x 1.5 Junction Pit w/Lid	No.	3	$ 4,500.00	$ 13,500
				Subtotal	*$ 49,100*
				Subtotal	**$ 358,408**
5	**Road Pavements**				
5.1	Trim & compact subgrade	sq.m	347	$ 2.87	$ 996
5.2	200 DGS40 Subbase - supply, place & compact	sq.m	347	$ 21.64	$ 7,509
5.3	120 DGB20 Basecourse - supply, place & compact	sq.m	347	$ 15.21	$ 5,278
5.4	7mm primer seal	sq.m	347	$ 5.69	$ 1,974
5.5	30mm AC10 wearing course	sq.m	347	$ 19.80	$ 6,871
				Subtotal	**$ 22,628**
6	**Concrete Works**				
6.1	Dish crossing	m	16	$ 125.00	$ 2,000
6.2	Trim and compact footpath subgrade	sq.m	375	$ 2.29	$ 859
6.3	1500mm wide reinforced concrete footpath	m	250	$ 89.50	$ 22,375
				Subtotal	**$ 25,234**
7	**Landscaping**				
7.1	Trim & compact subgrade	sq.m	11316	$ 2.87	$ 32,477
7.2	Supply and installation of Enkamat	sqm	440	$ 15.00	$ 6,600

Budget Cost Estimate

Haskoning Australia Pty Ltd

Date: 9-May-18

Client:	Molino Stewart	**RHDHV Job No.**	PA1707
Project Name:	Campbelltown FRMS&P Flood Mitigation Options		
Item:	**Option 3 - Manooka Reserve Basin**		

Item #	Description	Unit	Qty	Rate	Total
7.3	Replace topsoil 100 thk	sq.m	11316	$ 5.00	$ 56,581
7.4	Replace Turf	sq.m	11316	$ 6.00	$ 67,897
				Subtotal	**$ 163,554**
8	**Ancillary Works**				
8.1	speedhumps 0.3m	sqm	258	$ 98.00	$ 25,284
				Subtotal	**$ 25,284**
				SUBTOTAL (excl. GST)	**$ 2,926,781**
				Engineering Design (4%)	$ 117,071.24
				Environmental Assessment and Approvals	$ 50,000
				Tender Preparation (0.6%)	$ 17,561
				Supervision and Contract Administration (2%)	$ 58,535.62
				Contingency (30%)	$ 878,034
				TOTAL (excl. GST)	**$ 4,047,983**

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Budget Cost Estimate

Haskoning Australia Pty Ltd

Date: 9-May-18

Client: Molino Stewart
RHDHV Job No. PA1707
Project Name: Campbelltown FRMS&P Flood Mitigation Options
Item: **Option 4 - Epping Vale**

Item #	Description	Unit	Qty	Rate	Total
1	**Preliminaries**				
1.1	Project management & supervision	Item	1	$ 5,000.00	$ 5,000
1.2	Site compound	Item	1	$ 5,000.00	$ 5,000
1.3	Mobilisation	Item	1	$ 5,000.00	$ 5,000
1.4	Demobilisation	Item	1	$ 5,000.00	$ 5,000
1.5	OH&S allowances	Item	1	$ 1,000.00	$ 1,000
1.6	Site survey	Item	1	$ 1,500.00	$ 1,500
1.7	Works as executed	Item	1	$ 1,500.00	$ 1,500
1.8	Services location	Item	1	$ 1,000.00	$ 1,000
1.9	Erosion sediment and control	Item	1	$ 1,000.00	$ 1,000
1.10	Traffic management	Item	1	$ 5,000.00	$ 5,000
1.11	Engineering inspection and testing	Item	1	$ 1,000.00	$ 1,000
1.12	Insurances and security	Item	1	$ 1,000.00	$ 1,000
				Subtotal	**$ 33,000**
2	**Clearing & Demolition**				
2.4	Sawcaut existing roadway and kerb	m	39	$ 10.00	$ 385
2.5	Demolish and remove existing footpath <150thk	sq.m	42	$ 30.00	$ 1,260
2.7	Break up of existing pavement	sqm	568	$ 3.50	$ 1,988
				Subtotal	**$ 3,248**
3	**Earthworks**				
3.1	Excavate to design levels along walkway and roadway	cu.m	90	$ 5.40	$ 486
3.9	Trim and compact subgrade	sq.m	668	$ 2.29	$ 1,530
3.11	Allowance to haul and dispose off site surplus spoil (to Council site)	cu.m	90	$ 50.00	$ 4,500
				Subtotal	**$ 6,516**
4	**Retaining Wall**				
4.1	Sheetpilling along both sides of pathway corridor	sqm	90	$ 460.00	$ 41,400
5	**Road Pavements**				
5.2	200 DGS40 Subbase - supply, place & compact	sq.m	445	$ 21.64	$ 9,630
5.3	120 DGB20 Basecourse - supply, place & compact	sq.m	445	$ 15.21	$ 6,768
5.4	7mm primer seal	sq.m	445	$ 5.69	$ 2,532
5.5	30mm AC10 wearing course	sq.m	445	$ 19.80	$ 8,811
				Subtotal	**$ 27,741**
6	**Concrete Works**				
6.1	Dish crossing	m	12	$ 125.00	$ 1,438
6.2	1200 wide reinforced concrete footpath	sq.m	42	$ 105.00	$ 4,410
				Subtotal	**$ 5,848**
8	**Ancillary Works**				
8.1	speedhumps 0.3m	sqm	123	$ 49.00	$ 6,027
				Subtotal	**$ 6,027**
				SUBTOTAL (excl. GST)	**$ 82,380**
				Engineering Design (4%)	$ 3,295.18
				Environmental Assessment and Approvals	$ 5,000
				Tender Preparation (0.6%)	$ 494
				Supervision and Contract Administration (2%)	$ 1,647.59
				Contingency (30%)	$ 24,714
				TOTAL (excl. GST)	**$ 117,530**

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Budget Cost Estimate

Haskoning Australia Pty Ltd

Date: 9-May-18

Client: Molino Stewart | **RHDHV Job No.** PA1707
Project Name: Campbelltown FRMS&P Flood Mitigation Options
Item: **Option 5 - Harrow Road**

Item #	Description	Unit	Qty	Rate	Total
1	**Preliminaries**				
1.1	Project management & supervision	Item	1	$ 5,000.00	$ 5,000
1.2	Site compound	Item	1	$ 5,000.00	$ 5,000
1.3	Mobilisation	Item	1	$ 2,000.00	$ 2,000
1.4	Demobilisation	Item	1	$ 2,000.00	$ 2,000
1.5	OH&S allowances	Item	1	$ 1,000.00	$ 1,000
1.6	Site survey	Item	1	$ 1,500.00	$ 1,500
1.7	Works as executed	Item	1	$ 1,500.00	$ 1,500
1.8	Services location	Item	1	$ 1,000.00	$ 1,000
1.9	Erosion sediment and control	Item	1	$ 1,000.00	$ 1,000
1.10	Traffic management	Item	1	$ 5,000.00	$ 5,000
1.11	Engineering inspection and testing	Item	1	$ 1,000.00	$ 1,000
1.12	Insurances and security	Item	1	$ 1,000.00	$ 1,000
				Subtotal	**$ 27,000**
2	**Clearing & Demolition**				
2.1	Clear vegetation (Inc Turf) Where required	sq.m	231	$ 8.85	$ 2,044
2.2	Strip Topsoil	cu.m	23	$ 5.40	$ 125
				Subtotal	**$ 2,169**
3	**Earthworks**				
3.1	Excavation to design levels	cu.m	300	$ 8.70	$ 2,610
3.3	Excavate Trench for Ø375mm Pipe & Backfill	cu.m	25	$ 60.40	$ 1,510
3.6	Excavate Trench for Ø900mm Pipe & Backfill	cu.m	135	$ 60.40	$ 8,154
3.8	Excavate Trenches for Stormwater Pits	cu.m	5	$ 60.40	$ 302
3.9	Trench Shoring (where required)	sq.m	115	$ 30.60	$ 3,519
3.10	Trim and compact trench subgrade	sq.m	64	$ 2.29	$ 147
3.11	Place and compact bedding layer (150mm thk)	cu.m	10	$ 55.00	$ 528
3.12	Allowance to haul and dispose off site surplus spoil (to Council site)	cu.m	300	$ 50.00	$ 15,000
				Subtotal	**$ 31,770**
4	**Stomrwater Drainage**				
	Pipes				
4.1	Re Place Ø375mm Class 2 RCP	hrs	4	$ 125.00	$ 500
4.2	Re Place Ø900mm Class 2 RCP	hrs	4	$ 125.00	$ 500
				Subtotal	*$ 500*
	Pits				
4.3	Supply and Place 900mm dia. Pit w/lid	No.	1	$ 1,900.00	$ 1,900
4.4	Re Place 1.1m2 Grated Inlet Pit	hrs	4	$ 125.00	$ 500
4.5	Re Place 0.9 x 0.9 Junction Pit w/Lid	hrs	4	$ 125.00	$ 500
				Subtotal	*$ 500*
				Subtotal	**$ 3,900**
7	**Landscaping**				
7.1	Trim & compact subgrade	sq.m	231	$ 2.87	$ 663
7.2	Replace topsoil 100 thk	sq.m	231	$ 5.00	$ 1,155
7.3	Replace Turf	sq.m	231	$ 6.00	$ 1,386
				Subtotal	**$ 3,204**
				SUBTOTAL (excl. GST)	**$ 68,043**
				Engineering Design (4%)	$ 2,721.70
				Environmental Assessment and Approvals	$ 5,000
				Tender Preparation (0.6%)	$ 408
				Supervision and Contract Administration (2%)	$ 1,360.85
				Contingency (30%)	$ 20,413
				TOTAL (excl. GST)	**$ 97,946**

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Budget Cost Estimate

Haskoning Australia Pty Ltd

Date: 9-May-18

Client:	Molino Stewart	**RHDHV Job No.**	PA1707
Project Name:	Campbelltown FRMS&P Flood Mitigation Options		
Item:	**Option 6 - Sopwith Avenue and Spitfire Drive**		

Item #	Description	Unit	Qty	Rate	Total
1	**Preliminaries**				
1.1	Project management & supervision	Item	1	$ 90,000.00	$ 90,000
1.2	Site compound	Item	1	$ 25,000.00	$ 25,000
1.3	Mobilisation	Item	1	$ 35,000.00	$ 35,000
1.4	Demobilisation	Item	1	$ 30,000.00	$ 30,000
1.5	OH&S allowances	Item	1	$ 15,000.00	$ 15,000
1.6	Site survey	Item	1	$ 15,000.00	$ 15,000
1.7	Works as executed	Item	1	$ 1,500.00	$ 1,500
1.8	Services location	Item	1	$ 5,000.00	$ 5,000
1.9	Erosion sediment and control	Item	1	$ 40,000.00	$ 40,000
1.10	Traffic management	Item	1	$ 15,000.00	$ 15,000
1.11	Engineering inspection and testing	Item	1	$ 10,000.00	$ 10,000
1.12	Insurances and security	Item	1	$ 5,000.00	$ 5,000
				Subtotal	**$ 286,500**
2	**Clearing & Demolition**				
2.1	Clear vegetation (Inc Turf) Where required	sq.m	1078	$ 8.85	$ 9,540
2.2	Strip Topsoil (100mm)	cu.m	108	$ 5.40	$ 582
2.3	Sawcut concrete footpath	m	3.0	$ 10.00	$ 30
2.4	Demolish and remove existing footpath <150thk	sq.m	80	$ 30.00	$ 2,385
2.5	Sawcaut existing roadway and kerb	m	404	$ 10.00	$ 4,040
2.6	Break up of existing pavement	sqm	287	$ 3.50	$ 1,003
2.7	Break up existing car park pavement	sqm	125	$ 72.90	$ 9,113
				Subtotal	**$ 26,693**
3	**Earthworks**				
3.1	Excavation of Basin	cu.m	581	$ 8.70	$ 5,050
3.4	Excavate Trench for Ø600mm pipe & Backfill	cu.m	306	$ 60.40	$ 18,498
3.5	Excavate Trench for Ø1050mm pipe & Backfill	cu.m	1174	$ 60.40	$ 70,919
3.6	Excavate Trench for Ø1200mm pipe & Backfill	cu.m	689	$ 60.40	$ 41,608
3.8	Excavate Trenches for Stormwater Pits	cu.m	26	$ 60.40	$ 1,570
3.9	Trench Shoring (where required)	sq.m	1548	$ 30.60	$ 47,377
3.10	Trim and compact trench subgrade	sq.m	868	$ 2.29	$ 1,987
3.11	Place and compact bedding layer (150mm thk)	cu.m	130	$ 55.00	$ 7,159
3.12	Allowance to haul and dispose off site surplus spoil (to Council site)	cu.m	581	$ 50.00	$ 29,025
				Subtotal	**$ 223,194**
4	**Stomrwater Drainage**				
	Pipes				
4.1	Supply and Place ø600mm Class 2 RCP	m	123	$ 310.00	$ 37,975
4.2	Supply and Place ø1050mm Class 2 RCP	m	313	$ 742.50	$ 232,484
4.3	Supply and Place ø1200mm Class 2 RCP	m	184	$ 915.00	$ 168,086
				Subtotal	*$ 438,545*
	Pits				
4.4	Supply and Place Stormwater drainage pit w/ 2.4m Lintel	No.	9	$ 3,400.00	$ 30,600
4.5	Supply and Place Stormwater drainage pit w/ 3.6m Lintel	No.	1	$ 4,200.00	$ 4,200
4.6	Supply and Place Stormwater drainage pit w/ 4.8m Lintel	No.	1	$ 4,875.00	$ 4,875
4.7	Supply and Place 1.1m2 Grated Inlet Pit	No.	2	$ 3,200.00	$ 6,400
4.8	Supply and Place 6.48m2 Grated Inlet Pit	No.	2	$ 13,000.00	$ 26,000
				Subtotal	*$ 72,075*
				Subtotal	**$ 510,619.68**
	Pumps				
4.10	2m3/s Pumps	No.	3	$ 1,000,000.00	$ 3,000,000
				Subtotal	**$ 3,000,000**
5	**Road Pavements**				
5.1	Trim & compact subgrade	sq.m	412	$ 2.87	$ 1,181
5.2	200 DGS40 Subbase - supply, place & compact	sq.m	412	$ 21.64	$ 8,905
5.3	120 DGB20 Basecourse - supply, place & compact	sq.m	412	$ 15.21	$ 6,259
5.4	7mm primer seal	sq.m	412	$ 5.69	$ 2,341
5.5	30mm AC10 wearing course	sq.m	412	$ 19.80	$ 8,148
				Subtotal	**$ 26,834**
6	**Concrete Works**				
6.1	Kerb & gutter	m	10	$ 65.00	$ 650
6.2	Trim and compact footpath subgrade	sq.m	80	$ 2.29	$ 182
6.3	1200mm wide reinforced concrete footpath	m	65	$ 76.60	$ 4,979
6.4	1500mm wide reinforced concrete footpath	m	5	$ 89.50	$ 448
				Subtotal	**$ 6,259**
7	**Landscaping**				
7.1	Trim & compact subgrade	sq.m	1078	$ 2.87	$ 3,094

Budget Cost Estimate

Haskoning Australia Pty Ltd

Date: 9-May-18

Client:	Molino Stewart	**RHDHV Job No.**	PA1707
Project Name:	Campbelltown FRMS&P Flood Mitigation Options		
Item:	**Option 6 - Sopwith Avenue and Spitfire Drive**		

Item #	Description	Unit	Qty	Rate	Total
7.2	Replace topsoil 100 thk	sq.m	1078	$ 5.00	$ 5,390
7.3	Replace Turf	sq.m	1078	$ 6.00	$ 6,468
				Subtotal	**$ 14,952**
				SUBTOTAL (excl. GST)	**$ 4,095,050**
				Engineering Design (4%)	$ 163,802.01
				Environmental Assessment and Approvals	$ 50,000
				Tender Preparation (0.6%)	$ 24,570
				Supervision and Contract Administration (2%)	$ 81,901.01
				Contingency (30%)	$ 1,228,515
				TOTAL (excl. GST)	**$ 5,643,839**

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Budget Cost Estimate

Haskoning Australia Pty Ltd

Date: 9-May-18

Client: Molino Stewart
RHDHV Job No. PA1707
Project Name: Campbelltown FRMS&P Flood Mitigation Options
Item: **Option 7 - Dumaresq Street Drainage**

Item #	Description	Unit	Qty	Rate	Total
1	**Preliminaries**				
1.1	Project management & supervision	Item	1	$ 90,000.00	$ 90,000
1.2	Site compound	Item	1	$ 25,000.00	$ 25,000
1.3	Mobilisation	Item	1	$ 35,000.00	$ 35,000
1.4	Demobilisation	Item	1	$ 30,000.00	$ 30,000
1.5	OH&S allowances	Item	1	$ 15,000.00	$ 15,000
1.6	Site survey	Item	1	$ 15,000.00	$ 15,000
1.7	Works as executed	Item	1	$ 1,500.00	$ 1,500
1.8	Services location	Item	1	$ 20,000.00	$ 20,000
1.9	Erosion sediment and control	Item	1	$ 40,000.00	$ 40,000
1.10	Traffic management	Item	1	$ 50,000.00	$ 50,000
1.11	Engineering inspection and testing	Item	1	$ 10,000.00	$ 10,000
1.12	Insurances and security	Item	1	$ 5,000.00	$ 5,000
1.13	Allowance for 'possession' of railway line extent	Item	1	$ 200,000.00	$ 200,000
				Subtotal	**$ 536,500**
2	**Clearing & Demolition**				
2.7	Break up existing car park pavement	sqm	628	$ 72.90	$ 45,745
2.5	Sawcaut existing roadway and kerb	m	830	$ 10.00	$ 8,300
2.6	Break up of existing pavement	sqm	1400	$ 3.50	$ 4,900
				Subtotal	**$ 58,945**
3	**Earthworks**				
3.4	Excavate Trench for 2.4m(W) x 1.5m(H) Culvert & Backfill	cu.m	1785	$ 60.40	$ 107,814
3.5	Excavate Trench for 2.7m(W) x 1.5m(H) Culvert & Backfill	cu.m	2662	$ 60.40	$ 160,770
3.6	Excavate Trench for 3.6m(W) x 1.5m(H) Culvert & Backfill	cu.m	1902	$ 60.40	$ 114,890
3.9	Trench Shoring (where required)	sq.m	1693	$ 30.60	$ 51,812
3.10	Trim and compact trench subgrade	sq.m	2116	$ 2.29	$ 4,846
3.11	Place and compact bedding layer (150mm thk)	cu.m	317	$ 55.00	$ 17,459
3.12	Allowance to haul and dispose off site surplus spoil (to Council site)	cu.m	2737	$ 50.00	$ 136,852
3.13	Directional Drilling under railway	m	75	$ 2,000,000.00	$ 2,000,000
				Subtotal	**$ 2,594,443**
4	**Stomrwater Drainage**				
	Pipes				
4.1	Supply and Place 2.4m(W) x 1.5m(H) Culvert	m	170	$ 2,600.00	$ 442,000
4.2	Supply and Place 2.7m(W) x 1.5m(H) Culvert	m	284	$ 2,900.00	$ 822,150
4.3	Supply and Place 3.6m(W) x 1.5m(H) Culvert	m	181	$ 3,500.00	$ 633,150
				Subtotal	*$ 1,897,300*
	Pits				
4.4	Supply and Place 2m (L) x 2m (W) Grated Inlet Pit	No.	1	$ 8,600.00	$ 8,600
4.5	Supply and Place 4m (L) x 3m (W) Grated Inlet Pit	No.	1	$ 9,500.00	$ 9,500
4.6	Supply and Place 8m (L) x 6m (W) Grated Inlet Pit	No.	1	$ 23,500.00	$ 23,500
				Subtotal	*$ 41,600*
				Subtotal	**$ 1,938,900**
5	**Outlet Headwall**				
5.1	RC Concrete Headwall foundation	cu.m	1	$ 526.00	$ 526
5.2	RC Concrete Headwall (200mm thick)	sq.m	10	$ 456.00	$ 4,560
5.3	Construct reinforced concrete wingwalls	sqm.	20.0	$ 450.00	$ 9,000
5.4	Construct reinforced concrete apron	cum.	5.0	$ 330.00	$ 1,650
				Subtotal	**$ 15,736**
5	**Road Pavements**				
5.1	Trim & compact subgrade	sq.m	2028	$ 2.87	$ 5,819
5.2	200 DGS40 Subbase - supply, place & compact	sq.m	2028	$ 21.64	$ 43,875
5.3	120 DGB20 Basecourse - supply, place & compact	sq.m	2028	$ 15.21	$ 30,838
5.4	7mm primer seal	sq.m	2028	$ 5.69	$ 11,536
5.5	30mm AC10 wearing course	sq.m	2028	$ 19.80	$ 40,145
				Subtotal	**$ 132,213**
				SUBTOTAL (excl. GST)	**$ 5,276,737**
				Engineering Design (4%)	$ 211,069.48
				Environmental Assessment and Approvals	$ 50,000
				Tender Preparation (0.6%)	$ 31,660
				Supervision and Contract Administration (2%)	$ 105,534.74
				Contingency (30%)	$ 1,583,021
				TOTAL (excl. GST)	**$ 7,258,023**

Budget Cost Estimate

Haskoning Australia Pty Ltd

Date:	9-May-18		
Client:	Molino Stewart	**RHDHV Job No.**	PA1707
Project Name:	Campbelltown FRMS&P Flood Mitigation Options		
Item:	**Option 7 - Dumaresq Street Drainage**		

Item #	Description	Unit	Qty	Rate	Total

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APPENDIX C – Austroads Guide to Traffic Management (2016): Local Area Traffic Management - Vertical Deflection Devices

7.2 Vertical Deflection Devices

Vertical deflection devices force vertical changes in the ride alignment or travel path of a vehicle introduced as the result of a physical feature of a roadway. This deflection generally achieves a reduction in vehicle speeds as drivers attempt to avoid discomfort when travelling over the LATM measure. As a general rule LATM devices should not be placed at locations on roads with a longitudinal gradient of more than 10%. Refer to Section 8.6 for more information on gradients.

7.2.1 Road Humps

Description of road humps

A road hump is a speed reduction device in the form of a raised curved profile extending across the roadway. Road humps are typically 70 to 120 mm high with a total length of 3 to 4 m. On bus routes and cycle routes a hump height of 75 mm or less and a hump length of at least 3.7 m is recommended. The two main types of road hump are the sinusoidal profile hump and the Watts profile hump. The sinusoidal profile hump is more sympathetic to cyclists while the Watts profile hump has greater effect on drivers. The typical dimensions of the two different profiles are illustrated in Figure 7.3.

7.2.3 Flat-top Road Humps

Description of flat-top road humps

A flat-top road hump or raised table is a raised surface approximately 75–100 mm high and typically with a 2 to 6 m long platform ramped up from the normal level of the street. The raised section (or platform) is flat instead of being curved as is the case with a (round profile) road hump described in Section 7.2.1. Where it is acceptable to install this device on bus routes, a minimum platform length of 6 m, a platform height of 75 mm, and a ramp gradient of 1:20 is recommended. Where the platform extends more than 6 m in length the device is likely to function as a raised pavement (see Section 7.2.5).

7.2.4 Wombat Crossings

Description of wombat crossings

Wombat crossings are generally of the form of flat-top road humps with a pedestrian crossing on the raised flat surface and in some jurisdictions flashing amber lights. Although similar to a flat-top road hump, wombat crossings give priority to pedestrians while flat-top road humps do not. While wombat crossings may be installed at locations where there is a need to give pedestrians priority to safely cross the road, in the context of LATM, they should always be installed as part of a whole of street treatment.

The minimum length of the device **including ramps** is 6 m (platform = 3.6 m long) and the desirable height of the platform is 100 mm. Where it is acceptable to install this device on bus routes, a minimum 9 m long device (platform = 6 m long), a 75 mm high platform, and ramps with a gradient of 1:20 are recommended. Where buses do not regularly use a street, and it is acceptable to bus operators, a higher (e.g. 100 mm) and a shorter platform may be justified (e.g. 4.5 m long). Wombat crossings with ramp gradients of 1:15 to 1:20 are generally regarded as bicycle friendly.

APPENDIX F– COST-BENEFIT ANALYSIS OF FLOOD MODIFICATION OPTIONS

									Cost of Flood Modification				
Option Number (Appendix E)	**Description**		**Residential Annual Average Damages (including indirect)**	**Residential Annual Average Damages (including infrastructure and intangible damages)**	**Non Residential Annual Average Damages (direct and indirect)**	**Non Residential Annual Average Damages (including infrastructure and intangible damages)**	**Total Annual Average Damages (including infrastructure and intangible damages)**	**Total Annual Average Damages (net present value)**	**Capital Costs**	**Whole of Life Costs (net present value)**	**Total Option Cost (net present value)**	**Option Benefits (as reduction of damages)**	**Benefit/Cost Ratio**
6	Sopwith Ave and Spitfire Dr, Raby	Current Condition	$150,711	$210,996	$0	$0	$210,996	$2,911,746	na	na	na		
		With Flood Modification	$89,506	$125,308	$0	$0	$125,308	$1,729,253	$5,643,839	$97,850	$5,741,689	$1,182,492	**0.21**
1	Oxford Rd, Ingleburn	Current Condition	$71,305	$99,828	$0	$0	$99,828	$1,377,620	na	na	na		
		With Flood Modification	$57,265	$80,171	$0	$0	$80,171	$1,106,356	$1,440,354	$12,738	$1,453,092	$271,264	**0.19**
3	Manooka Res, Bradbury	Current Condition	$104,221	$145,909	$0	$0	$145,909	$2,013,544	na	na	na		
		With Flood Modification	$40,874	$57,223	$0	$0	$57,223	$789,679	$4,047,983	$3,120	$4,051,103	$1,223,866	**0.30**
2	Ingleburn CBD Stormwater Upgrades	Current Condition	$299,084	$418,718	$1,134,372	$1,588,120	$2,006,838	$27,694,364	na	na	na		
		With Flood Modification	$145,802	$204,123	$72,031	$100,843	$304,966	$4,208,530	$13,436,659	$49,911	$13,486,570	$23,485,835	**1.74**
5	Harrow Rd, Glenfield	Current Condition	$28,487	$39,882	$0	$0	$39,882	$550,373	na	na	na		
		With Flood Modification	$13,779	$19,290	$0	$0	$19,290	$266,208	$97,946	$0	$97,946	$284,165	**2.90**
4	Epping Vale, Kearns	Current Condition	$69,687	$97,561	$0	$0	$97,561	$1,346,347	na	na	na		
		With Flood Modification	$31,767	$44,473	$0	$0	$44,473	$613,731	$117,530	$0	$117,530	$732,616	**6.23**
7	Farrow Rd and Dumaresq St, Campbelltown	Current Condition	$0	$0	$3,049,255	$4,268,957	$4,268,957	$58,911,604	na	na	na		
		With Flood Modification	$0	$0	$2,519,042	$3,526,659	$3,526,659	$48,667,898	$7,258,023	$21,836	$7,279,859	$10,243,705	**1.41**