Leichhardt Floodplain Risk Management Study

NA49913094

Prepared for
Inner West Council

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Cardno
Shaping the Future

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Foreword

The NSW Government Flood Prone Land Policy is directed towards providing solutions to existing flood problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the Policy, the management of flood prone land is the responsibility of Local Government. The State Government may provide financial assistance for flood management measures to alleviate existing flooding problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities. The Commonwealth Government also assists with the subsidy of floodplain modification measures.

The Policy identifies the following floodplain management 'process' for the identification and management of flood risks:

1. Formation of a Committee -

Established by a Local Government Body (Local Council) and includes community group representatives and State agency specialists.

2. Data Collection -

The collection of data such as historical flood levels, rainfall records, land use, soil types etc.

3. Flood Study -

Determines the nature and extent of the flood problem.

4. Floodplain Risk Management Study –

Evaluates floodplain management measures for the floodplain in respect of both existing and proposed development.

5. Floodplain Risk Management Plan –

Involves formal adoption by Council of a management plan for the floodplain.

6. Implementation of the Plan –

Implementation of actions to manage flood risks for existing and new development.

This Leichhardt Floodplain Risk Management Study is developed from the previous Flood Study (Cardno, 2014).

Executive Summary

Cardno were commissioned by Leichhardt Council to undertake a Floodplain Risk Management Study (FRMS) and Floodplain Risk Management Draft Plan (FRMP) for the Leichhardt Local Government Area (LGA). Since the Council amalgamation in May 2016, the Leichhardt LGA is now part of the Inner West LGA. Therefore, the former Leichhardt LGA will be referred to in this document as the study area.

This FRMS has been undertaken to define the existing flooding behaviour and associated hazards, and to investigate possible mitigation options to reduce flood damage and risk. The tasks were undertaken alongside community consultation to ensure that community concerns were addressed.

The overall objective of this study is to develop a FRMP that address the existing, future and continuing flood problems, taking into account the potential impacts of climate change, in accordance with the NSW Government's Flood Policy, as detailed in the Floodplain Development Manual: The Management of Flood Liable Land (NSW Government, 2005).

The study area includes the suburbs of Annandale, Balmain, Balmain East, Birchgrove, Leichhardt, Lilyfield, and Rozelle. It is roughly bounded by Sydney Harbour to the north, Parramatta Road to the south, Johnstons Creek to the east and Hawthorne Canal to the West.

Major creek systems are located in the south of the study area and include Whites Creek, Johnstons Creek and Hawthorne Canal. Localised drainage systems distributed through the study area are either tributaries of these main creek systems or drain directly to Sydney Harbour. The majority of the trunk drainage systems throughout the study area, including the three main creek systems, are owned and managed by Sydney Water Corporation (Sydney Water or SWC).

A flood study was completed by Cardno in 2014 to define the flood behaviour in the study area, including both mainstream and overland flooding.

The impact of flooding across the catchment is significant, with the number of properties in the catchment that would be impacted by overfloor flooding in the 100 Year ARI flood event being 841 properties. Economic impacts of flooding are also significant due to flooding over the floor level of both residential and commercial properties, as well as garden damage for residential properties combining to represent a significant expense in flood events ranging from the 5 Year ARI to the PMF event. The Annual Average Damage for the catchment is expected to be approximately $16 million dollars with the contributions of the various design flood events summarised in the table below.

Design Event	Properties with Overfloor Flooding	Total Damage ($)
PMF	3500	287,113,000
100 Year ARI	841	69,229,000
50 Year ARI	760	62,828,000
20 Year ARI	630	54,233,000
10 Year ARI	547	47,604,000
5 Year ARI	412	34,876,000
Average Annual Damage (AAD)		$16,099,000

A number of flood mitigation options have been examined as part of this FRMS to manage flooding within the study area. The identification and examination of these options was done in accordance with the NSW Floodplain Development Manual: The Management of Flood Liable Land ("the Manual") (NSW Government, 2005).

A range of flood risk management options were considered to reduce the flood risk including flood modification, emergency response modification and property modification.

Flood modification measures are options aimed at preventing / avoiding or reducing the likelihood of flood risks. These measures reduce the risk through modification of the flood behaviour in the catchment. Forty-

Five possible flood modification measures were identified and assessed across the study area, including additional drainage, levees and detention basins. A summary of all works assessed is provided in **Section 12** of this Floodplain Risk Management Study. Hydraulic modelling and an economic analysis (option cost verses reduction in flood damages) was undertaken for each of the flood modification option assessed.

Property modification measures are focused on preventing / avoiding and reducing consequences of flood risks. Rather than modifying the flood behaviour, these measures aim to modify properties so that there is a reduction in flood risk. Property modification assessed for the study area included both revisions to the existing policy and planning measures for future development, and opportunities to improve the flood compatibility of at risk properties.

Emergency response modification measures aim to reduce the consequences of flood risks, by modifying the behaviour of people during a flood event. A range of emergency response options were assessed including actions to improve public awareness of flood risk, flood warning systems and improved response to flooding.

All of the viable flood risk management options were assessed using a Multi-Criteria Assessment (MCA). This assessment provided for a triple bottom line approach to account for the performance of the various options with respect to economic, social and environmental criteria. The outcomes of this ranking process of the options have been used to guide the implementation strategy which is the primary component of the Floodplain Risk Management Plan.

The overall recommendations of this study find that it is impractical to eliminate all flood risks from the study area. Instead, the aim of the recommendations of this FRMS is to ensure that existing and future development is exposed to an ‘acceptable’ level of risk.

The key findings of this FRMS is that although there is a significant flood risk within the study area, the potential for this flood behaviour to be managed through on ground works (such as drainage upgrades) is limited. This is due to the highly urbanised catchment, high density population and often steep catchment (and hence fast flowing floodwaters).

However, due to the generally shallow nature of the flow and the relatively short period of flooding, flood risk can be effectively managed through the implementation of development controls, emergency response measures and minor works. The effective implementation of development controls will be of key importance in reducing the damages and risk to life associated with flooding into the future through the construction of flood compatible buildings and assets.

The recommendations resulting from this Floodplain Risk Management Study (FRMS) and the proposed implementation strategy is outlined in the *Leichhardt Floodplain Risk Management Plan (FRMP)*. The FRMP is provided separately to this FRMS document.

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Glossary

Annual Exceedance Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded each year; it would occur quite often and would be relatively small. A 1% AEP flood has a low probability of occurrence or being exceeded each year; it would be fairly rare but it would be relatively large. The 1% AEP event is equivalent to the 1 in 100 year Average Recurrence Interval event.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Recurrence Interval (ARI)	The average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration. It is implicit in this definition that periods between exceedances are generally random. That is, an event of a certain magnitude may occur several times within its estimated return period.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design events. E.g., some roads may be designed to be overtopped in the 1 in 1 year ARI or 100% AEP flood event.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.
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 overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood Control Lots	A lot to which flood related development controls apply

Flood fringe	The remaining area of flood-prone land after floodway and flood storage areas have been defined.
Flood hazard	Potential risk to life and limb caused by flooding.
Flood-prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood-prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Floodplain management measures	The full range of techniques available to floodplain managers.
Floodplain management options	The measures which might be feasible for the management of a particular area.
Flood planning area	The area of land below the flood planning level and thus subject to flood related development controls.
Flood planning levels	Flood levels selected for planning purposes, as determined in flood studies or in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plains. The concept of FPLs supersedes the “Standard flood event” of the first edition of the Manual. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood storages	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, but not always, aligned with naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.
Geographical Information Systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.

High hazard	Flood conditions that pose a possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Low hazard	Flood conditions such that should it be necessary, people and their possessions could be evacuated by trucks; able-bodied adults would have little difficulty wading to safety.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Management plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.
NPER	National Professional Engineers Register. Maintained by Engineers Australia.
Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood	The flood calculated to be the maximum that is likely to occur.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a more detailed explanation see Annual Exceedance Probability.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.

Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Stormwater flooding	Inundation by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.
Topography	A surface which defines the ground level of a chosen area.

Abbreviations

1D	One Dimensional
2D	Two Dimensional
AHD	Australian Height Datum
ARI	Average Recurrence Interval
BoM	Bureau of Meteorology
DCP	Development Control Plan
DECCW	Department of Environment, Climate Change & Water (now OEH)
DEOCON	District Emergency Operations Controller
FPL	Flood Planning Level
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
FPRMSP	Floodplain Risk Management Study & Plan
ha	hectare
km	kilometres
km^2	Square kilometres
LEP	Local Environment Plan
LGA	Local Government Area
LEOCON	Local Emergency Operations Controller
m	metre
m^2	Square metres
m^3	Cubic metres
mAHD	Metres to Australian Height Datum
mm	millimetres
m/s	metres per second
NSW	New South Wales
OSD	On-site Detention
OEH	Office of Environment and Heritage
PMF	Probable Maximum Flood
SES	State Emergency Service
SWC	Sydney Water Corporation

1 Introduction

Cardno were commissioned by Leichhardt Council to undertake a Floodplain Risk Management Study (FRMS) and Floodplain Risk Management Draft Plan (FRMP) for the Leichhardt Local Government Area (LGA). Since the Council amalgamation in May 2016, Leichhardt LGA is now part of the Inner West LGA. Therefore, the former Leichhardt LGA will be referred to in this document as the study area.

This FRMS has been undertaken to define the existing flooding behaviour and associated hazards, and to investigate possible mitigation options to reduce flood damage and risk. The tasks were undertaken alongside community consultation to ensure that community concerns were addressed.

The overall objective of this study is to develop a FRMSP that address the existing, future and continuing flood problems, taking into account the potential impacts of climate change, in accordance with the NSW Government's Flood Policy, as detailed in the Floodplain Development Manual: The Management of Flood Liable Land (NSW Government, 2005).

The study area includes the suburbs of Annandale, Balmain, Balmain East, Birchgrove, Leichhardt, Lilyfield, and Rozelle. It is roughly bounded by Sydney Harbour to the north, Parramatta Road to the south, Johnstons Creek to the east and Hawthorne Canal to the West.

Major creek systems are located in the south of the study area and include Whites Creek, Johnstons Creek and Hawthorne Canal. Localised drainage systems distributed through the study area are either tributaries of these main creek systems or drain directly to Sydney Harbour. The majority of the trunk drainage systems throughout the study area, including the three main creek systems, are owned and managed by Sydney Water Corporation (Sydney Water or SWC).

A flood study was prepared by Cardno in 2014 to define the flood behaviour in the study area, including both mainstream and overland flooding.

A number of flood mitigation options have been examined as part of this Floodplain Risk Management Study to manage flooding within the study area. The identification and examination of these options was done in accordance with the NSW Floodplain Development Manual: The Management of Flood Liable Land ("the Manual") (NSW Government, 2005).

1.1 Study Context

The Floodplain Management Process progresses through six (6) stages, in an iterative process:

1) Formation of a Floodplain Management Committee;
2) Data collection;
3) Flood Study;
4) Floodplain Risk Management Study;
5) Floodplain Risk Management Plan; and
6) Implementation of the Floodplain Risk Management Plan.

This report addresses Stage 4.

1.2 Study Objectives

The overall objective of this study is to develop a FRMP that address the existing, future and continuing flood problems, taking into account the potential impacts of climate change, in accordance with the NSW Government's Flood Policy, as detailed in the Floodplain Development Manual: the Management of Flood Liable Land (NSW Government, 2005).

2 Catchment Description

The study area includes the suburbs of Annandale, Balmain, Balmain East, Birchgrove, Leichhardt, Lilyfield, and Rozelle. The study area covers an area of approximately 10.7 square kilometres. It is roughly bounded by Sydney Harbour to the north, Parramatta Road to the south, Johnstons Creek to the east and Hawthorne Canal to the West.

Major creek systems are located in the south of the study area and include Whites Creek, Johnstons Creek and Hawthorne Canal. Localised drainage systems distributed through the study area are either tributaries of these main creek systems or drain directly to Sydney Harbour. The majority of the trunk drainage systems throughout the study area, including the three main creek systems, are owned and managed by Sydney Water Corporation (Sydney Water or SWC).

The catchment and study area are shown in Figure 2-1.

Flooding throughout the catchment is a combination of overland flow and mainstream flooding. Mainstream flooding issues occur along the three main creek and channel systems; Hawthorn Canal, Whites Creek and Johnstons Creek. Elsewhere, flooding is primarily a result of overland flow and the capacity of the stormwater network and overland flowpaths.

The majority of overland flow is carried within the pipe network or road reserve, though in some locations historical development has occurred adjacent to natural flow paths, depressions, and low points leading to overland flow across these properties. In addition, the density of development across the study area, such as townhouses and terrace housing, can result in a complete obstruction to overland flow and the only overland flowpath available is directly through actual dwellings.

3 Available Data

3.1 Previous Studies and Reports

3.1.1 Leichhardt Flood Study (2014)

Cardno recently undertook a flood study for the entire former Leichhardt Local Government Area (LGA) or study area, with the primary objective of defining the flood behaviour in the former Leichhardt LGA or study area. The study was undertaken to determine flood behaviour for the 100 year, 50 year, 20 year, 10 year and 5 year ARI design floods and the Probable Maximum Flood (PMF). The primary flood characteristics reported for the design events considered include depths, levels, velocities and flow rates. The study also defined the Provisional Flood Hazard and Hydraulic Categories for flood-affected areas.

The assessment of catchment flooding in the report included both:

- ‘mainstream’ flooding – flooding associated with catchment rainfall flowing to a creek, open channel or open canal and the capacity of the channel is generally exceeded; and,
- ‘overland’ flooding – where catchment rainfall cannot enter the stormwater drainage system and flows ‘overland’, which can be through properties or down streets.

The method of assessment used for the Flood Study allowed for both types of catchment flooding to be considered at the same time.

The various components of the flood study can be grouped together into three main stages, with community consultation undertaken throughout. Firstly, all available data was compiled for the study. This involved the collection of available historical rainfall and flood level data. Secondly, a hydrologic investigation was carried out for the catchment using a hydrologic computer model to define the catchment flows (the conversion of rainfall to runoff). Thirdly, a hydraulic computer model of the study area was established to determine flood depths, velocities and extents.

These models were used throughout this study to investigate various management and flood mitigation options for the existing catchment conditions. The definition of existing flood risks assists the evaluation of long term flood management strategies in this report.

3.1.2 Leichhardt Estuarine Planning Levels Study (2010)

It is important to note that some properties in the study area may be affected by two types of flooding:

- Flooding from rainfall that becomes runoff (known as catchment flooding), and
- Flooding from inundation from Sydney Harbour (known as estuarine flooding).

Catchment flooding was assessed in the Leichhardt Flood Study (Cardno, 2014). The *Leichhardt Estuarine Planning Level Study* (Cardno Lawson Treloar, 2010) was undertaken to define storm tide, wave run-up and overtopping effects on the Harbour water level around the foreshore areas of the former Leichhardt LGA or study area, so that consistent and informed development decisions can be made for the management of these areas. This report addresses estuarine flooding and reports water levels (designated as a ‘still water level’) and wave impacts (a short-term process) that may be generated by a range of storm events, including the 5, 10, 20, 50, 100 and 200 year average recurrence interval (ARI) design conditions.

The study made use of numerical models, considering both hydrodynamic and nearshore wave process, to define the magnitude of various water level parameters along the Leichhardt Foreshore. The study provides a maximum level at each property, with simple adjustments to wave run-up that can be applied, depending on typical shoreline treatments, such as sloping embankments, beaches or vertical walls. Where properties are affected by inundation from both catchment flooding and estuarine inundation, both water levels are available from Council for planning and development purposes.

3.1.3 Additional Studies

Flood studies have been undertaken by Sydney Water (and its previous entity, the Water Board) for both Johnstons Creek and Whites Creek:

- Water Board (1990). Whites Creek SWC No: 95 Catchment Management Study, August.
- Water Board (1994). Whites Creek SWC No: 95 Detail Hydraulic Analysis, January.
- Sydney Water (1996). Johnstons Creek SWC No: 55 Flood Study, March.

These studies defined the mainstream flooding behaviour for these two creek systems. Historical flood levels identified during these studies were collated and used in the Leichhardt Flood Study for calibrating the model. Further information about these studies is available in the Leichhardt Flood Study (Cardno, 2014).

Several management options were identified as part of the Whites Creek Catchment Management Study (Water Board, 1990). A seventy five percent increase in channel width was suggested as the preferred structural management option to meet the objectives of a 20 year event, requiring:

- Widening or provision of an additional culvert at Piper Street and Brennan Street Bridges
- Provision of a diversion beneath the present Railway Parade Bridge leading out to the mouth of the creek via a new channel
- Provision of additional capacity underground

The use of retarding basins, levees and bypass channels were regarded as impractical propositions. The study considered non-structural management options including zoning, flood proofing and flood forecasting and warning. Where practical, these options have been integrated into this Floodplain Risk Management Study and Plan.

The Parramatta River Estuary Coastal Zone Management Study (CZMS) (Cardno, 2013) identified numerous options for management of the coastal zone taking into account the potential impacts of sea level rise on the estuary. Several of these management strategies were in response to Coastal Hazards, and included alteration to the foreshore and catchment. These management strategies include increasing the capacity of stormwater networks and restricting foreshore development in areas of tidal inundation hazards.

This Flood Risk Management Study and Plan has taken these management strategies into account to ensure flood options will not conflict with the outcomes of the CZMS.

3.2 Survey Information

3.2.1 Data Supplied for the Flood Study (Cardno, 2014)

A significant amount of survey data was utilised in the preparation of the Flood Study. 0 shows a breakdown of this data that was also utilised in the preparation of the FRMS.

Table 3-1 Data Utilised in Leichhardt Flood Study (Cardno, 2014)

Provided by Council / Sydney Water	Obtained by Cardno	Application of Data to FRMS
Airborne Laser Scanning (ALS). Council provided aerial survey across the entire catchment, captured on 26 August, 2006. This data was provided to Cardno on 19 November 2007. Generally, the accuracy of the ALS data is +/- 0.15m to one standard deviation on hard surfaces.	Pit and Pipe Field Survey – Council provided available stormwater drainage pit and pipe data in the study area. Cardno's Survey Team then completed a detailed field survey of all of the drainage system to update Council's information. More than 3500 pits and over 3000 pipes were surveyed over 2007 to 2008. This resulted in a 'pit and pipe database' which identifies the dimensions and locations of all Council's pit and pipes within the entire study area. In addition, photographs were taken of every pit and this information is integrated within the pit and pipe database.	This information has been utilised in the development of floodplain risk management options relating to pit and pipe drainage upgrades.
Pit and Pipe Data - Data held by Council was provided by Council.	Cross Sections and Culvert Dimensions – cross sections of the open channels and culvert dimensions within the study area were obtained.	These details are generally not adequately defined in the aerial survey provided and were therefore obtained as supplementary information.
Historical flood levels - historical levels identified as a part of the resident survey and from the previous Sydney Water studies (Water Board, 1994; Sydney Water, 1996).	Hydraulic Structures – details of all major hydraulic structures (such as culverts and bridges) were surveyed.	This data assisted with the assessment of management options relating to structure upgrades or modifications.
Sydney Water provided GIS layers of pit and pipe data based on their records on 25 June 2007.		This information has been utilised in the development of floodplain risk management options relating to pit and pipe drainage upgrades.
Council provided Geographic Information System (GIS) data for preparing the Leichhardt Catchment Flood Study model and reporting. The data included: • **Pit and Pipe data** • **Cadastre** • **2m Land Information Centre (LIC) contours** • **Aerial photography (2006) captured by Council prior to the commencement of the current study**	Historical flood levels identified in the community consultation and from previous studies.	GIS data has been key in developing strategies for managing flood risk and preparing appropriate maps and figures for the FRMS document.

3.2.2 Additional Data

Since the preparation of the Flood Study (Cardno, 2014), several data sets were updated and additional datasets were required for the assessment of flood management options. The updated and additional datasets include:

- Floor Level Survey of 1500 properties by Cardno (2014), including property condition and storey number data (additional details are provided in **Section 6**).
- Updated pit and pipe data supplied by Council including any modifications made between 2008 and 2014.
- Seawall condition assessment and design details including:

  - Public Seawalls Asset Evaluation (WMA, 2008)
  - Leichhardt Municipal Council Public Seawall Review Draft Report (WMA, 2012)
  - Parramatta River Estuary Study (AECOM, 2010)

3.3 GIS Data

The following Geographic Information System (GIS) data was provided by Council for this study:

- Pit and Pipe data (also described in **Section 2.2.1**)
- Cadastre (2011)
- 2m Land Information Centre (LIC) contours
- Aerial photography (2006) captured by Council, this data is consistent with the digital terrain utilised in the Flood Study (Cardno, 2014).
- Leichhardt Local Environment Plan (LEP) (2013) mapping.

3.4 Site Inspections

Detailed site inspections of the study area were conducted as part of the Flood Study on 12/07/2007, 02/08/2007, 16/03/2009 and 30/04/2009. The site visits provided the opportunity to fine tune the modelling approach to capture various street drainage features which are common in the study area, and to visually identify potential flooding hotspots in the catchment. The findings of these site inspections were incorporated into the Leichhardt Flood Study (Cardno, 2014). The information gathered on these site visits has also been utilised in the preparation of this Floodplain Risk Management Study.

Cardno undertook a further site investigation on 9 October 2013 for a preliminary analysis of flood management options.

4 Consultation

4.1 Community Consultation

The community consultation undertaken as part of the FRMS built on the consultation undertaken as part of the Leichhardt Flood Study (Cardno, 2014). The purpose of the flood study consultation was to inform the community about the study and gain an understanding of the communities experience with historical flooding in the catchment.

The purpose of the consultation undertaken as part of this FRMS was to inform the community about the study, identify community concerns and attitudes, to gather information from the community on management options for the floodplain and to develop and maintain community confidence in the study results.

Community consultation was undertaken primarily during the public exhibition of this document, and included:

- Public access to the draft FRMS and FRMP documents at Council's Leichhardt and Balmain Libraries, and at the Leichhardt Customer Service Centre;
- Public access to digital copies of the FRMS and FRMP on Council's website;
- Public information sessions to discuss the study, answer questions and gain feedback from the public on the study; and
- Opportunities to provide formal submissions regarding feedback on the study via Council's "YourSay" webpage and/or feedback boxes available in both Libraries, the Leichhardt Customer Service Centre and at the public information sessions.

4.1.1 Public Exhibition

This draft Floodplain Risk Management Study and Plan was placed on public exhibition for a period of 6 weeks from the 15th of August 2017 to the 29th of September 2017. During the public exhibition period, the community and interested parties reviewed the draft study and plan and submit comments on the study and plan and its outcomes.

Two community workshops were held during the public exhibition period to present the findings of the study and plan and seek input from the community. The first workshop was held on the 29th of August 2017 at Leichhardt Town Hall Council Chamber and the second was held on the 30th of August 2017 at Balmain Town Hall Meeting Room. A notification of these sessions was placed in the Inner West Courier on 15th and 22nd of August 2017 and on Council's website. Letters of invitation to attend were extended to owners of properties identified as Flood Control Lots or Foreshore Flood Control Lots.

Community members were invited to view the study and plan and indicate the extent of their support for the both. Community members were also able to provide comment on which options they support, which options they do not support and any matters related to flood mitigations and management that had not been addressed in the study and plan. During the exhibition period the webpage was visited 989 times and project documents were downloaded 866 times. A total of thirty-three submissions were received through the Council's website.

During the exhibition period Council also received approximately 40 queries via telephone during the exhibition. Around 90% of these calls were received within 2 days of the start of the exhibition period. Most of them were from residents with queries about the purpose of the study, and it's impact on their property, if any. Following clarification of their queries by Council, majority of the callers were in support of the FRMSP. Around 3 residents disputed the accuracy of the Flood Study which resulted in the inclusion of their property as a flood control lot. These were based on their experience of observing no flooding near their property.

Council also received 10 feedback emails during the exhibition period. Four (4) of these were received through the feedback forms provided at the community workshops and 1 was received via a submissions box at the library. Feedback was also received from Council's Development Advisory Service.

Of all the submission received from the public exhibition (including via emails and telephone), majority of the interest from residents was for the Hawthorne Canal and Whites Creek options assessment. Options FM1, FM3, and FM13 for Whites Creek received maximum support, endorsing the need for implementing these flood mitigation options.

Council's Development Advisory Service raised concerns that several of the Property Modification (PM) options and recommendations do not sufficiently consider protection of the heritage fabric and the built environment. The relevant chapters of the study and plan have been amended to include the following:

"It is noted that the there are no flood related provisions in the DCP for development in heritage conservation areas. Given that some of the heritage conservation areas within the study area are flood affected, it is recommended that Council consider provisions of flood related controls in the DCP for development in heritage conservation areas."

Council also received several comments from residents whose properties are classified as Flood Control lots. They voiced their concerns and desire for removing their property from the Flood Control Lot maps.

A summary of submissions received and responses to those submissions are provided in **Appendix G**. Based on the submissions received, any adjustment or further assessment to address issues raised were not warranted based on the outcomes of the public exhibition.

4.1.2 Website

Council's website had a dedicated page providing information relating to this study. The webpage provided information including:

- An overview of the purpose and scope of the study;
- Information on the Flood Risk Management Committee;
- The study area;
- Past related studies;
- The flood mapping tool;
- How community have been and can be involved in the study;
- Relevant development controls; and

4.2 Floodplain Risk Management Committee

4.2.1 Floodplain Risk Management Committee

At its meeting on 23 July 2013 Council resolved to establish the Advisory Leichhardt Floodplain Risk Management Committee (FRMC). Following the proclamation of the Inner West Council in May 2016, the Advisory Leichhardt Floodplain Risk Management Committee was dissolved. The Inner West Council formed the Flood Management Advisory Committee in November 2016.

The purpose of the Committee is to assist Council in the preparation and implementation of the Flood Risk Management Plan. The Committee provides the mechanism for formal engagement with the community. The Committee meets at key stages throughout the project.

The FRMC is made up of a balanced representation of stakeholders, such as agencies, groups and individuals affected by floodplain risk management or involved in its coordination.

State agencies and Councils were invited to join the Committee. Council also invited nominations from the local community and businesses, via advertising in the local paper.

5 Existing Flood Behaviour

5.1 Flood Study

A detailed 1D/2D hydraulic model was established for the Leichhardt Flood Study (Cardno, 2014). The model incorporated pipes upwards of 225 millimetres in diameter and had a fine 2D resolution of 1 metre grid cells.

Hydrological modelling was undertaken utilising a combination of Direct Rainfall within the study area and traditional hydrological modelling for catchments external to the study area.

The models were calibrated to three historical flood events; 1991, 1993 and 1998. A good agreement was found between the model results and observed flood levels from these events.

Using the established models, the study determined the flood behaviour for the 100 year, 50 year, 20 year, 10 year and 5 year ARI design floods and the Probable Maximum Flood (PMF). The primary flood characteristics reported for the design events considered include depths, levels, velocities and flow rates.

Council acknowledges that there is a separate Flood Study for Hawthorne Canal upstream of Parramatta Road. This model produces variances in the results in some locations downstream of Parramatta Road. Council is currently undertaking a review to reconcile these differences. In the interim, the higher levels will be used for planning purposes.

5.2 Flood Study Addendum

Since the modelling undertaken in 2010 – 2014 as part of the Leichhardt Flood Study (Cardno, 2014) there have been several upgrades to drainage infrastructure along with confirmation of drainage infrastructure connections, sizes and locations that were previously uncertain. A Flood Study Addendum has been prepared as part of the Floodplain Risk Management Study that provides the outcomes of the updated modelling undertaken to incorporate these upgrades.

The Flood Study Addendum can be found in **Appendix A**.

Modifications to the hydraulic model were only required in four of the nine model zones. The model zones are shown in **Figure 5-1** (also see Figure 6.2 in the Flood Study). This Addendum presents the outcomes of additional flood modelling undertaken within the following model zones:

- Rozelle Bay Catchment;
- Whites Creek Catchment;
- White Bay Catchment; and
- Mort Bay Catchment.

The Addendum provides details of the impacts on the flood levels as a result of the modelling and includes updated figures that superseded those provided in the Flood Study (Cardno,2014).

As an outcome of the revised modelling, the flood control lots were also reviewed. The changes to flood control lots are provided in the Flood Study Addendum.

5.3 Flooding Behaviour

The defined creek and channel systems within the study area are primarily Hawthorne Canal, Whites Creek and Johnstons Creek. Mainstream flooding occurs along these systems when the channel capacity is exceeded. A large majority of the flooding within the study area occurs outside of the main creek systems, when the capacity of stormwater pits and pipes are exceeded. When this occurs, overland flows proceed down roads and through properties. At a number of locations within the study area, historical development has occurred perpendicular to the overland flow paths and across existing depressions and low points. Therefore, rather than follow the roads or via designated flowpaths, the overland flows tend to proceed through properties. In addition, the density of development across the study area, such as townhouses and terrace housing, can result in a complete obstruction to overland flow and the only overland flowpath available is directly through actual dwellings.

Further discussion of the flood behaviour is provided in the Flood Study (Cardno,2014).

5.4 Flood Hazard

Flood hazard can be defined as the risk to life and limb caused by a flood. The hazard caused by a flood varies both in time and place across the floodplain.

5.4.1 Provisional Flood Hazard

Provisional flood hazard is determined through a relationship developed between the depth and velocity of floodwaters. The Floodplain Development Manual (2005) defines two categories for provisional hazard - High and Low.

- 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; and
- Low hazard – should it be necessary, a truck could be used to evacuate people and their possessions, able-bodied adults would have little difficulty in wading to safety.

The provisional flood hazard was defined as part of the Flood Study (Cardno, 2014) for the 5 and 100 Year ARI and PMF events using an in-house developed program, which utilises the model results of flood depths and velocity. The provisional flood hazard mapping was updated as part of the Flood Study Addendum (**Appendix A**).

5.4.2 True Hazard Assessment

Provisional flood hazard categorisation is based around a function of velocity and depth, and does not consider a range of other factors that influence the "true" flood hazard. In addition to water depth and velocity, other factors contributing to the true flood hazard include:

- Size of the flood,
- Effective warning time,
- Flood readiness,
- Rate of rise of floodwaters,
- Duration of flooding,
- Ease of evacuation,
- Effective flood access, and
- Type of development in the floodplain.

In the study area, many of the above factors are not applicable in terms of affecting the hazard mapping. However, consideration of the above listed factors is an important process to identify the particular issues, which may result in hazardous conditions for specific locations or the entire study area.

5.4.2.1 Size of Flood

The size of a flood and the damage it causes varies from one event to another. For the purposes of this Floodplain Risk Management Study, provisional flood hazard has been assessed for the 5 and 100 Year ARI and PMF events. True hazard has also been assessed for these events.

Council's DCP (2013) identifies specific controls that relate to proposed development within the high hazard extent. It is the objective of the Floodplain Risk Management Study to identify the appropriate design event upon which the high hazard conditions should be based for planning purposes. The 100 year ARI event is commonly adopted across NSW to define the high hazard extent for planning purposes (often referred to as the high risk category). In the absence of any specific rational for adopting an event other than the 100 Year ARI event to define High hazard for planning purposes, it is recommended that the 100 Year ARI High Hazard extent be used for planning purposes within the study area.

5.4.2.2 *Effective Warning Time*

The effective warning time is the actual time available prior to a flood during which people may undertake appropriate actions (such as lift or transport belongings and/or evacuation). Effective warning time is always less than the total warning time available to emergency service agencies. This is related to the time needed to pass the flood warning to people located in the floodplain and for them to begin effective property protection and/or evacuation procedures.

The critical duration for the 5 and 100 Year ARI events ranges from 15 minutes to 2 hours, while that of the PMF ranges from 15 to 45 minutes throughout most of the catchment. The peak of the flow would therefore generally occur at various locations within the catchment within 15 minutes to 2 hours from the start of the rainfall. These short critical durations suggest that there is insufficient time to alert residents for the purposes of evacuation of significant flood preparations. This has been considered in the review of emergency response arrangement outlined in **Section 8**.

As critical durations are fairly homogenous throughout the catchment, all regions are subject to flash flooding, and consequently no region is more at risk due to warning time than any other. As such, no changes to the hazard mapping have been recommended as an outcome of effective warning time.

5.4.2.3 *Flood Readiness*

Flood readiness or preparedness can greatly influence the time taken by flood-affected residents and visitors to respond in an efficient manner to flood warnings. In communities with a high degree of flood readiness, the response to flood warnings can be prompt, efficient and effective.

Flood readiness is generally influenced by the time elapsed since the area last experienced severe flooding. The major flood events occurred in the catchment were in February 1993 which was roughly equivalent to a 50 Year ARI event, January 1991 which is approximately 20 Year ARI event and April 1998 which is approximately 10 Year ARI event. Based on the responses from the resident survey conducted for the Leichhardt Flood Study (Cardno, 2014), approximately 28% of respondents have been living in the catchment at the time of the 1993 flood event.

The responses from the Flood Study (Cardno, 2014) resident survey suggest that around 33% of the respondents were not aware of flooding in the catchment. This can be a function of the misconception of overland flooding, which is commonly associated with stormwater flooding. Furthermore, the short duration of flooding in the catchment may mean that the flooding occurs when the residents are not at home or during the night and so the flooding is not observed.

The results of the community survey suggest that the flood events that have occurred in the catchment since the 1990s can be used effectively for flood education purposes (see option EM3). This will assist in increasing the flood readiness of the residents.

Based on the available information it is assumed that flood awareness across the study area of larger floods is likely to be relatively low and no particular part of the catchment appears to have more flood awareness than another. As a result, the provisional high hazard extents are not recommended to be altered as a result of flood readiness.

5.4.2.4 *Rate of Rise of Floodwaters*

The rate of rise of floodwaters affects the consequences of a flood. Situations where floodwaters rise rapidly are potentially far more dangerous and cause more damage than situations where flood levels increase slowly. Both the catchment and floodplain characteristics affect the rate of rise.

A rate of rise of 0.5 m/hr has been adopted as indicative of hazardous conditions. There are no conclusive guidelines on this parameter. As such this value has been selected arbitrarily to provide an indication of locations where waters can reach hazardous depths in a relatively short period of time.

It is important to note that a rate of rise greater than 0.5 m/hr on its own is not necessarily hazardous. For instance, if the rate of rise is very high but flood depths only reach 200 mm, this is not considered to pose any greater hazard than slowly rising waters. Therefore, peak flood depths were considered in conjunction with the rate of rise in identifying hazardous areas.

A flood depth of 500 mm, combined with a rate of rise greater than 0.5 mm/hr was selected as the trigger depth to identify hazardous conditions. A 500 mm flood depth is well within the range of available information as to when vehicles become unstable even with no flow velocity (NSW Government, 2005).

The mapping provided in **Figure 5-2 to Figure 5-4,** show that in general the flooded areas where a high rate of rise to significant depth occurs are generally confined to the areas already classified as high hazard. However, there are some additional areas, currently considered low hazard where high rate of rise of flood water could be an issue. It is not recommended that these areas be classified as high hazard for planning purposes (i.e. the application of high hazard development controls (see DCP2013) on these properties would not be effective in managing the risk of fast rising water). Instead, it is recommended that these locations being noted by Council and the SES with regards to emergency response planning.

5.4.2.5 Duration of Flooding

The duration of flooding or length of time a community, suburb or single dwelling is cut off by floodwaters can have a significant impact on the costs and disruption associated with flooding. Flooding durations are generally less than a couple of hours, and as such this is not considered as a key issue for the study area.

5.4.2.6 Ease of Evacuation

The levels of damage and disruption caused by a flood are also influenced by the difficulty of evacuating flood-affected people and property. Evacuation may be difficult because of a number of factors, including:

- The number of people requiring assistance;
- Mobility of people;
- Time of day; and
- Lack of suitable evacuation equipment.

A flood event in the catchment is likely to be a flash flood scenario, with limited warning time and exposure time (additional details provided in **Section 8**); therefore, evacuation may not be viable.

Based on the 2011 census, it is noted that the percentage of people aged between 0 and 10 is higher in the study area than the average for NSW. Furthermore, a reported 1,665 residents of the study area population identify as requiring assistance during past emergency events, while 61% of residents over 65 have profound or severe disability (2011).

A review of development types within the study area, considered both aged care and childcare facilities as having difficult evacuation requirements due to the demographics of the residents at these locations. Two of these facilities have been identified within flood extents. However, it is worth noting that the locations are only affected in major events such as the PMF.

Evacuation (or lack of evacuation potential) is a key issue with regards to flood risk and hazard within the study area. However, the provisional hazard mapping is not recommended to be modified as an outcome of evacuation issues in the study area.

5.4.2.7 Effective Flood Access

The availability of effective access routes from flood prone areas can directly influence personal danger. Effective access means an exit route that remains trafficable for sufficient time to evacuate people and possessions.

Flood access issues vary across the study area. Both flood affected and flood free properties were assessed for their effective flood access. Effective flood access has been defined as a road which is flooded by less than 0.3m depth of water. Most vehicles start to become unstable at a depth of 0.3m.

The effective flood access mapping shown in **Figure 5-5 to Figure 5-7** identify that there are significant areas in the 100 Year ARI, which do not have effective flood access. In these areas, for the duration of the flooding, evacuation is generally not recommended. In this type of short duration flooding, residents are as likely to put themselves in harm's way by evacuating rather than staying indoors. However, will be dependent on the flood impacts on the building within which they are taking shelter.

These locations and the access issues associated with them have been considered in **Section 9**, with regards to identifying the need for any planning requirements to manage this issue into the future (e.g. appropriate develop types or facilities).

Options associated with road raising and improvements have also been considered as a result of this assessment and are outlined as part of Option EM7. Possible locations for flood depth markers have been outlined in Option EM5 (**Section 12.4**).

5.4.2.8 Type of Development in the Floodplain

The degree of hazard to be managed is a function of the type of development and resident mobility. This may alter the type of development considered appropriate in new development areas and may also change management strategies in existing development areas. The land-use in the study area is predominantly residential, with some commercial and industrial areas. The risk for commercial property is considered to have lower consequences that for residential development due to the application of insurances which are factored into a business's costs that would cover the financial damages incurred by a flood. However, the application of this issue is most appropriately dealt with the development controls applied to the different development types rather than an amendment to the high hazard mapping. Council's existing development controls have been reviewed in **Section 9**.

5.4.2.9 Outcome of True Hazard Assessment

The true hazard assessment outlined in the preceding sections did not identify any specific issues which would result in additional land being classified as high hazard for the 5, 20 and 100 Year ARI events or the PMF event. Nor was it identified as necessary to reduce the high hazard extent for these design events. However, several issues relating to flood risk were identified through this assessment that have been considered in the review of emergency response arrangement and development of floodplain risk management options. A summary of the outcome of the true hazard assessment is provided in **Table 5-1**.

Table 5-1 True Hazard Assessment Outcomes

True Hazard Factor	Outcome of Assessment	Actions for the FRMS
Size of Flood	Provisional flood hazard has been assessed for the 5, 20 and 100 Year ARI and PMF events. True hazard has also been assessed for these events. It is recommended that the 100 Year ARI High Hazard extent be used for planning purposes within the study area	The review of Council's planning controls should consider the 100 Year ARI High Hazard extent for planning purposes.
Effective Warning Time	The critical duration for the 5, 20 and 100 Year ARI events ranges from 15 min to 2 hours, while that of the PMF ranges from 15 to 45 mins throughout most of the catchment. The peak of the flow would therefore generally occur at various locations within the catchment within 15 minutes to 2 hours from the start of the rainfall. These short critical durations suggest that there is insufficient time to alert residents for the purposes of evacuation of significant flood preparations. As critical durations are fairly homogenous throughout the catchment, all regions are subject to flash flooding, and consequently no region is more at risk due to warning time than any other. As such, no changes to the hazard mapping have been recommended as an outcome of effective warning time.	The relatively short warning time until flooding occurs has been considered in the review of emergency response arrangement.

True Hazard Factor	Outcome of Assessment	Actions for the FRMS
Flood Readiness	The major flood events occurred in the catchment were in February 1993 which was roughly equivalent to a 50 Year ARI event, January 1991 which is approximately 20 Year ARI event and April 1998 which is approximately 10 Year ARI event. Based on the responses from the resident survey conducted for the Leichhardt Flood Study (Cardno, 2014), approximately 28% of respondents have been living in the catchment at the time of the 1993 flood event. The responses from the resident survey also suggest that around 33% of the respondents were not aware of flooding in the catchment. Based on the available information it is assumed that flood awareness across the study area of larger floods is likely to be relatively low and no particular part of the catchment appears to have more flood awareness than another. As a result, the provisional high hazard extents are not recommended to be altered as a result of flood readiness.	The results of the community survey suggest that the flood events that have occurred in the catchment since the 1990s can be used effectively for flood education purposes (see option EM3). This will assist in increasing the flood readiness of the residents.
Rate of Rise of Floodwaters	A flood depth of 500 mm, combined with a rate of rise greater than 0.5 mm/hr was selected as the trigger depth to identify hazardous conditions. The mapping provided in Figure 5-2 to Figure 5-4, show there are only a few properties with flow behaviour of these constraints which are not already selected by the provisional high hazard criteria. It is not recommended that these areas be classified as high hazard for planning purposes (i.e. the application of high hazard development controls (see DCP2013) on these properties would not be effective in managing the risk of fast rising water).	It is recommended that the locations with high rate of rise be noted by Council and the SES with regards to emergency response planning. This has also been considered in the review of emergency response arrangements (**Section 8**).
Duration of Flooding	Flooding durations are generally less than a couple of hours, and as such this is not considered as a key issue for study area with regards to increased flood risk or high hazardous conditions.	No Action.
Ease of Evacuation	The land-use in the study area is predominantly residential, with some commercial and industrial areas. The implications of flood risk for different development types is most appropriately dealt with through development controls applied to the different development types rather than an amendment to high hazard mapping.	Council's existing development controls have been reviewed in **Section 9**. The controls applied to different development types have been considered in this review.
Effective Flood Access	It was determined that effective access is a road which is flooded by less than 0.3m of water. The effective flood access mapping shown in Figure 5-5 to Figure 5-8 identify that there are significant areas within the catchment which do not have effective flood access. In these areas, for the duration of the flooding, evacuation is generally not recommended. In this type of short duration flooding, residents are as likely to put themselves in harm's way by evacuating rather than staying indoors. This is primarily an emergency response issue, and as such no changes are recommended to the high hazard mapping as a result of these issues.	It is recommended that the locations with no ease of evacuation be noted by Council and the SES with regards to emergency response planning. This has also been considered in the review of emergency response arrangements (**Section 9**).

True Hazard Factor	Outcome of Assessment	Actions for the FRMS
Type of Development in the Floodplain	The land-use in the study area is predominantly residential, with some commercial and industrial areas. The risk to commercial property is considered to have lower consequences that for residential development due to the application of insurances which are factored into a business's costs that would cover the financial damages incurred by a flood. However, the application of this issue is most appropriately dealt with the development controls applied to the different development types rather than an amendment to the high hazard mapping.	Council's existing development controls have been reviewed in **Section 9**. The controls applied to different development types have been considered in this review.

5.5 Hydraulic Categorisation

While Flood Hazard (described in the sections above) relates to the impact of flooding on development and people, Hydraulic Categorisation is used to reflect the impact of development activity on flood behaviour. The Floodplain Development Manual (2005) defines flood prone land to be one of the following three hydraulic categories:

- **Floodway –** Areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas.
- **Flood Storage –** Areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges. Flood storage areas, if completely blocked would cause peak flood levels to increase by 0.1m and/or would cause the peak discharge to increase by more than 10 percent.
- **Flood Fringe –** Remaining area of flood prone land after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant effect on the flood pattern or flood levels.

Hydraulic categorisation mapping has been undertaken for the 5 and 100 Year ARI together with the PMF using the results from the Leichhardt Flood Study (Cardno, 2014).

The criteria used to define floodways and flood storage is described below (based on Howells et al, 2003). It provides a framework for the FRMSP and guides planning for properties potentially requiring a detailed assessment for future development.

As a minimum, the floodway was assumed to follow the channels from bank to bank. In addition, the following depth and velocity criteria were used to define a floodway:

- Velocity x Depth product must be greater than 0.25 m^2/s and velocity must be greater than 0.25 m/s; OR
- Velocity is greater than 1 m/s.

Flood storage was defined as those areas outside the floodway, which if completely filled would cause peak flood levels to increase by 0.1 m and/or would cause peak discharges to increase by more than 10 percent. The criteria were applied to the model results as described below.

Previous analysis of flood storage in 1D cross sections assumed that if the cross-sectional area is reduced such that 10 percent of the conveyance is lost, the criteria for flood storage would be satisfied. To determine the limits of 10 percent conveyance in a cross-section, the depth was determined at which 10 percent of the flow was conveyed. This depth averaged over several cross-sections was found to be 0.2m (Howells et al, 2003). Thus the criteria used to determine the flood storage is:

- Depth greater than 0.2m; AND
- Not classified as floodway.

The hydraulic categories for the 5 and 100 Year ARI and PMF events are shown in **Figures 5-8 to 5-10**.

5.6 Foreshore Inundation

The Leichhardt Estuarine Planning Levels Study (Cardno, 2010) identified Estuarine Planning Levels (EPLs) along the study area foreshore for a range of edge treatment types and heights and a range of mean sea level rise scenarios. These scenarios included:

- Foreshore edge types, including
  - 1 in 20 natural slopes
  - 1 in 10 beach faces
  - 1 in 5 embankments
  - 1 in 2 seawalls; and
  - Vertical Walls
- Foreshore edge crest levels of:
  - 1.5, 2.0, 2.5 and 3m AHD
- Sea level rise scenarios of:
  - 0.4m, 0.9m and 1.1m.

The Leichhardt Estuarine Planning Levels Study (Cardno, 2010) did not include the mapping of estuarine inundation risk and 'flood extents'. To better understand the extent of the foreshore risk under the scenarios outlined above, estuarine risk mapping has been undertaken as part of the FRMS using the data from the 2010 study.

The predicted inundation extents for the still water levels (SWL) and EPLs for the following conditions are shown in **Appendix E**:

- Existing;
- 2050 – 0.4m Sea Level Rise;
- 2100 – 0.9m Sea Level Rise; and
- 2100 – 1.1m Sea Level Rise.

The majority of land affected by sea level rise in the study area occurs is recreational land, including a significant portion of the Bay Run, Callan Park, King George Park and Birchgrove Oval. These areas are significantly affected by storm event in future sea level rise scenarios. Beyond these recreational spaces, the majority of land in the study area is relatively steep, and therefore not significantly affected by sea level rise scenarios.

6 Current Economic Impact of Flooding

6.1 Background

The economic impact of flooding can be defined by what is commonly referred to as flood damages. The various types of flood damages are categorised in **Table 6-1.**

Table 6-1 Flood Damages Categories

Type of Flood Damages	Description
Direct	Building contents (internal) Structure (building repair and clean) External items (vehicles, contents of sheds etc.) Infrastructure
Indirect	Clean-up (immediate removal of debris) Financial (loss of revenue, extra expenditure) Opportunity (non-provision of public services)
Intangible	Social – increased levels of insecurity, depression, stress General inconvenience in post-flood stage

Direct damage costs are just one component of the entire cost of a flood event. There are also indirect costs. Both direct and indirect costs are referred to as tangible costs. In addition to this there are also intangible costs such as social distress. The flood damage values discussed in this report are the tangible damages and do not include an assessment of the intangible costs which are difficult to calculate in economic terms.

The assessment is based on a relationship between the depths of flooding on a property and the likely damage within the property.

6.2 Floor Level and Property Survey

A combination of floor level and property survey was used for the flood damage estimation. The floor level survey consists of data from the following sources:

- A detailed floor level and property survey undertaken by Cardno of 1,463 properties; and
- Property data obtained from Cadastral and LEP GIS layers provided by Council.

The property survey data contains the following information:

- A single floor level for each property (as seen from the street frontage);
- Property type (residential, commercial or industrial);
- Wall Construction (e.g. weatherboard, rendered, brick etc.);
- Ground level;
- Floor type (e.g. slab on ground);

One of the limitations of this data is that the floor level represents only the floor level that could be seen from the street frontage. If the floor levels at the rear of the property are significantly different then this will not have been captured.

6.3 Flood Levels and Depth of Flooding Calculations

A combination of floor levels, ground levels and flood levels was analysed to identify a representative depth for each property to estimate the cost of flood damages associated with each design rainfall event.

The location for extraction of flood levels was adopted as:

- The point of the surveyed floor and ground level (where available); or,
- The point of maximum depth over the cadastral lot in the PMF scenario.

The peak water level for each ARI was extracted from the model results for the locations identified above. The approach is somewhat limited in that it does not necessarily account for variations in water level across a property. For example, the point of maximum depth in a given lot may occur away from the building.

Ground levels were adopted as surveyed ground levels where available. For unsurveyed properties, a ground level was extracted from the model terrain at the same location as the flood level extraction.

The floor levels were adopted as surveyed or, in the absence of survey data, they were estimated as the ground level plus a representative height for each property type within the catchment.

It is important to note the limitations of the damages assessment with regards to the location of flood level extraction and corresponding floor levels. However, it is considered an appropriate approach for the purposes of this FRMS, in that the damages provide a representation of flood damages across the study are, rather than detailed damages for individual properties. The damages also a benchmark to ascertain the economic benefits of flood mitigation options in the FRMS.

6.4 Property Damages Analysis

A flood damage assessment for the existing study area and floodplain conditions has been undertaken as part of the current study. The assessment is based on damage curves that relate the depth of flooding on a property, to the potential damage within the property.

Ideally, the damage curves should be prepared for the particular catchment for which the study is being carried out. However, damage data in most catchments are not available and recourse is generally made to damage curves from other catchments. NSW Office of Environment and Heritage (OEH) has carried out research and prepared a methodology (draft) to develop damage curves based on state-wide historical data. This methodology is only for residential properties and does not cover industrial or commercial properties.

The OEH methodology is only a recommendation and there are currently no strict guidelines regarding the use of damage curves in NSW. OEH guidelines include a template spreadsheet program that determines damage curves for residential properties including:

- Single storey, slab on ground;
- Two storey, slab on ground; and
- Single storey, high set.

The methodology for determination of flood damages within the study area is outlined in the following sections.

6.4.1 Residential Damage Curves

There are a number of input parameters required for the damage curves including floor area and level of flood awareness. The following parameters were adopted in developing the residential damage curves for the study area:

- Damages are generally incurred on a property prior to any overfloor flooding. The default OEH curves allow for external damage of $11,497 ($2016 dollars) to be incurred when the water level reaches the base of the house (the base of the house is determined by 0.5m below the floor level for slab on ground). This has been adjusted so that a nominal value of $3,000 ($2016 dollars) is used to represent external damage (e.g. damage to gardens), where the ground level of the property is overtopped. The base of the house has also been adjusted so that it is 0.3m below floor for slab on ground. These conditions are believed to be more representative for residential properties in the study area.

> Floor Area was not provided in the floor level survey. Floor areas were estimated from a desktop analysis of aerial photography. The average floor area for a residential dwelling was approximately 150 m^2. With a floor area of 150m^2, the default contents value is $96,910 ($2016 dollars);

> All single storey properties have been classified as “slab-on ground.”

> The Effective Warning Time has been assumed to be zero due to the absence of any flood warning systems in the study area. A long Effective Warning Time allows residents to prepare for flooding by moving valuable household contents (e.g. the placement of valuables on top of tables and benches); and

> The study area is part of the overall larger Sydney Metropolitan area and as such is not likely to cause any post flood inflation. These inflation costs are generally experienced in small towns in regional areas, where re-construction resources are limited and large floods can cause a strain on these resources.

6.4.2 Average Weekly Earnings

OEH damage curves were derived for late 2001. To convert damages to today’s dollars, it is recommended that values in residential damage curves are adjusted by Average Weekly Earnings (AWE) rather than by the inflation rate as measured by the Consumer Price Index (CPI). AWE is considered a better representation of societal wealth, and hence an indirect measure of the building and contents value of a home.

The most recent data from the Australian Bureau of Statistics website (www.abs.gov.au) at the time of this study is for May 2016. The November 2001 AWE is shown in Table D1 of the OEH guidelines. The May 2016 AWE were taken from the Australian Bureau of Statistics website. Both are shown in **Table 6-2**. Consequently, all ordinates on the residential damage curves have been increased by 72%. In addition, all damage curves include GST as per OEH recommendations.

Table 6-2 AWE Statistics for Residential Damage Curves

Month	Year	AWE
November	2001	$676.40
May	2016	$1,160.20
Change	72%	

6.4.3 Commercial Damage Curves

Commercial damage curves were adopted based on the FLDamage Manual (Water Studies Pty Ltd, 1992). FLDamage allows for three types of commercial properties:

> Low value commercial;

> Medium value commercial; and

> High value commercial.

For the purpose of this assessment all commercial properties have been classified as low value commercial, as no other information was available in the survey obtained for this project. In determination of these damage curves, it has been assumed that the effective warning time is zero and the loss of trading days as a result of the flooding has been taken as 10.

These curves are derived assuming a property floor area of 100 m^2. Floor areas for commercial properties within the study area were estimated from a desktop analysis of aerial photography. Damages from the curves were scaled according to the estimated floor area for each commercial property. The average floor area for commercial properties was approximately 500 m^2.

The Consumer Price Index (CPI) obtained from the Australian Bureau of Statistics website was used to bring the 1990 data to June 2016 dollars resulting in an increase of 89%. It was assumed that the Water Studies Pty Ltd data was in June 1990 dollars. CPI statistics are shown in **Table 6-3**.

Table 6-3 CPI Statistics for Commercial Property Damage Estimation

Month	Year	CPI
June	1990	102.50
June	2016	194.15
Change	89%	

6.4.4 Industrial Damage Curves

Cardno conducted a survey of industrial properties in 1998 for Wollongong City Council as part of another project. The damage curves derived from this survey are more recent than those presented in FLDamage and have been used in a number of previous studies. These damage curves have also been adopted in this assessment.

The curves were prepared for three categories:

> Low Value Industrial; and

> Medium Value Industrial.

For the purpose of this assessment all industrial properties have been classified as low value industrial, as no other information was available in the survey obtained for this project.

These curves are derived assuming a property floor area of 100 m^2. Floor areas for industrial properties within the study area were estimated from a desktop analysis of aerial photography. Damages from the curves were scaled according to the estimated floor area for each industrial property. The average floor area for industrial properties was approximately 700 m^2.

The survey conducted only accounts for structural and contents damage to the property. Clean up costs and indirect financial costs were estimated based on the FLDamage Manual. Actual internal damage could be estimated, along with potential internal damage, using various factors within FLDamage. Using both the actual and potential internal damages, estimation of both the clean-up costs and indirect financial costs could be made.

The values were adjusted to June 2016 dollars using CPI statistics resulting in an increase of 60% compared to 1998 values. CPI statistics are shown in **Table 6-4**.

Table 6-4 CPI Statistics for Industrial Property Damage Estimation

Month	Year	CPI
June	1998	121.00
June	2016	194.15
Change	60%	

6.5 Adopted Damage Curves

The adopted damage curves are shown in **Figure 6-1**. Damage estimates for each property are dependent on their floor area. Curves have been provided for average floor areas across the study area (i.e. 150 m^2 for residential, 500 m^2 for commercial and 700 m^2 for industrial).

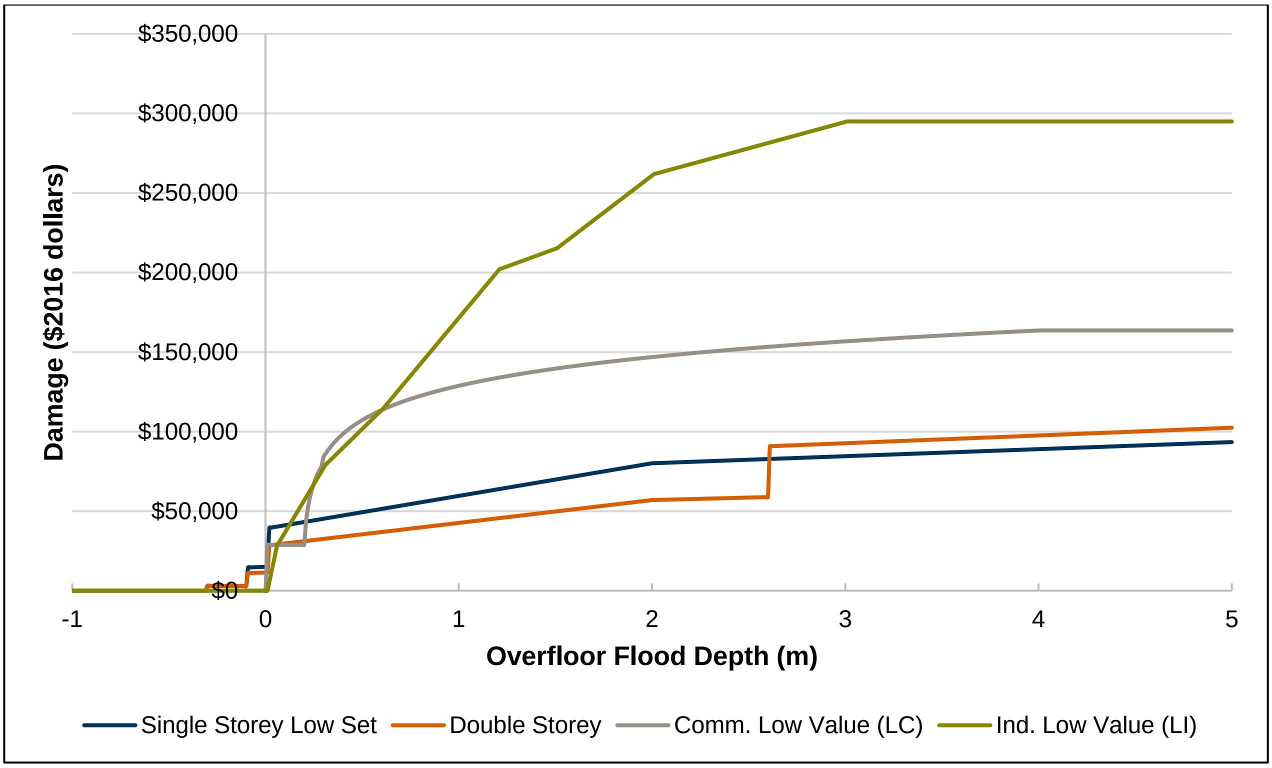

Figure 6-1 Residential, Commercial and Industrial Damage Curves

6.6 Average Annual Damage

Annual Average Damage (AAD) is calculated on a probability approach, using the flood damages calculated for each design event. Flood damages for each design event are calculated by using the 'damage curves' described in **Section 6.4.** The total damage for a design event is determined by adding all the individual property damages for that event.

Figure 6-2 is a probability curve based on the flood damages calculated for each design event. For example, the 100 Year ARI design event has a probability of occurring of 1% in any given year, and as such the 100 Year ARI flood damage is plotted at this point on the AAD curve. AAD is then calculated by determining the area under this curve. For this study, the damage resulting from events more frequent that a 5 Year ARI were assumed to be zero for the AAD analysis. Further information on the calculation of AAD is provided in Appendix M of the Floodplain Development Manual (2005).

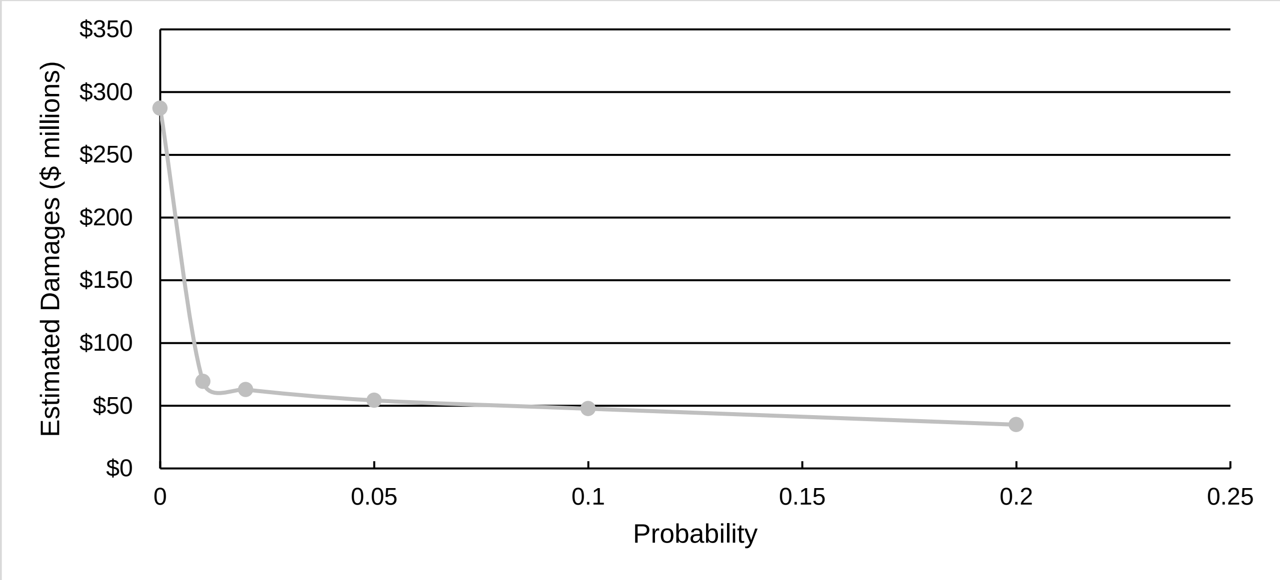

Figure 6-2 Average Annual Damage Curve for the Leichhardt Study Area

6.7 Results

The results of the flood damage assessment are provided for the entire study area in **Table 6-5** and for each of the sub-catchments of the study area in **Table 6-6**.

It should be noted that there are a number of properties along the sub-catchment boundaries that have the potential to be impacted by flood from more than one sub-catchment. As such, the values in **Table 6-5** are not simply the sum of the values in **Table 6-6**.

Table 6-5 Flood Damage Assessment Summary

Event / Property type	Properties with Overfloor Flooding *Existing Case*	Properties with Overground Flooding *Existing Case*	Estimated Total Damage ($ May 2016) *Existing Case*
PMF Event			
Residential	2957	5054	$202,106,000
Commercial	277	357	$25,804,000
Industrial	266	295	$59,203,000
PMF Total	**3500**	**5706**	$287,113,000
100yr ARI			
Residential	650	1234	$38,374,000
Commercial	82	124	$8,473,000
Industrial	109	124	$22,382,000
100yr ARI Total	**841**	**1482**	$69,229,000
50yr ARI			
Residential	578	1167	$34,396,000
Commercial	77	118	$8,062,000
Industrial	105	118	$20,370,000
50yr ARI Total	**760**	**1403**	$62,828,000
20yr ARI			
Residential	476	1042	$29,061,000
Commercial	66	103	$7,380,000
Industrial	88	105	$17,793,000
20yr ARI Total	**630**	**1250**	$54,234,000
10yr ARI			
Residential	407	924	$25,039,000
Commercial	58	96	$7,008,000
Industrial	82	96	$15,557,000
10yr ARI Total	**547**	**1116**	$47,604,000
5yr ARI			
Residential	289	690	$18,814,000
Commercial	56	90	$6,652,000
Industrial	67	75	$9,410,000
5yr ARI Total	**412**	**855**	$34,876,000
Total Annual Average Damage			**$16,099,195**

Table 6-6 Catchment Flood Damage Assessment Summary

	Properties with Overfloor Flooding	Properties with Overground Flooding	Estimated Total Damage ($2016)
Hawthorne Canal			
PMF	719	1268	$60,700,000
100 Year ARI	212	421	$15,735,000
50 Year ARI	191	391	$14,052,000
20 Year ARI	159	350	$11,639,000
10 Year ARI	139	313	$10,048,000
5 Year ARI	110	244	$7,783,000
Average Annual Damage			$3,518,000
Johnstons Creek			
PMF	450	654	$32,825,000
100 Year ARI	116	217	$7,346,000
50 Year ARI	110	199	$6,663,000
20 Year ARI	100	174	$5,952,000
10 Year ARI	93	160	$5,175,000
5 Year ARI	77	128	$4,160,000
Average Annual Damage			$1,827,000
Whites Creek			
PMF	1025	1609	$68,393,000
100 Year ARI	302	522	$18,293,000
50 Year ARI	257	497	$16,065,000
20 Year ARI	177	438	$12,553,000
10 Year ARI	134	379	$10,253,000
5 Year ARI	98	282	$8,087,000
Average Annual Damage			$3,734,000
Iron Cove			
PMF	176	274	$20,216,000
100 Year ARI	17	20	$3,205,000
50 Year ARI	17	19	$3,162,000
20 Year ARI	17	19	$3,119,000
10 Year ARI	15	19	$3,054,000
5 Year ARI	11	14	$2,799,000
Average Annual Damage			$1,110,000
Mort Bay			
PMF	304	539	$22,171,000
100 Year ARI	11	32	$527,000
50 Year ARI	11	28	$483,000
20 Year ARI	9	26	$415,000
10 Year ARI	7	26	$380,000
5 Year ARI	6	19	$311,000
Average Annual Damage			$233,000

	Properties with Overfloor Flooding	Properties with Overground Flooding	Estimated Total Damage ($2016)
Parramatta River			
PMF	70	98	$7,852,000
100 Year ARI	4	4	$244,000
50 Year ARI	4	4	$234,000
20 Year ARI	4	4	$214,000
10 Year ARI	4	4	$197,000
5 Year ARI	3	3	$132,000
Average Annual Damage			$96,000
Rozelle Bay			
PMF	488	777	$35,037,000
100 Year ARI	111	178	$6,963,000
50 Year ARI	105	165	$6,303,000
20 Year ARI	69	147	$4,474,000
10 Year ARI	47	132	$3,609,000
5 Year ARI	24	82	$2,365,000
Average Annual Damage			$1,304,000
Snails Bay			
PMF	70	98	$7,852,000
100 Year ARI	4	4	$244,000
50 Year ARI	4	4	$234,000
20 Year ARI	4	4	$214,000
10 Year ARI	4	4	$197,000
5 Year ARI	3	3	$132,000
Average Annual Damage			$96,000
White Bay			
PMF	556	850	$57,623,000
100 Year ARI	162	227	$21,056,000
50 Year ARI	150	223	$19,427,000
20 Year ARI	135	207	$17,447,000
10 Year ARI	121	186	$15,633,000
5 Year ARI	84	135	$9,343,000
Average Annual Damage			$4,626,000

7 Environmental and Social Characteristics

Environmental and social characteristics of the study area may influence the type and extent of flood mitigation options able to be implemented. Environmental characteristics, such as habitats, threatened species, topography and geology are constraints of structural flood mitigation sites.

Social characteristics such as housing and demographics may impact the community's response to flooding and therefore affect the type of flood mitigation options proposed.

The following environmental and social characteristics have been considered in the assessment:

- Geology, Soils, Geomorphology and Groundwater;
- Demographic Characteristics;
- Flora and Fauna; and
- Aboriginal and Non-Aboriginal Cultural Heritage.

The detailed environmental and social assessment is provided in **Appendix B**.

Environmental and social issues to be considered in the development of floodplain management strategies for the study area include:

- The high probability of Acid Sulfate Soils in the Parramatta River and Hawthorne Canal, which if disturbed could cause serious environmental risk;
- There are 7 known contaminated sites which may require further investigation;
- Potential for the grey-headed flying fox to be disturbed; and
- There are 9 Aboriginal sites listed under the National Parks and Wildlife Act 1974, 21 non-Aboriginal heritage sites found on the State Heritage Register and 669 heritage items of significance under the Leichhardt LEP.
- The median age of people in the study area is 37 years as of 2011 census, which is a similar figure to Australia's median age. In fact almost 40% of people living in the study area are within the 25-44 age group, only 4% are above 75 year age and children under 14 year age comprise 16.8%. This results in a community which may be primarily able-bodied, able to evacuate effectively and/or assist with evacuation procedures.
- In the study area, 79.4% of people only speak English at home. The most common languages spoken at home other than English include Italian 3.0%, Greek 1.4%, Spanish 1.0%, Cantonese 0.8% and Mandarin 0.7%. Flood information provided to the community should consider the range of languages spoken.
- The median weekly personal income for people aged 15 years and over in the study area was $1,086 as of 2011 Census, compared to the NSW average of $561. This trend of well above average income for the region compared to the NSW average was also evident for family and household incomes. This may have implications for the economic damages incurred on property contents during a flood event.
- When the social assessment was undertaken in 2013, the median house price in the study area was $805,000, and the median unit price was $612,500. In NSW, the median house price was $440,000, and median unit price was $445,000 (APM, 2012). This information has implications for the economic damages incurred during a flood event.

8 Flood Emergency Response Arrangements

8.1 Flood Emergency Response

The majority of flooding within the study area catchments is characterised by both major creek flooding and overland flow. The critical storm duration is between 15 minutes and 2 hours across the catchment, with the peak of the flood reached approximately 30 minutes to 1 hour after the start of the storm. This is considered short duration “flash” flooding.

Due to the short interval between the start of the storm and the peak of the flood, there is little in the way of warning that can be provided to people in the floodplain. Any warning provided would be for immediate safety precautions such as temporary refuge (if available nearby or onsite), raising of items off the ground and accounting for people on site.

The short duration until flooding occurs does not allow sufficient time to evacuate residents from their properties. In these situations, evacuation is generally not recommended as the response during a flood event as it is likely to be hurried and uncoordinated, which can expose evacuees to a hazardous situation. As such, the preferred response to flooding in flash flooding catchments is for people to remain within the property, preferably within the upper levels, if available. The suitability of the shelter-in-place approach should be considered in consultation with the State Emergency Service for the preparation of a Local Flood Plan (**Section 8.3.2**).

It is important that residents are aware of signs that will signal an approaching flood, and are aware of the correct response such that the small time period before the flood arrives may be used as effectively as possible to move people and belongings to a close, safe location.

Longer term regional storm warning can be of use in preparing for a flood event if the likely implications of flooding are known such as high risk areas, likely depth of flooding and flood free areas for refuge. The flood mapping presented in the Flood Study (Cardno, 2014) forms the basis for this information. The recommendations in this working paper with regards to available warning systems, community awareness and data transfer have been developed in order to facilitate this process.

The following sections provide an overview of the existing emergency response arrangements and policies, the impacts of flooding on access roads and the availability of evacuation centres. The outcomes of this review have been used to develop the Emergency Response Flood Modification Options (**Section 12.4**).

8.2 Emergency Service Operators

The emergency response to any flooding of the study area will be coordinated by the lead combat agency, the SES, from their Local Command Centre located at Haberfield.

The SES is responsible for communicating Flood Advices and Evacuation Warnings to the flood affected communities via electronic media, both the Local and District Emergency Operations Controllers (LEOCON and DEOCON respectively), and any relevant Participating Organisations. The LEOCON must be a Police Officer stationed within the study area while the DEOCON is responsible for the entire Sydney Metropolitan District.

The relevant flood information from the Leichhardt Flood Study (Cardno, 2014) should be transferred to the Local SES Command Centre as well as the Local and District Emergency Operations Controllers.

8.3 Flood Emergency Responses Documentation

Emergency response documentation provides 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.

8.3.1 EMPLAN

The State Emergency Management Plan (EMPLAN) describes the New South Wales approach to emergency management, the governance and coordination arrangements and roles and responsibilities of agencies. The EMPLAN was developed with a comprehensive approach to emergency management. The Plan considers aspects of prevention, preparation, response and recovery with the aim of reducing the impacts of emergencies on communities in NSW.

Emergency Management Districts were changed to Emergency Management Regions in 2012. Regional Emergency Management Plans are being developed to replace the District Disaster Plans (DISPLANs). Until the new plans are passed and available the District Emergency Management Plans remain in place.

The study area is located within the Sydney Metropolitan Emergency Management Region. However, as a Sydney Metropolitan EMPLAN is yet to be published, emergency management for the study area is currently organised under the Sydney Mid West DISPLAN (2004).

The DISPLAN details emergency preparedness, response and recovery arrangements for the Mid-West district to ensure the coordinated response to emergencies by all agencies having responsibilities and functions in emergencies. The DISPLAN rates flooding hazards in Sydney Mid-West as 'High possibility, moderate consequence.' State Emergency Services is the designated combat agency for dealing with floods and to coordinate the rescue, evacuation and welfare of affected communities.

8.3.2 Local Flood Plan

A local flood plan has not been prepared for the local area containing the study area. As such, the New South Wales State Flood Plan (2014) is used to set out the arrangements for the emergency management of flooding.

The State Flood Plan is a sub-plan to the state EMPLAN. The Flood Plan sets out the emergency management aspects of prevention; preparation; response and initial recovery arrangements for flooding and the responsibilities of individuals, agencies and organisations with regards to these functions

It is identified in the State Flood Plan that Local Government plays an important role at the local level in all phases of emergency management. The Local Government role that may vary from area to area. The agreed responsibilities of Local Governments are to be listed in Local Flood Sub-Plans.

The State Flood Plan sets out the planning framework for the development and maintenance of a Flood Sub Plan at the following levels:

- The State of New South Wales;
- NSW SES Regions; and
- Each council area with a significant flood problem. In some cases the flood problems of more than one council area may be addressed in a single plan or the problems of a single council area may be addressed in more than one plan.

At present, a Local Flood Plan (LFP) for the study area (sub-plan to the State Flood Plan) does not exist. However, it is understood that the SES, in conjunction with Inner West Council, are in the process of preparing a local flood plan to outline local arrangements for flood prevention, preparedness, response and recovery. The outcomes of the Leichhardt Flood Study (Cardno, 2014) and this FRMS will form key inputs to this plan.

8.3.3 Emergency Response Guideline for Flash Flooding

In 2013, the Australian Fire and Emergency Service Authorities Council (AFAC) released a guideline on emergency planning for flash flood events providing a useful insight into the position of the emergency services authorities' council, of which NSW SES is a member. The guideline reflects a consensus on best practice for managing flash flooding, focussing on risk to life. The AFAC define flash flooding as:

Flash flooding may be defined as flooding that occurs within 6 hours or less of the flood-producing rainfall within the affected catchment. Flash flood environments are characterized by the rapid onset of flooding from when rainfall begins (often within tens of minutes to a few hours) and by rapid rates of rise and by high flow velocity.

Flooding within the study area can be described as flash flooding based on the above definition as there is a rapid rate of rise and most roads throughout the floodplain are flooded in under 6 hours.

The guideline provides the following comments relating to appropriate emergency response in relation to flash flooding:

- The safest place to be in a flash flood is well away from the affected area. Accordingly, pre-event planning for flash floods should commence with an assumption that evacuation is the most effective strategy, provided evacuation can be safely implemented;
- Evacuation too late may be worse than not evacuating at all because of the dangers inherent in moving through flood waters. The timescale at which flash floods occur may limit the feasibility of evacuation as a response measure;
- A structurally suitable building means a building which is strong enough to withstand lateral flood flow, buoyancy, and suction effects and debris impact load;
- In the absence of a more detailed engineering-based code the following observations can be made regarding structural suitability for shelter-in-place buildings:
  - Single storey slab-on-ground dwellings, and relocatable homes and caravans are unlikely to be suitable;
  - Reinforced concrete or steel-framed multi-level buildings are more likely to be suitable; and,
  - Ideally the building should have sufficient area of habitable floor that will be flood free in a Probable Maximum Flood (PMF) event to accommodate the likely number of occupants;
- The pre-incident planning of evacuation must include operational contingency plans for the rescue of individuals who do not evacuate in a timely manner;
- 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 and as a result provide limited prospects for using such systems to trigger planned and effective evacuation,
- The dangers to be considered in relation to evacuation include evacuees being overwhelmed by floodwaters, and exposure to adverse weather such as lightning, hail, heavy rain, strong winds, flying debris, or falling trees and power lines,
- The dangers to be considered for shelter-in-place include risks resulting from:
  - Their own decision making (drowning if they change their mind);
  - Their mobility (not being able to reach the highest part of the building);
  - Their personal safety within the building (fire and accident); and,
  - Their health while isolated (pre-existing condition or sudden onset).

For these reasons, 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. Where the available warning time and resources permit, evacuation should be the primary response strategy.

8.4 Emergency Response Design Event

Emergency response can be designed to cater for a range of flood events, from the more frequent flood events such as the 5 Year ARI event, through to the less frequent flood events up to the PMF Event. The more likely a flood event, the less likely it is to cause harm to people or property.

To determine the cumulative risk at any given location accounting for all flood events it is necessary to adopt a single design event upon which to derive emergency response provisions.

The NSW Government's *Floodplain Development Manual* (2005) states the following:

"Response planning for the consequences of the PMF provides for effective management of smaller events, particularly those rarer than the flood event selected as the basis of the Flood Planning Level (FPL). For example, where 1% AEP flood is used as the basis for minimum floor levels or protection from a levee, a 0.5% AEP flood event will probably overwhelm these measures. This event, whilst smaller, but significantly more likely than the PMF, will have major consequences to people, property, and infrastructure and needs to be accounted for in emergency response planning."

"An assessment of the full range of events therefore provides key information for flood response studies".

"It is critical that relevant information on evacuation is provided on events up to the PMF".

Based on these comments, the PMF should be adopted as the design flood event when considering emergency response. This is an envelope approach as the risk associated with all flood events is encompassed within the consideration of the Probable Maximum Flood. As noted above the Flood Planning Level is based on the 100 Year ARI event so the most significant risk to life and property occurs in events greater than this**.**

8.5 Flood Warning Systems

Flood warnings are issued by the BoM to advise that flooding is occurring or expected to occur in a geographical area based on defined criteria. Flood warnings may include either qualitative or quantitative predictions or may include a statement about future flooding that is more generalised. The type of prediction provided depends on the quality of real-time rainfall and river level data, the capability of rainfall and hydrological forecast models and the level of service required.

The critical duration and response times for the study area floodplain limit the implementation of a flood warning system. As part of its Severe Weather Warning Service, the Bureau also provides warnings for severe weather that may cause flash flooding. State emergency services or local authorities may provide flash flood warnings in some locations. These services are typically issued for a much larger region, or catchment, that includes the local flash flood site. This information can sometime be used at a local level as discussed below.

In order to get the most benefit from flood warnings people in flood prone areas will need to know what, if any, effect the flood will have on their property and some knowledge of how best to deal with a flood situation. Recommendations to raise public awareness of local flooding issues are outlined in **Section 12.4.3**.

Flood Warnings Issued by BoM

The study area catchment is affected by flash flooding (i.e. floods where the warning time is less than 6 hours). As such it is difficult to provide any flood warning in advance of floods. Where possible, the Bureau of Meteorology (BoM) will issue a severe weather / flood warning to the Sydney Western Regional SES headquarters. Where that alert is relevant to the study area (which is within the Ashfield-Leichhardt Local Unit), the SES Regional Command will pass the BoM's warning on to the Local Command based in Haberfield. In some cases, 2-3 days advanced notice may be available (e.g. where an East Coast Low develops off Sydney). However, at other times it may only be possible to issue a flood warning a few hours in advance, if at all.

Accessing Flood Warnings

Flood Warnings can be available to the public via the following:

- **Local Response Organisations:** These include the Council, Police, and State Emergency Service in the local area. There is currently no flood or sever weather warning procedure in place within the study area for the public from local organisations. Recommendations for options to address this are provided in **Section 12.4.**
- **Bureau of Meteorology:** Flood Warnings, Flood Watches and general information are available directly from the Bureau of Meteorology, including:
  - On the web at: www.bom.gov.au/australia/warnings
  - Through the Telephone weather warnings service. Flood Warnings and Flood Watches in most States are available on the Bureau of Meteorology's recorded message service. Charges apply.
- **Radio:** Radio stations, particularly local ABC and local commercial stations broadcast flood warning information as part of their new bulletins, or whenever practicable.

Activation of Local SES Command

SES staff are advised and placed on alert when the SES Local Command has been issued with a flood warning by the BoM. The BoM's flood warning is also forwarded by SMS to the relevant individuals and organisations.

It is noted that the SES is the designated lead combat agency in an emergency such as a flood event. However, local authorities may wish to act on the advice provided by the SES to minimise the level of risk in the lead up to the flood event.

Depending on the amount of lead time provided, Council may undertake any relevant priority works, such as cleaning out stormwater pits to reduce the risk of blockage. In addition, Council's Rangers can be placed on standby and report any issue directly to the SES (e.g. cars parked in overland flow paths, etc.).

8.6 Access and Movement During Flood Events

Any flood response suggested for the study area must take into account the availability of flood free access, and the ease with which movement may be accomplished. Movement may be evacuation from flood affected areas, medical personnel attempting to provide aid, or SES personnel installing flood defences.

Table 8-1 provides a summary of road flooding in the study area. It is recommended that permanent flood depth markers be considered for installation on either side of roads which are subject to significant inundation to provide an indication to motorists of water levels at these locations when the road is flooded. Locations inundated in the 5 Year ARI event and which exceed 0.3m depth in any event up to the 100 Year ARI have been identified in **Table 8-1** and depth markers will be considered at these locations as part of the options assessment.

Refer to **Figure 8-1** for map of Access Road Flooding Location ID's.

Table 8-1 Access Road Flooding

Location ID	Road	5 Year ARI	10 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI	PMF
1	Parramatta Road / Flood Street	1.19	1.27	1.41	1.55	1.70	3.28
2	Tebbutt Street	0.55	0.63	0.74	0.83	0.88	1.64
3	Marion Street	0.20	0.21	0.24	0.26	0.29	1.67
4	Flood Street	0.31	0.33	0.37	0.40	0.41	0.72
5	Burfit Street	0.31	0.33	0.37	0.40	0.45	1.17
6	Foster Street	0.27	0.29	0.32	0.35	0.41	1.08
7	Daniel Street	0.33	0.38	0.45	0.75	0.85	1.73
8	Loftus Street	0.70	0.91	1.13	1.43	1.53	2.40
9	Flood Street	0.42	0.47	0.52	0.57	0.65	1.36
10	Edith Street	0.87	0.96	1.05	1.12	1.21	1.95
11	Elswick Street	0.71	0.72	0.73	0.57	0.88	1.15
12	Macauley Street	0.00	0.00	0.16	0.18	0.18	0.32
13	Allen Street	0.24	0.30	0.34	0.36	0.41	0.82
14	Norton Street	0.21	0.23	0.25	0.26	0.28	0.48
15	James Street	0.18	0.20	0.21	0.23	0.23	0.50
16	William Street	0.60	0.74	0.81	0.87	0.91	1.46
17	Hubert Street	0.47	0.56	0.61	0.65	0.69	1.40
18	Charles Street	0.50	0.59	0.67	0.74	0.76	1.71
19	Darley Road	0.64	0.74	0.89	1.06	1.15	2.09
20	Norton Street	0.33	0.34	0.36	0.35	0.39	0.61
21	Balmain Road	0.56	0.63	0.68	0.78	0.79	1.34
22	Hay Street	0.31	0.35	0.40	0.47	0.47	1.07
23	Redmond Street	0.51	0.56	0.62	0.69	0.72	1.53
24	Catherine Street	0.34	0.38	0.44	0.52	0.60	1.78
25	Parramatta Road	0.43	0.48	0.53	0.61	0.65	1.42
26	Hearn Street	0.54	0.60	0.66	0.71	0.75	1.34

Location ID	Road	5 Year ARI	10 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI	PMF
27	Albion Street	0.48	0.51	0.56	0.60	0.64	1.41
28	Parramatta Road	0.34	0.37	0.41	0.43	0.47	0.71
29	Ferris Street	0.23	0.24	0.24	0.26	0.25	0.78
30	Mackenzie Street	0.38	0.43	0.49	0.53	0.58	1.29
31	Coleridge street	0.55	0.63	0.71	0.80	0.87	1.87
32	Catherine Street	0.70	0.78	0.87	0.92	1.02	1.86
33	Emma Street	0.00	0.08	0.10	0.13	0.13	0.79
34	Styles Street	0.44	0.53	0.62	0.69	0.76	1.84
35	Annandale Street	0.36	0.36	0.38	0.38	0.39	0.84
36	Young Street	0.63	0.65	0.67	0.68	0.70	1.00
37	Alfred Street	0.24	0.27	0.29	0.32	0.33	1.11
38	Ainsworth Street	0.59	0.61	0.64	0.75	0.68	1.01
39	Catherine Street	0.67	0.79	0.87	0.96	0.95	1.26
40	White Street	0.80	0.86	0.98	0.91	1.14	2.27
41	Trafalgar Street	0.46	0.50	0.54	0.56	0.59	0.82
42	Nelson Street	0.36	0.40	0.41	0.42	0.48	1.11
43	Parramatta Road	0.19	0.23	0.26	0.30	0.40	2.89
44	Paramatta Road	0.18	0.21	0.24	0.25	0.30	0.62
45	Johnston Street	0.41	0.45	0.47	0.50	0.50	0.62
46	The Crescent / Trafalgar Street	0.61	0.66	0.73	0.75	0.80	1.64
47	Brenan Street	0.41	0.52	0.83	1.13	1.26	3.11
48	Railway parade	0.70	0.89	1.13	1.35	1.57	3.53
49	Edward Street	0.71	0.75	0.79	0.78	0.87	1.38
50	Lilyfield Road / Justin Street	0.37	0.39	0.41	0.44	0.46	0.63
51	Foucart Street	0.34	0.37	0.40	0.43	0.45	0.83
52	Denison Street / Alfred Street	0.21	0.24	0.29	0.33	0.38	1.07
53	Denison Street	0.64	0.72	0.76	0.81	0.82	0.96
54	Lilyfield Road	0.58	0.66	0.75	0.82	0.93	2.08
55	The Crescent / City West Link	0.19	0.19	0.27	0.37	0.44	1.24
56	Beattie Street	0.18	0.22	0.25	0.29	0.33	0.70
57	Roseberry Street	0.70	0.82	0.94	1.04	1.17	2.25
58	Goodsir Street	0.59	0.91	1.02	1.11	1.17	1.96
59	Perrett Street	0.53	0.61	0.75	0.85	0.90	1.70
60	Pine Street	0.44	0.46	0.56	0.61	0.71	1.44
61	Mansfield Street	0.33	0.36	0.45	0.57	0.64	1.62
62	Parsons Street	0.72	0.81	0.92	1.10	1.19	2.18
63	Robert Street	0.56	0.63	0.70	0.83	0.85	1.66
64	Creek Street	0.22	0.24	0.26	0.27	0.31	1.52

Location ID	Road	5 Year ARI	10 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI	PMF
65	Wortley Street	0.37	0.42	0.47	0.51	0.56	0.82
66	Foy Street	0.21	0.28	0.34	0.45	0.55	1.38
67	Hyam Street	0.36	0.42	0.47	0.52	0.56	1.25
68	Buchanan Street	0.68	0.73	0.78	0.86	0.88	1.36
69	North Street	0.17	0.17	0.22	0.26	0.29	0.84
70	McKell Street	0.33	0.40	0.48	0.53	0.58	1.02
71	Walumil Street	0.53	0.56	0.58	0.62	0.62	0.79
72	Canal Road	0.64	0.70	0.75	0.79	0.82	1.72

8.7 Evacuation Centres

Due to the flash flooding nature of catchment flooding within the LGA evacuation may not always be possible or the best response. However, evacuation centres may be required for residents affected by foreshore inundation or immediately after a flood event if significant damage is incurred on a property. In other situations residents may not be able to return to the homes due to road flooding and may need temporary refuge until the floodwaters recede.

Several flood free locations have been identified in **Table 8-2** that may be suitable to function as evacuation centres during and following a flood event in the study area. Council and the SES should liaise with the owners and / or managers of the venues identified to determine appropriate evacuation centres. The selected locations should be identified in a local flood plan when it is prepared and details provided to residents in FloodSafe brochures or similar.

Refer to **Figure 8-2** for map of potential evacuation centre location ID’s

Table 8-2 Potential Evacuation Centres

ID*	Name of Venue	Address
1	Kegworth Public School	60 Tebbutt Street, Leichhardt NSW 2040
2	Catholic Education Office	38 Renwick Street, Leichhardt NSW 2040
3	St Fiacre’s Catholic Primary School	98 Catherine Street, Leichhardt NSW 2040
4	Sydney Secondary College	210 Balmain Road, Leichhardt NSW 2040
5	ST Columba's Primary School	215 Elswick St, Leichhardt NSW 2040
6	Leichhardt Public School	Marion Street, Leichhardt NSW 2040
7	Leichhardt Town Hall	107 Norton Street, Leichhardt NSW 2040
8	Annandale Neighbourhood Centre	79 Johnston Street, Annandale NSW 2038
9	Annandale Public School	25 Johnston Street, Annandale NSW 2038
10	Annandale North Public School	206 Johnston Street, Annandale NSW 2038
11	Village Church Annandale	122 Johnston Street, Annandale NSW 2038
12	Orange Grove Public School	Perry Street, Lilyfield NSW 2040
13	Sydney Community College	2A Gordon Street, Rozelle NSW 2039
14	Rozelle Child Care Centre	Cnr Balmain Rd & Cecily St, Lilyfield NSW 2039
15	ST Joseph's Catholic Church	15 Quirk Street, Rozelle NSW 2039
16	Rozelle Public School	663 Darling Street, Rozelle NSW 2039
17	Sydney Secondary College	23-33 Terry Street, Rozelle NSW 2039
18	Balmain Library	370 Darling Street, Balmain NSW 2041
19	Balmain Public School	1 Eaton Street, Balmain NSW 2041

ID*	Name of Venue	Address
20	Inner Sydney Montessori School	44 Smith Street, Balmain NSW 2041
21	Birchgrove Public School	Birchgrove Road, Balmain NSW 2041
22	Anglican Church Sydney Diocese	16A Spring Street, Birchgrove NSW 2041
23	Darling St Anglican Church	85 Darling Street, Sydney NSW 2037
24	Nicholson Street Public School	Nicholson Street, Sydney NSW 2041

8.8 Flood Emergency Response Planning Classifications

To assist in the planning and implementation of response strategies the State Emergency Service (SES) classifies communities according to the impact flooding has on them. Flood affected communities are those in which the normal functioning of services is altered either directly or indirectly because a flood and results in the need for external assistance. This impact relates directly to the operational issues of evacuation, resupply and rescue. The classifications (DECC, 2007) adopted by the SES are:

- **Flood Islands.** These are 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. Flood islands can be further classified as:
    - High Flood Island (the flood island contains enough flood free land to cope with the number of people in the area or there is opportunity for people to retreat to higher ground).
    - Low Flood Island (the flood island does not have enough flood free land to cope with the number of people in the area or the island will eventually become inundated by flood waters).
- **Trapped Perimeter Areas.** These would generally be inhabited 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 further classified according to their evacuation route:
    - High Trapped Perimeter (the area contains enough flood free land to cope with the number of people in the area or there is opportunity for people to retreat to higher ground).
    - Low Trapped Perimeter (the area does not have enough flood free land to cope with the number of people in the area or the island will eventually become inundated by flood waters).
- **Areas Able to be Evacuated.** These are inhabited areas on flood prone ridges jutting into the floodplain or on the valley side that are able to be evacuated.
    - Areas with Overland Escape Route (access roads to flood free land cross lower lying flood prone land).
    - Areas with Rising Road Access (access roads rise steadily uphill and away from the rising floodwaters).
- **Indirectly Affected Areas.** These are areas which are outside the limit of flooding and therefore will not be inundated nor will they lose road access. However, they may be indirectly affected as a result of flood damaged infrastructure or due to the loss of transport links, electricity supply, water supply, sewage or telecommunications services and they may therefore require resupply or in the worst case, evacuation.
- **Overland Refuge Areas.** These are areas that other areas of the floodplain may be evacuated to, at least temporarily, but which are isolated from the edge of the floodplain by floodwaters and are therefore effectively flood islands or trapped perimeter areas.

The flood emergency response planning classifications for the floodplain in a PMF scenario are shown in **Figure 8-3**. The majority of the flood affected properties are able to be accessed for a period of time (i.e. rising road access) or via a short overland route (this maybe on foot).

Some of the properties at the downstream end of the floodplain, fall within the classification of low flood island. However, it is noted that the period of inundation is generally only a few hours, not days.

9 Policies and Planning

Within the study area, development is controlled through the Leichhardt Local Environment Plan (LEP) 2013 and the Leichhardt Development Control Plan (DCP) 2013. The LEP is a planning instrument which designates land uses and development in the study area, while the DCPs regulates development with specific guidelines and parameters. There are also a number of planning documents that can affect property within the study area. These may be in the form of State Government controls or Council plans, policies or other publications.

This section reviews flood related controls covered by the LEP, relevant DCPs, State Government controls, Council policies and plans.

9.1 Leichhardt Local Environment Plan 2013

The Leichhardt Local Environmental Plan (LEP) 2013 commenced Monday 3 February 2014. The Leichhardt LEP 2013 is a legal document that sets the direction for growth in the study area by providing controls and guidelines for development. It determines what can be built, where it can be built and what activities can occur on land.

The Leichhardt LEP 2013 is based on a standard format used by all Councils in NSW and can be viewed on the NSW legislation website.

9.1.1 Flood Controls

The objectives for land at or below the projected sea level rise, and other land at or below the flood planning level (100 Year ARI event plus 0.5m freeboard) are outlined in *Section 6.3* of the LEP. The objectives of this section are:

- to minimise the flood risk to life and property associated with the use of land,
- 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, and
- to avoid significant adverse impacts on flood behaviour and the environment.

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

- is compatible with the flood hazard of the land,
- will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties,
- incorporates appropriate measures to manage risk to life from flood,
- 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
- is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

In addition to the flood related objectives above, *Section 6* of the LEP outlines the objectives relating to stormwater management. The objective of this clause is to minimise the impacts of urban stormwater on land to which this clause applies and on adjoining properties, native bushland and receiving waters.

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

- is designed to maximise the use of water permeable surfaces on the land having regard to the soil characteristics affecting on-site infiltration of water,
- includes, if practicable, on-site stormwater retention for use as an alternative supply to mains water, groundwater or river water, and

- avoids any significant adverse impacts of stormwater runoff on adjoining properties, native bushland and receiving waters, or if that impact cannot be reasonably avoided, minimises and mitigates the impact.

9.1.2 Current Land Use and Zoning

The study area is primarily comprised of a combination of urban zones with some areas of open space. The land use within the study area is controlled by the Leichhardt LEP 2013. The descriptions of the zones and the flood affected areas within each zone are described in **Table 9-1**. It can be seen that the General Residential zone is the most flood affected, with an affected area of 44.81ha in the 100 Year ARI and 190.37ha in the PMF case (corresponding to 7% and 30% of General Residential area respectively).

Flood mitigation works are permitted within the following zones, with consent:

- Zone SP2 Infrastructure
- Zone RE1 Public Recreation
- Zone RE2 Private Recreation

Each of the proposed flood mitigation works will be assessed for their compatibility with the land use zone within which they are proposed. The outcomes of this assessment will comprise a component of the overall score allocated to the option in the multi-criteria assessment (**Section 14**).

In high flood risk locations, it may be appropriate to consider rezoning of land to a more flood compatible land use. It can be seen in **Table 9-1** that the majority of flooding in a 100 Year ARI event impacts general residential land use (R1), with no medium density residential being flood affected (R2). This would suggest that rezoning is unlikely to be a necessary approach to floodplain risk management. However, this may be an issue that Council reviews, if additional information becomes available for specific locations in the future.

Table 9-1 Land Use and Flood Affectation

Zone	Objectives of Zone	Flood Affected Area (100 Year ARI) (ha)	Flood Affected Area (PMF) (ha)
Residential Zones			
R1 General Residential	▪ To provide for the housing needs of the community. ▪ To provide for a variety of housing types and densities. ▪ To enable other land uses that provide facilities or services to meet the day to day needs of residents. ▪ To improve opportunities to work from home. ▪ To provide housing that is compatible with the character, style, orientation and pattern of surrounding buildings, streetscapes, works and landscaped areas. ▪ To provide landscaped areas for the use and enjoyment of existing and future residents. ▪ To ensure that subdivision creates lots of regular shapes that are complementary to, and compatible with, the character, style, orientation and pattern of the surrounding area. ▪ To protect and enhance the amenity of existing and future residents and the neighbourhood.	44.81	190.37
R3 Medium Density Residential	▪ To provide for the housing needs of the community within a medium density residential environment. ▪ To provide a variety of housing types within a medium density residential environment. ▪ To enable other land uses that provide facilities or services to meet the day to day needs of residents. ▪ To permit increased residential density in accessible locations so as to maximise public transport patronage and to encourage walking and cycling. ▪ To ensure that a high level of residential amenity is achieved and maintained.	0	0.38
Business Zones			
B1 Neighbourhood Centre	▪ To provide a range of small-scale retail, business and community uses that serve the needs of people who live or work in the surrounding neighbourhood. ▪ To ensure that development is appropriately designed to minimise amenity impacts. ▪ To allow appropriate residential uses to support the vitality of neighbourhood centres.	0	0.32

Zone	Objectives of Zone	Flood Affected Area (100 Year ARI) (ha)	Flood Affected Area (PMF) (ha)
B2 Local Centre	▪ To provide a range of retail, business, entertainment and community uses that serve the needs of people who live in, work in and visit the local area. ▪ To encourage employment opportunities in accessible locations. ▪ To maximise public transport patronage and encourage walking and cycling. ▪ To ensure that development is appropriately designed to minimise amenity impacts. ▪ To allow appropriate residential uses to support the vitality of local centres. ▪ To ensure that uses support the viability of local centres. ▪ To provide a mixture of compatible land uses. ▪ To reinforce and enhance the role, function and identity of local centres by encouraging appropriate development to ensure that surrounding development does not detract from the function of local centres. ▪ To integrate suitable business, office, residential, retail and other development in accessible locations.	2.96	9.45
B4 Mixed Use	▪ To provide a mixture of compatible land uses. ▪ To integrate suitable business, office, residential, retail and other development in accessible locations so as to maximise public transport patronage and encourage walking and cycling. ▪ To support the renewal of specific areas by providing for quality medium density residential and small-scale retail and commercial uses. ▪ To ensure that development is appropriately designed to enhance the amenity of existing and future residents and the neighbourhood. ▪ To constrain parking and restrict car use.	0.49	0.54
B7 Business Park	▪ To provide a range of office and light industrial uses. ▪ To encourage employment opportunities. ▪ To enable other land uses that provide facilities or services to meet the day to day needs of workers in the area. ▪ To provide for limited residential development in conjunction with permissible active ground floor uses. ▪ To provide for certain business and office premises and light industries in the arts, technology, production and design sectors.	0.01	0.27

Zone	Objectives of Zone	Flood Affected Area (100 Year ARI) (ha)	Flood Affected Area (PMF) (ha)
Industrial Zones			
IN2 Light Industrial	▪ To provide a wide range of light industrial, warehouse and related land uses. ▪ To encourage employment opportunities and to support the viability of centres. ▪ To minimise any adverse effect of industry on other land uses. ▪ To enable other land uses that provide facilities or services to meet the day to day needs of workers in the area. ▪ To support and protect industrial land for industrial uses. ▪ To retain existing employment uses and foster a range of new industrial uses to meet the needs of the community. ▪ To ensure the provision of appropriate infrastructure that supports Leichhardt's employment opportunities. ▪ To retain and encourage waterfront industrial and maritime activities. ▪ To provide for certain business and office premises and light industries in the arts, technology, production and design sectors.	5.62	16.66
SP1 Special Activities	▪ To provide for special land uses that are not provided for in other zones. ▪ To provide for sites with special natural characteristics that are not provided for in other zones. ▪ To facilitate development that is in keeping with the special characteristics of the site or its existing or intended special use, and that minimises any adverse impacts on surrounding land.	1.80	3.56
SP2 Infrastructure	▪ To provide for infrastructure and related uses. ▪ To prevent development that is not compatible with or that may detract from the provision of infrastructure. ▪ To ensure the adequate provision of public, community and social infrastructure.	9.02	23.25

Zone	Objectives of Zone	Flood Affected Area (100 Year ARI) (ha)	Flood Affected Area (PMF) (ha)
Recreation Zones			
RE1 Public Recreation	▪ To enable land to be used for public open space or recreational purposes. ▪ To provide a range of recreational settings and activities and compatible land uses. ▪ To protect and enhance the natural environment for recreational purposes. ▪ To maximise the quantity and quality of open space areas to meet the existing and future needs of the community. ▪ To ensure the equitable distribution of, and access to, open space and recreation facilities. ▪ To retain, protect and promote public access to foreshore areas and to provide links between open space areas. ▪ To provide opportunities in open space for public art. ▪ To conserve, protect and enhance the natural environment, including terrestrial, aquatic and riparian habitats.	21.23	40.50
RE2 Private Recreation	▪ To enable land to be used for private open space or recreational purposes. ▪ To provide a range of recreational settings and activities and compatible land uses. ▪ To protect and enhance the natural environment for recreational purposes.	0	0.01

9.2 Development Control Plan 2013

The Leichhardt Development Control Plan (DCP) 2013 commenced Monday 3 February 2014. DCP 2013 applies to virtually every property within the Local Government Area and outlines detailed planning and design guidelines for particular types of development. The plan supports the Leichhardt Local Environmental Plan 2013. DCP 2013 replaces all of the 12 former DCPs.

Part E of the DCP outlines the water related controls. The flooding related objective of these controls is to:

> *Reduce and manage the social, environmental and economic risks and impacts associated with major flood or tidal inundation events.*

Section E1.3 outlines the flood related controls, with the objective of these controls being *to:*

> *Manage development of flood control lots and flood prone land to reduce the risks and costs associated with flooding.*

The flood controls are separated into different development types and generally relate to floor levels. For development proposed within high hazard areas, additional controls apply relating to impacts on flood behaviour. Allowance is provided within the controls for developers to mitigate flooding through ground works and hence optimise the development potential of their site.

A *Flood Risk Management Report* is required for proposed development on properties that are identified as flood control lots. This report is not required where the assessed value of the works is under $50,000 except where, in the opinion of Council, those works are likely to substantially increase the risk of flood to the subject or adjoining or nearby sites.

It is noted that the there are no flood related provisions in the DCP for development in heritage conservation areas. Given that some of the heritage conservation areas within the study area are flood affected, it is recommended that Council consider provisions of flood related controls in the DCP for development in heritage conservation areas.

9.3 State Environmental Planning Policies

The State Government has a range of controls that may affect development within the study area such as the State Environmental Planning Policies (SEPP's). SEPPs deal with issues significant to the state and people of New South Wales.

The following key SEPPs contain flood related controls that may apply to particular development types within the study area. Where these SEPPs apply, if there is an inconsistency between the SEPP and the Leichhardt LEP the SEPP prevails to the extent of the inconsistency.

Table 9-2 Relevant SEPPs

SEPP	Flood Management Objectives and Controls
State Environmental Planning Policy (Exempt and Complying Development Codes) 2008	The development must not be on any part of a flood control lot unless that part of the lot has been certified, for the purposes of the issue of the relevant complying development certificate, by the council or a professional engineer who specialises in hydraulic engineering, as not being any of the following: a flood storage area, a floodway area, a flow path, a high hazard area or a high risk area. The development must, to the extent it is within a flood planning area: • have a minimum floor level no lower than the floor levels set by the council for that lot, • have the part of the development at or below the flood planning level constructed of flood compatible material, • be able to withstand the forces of floodwater, debris and buoyancy up to the flood planning level (or, if on-site refuge is proposed, the probable maximum flood level), • not increase flood affectation elsewhere in the floodplain, • have reliable access for pedestrians and vehicles from the development, at a minimum level equal to the lowest floor level of the development, to a safe refuge,

SEPP	Flood Management Objectives and Controls
	• have open car parking spaces or carports that are no lower than the 20-year flood level, and • have driveways between car parking spaces and the connecting public roadway that will not be inundated by a depth of water greater than 0.3m during a 1:100 ARI (average recurrent interval) flood event.
State Environmental Planning Policy (Infrastructure) 2007	A public authority, or a person acting on behalf of a public authority, must not carry out, on flood liable land, development that this Policy provides may be carried out without consent and that will change flood patterns other than to a minor extent unless the authority or person has: • given written notice of the intention to carry out the development to the council for the area in which the land is located, and • taken into consideration any response to the notice that is received from the council within 21 days after the notice is given.
SEPP (Major Development) 2005	The objectives are as follows: • to minimise the flood risk to life and property associated with the use of land, • 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, • to avoid significant adverse impacts on flood behavior and the environment. The controls (applied to land at or below the flood planning level) state that development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development: • is compatible with the flood hazard of the land, • will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, • incorporates appropriate measures to manage risk to life from flood, • will not significantly adversely affect the environment or cause avoidable erosion, siltation, destruction or riparian vegetation or a reduction in the stability of river banks or watercourses, and • is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

9.4 Relevant Policies and Plans

9.4.1 Draft Stormwater Drainage Code (1995)

Council's draft drainage code provides stormwater requirements for development in the study area including information concerning drainage concept plans and on-site detention (OSD). This code has been reviewed in detail with regards to OSD as outlined in **Section 11**. Recommendations have been made with regards to OSD requirements as an outcome of this review.

9.4.2 Leichhardt Council Climate Change Plan

Leichhardt's Climate Change Plan (CCP) was adopted in May 2013 as the principal policy framework for corporate decision-making in response to climate change. The following actions were identified in the CCP and will be addressed fully or in part in this FRMS.

- Develop the Leichhardt Flood Risk Management Plan to address priorities for inundation and flooding as a consequence of climate change including flash flooding, sea-level rise, tides and storm surges.
- Based on the Flood Risk Management Study, review current Development Control Plans including flood and foreshore related development controls and mapping, rainwater harvesting, and on-site detention of stormwater.
- As part of the Floodplain Risk Management Study consider the Multi Criteria Analysis (MCA) tools being developed by Sydney Coastal Councils Coastal Adaptation Decision Pathways Project to support consideration of diverse adaptation, management alternatives around future protection, development or redevelopment of foreshore land.

9.4.3 Plans of Management

Plans of Management must be prepared for all community land. This is a legal requirement under the Local Government Act (1993). An essential management tool, Plans of Management:

- Are written by Council in consultation with the community;
- Identify the important features of the land;
- Clarify how Council will manage the land; and
- Indicate how the land may be used or developed.

There are several Plans of Management relevant to the community land within the study area. These Plans should be considered when developing and assessing floodplain management options. All of the assessed options will be considered against relevant Plans of Management to inform the scoring of the options in the multi-criteria matrix assessment.

9.5 Planning Recommendations

Following the review of the policy and planning documents, several recommendations for modifications or inclusions have been identified. These are discussed below and included in the relevant floodplain management options in the FRMS.

9.5.1 Leichhardt Local Environment Plan 2013

Under the current wording of the LEP, the flooding provisions of the LEP may only be applied to land at or below the 1% AEP plus 0.5m freeboard, in accordance with the provisions of the standard template. However, subsequent policies and plans assign development controls up to the PMF event (e.g. controls on Special Uses land types). Given the additional legal weight of the LEP some Councils in NSW have begun incorporating a second flood related section of the LEP that addresses development controls that are applicable above the 1% AEP plus 500mm freeboard or simply amending the wording in the LEP to identify the Flood Planning Level to be defined by the Floodplain Risk Management Plan.

This recommendation will be included in the options assessment as option **PM1**.

9.5.2 Leichhardt Development Control Plan 2013

The DCP has recently been revised following consultation with the community. Detailed controls relating to relevant development types have been included. No significant additional requirements for inclusion have been identified as part of this FRMS. However, it was identified that the DCP does not have provisions to assess the impact of flooding on effective access to a property.

The emergency management review (**Section 8**) identified a number of properties that would effectively be "cut off" during a flooding event. The impact of this on each property would depend on both the duration of flooded access and on the nature of the land use. There are likely to be greater impacts on a special use (e.g. aged care or child care centre) compared with a single use dwelling. As such, the impacts of flooding on property access should be considered when assessing development applications, especially if a change of use or increase in dwelling density is proposed.

Lack of effective access during a flood event can impact both flooded and flood free properties. Therefore, the impact of flooding on access to a property should be considered during the development application process for both flooded and flood free properties.

This recommendation will be included in the options assessment as option **PM2**.

It was also identified that the determination of Flood Planning levels in overland flooding areas could be reviewed. The review of the flood planning levels has been provided separately in **Section 10**.

As previously stated, there are no flood related provisions in the DCP for development in heritage conservation areas. Given that some of the heritage conservation areas within the study area are flood affected, it is recommended that Council consider provisions of flood related controls in the DCP for development in heritage conservation areas.

9.5.3 Complying Development

Development on a flood control lot may be considered 'Complying' in accordance with the SEPP (Exempt and Complying Development Codes) 2008 if the development is not within a flood storage area, a floodway area, a flow path, a high hazard area or a high risk area. Therefore, a development impacted by Low hazard and/or Flood Fringe could be a 'Complying Development'. A review of the controls outlined in the SEPP would indicate that for these developments, the controls relating to car parking differ from those outlined in Council's DCP as outlined in **Table 9-3**. This should be reviewed by Council to ensure consistency.

Table 9-3 Car Parking Controls for Complying Development and Leichhardt DCP 2013

Complying Development	Leichhardt DCP 2013 Controls
Open car parking spaces or carports are no lower than the 20-year flood level. Driveways between car parking spaces and the connecting public roadway will not be inundated by a depth of water greater than 0.3m during a 1:100 ARI (average recurrent interval) flood event.	The floor level of new enclosed garages must be at or above the Flood Planning Level. Consideration may be given to a floor level at a lower level, within 500mm of the Flood Planning Level, where it can be demonstrated that providing the floor level at the Flood Planning Level is not practical within the constraints of compliance with Australian Standard AS/NZS 2890.1 Parking facilities as amended. The floor levels of open car park areas and carports are permissible below the Flood Planning Level, subject to being raised as high as practical within the constraints of compliance with Australian Standard AS/NZS 2890.1 Parking facilities as amended. Basement (below natural ground level) car parking must have all access and potential water entry points above the Probable Maximum Flood Level or Flood Planning Level whichever is the higher, and a clearly signposted flood free pedestrian evacuation route from the basement area separate to the vehicular access ramps. New car parking areas and access are not affected by the High Hazard Category.

This recommendation has been included in the options assessment as option **PM3**.

9.5.4 Draft Stormwater Drainage Code

It is understood that Council is currently updating the Draft Stormwater Drainage Code. The outcomes of the On-site Detention assessment undertaken in **Section 11** should be considered in the revised code.

This recommendation has been included in the options assessment as option **PM4**.

9.5.5 Climate Change

The wording of the LEP and DCP allow scope for Council to apply flood related controls to manage the flood impacts associated with climate change scenarios. Therefore, no additional recommendations have been made for these documents with regards to climate change.

In accordance with the actions outlined in Council's CCP several options for managing the impacts associated with sea level rise have been included in the foreshore options assessment (**Section 12.3.10**).

10 Flood Planning Level Review

10.1 Background

The Flood Planning Level (FPL) is a concept established within the NSW Floodplain Development Manual (FDM) (NSW Government, 2005). The objective of the FPL is to establish a minimum level of flood protection for property, typically through minimum floor level requirements.

The Flood Planning Level (FPL) for the majority of areas across New South Wales has traditionally been based on the 100 Year ARI flood level plus a freeboard. The freeboard is generally set between 0.3m – 0.5m for habitable floor levels of residential properties, and can vary for industrial and commercial properties.

A variety of factors require consideration in determining an appropriate FPL. A key consideration in the development of an FPL, is the flood behaviour and the risk posed by the flood behaviour to life and property in different areas of the floodplain and different types of land use.

The Floodplain Development Manual (NSW Government, 2005) identifies the following issues to be considered:

- Risk to life;
- Long term strategic plan for land use near and on the floodplain;
- Existing and potential land use;
- Current flood level used for planning purposes;
- Land availability and its needs;
- FPL for flood modification measures (levee banks etc.);
- Changes in potential flood damages caused by selecting a particular flood planning level;
- Consequences of floods larger than that selected for the FPL;
- Environmental issues along the flood corridor;
- Flood warning, emergency response and evacuation issues;
- Flood readiness of the community (both present and future);
- Possibility of creating a false sense if security within the community;
- Land values and social equity;
- Potential impact of future development on flooding;
- Duty of care.

These issues are dealt with collectively in the following sections.

10.2 Existing Flood Planning Levels

The current FPL for all development in the study area is equal to the 100 Year ARI level plus 0.5m freeboard, which is typically the standard for Councils across NSW. Table 10-1 summarises the circumstances where exceptions to this requirement may be available under Leichhardt DCP 2013, for certain types on development.

Table 10-1 Flood Planning Level Exceptions (DCP 2013)

Single Dwelling

For alterations and additions to a residential dwelling, some or all of the existing floor levels may be retained below the Flood Planning Level provided that each of the following is complied with:

a) Floor levels of additions/ altered above or raised to the FPL
b) Where alteration/additions affect <60% of total existing habitable ground floor area, those existing areas not significantly altered may be retained below FPL.
c) Where >60% but raising impracticable due to Heritage or Conservation Area constraints.
d) Design /constructed they do not preclude the raising of existing areas to FPL at future date.
e) For any addition above ground floor, the floor level of the addition must be at a height that allows for the ground floor below to be raised in the future (if not required to be raised under the above controls) to the Flood Planning Level, whilst maintaining minimum floor to ceiling height requirements.

Commercial, Industrial and Mixed Use

Where constructing the floor level / raising is impracticable, consideration may be given to some or all of the non-residential floor levels having a freeboard of less than 500mm above the 100 year ARI provided satisfactory flood proofing.

Special uses (emergency services, accommodation or treatment of children, the aged, disabled or vulnerable)

All floor levels are to be at or above the Probable Maximum Flood Level or Flood Planning Level, whichever is the highest.

High Hazard Land

a) the underside of all new floors are above the Probable Maximum Flood Level or Flood Planning Level, whichever is the highest, and all structures designed to withstand the High Hazard condition;
b) the principle entries to all dwellings and common areas are located above the Probable Maximum Flood Level or Flood Planning Level, whichever is the highest, and an evacuation route is provided clear of the floodway.

Car Parking Facilities and Basements

c) Floor level of new enclosed garages must be at or above the Flood Planning Level. Consideration may be given to a floor level at a lower level, within 500mm of the FPL, where demonstrated FPL is not practical.
d) Basement (below natural ground level) car parking must have all access and potential water entry points above the Probable Maximum Flood Level or Flood Planning Level whichever is the higher, and a clearly signposted flood free pedestrian evacuation route from the basement area separate to the vehicular access ramps.

10.3 Flood Planning Area

The flood planning area is commonly referred to as the area below the flood planning level. However, it is noted that the flood planning level may vary within a study area dependant on the type of development being proposed or the current land use and associated flood risk.

The flood planning area is defined in the Flood Study (Cardno, 2014) as follows:

- The Flood Planning Area includes the 100 year ARI flood extent;
- At the low points in roads or where the direction of the flood flow is generally perpendicular to the alignment of a road, the Flood Planning Area extends to the extent of the PMF level, or to the extent defined by a level 500mm above the 100 year ARI flood level, whichever is the lesser extent;
- Where flow proceeds through properties, the Flood Planning Area extends to the PMF level, or the extent defined by a level 500mm above the 100 year ARI flood level, whichever is the lesser extent;
- For Whites Creek, Johnstons Creek and Hawthorne Canal, the Flood Planning Area was determined by the extent defined by a level 500mm above the 100 year ARI flood level.

Properties within the Flood Planning Area are known as Flood Control Lots and may be subject to flood related development controls. These controls often refer to a flood planning level. The purpose of this review is to identify appropriate flood planning levels for these properties.

10.4 Likelihood of Flooding

As a guide, **Table 10-2** has been reproduced from the NSW Floodplain Development Manual (2005) to indicate the likelihood of the occurrence of an event in an average lifetime to indicate the potential risk to life.

Analysis of the data presented in **Table 10-2** gives a perspective on the flood risk over an average lifetime. The data indicates that there is a 50% chance of a 100 Year ARI event occurring at least once in a 70-year period. Given this potential, it is reasonable from a risk management perspective to give further consideration to the adoption of the 100 Year ARI flood event as the basis for the FPL. Given the social issues associated with a flood event, and the non-tangible effects such as stress and trauma, it is appropriate to limit the exposure of people to floods.

Note that there still remains a 30% chance of exposure to at least one flood of a 200 Year ARI magnitude over a 70-year period. This gives rise to the consideration of the adoption of a rarer flood event (such as the PMF) as the flood planning level for some types of development.

Table 10-2 Probability of Experiencing a Given Size Flood or Higher in an Average Lifetime (70 years)

Likelihood of Occurrence in Any Year (ARI)	Probably of Experiencing At Least One Event in 70 Years (%)	Probability of Experiencing At Least Two Events in 70 Years (%)
10 Year ARI	99.9	99.3
20 Year ARI	97	86
50 Year ARI	75	41
100 Year ARI	50	16
200 Year ARI	30	5

10.5 Land Use and Planning

Section 9.1.2 provides a summary of the different land use types impacted by flooding with a comparison of the flood affected area within each zone for the 100 Year ARI and PMF. This analysis has been extended to assess the number of properties within the Residential, Business and Industrial Zones impacted by the 20 Year ARI, 100 Year ARI extent and the PMF extents.

The summary provided in Table 10-3 identifies that:

- The majority of residential properties impacted by 20 Year ARI flooding are also impacted by 100 Year ARI flooding. As a result, regardless of whether the 20 Year ARI or 100 Year ARI level is selected for planning purposes, there would be FPL requirements (i.e. above ground level) for a similar number of properties. However, the reduction in risk would be significantly greater by selecting the 100 Year ARI level.
- There are significantly more properties impacted by PMF when compared to the 100 Year ARI. Therefore, if the PMF was used for planning purposes this would likely put much more onerous requirements on a large number of properties.
- When comparing the business and industrial lots impacted by the 20 and 100 Year ARI extents, it can be seen that if the floor level requirements for these properties was set at the 20 Year ARI level, then more than 20 percent of the flood control lots would have floor level heights above ground level set at equal to or less than the freeboard. The risk implications of setting the FPL at the 20 Year ARI event for business and industrial properties is discussed further in **Section 10.9**.

Table 10-3 Impacted Properties

Zone	Impacted Properties 20 Year ARI	Impacted Properties 100 Year ARI	Impacted Properties PMF
Residential Zones	**2238**	**2454**	**7813**
R1 General Residential	*2238*	*2453*	*7805*
R3 Medium Density Residential	*0*	*1*	*8*
Business and Industrial Zones	**521**	**656**	**1431**
B1 Neighbourhood Centre	*0*	*0*	*13*
B2 Local Centre	*136*	*171*	*429*
B4 Mixed Use	*1*	*2*	*2*
B7 Business Park	*2*	*2*	*14*
IN2 Light Industrial	*173*	*203*	*406*
SP1 Special Activities	*1*	*3*	*8*
SP2 Infrastructure	*208*	*275*	*559*

10.6 Damage Cost Differential Between Events

Based on an estimated flood damages for a property of $50,000, the incremental difference in Annual Average Damage (AAD) for different recurrence intervals for an example property is shown in **Table 10-4**. The table shows the AAD of an example property that experiences over-floor flooding in each design event, and the net present value (NPV) of those damages over 50 years at 7 percent.

Table 10-4 indicates that the largest incremental differences between AAD per property occurs between the more frequent events. The greatest difference between damages occurs between the 1 and 2 Year ARI events and 2 and 5 Year ARI events. It can be seen that the differences between the larger events are relatively small, suggesting that increasing the FPL beyond the 20 Year ARI level does not significantly alter the savings achieved from a reduction in damages.

Table 10-4 Damage Difference Costs

Event	AAD per Property	Change in AAD	NPV of AAD	Change in NPV
1 Year ARI	$50,000	-	$690,037	**-**
2 Year ARI	$25,000	$25,000	$345,019	$345,018
5 Year ARI	$10,000	$15,000	$138,007	$207,012
10 Year ARI	$5,000	$5,000	$69,004	$69,003
20 Year ARI	$2,500	$2,500	$34,502	$34,502
100 Year ARI	$500	$2,000	$6,900	$27,602
PMF	$0	$500	$0	$6,900

10.7 Incremental Height Difference between events

Consideration of the average height difference between various flood levels can provide another measure for selecting an appropriate FPL.

Based on the existing flood behaviour, the incremental height difference between events is shown in **Table 10-5** for selected events. These are average height differences determined based on the flood levels at each of the flood affected properties within the catchment as part of the flood damages analysis.

Table 10-5 Relative Differences Between Design Flood Levels

	Average Difference (m) to				
Event	**PMF**	**100 Year ARI**	**50 Year ARI**	**20 Year ARI**	**10 Year ARI**
100 Year ARI	0.44	-	-	-	-
50 Year ARI	0.48	0.04	-	-	-
20 Year ARI	0.51	0.07	0.06	-	-
10 Year ARI	0.54	0.10	0.10	0.04	-
5 Year ARI	0.57	0.13	0.13	0.07	0.03

Table 10-5 indicates a larger difference in the flood level of the PMF event compared to other events. The adoption of the PMF event as the flood planning level would result in more significant increases in levels over the 100 Year ARI event (in the order of 0.44 metres) and may therefore potentially present an issue for the setting of flood planning levels in the catchment.

The adoption of the 100 Year ARI event as the flood planning level is only marginally different from that of the 20 Year ARI (on average 0.07 m higher). Therefore, the adoption of the 100 Year ARI event would provide an increased level of risk reduction over the 20 Year ARI event, without a significant difference in the flood planning level height.

With regards to an appropriate freeboard, the average difference between the PMF and the 100 Year ARI is 0.44 m, indicating that basing the FPL on the 100 Year ARI level, with an appropriate freeboard may result in the protection of some buildings in the PMF event.

10.8 Consequences of Adopting the PMF as a Flood Planning Level

The use of the PMF as a flood planning level provides the greatest level of risk reduction available with regards to planning levels. However, the economic and planning consequences of the adoption of the PMF for these purposes often outweigh the potential benefits.

Analysis of the theoretical flood damages for an example property (**Table 10-4**) indicates that the choice of the PMF event over the 100 Year ARI event as the FPL would result in limited economic benefits (in annualised terms) to the community. When also considering that a freeboard in addition to the 100 Year ARI event would comprise the Flood Planning Level, the reduction in damages from the use of the PMF would be negligible.

The difference in average flood levels between the 100 Year ARI and the PMF event (**Table 10-5**) indicate that the use of the PMF as the FPL would result in higher levels (0.44 metres on average), and as a result higher economic costs and inconvenience to the community.

The use of the PMF level as the FPL may conflict with other development / building controls in the Council's DCPs and hinder access from adjoining street frontages.

10.9 Consequences of Adopting the 20 Year ARI Event for Commercial Property FPLs

Commercial and industrial properties have often adopted high frequency flood events such as the 20 year ARI event. This is based on the perception of risk. Occupiers of these properties can make informed commercial decisions on their ability to bear the burden of economic loss through flood damage, while residential lots do not generally provide an income to offset the losses. Additionally, inventory, machinery and other assets can be stored above higher flood levels (e.g. 100 Year ARI) to lessen the economic loss as a result of a flood event.

However, considering there is only an average difference of 0.07m between the 20 year ARI and 100 year ARI event, the large number of industrial and commercial properties within the floodplain and the great diversity of commercial uses, it is recommended that the 100 year ARI plus 0.5m be adopted for commercial and industrial properties. This would also provide consistency with residential FPLs and reduce risk with potential change in use of buildings into the future.

10.10 Critical Infrastructure

Critical infrastructure, such as hospitals, fire stations, electricity sub-stations and other critical infrastructure, has wider spread implications should inundation occur. As such, FPLs are typically selected for these types of structures higher than for residential, commercial or industrial properties.

Given the risk of exposure outlined in **Table 10-2**, it is recommended that emergency response facilities be located outside of the floodplain and any other future planning ensure critical facilities be limited to areas outside of the floodplain. Modifications to existing critical facilities within the floodplain are suggested to have a floor level at the PMF level.

10.11 Basement Car Parking

Basement car parking areas can be particularly vulnerable to flood risk as floodwaters can enter a basement at a rapid rate once the entry threshold level is exceeded.

The general approach to planning for the protection of basement car parking in many areas of New South Wales has been to set the threshold level such that floodwaters can only enter in events greater than the event for which the threshold is set. For example, if a Development Control Plan (DCP) specifies that the driveway crest is to be set at the flood planning level (commonly the 1% annual exceedance probability (AEP) plus a freeboard, commonly of 0.5 m), then the basement is protected up to that level. Events in which the flood level exceeds this crest level have traditionally been considered sufficiently rare as to not warrant protection.

However, this approach fails to rigorously consider the risk associated with the crest being exceeded, where risk is defined in accordance with the International Standard for Risk Management (ISO 31000:2009, Risk management – Principles and guidelines): that risk is a function of likelihood (probability) and consequence.

Adopting a risk based approach to basement car parking controls is recommended for consideration by Council, the following considerations and recommendations were outlined in Collier et al (2017):

- For new development within floodplain areas (mainstream and overland flow) the site should be designed in a manner such that the crest of the entry point to all basements for all land use types (except vulnerable-type developments, for example developments for older persons, hospitals, emergency services and the like) should be set at the flood planning level (FPL), provided that the PMF level is less than the FPL. If the PMF is greater than the FPL and the crest is not set at the PMF, it would be appropriate to seek additional risk information, such as the depth of flooding within the basement and the rate of filling if the crest is exceeded, available escape routes and signage,
- For vulnerable development within the floodplain, the crest of the entry point to all basement carparks should be set at the PMF. Given the type of occupants of vulnerable developments, it would unsuitable to incorporate a basement if this criterion cannot be met through suitable design.
- Where alteration and additions are proposed retrofit solutions using mechanical barriers for existing basements affected by flooding, may be appropriate only where it is not possible to regrade an existing entry point to provide passive protection or provide a new entry point from a less flood prone portion of the site. Any mechanical solution should be provided to protect the basement to the flood planning level as a minimum.

10.12 Climate Change

Climate change impacts on catchment flooding were assessed in the flood study through sensitivity testing of twenty percent increases in rainfall intensity. An increase in peak rainfall of 20% results in a general increase in peak water levels throughout the study area. For the majority of the overland flow areas, these increases are typically less than 0.1 metres. Along the main creeks, the increases are typically less than 0.2 metres, with the exception of the downstream end of Whites Creek, where increases up to 0.5 metres are observed.

Climate change impacts on sea level rise have been considered separately as part of the Estuary Planning Level Study (Cardno, 2010) and are incorporated into the Estuary Planning Levels.

Climate change impacts on flooding can be incorporated into FPLs either directly, i.e. incorporated into the modelling of the design event, or as a component of the FPL.

There is greater certainty regarding the impacts of climate change on sea levels when compared to rainfall changes, and as such sea level rise is more often included in the design modelling. Only one sensitivity run was undertaken to assess the potential impacts of increased rainfall on catchment flooding and as such, it is not recommended that these results replace the design event results used in determining FPLs.

As stated in the *2010 Flood Risk Management Guide: Incorporating sea level rise benchmarks in flood risk assessment*, the freeboard provides a relatively small allowance to accommodate some of the projected increases in rainfall intensity and sea level rise associated with climate change. This allowance is generally considered to approximately 0.2 metres. This value is comparable to the increases in overland flow depths identified from the sensitivity modelling.

It is recommended that climate change be considered within the allowance for an appropriate freeboard.

10.13 Stormwater Pit and Culvert Blockage

The Flood Study (Cardno, 2014) results used to inform Flood Planning Levels do not include any allowance for blockage of stormwater pits or culverts.

An analysis of the effect of stormwater pit blockages on flood behaviour was undertaken as part of the Flood Study (Cardno 2014) for the 100 year ARI by assuming that all pits within the study area were blocked by 50%.

The results showed that the impacts of pit blockages generally resulted in only minor increases in flood levels, with very few increases greater than 0.2m.

The following culvert blockage scenarios were modelled as part of the Flood Study (Cardno, 2014):

- 100% blockage for structures with a major diagonal opening width of less than 6 metres;
- 25% bottom up blockage for structures with a major diagonal opening width of greater than 6 metres;
- 100% blockage for handrails over structures in both (i) and (ii) when overtopping occurs.

The results showed that the impacts of culvert blockages were more significant than the impacts of pit blockages, with increases on up to 0.5m in mainstream flooding areas. The impact of blockage on flood levels is a factor for consideration when selecting an appropriate freeboard.

10.14 Freeboard Selection

A freeboard from 0.3m – 0.5 metres is commonly adopted in determining the FPL across NSW. The freeboard accounts for uncertainties in deriving the design flood levels and as such should be used as a safety margin for the adopted FPL. The freeboard may account for factors such as:

- Changes in the catchment;
- Changes in the creek / channel vegetation;
- Accuracy of the model inputs (e.g. ground survey, design rainfall inputs for the area);
- Model sensitivity:
    - Local flood behaviour (due to local obstructions);
    - Wave action (e.g. from vehicles);
    - Culvert blockage (up to 0.5m increase in levels in mainstream areas); and
    - Climate change (affecting both rainfall and ocean levels).

The various elements factored into a freeboard can be summarised as follows:

- Afflux (local increase in flood levels due to small local obstructions not accounted for in the modelling) (+0.1m) (Gillespie, 2005).
- Local wave action (trucks and other vehicles) (allowances of +0.1m are typical).
- Accuracy of ground / aerial survey (+/- 0.15m).
- Climate change impacts on rainfall (+0.2m).
- Sensitivity of the model to roughness changes (+/-0.1m).

Council currently adopts a freeboard of 0.5m within the FPL.

Based on this analysis, the total sum of the likely variations is in the order of 550mm. Although it is unlikely that all variation would occur cumulatively. An additional consideration is the impact of blockages, which is seen to be up to 0.5m in mainstream areas.

This would suggest that a freeboard allowance of 500mm would be appropriate for the study area.

10.14.1 Consideration of Overland Flow

It should also be noted that flooding within the study area in many locations could be categorised as overland flow. A shallow overland flowpath may not be significantly impacted with respect to several of the freeboard factors listed above. However, overland flow can be significantly more sensitive to flow obstructions not included in the modelling (e.g. landscaping, fences or temporary structures). This is particularly relevant where the flow is limited to a narrow flow path (e.g. a small space between two buildings or other structures).

The consideration of reduced freeboard allowances for shallow overland flow (i.e. less than 0.25m depth) is discussed in more detail in **Section 10.15.1**.

10.15 Recommendations from Guidelines and Directives

With respect to the design flood event to be adopted for the FPL the Floodplain Development Manual (NSW Government, 2005) states the following:

> *In general, the FPL (minimum floor level) for standard residential development would be the 1% AEP flood event plus a freeboard (typically 0.5m).*

The guidance within the FDM related to the residential FPL is further reinforced within the *Guideline on development controls for low flood risk areas – floodplain development manual* (NSW Government, 2007). Within this directive it is stated that:

> *This Guideline confirms that, unless there are exceptional circumstances, councils should adopt the 100 year flood as the FPL for residential development.*

Based on this guidance there is limited scope for revision of the residential FPL without an application for exceptional circumstances to the NSW Government. Based on the analysis of flood behaviour in this study, there is limited evidence that would support the study area floodplain qualifying for ‘exceptional circumstances’.

10.16 Flood Planning Level Recommendations

Based on the previous assessments, it is recommended that Council adopt a FPL of 100 Year ARI and a 0.5m freeboard for residential and commercial development.

Underground car park entrances in addition to vents and openings are also to be set at the 100 year ARI + 0.5m, or PMF, whichever is the higher. These locations are a particularly high risk to life. Further details are provided in **Section 10.11**.

For critical infrastructure, such as hospitals, police stations and aged care, the PMF should be adopted as the FPL. It is important that these facilities, which are either difficult to evacuate or are essential during an emergency, remain flood free.

10.16.1 <u>Consideration of Overland Flow</u>

Determining the FPL for properties affected by overland flow has some additional considerations. The flood level on a property affected by overland flow can vary significantly across the site. This is particularly relevant for flowpaths with steep grades. In these instances, the design flood levels for two boundaries of a site may vary in the order of a couple of metres, meaning it is not appropriate to adopt the maximum water level and apply it to the entire site at all locations. This is contrary to more mainstream flooding where design flood levels are at a comparatively flat grade across the length of a property and it is far more feasible to adopt one single design flood level for an entire property.

Overland flow can also behave differently to mainstream flooding. In some situations, the flood risk to life and property may be less due to shallow and / or slow moving water. However, overland flow can be highly sensitive to flow obstructions, with small obstructions such as temporary structures, landscaping works or debris causing significant increases in flood depths.

The consideration of an appropriate freeboard for overland flow needs to consider both:

- The flood depth as compared to flood level; and
- The width of the flow path (i.e. the ability of the flow to be obstructed).

Flood Depth

As discussed above, the use of maximum flood levels rather than maximum flood depths for property planning can be misleading in the case of overland flow. To reconcile these issues with overland flow affectation and FPL, it is appropriate to allow for a design depth rather than a design water level to be used to determine the FPL.

Figure 10-1 provides a theoretical long sections along a 10 metre stretch of steep land. This illustration provides representation of defining the FPL based on:

- the maximum <u>water level</u> on the site; and
- the maximum <u>depth</u> at the location of the development.

Three approaches to freeboard are also illustrated including:

- 0.5m freeboard applied to the maximum water level;
- 0.5m freeboard applied to all depths; and
- a freeboard equal to twice the depth for depths less than 0.25m.

The illustration shows an example where the depth varies across a property from 0.15m to 0.4m, whilst the water level varies from 34.15m AHD to 33.4m AHD. It has been assumed that the water surface varies linearly between the upstream and downstream end of the property. This is likely to be the adopted approach when utilising information provided on flood certificates issued by Council.

If the maximum water level plus 0.5m freeboard is used as the FPL for the entire site, it can be seen that this level is 1.25m above the water level at the downstream end of the site.

If the FPL is equal to the depth plus 0.5m freeboard, the water level and depth based FPLs are equivalent at the upstream end of the site, but there is a difference of 0.75m between the two at the downstream end of the site.

When considering a reduced freeboard for shallow flow, this illustration is useful in showing the implications. It can be seen that at the upstream end of the site where the depth is 0.15m, the freeboard is equal to 0.3m. This approach provides equivalent FPLs as the depth plus 0.5m freeboard for depths greater than 0.25m (as shown at chainage 4m). This approach would provide some reduction in the FPL in this example for development proposed on the upstream portion of the site.

Flow Path Width

In a location where the flow path width in confined, even if the flow depth is less than 0.25m, it may still be appropriate to adopt a flood planning level of 0.5m. Council may wish to consider the application of a 500mm freeboard on overland flow depths less than 0.25m on a merits based approach.

Key issues to be considered in this regard include:

- The width of the flow path. Where the available flow path is less than 900mm wide, Council may need to evaluate the need for a 0.5m freeboard.
- The likelihood of blockage. If the flowpath is narrow but part of an open stormwater easement, the likelihood of blockage may not be high. However, if a narrow flow path exists down the side of a residential property (between a building and a fence) there is a higher likelihood of blockage occurring from debris or movable objects placed in the flowpath.
- The impacts if blockage of flood depths. Shallow, slow moving flow is less likely to be impacted by blockages. Further, the volume of flow can be a contributing factor to flood depth increase, i.e. a small upstream catchment is less likely to contribute large volumes of flow, resulting in less likelihood of flood level increases in the event of a blockage.

10.16.2 Consideration of Exceptions

The Leichhardt DCP 2013 currently provides for circumstances where an FPL other than the 100 Year ARI plus 0.5m freeboard will be considered (**Section 10.2**). These have been reviewed against the assessments undertaken. The following additional considerations should be given to ground floor and above ground additions:

- Where the proposed habitable ground floor area of an addition to an existing dwelling exceeds 60% of the total retained existing habitable ground floor area, the existing ground floor must also be raised to the FPL.
- Where the habitable floor area of above ground floor additions is equal to or exceeds the existing total habitable floor area, the existing ground floor area must also be raised to the FPL.

It is also recommended that Council include clear provisions for the limit of these exceptions, particularly where exception may be requested several times for the same property over multiple development applications.

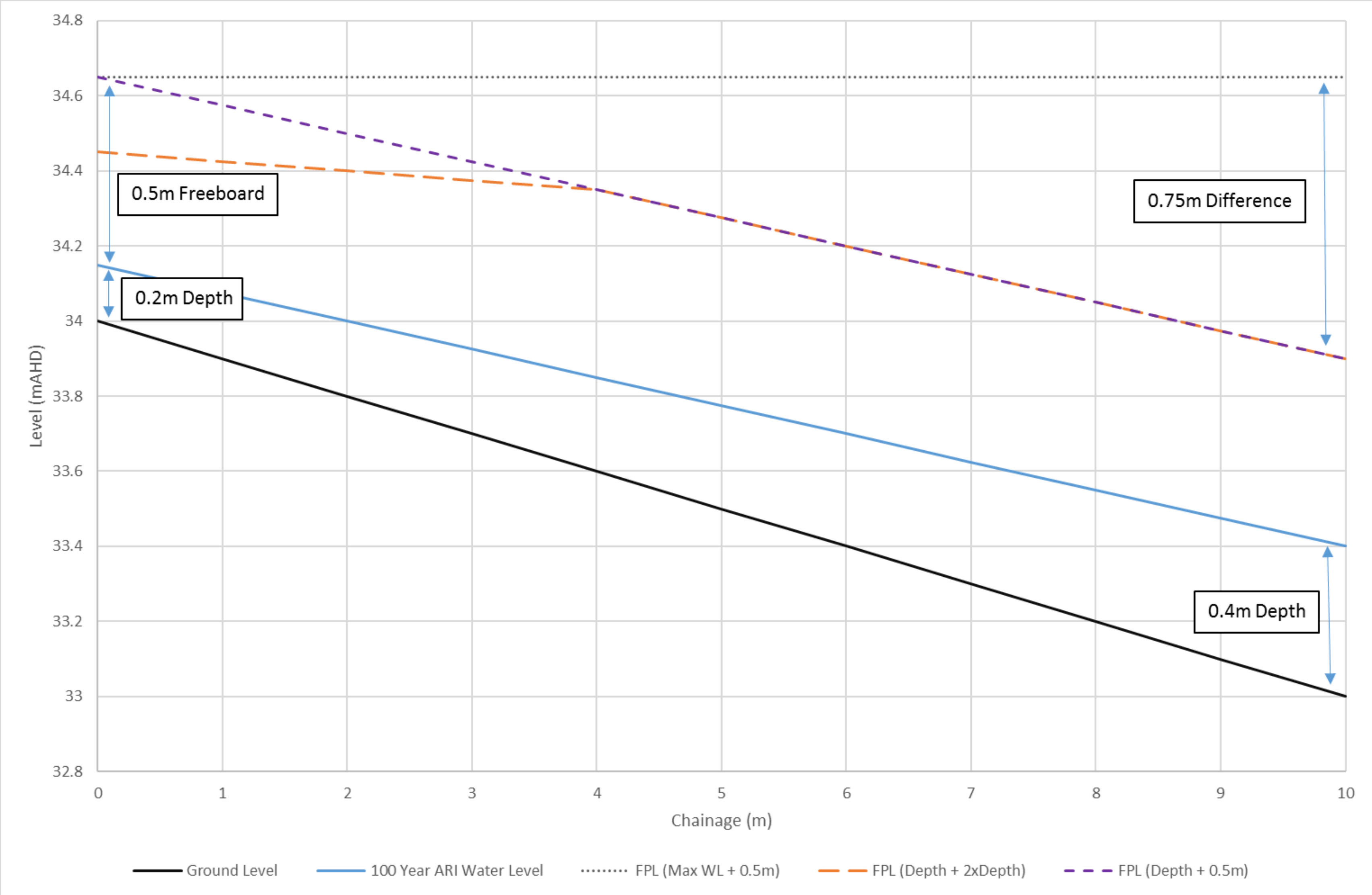

Figure 10-1 Theoretical Long Section of Overland Flow FPLs

11 Onsite Detention

11.1 Background

On-site detention (OSD) is the temporary storage of site stormwater so as to restrict the discharge leaving the site to a predetermined rate. The purpose of OSD is to either ensure no worsening of downstream flooding issues as a result of a development or it can also be used to decrease flooding downstream.

Requirements for OSD within the former Leichhardt Local Government Area (study area) are set out in Leichhardt Development Control Plan (DCP) 2013. These requirements currently aim to reduce flooding within the study area by applying OSD to significant proposed developments.

A review has been undertaken as part of the Leichhardt Floodplain Risk Management Study to incorporate the findings of Leichhardt LGA Flood Study into Council's OSD Policy and to review Council's Policy against current best practice. Catchment based analysis is being undertaken to determine the effectiveness of the current OSD policies as a flood mitigation / management tool.

11.2 Existing Onsite Detention Policy

Leichhardt Development Control Plan (DCP) 2013 requires that residential and non-residential developments incorporate OSD in accordance with Council's Stormwater Management Policy (outlined in the Draft Drainage Code, 1995).

The policy specifies that hydraulic calculations are required to demonstrate the 100 Year Average Recurrence Interval (ARI) post development site run-off does not exceed the 5 year ARI pre-development site runoff.

Further details of the existing OSD policy for the study area is provided in **Appendix C**. A review of OSD guidelines in similar governance areas is also provided in **Appendix C**.

11.2.1 Review of Existing Policy

An XP-RAFTS hydrological model was established for the Whites Creek Catchment to evaluate the effectiveness of various onsite detention and retention scenarios. The details of the model set up and validation is provided in **Appendix C**.

Council's existing onsite detention policy was evaluated using the XP-RAFTS model. The results of the modelling found:

- To achieve a reduction in the 100 Year ARI post development flow from the site to the 5 Year ARI pre-development flows, a Site Storage Requirement (SSR) of 300 m^3/ha and a Permissible Site Discharge (PSD) of 300 L/s/ha are required. However, it was found that while the OSD parameters calculated for the individual property were effective, the larger the contributing catchment became, the less effective the same OSD parameters were.
- The majority of developments undertaken prior to this review incorporated site storage requirements of approximately 2,000 L per lot (comparable to 68 m^3/ha), which is significantly less that the SSR calculated by the modelling above. Modelling determined that the application of this storage resulted in a reduction in the flows from the property from 100 Year ARI flows to 35 Year ARI flows. The benefits became almost negligible when these OSD parameters were applied across the wider catchment.

Further details of the modelling undertaken to evaluate the existing OSD policy is provided in **Appendix C**.

11.3 Onsite Detention Catchment Modelling

The hydrological model established to evaluate Councils existing OSD policy was then used to assess various OSD and OSR scenarios to determine the most effective and practical approach to OSD for the study area.

A summary of the model scenarios and results is provided below, further details are provided in **Appendix C**.

11.3.1 OSD Applied to Entire Catchment

While the initial modelling identified that a SSR of 300m^3/ha did not fully achieve Council's policy objective of reducing 100 Year ARI flows to 5 Year ARI flows across the entire catchment (**Section 11.2.1**), there were still appreciable reductions in local flows and flood flows within the main flooding areas.

OSD was applied in the model to all development (excluding roads and open space) within the catchment at a rate of SSR = 300 m^3/ha and PSD = 300 L/s/ha. The model results indicate that for the majority of the catchment the OSD requirements above reduce local drainage flows from 100 Year ARI to approximately 5 Year ARI flows. However, the flows within the existing 100 Year ARI extent are not reduced to the same degree, with the greatest benefits seen in the upstream portions of the flows paths (approximately 10 Year ARI), reducing in benefit towards the downstream end of the catchment, with no significant benefit in the vicinity of Whites Creek and Railway Parade.

The model results are shown in **Appendix C**.

11.3.2 No OSD in Downstream Portion of Catchment

Exclusion zones for OSD can be applied where the implementation of OSD has negligible benefits or in some cases, actually worsens flooding. For example, it may be beneficial to allow the flows in the downstream portions of the catchment to be discharged prior to the flows from the upstream areas "coming through". By detaining the local flows in the downstream areas, the flood peaks may actually end up coinciding with other catchment flows, thereby resulting in increased flood levels or durations of flooding.

Hydrological modelling was undertaken to assess the impacts of not applying OSD to the downstream portions of the Whites Creek Catchment. The results indicate that there is negligible difference in flood behaviour within the 100 Year ARI flood extent when comparing the application of OSD in the exclusion zones and without OSD in these zones.

Although there is no appreciable difference in the major flood flows when applying or not applying OSD to the downstream portion of the catchment, the application of OSD in these areas still has benefits with regards to local flows which impact on street and property drainage.

The model results are shown in **Appendix C**.

11.3.3 No OSD on Low Density Residential Development

While OSD can often more readily be included in commercial, industrial and high density developments, low density (i.e. single lot) residential development can be restricted by lot size and other site constraints such as the ability to excavate for OSD. As such, the impacts of not applying OSD to low density residential development was assessed.

The following OSD parameters were applied:

- Low density (i.e. single lot) residential development: no OSD or OSR
- All other development type: SSR = 300 m^3/ha and PSD = 300 L/s/ha

The model results showed that due to the fact that the majority of land use in the catchment is low density residential development, the lack of OSD on these properties resulted in almost no reduction in flood flows across the catchment.

The model results are shown in **Appendix C**.

11.3.4 Rainwater Tank Offsets

The research currently available regarding the use of rainwater tanks for OSD suggests that there are considerable opportunities for providing OSD offsets in traditional rainwater tanks. The consensus as to the appropriate offset volume varies.

Council has in the past allowed a rainwater tank offset of 2.5 OSR : 1 OSD. The effectiveness of this approach was tested by reducing the OSD for all lots by $1m^3$ and applying a rainwater tank volume of 2,500 L ($2.5m^3$). It was found that this significantly reduced the effectiveness of OSD, with the 100 Year ARI Flows in the upstream reaches being reduced to approximately 50 Year ARI flows.

An alternative approach was then assessed as follows:

- OSD was applied to all development except low density (i.e. single lot) residential development at the following rate:
    - SSR = $300m^3$/ha and PSD = 300 L/s.
- OSR was applied to all low density (i.e. single lot) residential development, using 5,000 L/lot.

The results identified that while the flood management outcomes are not as beneficial as applying OSD to all development types (**Section 11.3.1**), there is still a flood benefit from this approach (reductions of the 100 Year ARI flows to approximately 20 Year ARI flows in the upstream reaches of the floodplain). Further, there is a greater benefit than not applying OSD or OSR at all to low density (i.e. single lot) residential development.

The model results are shown in **Appendix C**.

11.3.5 High Early Discharge

High early discharge (HED) systems work by routing stormwater runoff into a smaller secondary pit, located inside the OSD system at the location of the control outlet, allowing overflow to spill stormwater runoff to the main OSD storage. The stormwater runoff reaches its peak discharge rate faster as the water in the secondary pit fills up quicker due to the smaller area of the secondary pit. By allowing a greater rate of runoff at the commencement of the storm event the OSD volume to be provided to restrict post development flows back to pre-development levels may be reduced.

All hydrologic modelling was undertaken for scenarios with High Early Discharge (HED) turned on and off. The use of OSD without HED reduces the peak local drainage discharges when compared to OSD with HED.

11.4 Recommendations

The OSD assessments undertaken as part of this FRMS will be used to inform the revision of Council's OSD policy in their DCP. The following recommendations have been made for consideration in this process.

11.4.1 Onsite Detention and Retention Requirements

The modelling and associated analysis identified that OSD is a viable and beneficial floodplain risk management measure for the study area. The results indicate that the following OSD parameters achieve a significant reduction in flood flows across the majority of the catchment and are feasible for many types of development:

SSR = 300 m^3/ha

PSD = 300 l/s/ha

Example:

Development on a 1,000 m2 property that proposes to be 80% impervious. The OSD requirements would be:

$$SSR = (1{,}000 \times 80\%) / 10{,}000 \times 300 = 24\ m^3$$

$$PSD = (1{,}000 \times 80\%) / 10{,}000 \times 300 = 24\ l/s$$

However, it is recognised that not all development will practically be able to incorporate SSR of this volume, for example low density residential and small lot commercial. In these cases, Council may look at allowing the use of reduced SSR or the use of OSR in place of OSD.

The review of Council's current practices regarding OSD, identified that if an SSR of 68m^3/ha is applied the reduction in flood flows across the catchment is limited. Therefore, any reduction in SSR from the 300 m^3/ha outlined above, should still result in SSR greater than 68 m^3/ha. It is considered reasonable to look at applying an SSR on smaller lots and low density residential lots of 180 m^3/ha.

The modelling of rainwater tanks identified that the use of a rainwater tank of 5,000L instead of OSD produced significant reductions in flood flows across the majority of the catchment. Modelling of a rainwater tank of 2,500L resulted in only minor reductions in flood flows. Based on these outcomes, the following OSR requirements are recommended for low density residential development:

- Lot size greater than 200m^2; OSR (rainwater tank volume) = 5,000L
- Lot size less than 100m^2; OSR (rainwater tank volume) = 3,000L

For properties between 100m^2 and 200m^2 the OSR volume should be calculated proportionally between 5,000L and 3,000L.

The use of High Early Discharge (HED) is not recommended for OSD in the study area.

11.4.2 Onsite Detention Exclusion Zones

The modelling identified that the exclusion of OSD in the downstream portion of the catchment did not improve the outcome of applying OSD to the entire catchment. Further, the application of OSD had benefits with regards to local flows, reducing gutter, street and property drainage issues. Therefore, no exclusion zones are recommended as an outcome of this study.

Whilst it is recognised that those properties in the downstream portion of the catchment which discharge directly into watercourses would be unlikely to contribute to overland flow across properties, streets, open space and other facilities, there are no properties with direct frontage to the creeklines in the lower reaches of Whites Creek, Johnstons Creek and Hawthorne Canal.

Where natural watercourses are present (or proposed) the discharge of flows into these watercourses should be controlled to reduce potential impacts such as reducing aquatic and riparian habitat, promoting the formation of unnatural drainage lines, weed invasion and accelerated erosion and sedimentation

11.4.3 Onsite Retention Offsets

In addition to the rainwater tank size requirements outline in **Section 11.4.1** for small lots and low density (i.e. single lot) residential development, Council may want to look at OSR offsets for other development types (e.g. larger scale mixed use).

Studies have been done within the stormwater industry assessing the appropriateness of incorporating rainwater tanks and OSD. Several key studies and their findings have been discussed in **Appendix C**.

The research currently available regarding the use of rainwater tanks for OSD suggests that there are considerable opportunities for providing OSD offsets in traditional rainwater tanks. The consensus as to the appropriate offset volume varies. However, the research undertaken by and on behalf of the UPRCT is widely accepted as being comprehensive and is often being used by Councils in other areas to assist in developing their own OSD policies. Based on this evidence and the similar nature of the study area to much of the UPRCT area, it is recommended that Council draw on the results presented in the UPRCT Handbook 4th edition (2005), Coombes et al (2001) and Cardno Willings (2004 and 2005) when considering OSR offsets for OSD.

11.4.4 Areas not Directed to Onsite Detention

Where possible, the drainage system should be designed to direct runoff from the entire site to the OSD system. However, sometimes, because of ground levels, the receiving drainage system or because of other circumstances, this will not be feasible.

The following measures should be implemented, where possible in order to achieve compliance with Council's OSD Policy:

- Above ground OSD tanks should be installed where this will allow for free drainage to the Council's drainage system.
- Where a portion of the site does not drain to the OSD, the storage volume should still be calculated on the impervious portion of the site area while the PSD is adjusted downwards.
- Where SSR requirements cannot be met by OSD alone (or at all) due to site constraints, onsite retention (i.e. rainwater tanks) should be used.

12 Floodplain Risk Management Options

12.1 Managing Flood Risk

Flood Risk can be categorised as existing, future or residual risk:

- **Existing Flood Risk** – existing buildings and developments on flood prone land. Such buildings and developments by virtue of their presence and location are exposed to an 'existing' risk of flooding.
- **Future Flood Risk** – buildings and developments that may be built on flood prone land. Such buildings and developments would be exposed to a flood risk when they are built.
- **Residual Flood Risk** – buildings and development that would be at risk if a flood were to exceed management measures already in place. Unless a floodplain management measure is designed to withstand the PMF, it may be exceeded by a sufficiently large event at some time in the future.

The alternate approaches to managing risk are outlined in **Table 12-1**.

Table 12-1 Flood Risk Management Alternatives (SCARM, 2000)

Alternative	Examples
Preventing / Avoiding risk	Appropriate development within the flood extent, setting suitable planning levels.
Reducing likelihood of risk	Structural measures to reduce flooding risk such as drainage augmentation, levees, and detention.
Reducing consequences of risk	Development controls to ensure structures are built to withstand flooding.
Transferring risk	Via insurance – may be applicable in some areas depending on insurer.
Financing risk	Natural disaster funding.
Accepting risk	Accepting the risk of flooding as a consequence of having the structure where it is.

Measures available for the management of flood risk can be categorised according to the way in which the risk is managed. There are three broad categories of management:

- **Flood modification measures** – Flood modification measures are options aimed at preventing / avoiding or reducing the likelihood of flood risks. These options reduce the risk through modification of the flood behaviour in the catchment.
- **Property modification measures** – Property modification measures are focused on preventing / avoiding and reducing consequences of flood risks. Rather than necessarily modify the flood behaviour, these options aim to modify properties (both existing and future) so that there is a reduction in flood risk.
- **Emergency response modification measures** – Emergency response modification measures aim to reduce the consequences of flood risks. These measures generally aim to modify the behaviour of people during a flood event.

12.2 Flood Modification Measures

The existing flood behaviour within the study area is detailed in the Leichhardt Flood Study (Cardno 2014) and Section 5 of this FRMS. Based on the flood model results, historical information and engineering judgement, possible flood modification measures (i.e. structural measures) for the study area were identified.

The various management options were identified taking into consideration the:

- *Flood behaviour and overland flow in the 20 year ARI event:* all areas affected by overland flow in a 20 year ARI event were considered for potential overland flow management measures.
- *The grade of the stormwater pipes;* the grade of stormwater pipes both upstream and downstream of the areas impacted by 20 year ARI overland flow were identified, along with the permissible grade of the proposed upgraded pipes. The grade of the pipes affects the potential capacity of the pipes (both existing and proposed).
- *Availability and location of easements:* a preliminary review of existing easements was undertaken to assess the viability of various options and, where relevant, the requirement for acquisition of private property.

Flood modification measures for the study area have been identified based on opportunities to connect with future upgrades and improvements and can be used to inform design and planning decisions into the future.

The measures or options have been divided according to the catchment areas within the study area. These catchments are represented by each of the hydraulic model zones from the Flood Study (Cardno, 2014) and are shown in **Figure 5-1**. The study area has nine major sub-catchments:

1. Hawthorne Canal
2. Johnstons Creek
3. Whites Creek
4. Iron Cove
5. Mort Bay
6. Parramatta River
7. Snails Bay
8. Rozelle Bay
9. White Bay

An overview of the flood modification options is provided in **Table 12-2**. Details of each of the options, the modelling outcomes and the economic analysis are provided in **Appendix D**, where a separate report has been prepared for each sub-catchment.

12.2.1 Hydraulic Modelling of Options

The hydraulic model (Sobek) developed for the Flood Study (Cardno, 2014) was modified to assess the performance of each of the proposed flood modification options. The results of the modelling are provided in **Appendix D**.

12.2.2 Economic Assessment of Options

12.2.2.1 Preliminary Costing of Options

In addition to Council and OEH, Sydney Water and RMS may also play a major role in regards to fund allocation for the options recommended. Sydney Water's approach to flood-related improvement works on its assets is that Sydney Water will work with Councils to deliver the works (typically on a 50:50 cost-sharing basis) and provided Sydney Water has funding available within its Flood Risk Program. It is assumed that RMS will provide all the funding for the transverse pipe sections across State roads (Parramatta Road, Victoria Road, Darley Road, Foster Street, Tebutt Street, City West Link, The Crescent and Balmain Road/Perry Street between Victoria Road and City West Link). Currently no allocation of RMS funding has been assigned for infrastructure travelling longitudinally along State Roads. It is likely that some contribution would be required from RMS for these upgrades in State Road easements. For detention basins, it was assumed that Council will be responsible for all associated costs.

The capital and recurrent costs are provided for each option in **Table 12-2**.

12.2.2.2 Average Annual Damage Assessment of Options

An assessment of damages for the existing condition in the study area was presented in **Section 6**. As the flood modification options selected are predominantly concerned with the reduction of local flood impacts, rather than assess the catchment wide damages, the reduction in damages resulting from local decreases in flood depths and extents has been considered.

The economic flood damage results for each of the options is presented in **Appendix D**. The reduction in AAD is provided for each option in **Table 12-2**. This effectively represent the reduction in flood damage costs per year as a result of the option.

12.2.2.3 Benefit Cost Ratio of Options

The economic evaluation of each modelled measure was assessed by considering the reduction in the amount of flood damages incurred for the design events and by then comparing this value with the cost of implementing the measure.

The indicator adopted to rank these measures on economic merit is the benefit-cost ratio (BCR), which is based on the net present worth (NPW) of the benefits (reduction in AAD) and the costs (capital and ongoing), adopting a 7% discount rate and an implementation period of 50 years.

The benefit-cost ratio provides an insight into how the damage savings from a measure, relate to its cost of construction and maintenance:

- Where the benefit-cost is greater than 1 the economic benefits are greater than the cost of implementing the measure;
- Where the benefit-cost is less than 1 but greater than 0, there is still an economic benefit from implementing the measure but the cost of implementing the measure is greater than the economic benefit;
- Where the benefit-cost is equal to zero, there is no economic benefit from implementing the measure; and
- Where the benefit-cost is less than zero, there is a negative economic impact of implementing the measure.

The details of the BCR assessment are provided in **Appendix D**, the resulting BCR for each option in provided in **Table 12-2**.

12.2.3 Implementation of Flood Modification Options

Council’s capacity to construct additional pipelines within roadways is primarily limited by cost and the presence of buried utility services. However, upgrade or construction of additional pipelines through private property contains significant additional constraints associated with land ownership and the nature and extent of development, primarily buildings, on the land. In almost all cases where additional pipelines are proposed through private property, the existing and proposed pipelines pass beneath multiple properties and on a diagonal to the property boundaries, as depicted in **Plate A**. Properties are generally developed with buildings extending to or very close to the side boundaries of the property.

Implementation of the structural mitigation options could present Council with an opportunity to develop a land use plan that will combine construction of the structural flood mitigation options (the engineering solution) with compatible land use possibilities such as parks and transport links, in alignment with Council’s corporate strategic plans for access, transport, recreation etc. (the social solution).

Plates B, C and D identify some of the corporate benefits that could be achieved if Council were to acquire strategic properties along the corridor.

Table 12-2 Flood Modification Options

Option ID	Option Description	Capital Cost	Annual Costs	Reduction in AAD	BCR
HC_FM1	Additional pipes /culverts from Parramatta Road to Hawthorne Canal via Beeson Street.	$11,483,000	$8,000	$594,290	0.71
HC_FM2	Additional pipes or duplication of existing network from Reuss Street to Hawthorne Canal via Elswick Street, Flood Street and Marion Street.	$10,479,000	$11,000	$130,510	0.17
HC_FM3	Additional pipes/culverts from Elswick Street to Hawthorne Canal (via Regent Street and Darley Road). Also extra pipes at Darley Road to reduce flood depths on the Road.	$17,045,000	$11,000	$162,110	0.13
HC_FM4	Additional pipes/ culverts from William Street to Hawthorne Canal via Hubert Street and Darley Road.	$8,300,000	$7,000	$101,410	0.17
HC_FM5	Proposed culverts through the rail embankment to drain flood waters from Darley Road to Hawthorne Canal.	$2,689,000	$3,000	$34,130	0.17
JC-FM1	Johnston Street Flow Path – Proposing additional pipes/ culverts and duplication of existing pipe network from Johnston St to Johnstons Creek open channel. Additional pipes on Parramatta Rd, Trafalgar St, Albion St and Nelson St.	$7,935,000	$13,000	$143,970	0.25
JC-FM2	Pyrmont Bridge Road Flow Path – Additional pipes or duplication of existing network from Parramatta Rd to Johnstons Creek via Pyrmont Bridge Rd.	$6,121,000	$4,000	$141,190	0.32
JC-FM3	View Street Flow Path – Duplication of existing pipe network or additional pipes from View St to Johnston Creek (via Trafalgar St, Nelson St and Taylor St).	$2,963,000	$6,000	$23,040	0.10
JC-FM4	Rose Street Flow Path - Additional pipes from Rose St/Johnston St to Federal Park via View St and Trafalgar St. Proposed Easement downstream of The Crescent to drain flood waters from the low point of the Rd.	$3,413,000	$6,000	$53,650	0.21
JC-FM5	Additional pipes within Johnstons Creek Catchment – At Bayview Crescent, Piper St and at Wigram Rd.	$2,386,000	$4,000	-$100	0.00
JC-FM6	A levee or embankment on Nelson Lane, starting from the northern end of Taylor Street in order to minimise flooding adjacent to Johnstons Creek.	$558,000	$5,000	-$126,920	-2.77
WC-FM1	Whites Creek Culvert – additional culvert or duplication of existing Whites Creek culvert from Parramatta Rd to the open channel downstream of Moore St (at Wisdom Street). Also combining WC-FM2 along with this option.	$20,455,000	$16,000	$316,440	0.21
WC-FM2	Young Street Flow Path – new pipe network from Young Street/Parramatta Road to Whites Creek culvert via Young St, Albion St, Ferris St and Clarke St. Additional pipe network from Young St to Albion Street.	$4,223,000	$5,000	$39,810	0.13

Option ID	Option Description	Capital Cost	Annual Costs	Reduction in AAD	BCR
WC-FM3	Balmain Road Flow Path – Additional pipe from the low point on Norton St to the existing pipe network (towards Parramatta Rd). Duplication of existing pipe network or extra pipes from Balmain Rd to Whites Creek Culvert at Hearn St.	$7,048,000	$7,000	$822,760	1.59
WC-FM4	Hearn Street – Detention Basin or Large Inlet Pits at Hearn St to collect flood waters and convey into the proposed Whites Creek Culvert. Additional pipes from Albion St to Whites Creek culvert.	Not viable - See Appendix D for details			
WC-FM5	Detention Basin at Mackenzie Street (upstream at the intersection of Mackenzie and Milton St)	$934,000	$5,000	$134,270	1.85
WC-FM6	Styles Street Flow Path – Additional pipes from Mackenzie St to Whites Creek Culvert.	$9,399,000	$6,000	$194,950	0.28
WC-FM7	Detention Basin at Evan Jones Park	Not viable - See Appendix D for details			
WC-FM8	Annandale Street Flow Path – Duplication of existing pipe network or additional pipes from Annandale St to Whites Creek culvert.	$3,927,000	$3,000	$40,800	0.14
WC-FM10	Detention Basin at Catherine Street (War Memorial Park)	$2,152,000	$5,000	$34,170	0.21
WC-FM11	Moore Street Flow Path – Additional Pipes from Catherine St to Whites Creek along Moore Lane.	$3,653,000	$5,000	$15,430	0.13
WC-FM12	Additional pipes at Brenan St and Railway PDE to reduce flooding on the roads.	$2,719,000	$5,000	$26,350	0.13
WC-FM13	Whites Creek Culvert/Open Channel – additional culvert or duplication of existing Whites Creek culvert from Parramatta Rd to the open channel downstream of Moore St (WC-FM1). Widening of the open channel to convey additional flows. Upgrade Bridges at Piper Street and Brenan Street (WC-FM14)	$28,520,000	$16,000	$473,530	0.23
WC-FM14	Whites Creek Bridge Upgrades –Upgrade Bridges at Piper Street and Brenan Street.	$5,817,000	$58,000	$15,430	0.03
IC_FM1	Victoria Road Branch – Additional pipes from the Victoria Rd/Terry St intersection that drains into Iron Cove	$1,539,000	$3,000	$20	0.00
IC_FM2	Manning Street Branch – Additional pipes that crosses Mannings St at three locations onto other street. Toelle St, Callan St and Springside St.	$2,220,000	$5,000	$1,280	0.01
IC_FM3	Glover Street Branch – Additional pipe along Glover St between Perry St and Church St.	$1,472,000	$3,000	$80	0.00
IC_FM4	Longview Street Branch – Additional pipes to drain flooding from the low point on Longview Street.	$307,000	$1,000	$10	0.00
MB_FM1	Colgate Street Branch – additional pipes to be incorporated into the existing network. Starting from Darling St/Queens Pl intersection, passes along Colgate Av and drains into Mort Bay. There are also additional pipes on St Andrews St and Cooper St.	$4,185,000	$8,000	$2,360	0.01

Option ID	Option Description	Capital Cost	Annual Costs	Reduction in AAD	BCR
MB_FM3	Curtis Rd Branch – additional pipes along Mort St and Clayton St and connecting to an additional proposed pipe on Cameron St (MB-FM4) which drains into Mort Bay.	$4,705,000	$8,000	$1,090	0.00
MB_FM4	College Street Branch – Additional pipe network starting from the Cardwell/North St intersection, travelling along (SE) Macquarie St and the Curtis Rd. The pipe branches off into Phillip St, Church St and College St and finally connects into the existing Sydney Water pipe and to the proposed pipe on Cameron St which drains into Mort Bay.	$8,672,000	$14,000	$1,550	0.00
MB_FM5	McKell Street Branch – Additional pipe from Short St that crosses McKell St and drain into Mort Bay	$631,000	$1,000	$3,660	0.08
SB_FM1	Cove Street Branch – The proposed pipe starts from the Cove/Birchgrove St Intersection and then goes along Ferdinand St and connects to the existing pipe network in The Terrace. Additional pipes along Grove St, Rose St and Bay St.	$2,918,000	$6,000	$360	0.00
RB-FM1	Lilyfield Road Flow Path – additional pipes or duplication of existing pipe network. Proposed pipes connecting into the existing network at O' Neill St. Additional pipes from the low point on Denison St to the outlet at Rozelle Bay. Additional pipe network in Quirk Street, Gordon Street and Lilyfield Road with a branch along Alfred Street.	$18,284,000	$17,000	$492,640	0.37
RB-FM2	Additional Culverts/Pipes across Lilyfield Road at four locations. From Joseph Street along Halloran Street to Lilyfield Road, Edward St, Justin St, Cecily St and Brenan Street South of the railyards.	$3,036,000	$5,000	$9,110	0.04
WB-FM1	Beattie Street Branch – a new pipe network or duplication of existing pipe network. Starting from Llewellyn St to the outlet at White Bay. The trunk drainage starts from Roseberry St at the start and Robert St to the end. Then travelling East, parallel to Robert St and eventually draining into White Bay.	$25,686,000	$27,000	$384,770	0.20
WB-FM2	Wortley Street Branch – additional pipes to be incorporated into the existing pipe network. Additions at Creek St, Wortley St, Foy St, Hyam St, Roseberry Place and eventually crossing Robert St to drain into White bay.	$8,513,000	$12,000	$259,540	0.41
WB-FM3	Reynolds Street (Wortley Street) Detention Basin – Detention basin in Punch park, situated next to Reynolds St.	$1,659,000	$5,000	$49,440	0.39
WB-FM4	Montague Street Branch and additional pipes – additional pipes from Montague St that connect into the existing network.	$2,132,000	$4,000	$23,310	0.15
WB-FM5	Booth Street Detention Basin – at Gladstone park (Balmain Public School) next to Booth St.	Not viable - See Appendix D for details			
WB-FM6	A detention basin at the grounds North-East of the Elliot Street/Beattie Street intersection.	Not viable - See Appendix D for details			

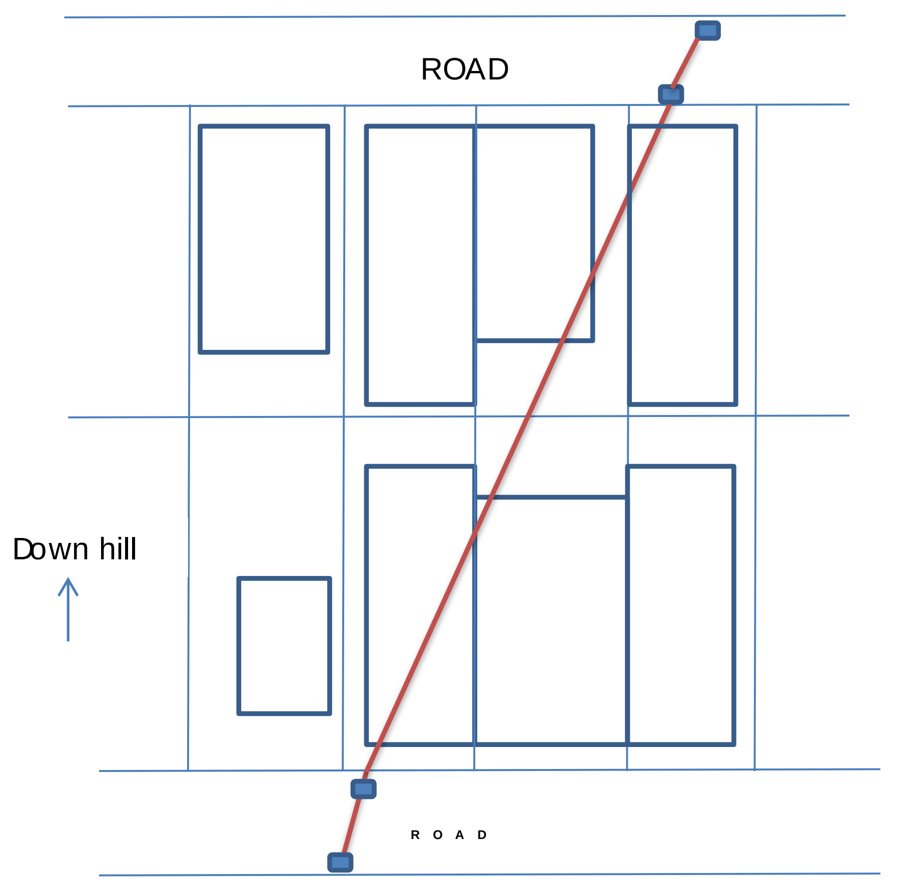	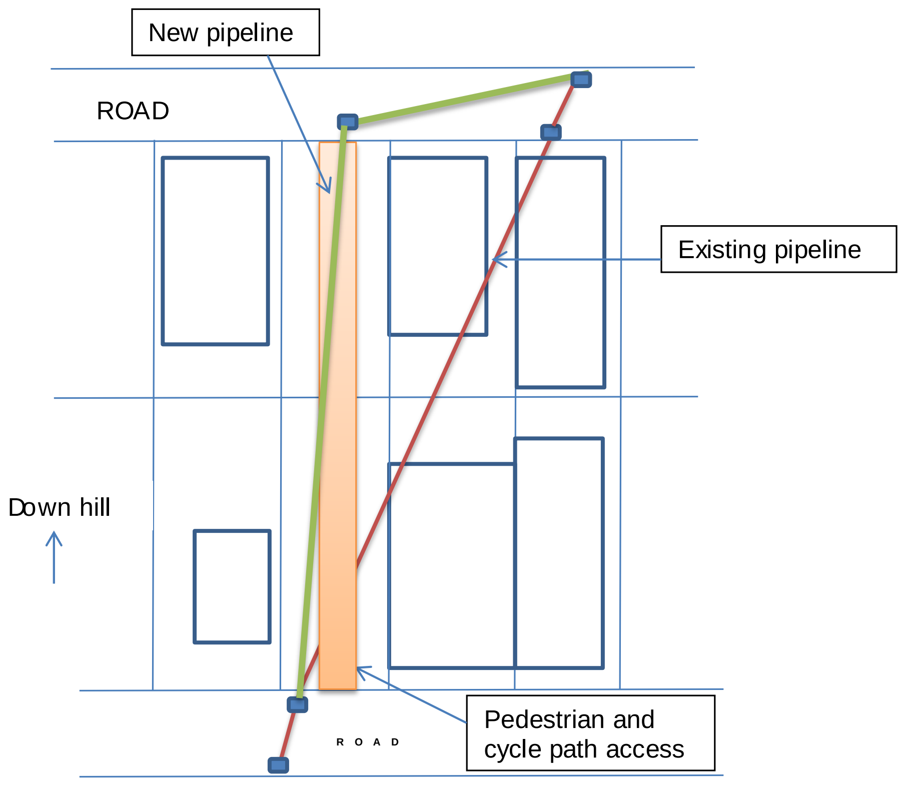
Plate A Pipeline passes beneath multiple properties and on a diagonal to the property boundaries	**Plate B Demolition of existing dwellings and construction of pedestrian/cycle access**

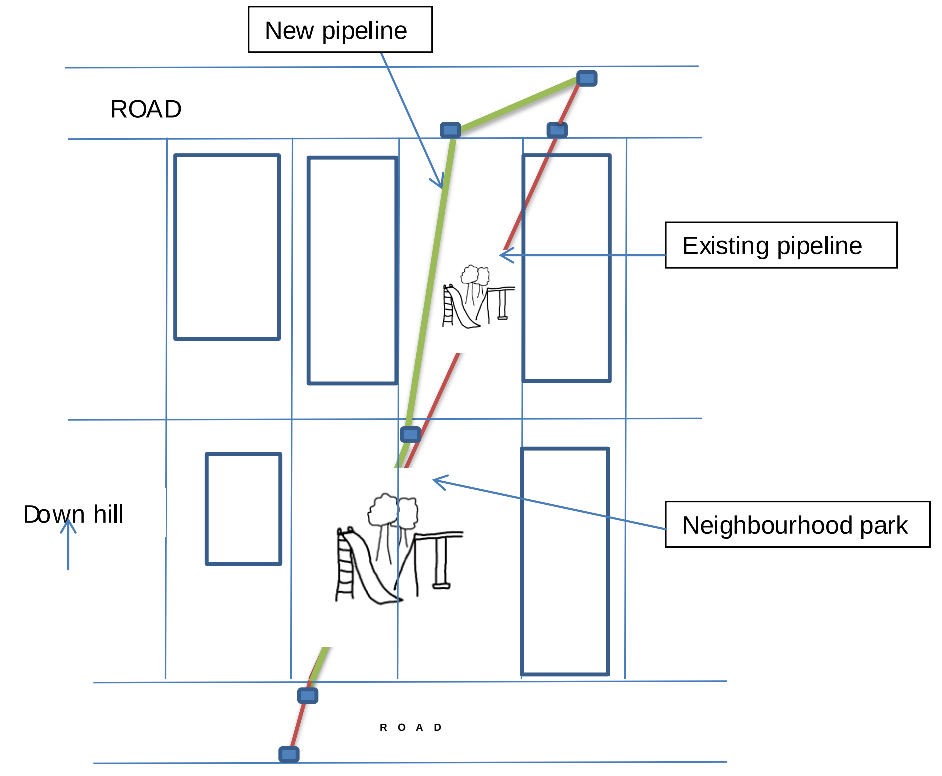

Plate C Demolition of existing dwellings and construction of a park

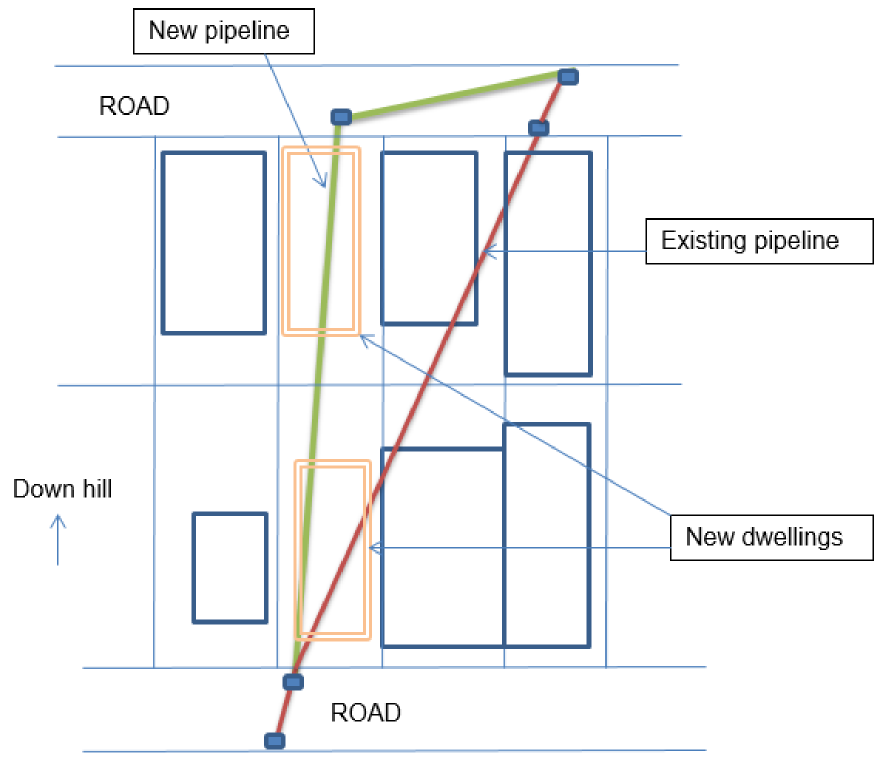

Plate D Demolition of existing buildings. Construction of pipeline and easement then resale of the land for development

(Council could develop the land and then resell the developed land.)

12.3 Property Modification Options

Property modification options refer to options that aim to reduce the impact of flooding on existing or future development and ensure that future development does not impact flood behaviour such that it creates adverse impacts for adjacent and surrounding properties. These options can be related to proposed changes to existing development but primarily focus on developing appropriate planning measures for future development. The planning recommendation provided within these options have been developed from the review undertaken of the existing policies and plans (**Section 9**), the Flood Planning Level (**Section 10**) and onsite detention requirements (**Section 11**).

12.3.1 PM1 – Review of LEP Wording

Under the current wording of the LEP, the flooding provisions of the LEP may only be applied to land at or below the 100 Year ARI (referred to as 1% AEP in LEP) plus 0.5m freeboard, in accordance with the provisions of the standard template. However, subsequent policies and plans assign development controls up to the PMF event (e.g. controls on Special Uses land types). Given the additional legal weight of the LEP some Councils in NSW have begun incorporating a second flood related section of the LEP that addresses development controls that are applicable above the 1% AEP (100 Year ARI) plus 500mm freeboard or simply amending the wording in the LEP to identify the Flood Planning Level to be defined by the Floodplain Risk Management Plan.

12.3.2 PM2 – DCP Review for Effective Flood Access

The emergency management review (**Section 8**) identified a number of properties that would effectively be “cut off” during a flooding event. The impact of this on each property would depend on both the duration of flooded access and on the nature of the land use. There are likely to be greater impacts on a special use (e.g. aged care or child care centre) compared with a single use dwelling. As such, the impacts of flooding on property access should be considered when assessing development applications, especially if a change of use or increase in dwelling density is proposed.

Lack of effective access during a flood event can impact both flooded and flood free properties. Therefore, the impact of flooding on access to a property should be considered during the development application process for both flooded and flood free properties.

12.3.3 PM3 – DCP 2013 Review for Car Parking Controls

A review of the controls outlined in the Exempt and Complying Development Codes SEPP would indicate that for these developments, the controls relating to car parking differ from those outlined in Council’s DCP as outlined in **Table 9-3**. This should be reviewed by Council to ensure consistency.

12.3.4 PM4 – Onsite Detention Requirements

It is understood that Council is currently updating the Draft Stormwater Drainage Code. The outcomes of the On-site Detention assessment undertaken in **Section 11** should be considered in the revised code.

12.3.5 PM5 – Flood Planning Level

The Flood Planning Level review (**Section 10**) made the following recommendations with regards to appropriate Flood Planning Levels in the study area:

- Council adopt a FPL of 100 Year ARI flood level plus a 0.5m freeboard for residential and commercial development.
- Underground car park entrances in addition to vents and openings are also to be set at the 100 year ARI flood level plus 0.5m freeboard, or PMF, whichever is the higher. These locations are a particularly high risk to life.
- For critical infrastructure, such as hospitals, police stations and aged care, the PMF should be adopted as the FPL. It is important that these facilities, which are either difficult to evacuate or are essential during an emergency, remain flood free.
- The Leichhardt DCP 2013 currently provides for circumstances where an FPL other than the 100 Year ARI plus 0.5m freeboard will be considered. These have been reviewed against the

assessments undertaken. The following additional considerations should be given to ground floor and above ground additions:

 - Where the proposed habitable ground floor area of an addition to an existing dwelling exceeds 60% of the total existing retained habitable ground floor area, the existing ground floor must be raised to the FPL.
 - Where the habitable floor area of above ground floor additions is equal to or exceeds the existing total habitable floor area, the existing ground floor area must also be raised to the FPL.
 - It is also recommended that Council include clear provisions for the limit of these exceptions, particularly where exception may be requested several times for the same property over multiple development applications.

It is noted that these recommendations could likely impact the existing streetscape and heritage properties. In addition, the recommendations will have to be assessed for their impact on neighbouring properties – such as overshadowing, privacy and/or view loss. Protection of the heritage fabric and the built environment will need to be given a higher priority in consideration of the above recommendations.

- The FPL for overland flow with a depth of 0.25m or less should be determined as: the 100 Year ARI Flood Depth plus a freeboard equal to twice the depth. This will result in a FPL equal to three times the depth of flow above the ground level. This height should never be less than 0.3m above the ground level. Exception to this may be applied (i.e. a 0.5m freeboard may be required) where there is a likelihood of increased flood depths based on site conditions. Where the freeboard is less than 0.5m, it must be ensure that suitable provision for overland flow be provided. Additional details are provided on **Section 10.15.1**.

12.3.6 PM6 – Voluntary House Purchase

Voluntary purchase (VP) is the optional purchase of pre-selected properties funded jointly by Council and the State Government. Those properties are commonly converted into public open space or other flood compatible uses whilst the original property owner finds an alternate, flood-free place to live. The resultant land use of the property is intended to be more compatible with the flood risk and therefore the resultant flood damages are negated for those properties.

This option identifies the worst affected properties on the floodplain and, through state government assistance; properties become eligible for voluntary purchase so that the flood risk for these properties can be removed.

Voluntary House Purchase is funded by Council with assistance from the State Government. However, due to the relatively expensive nature of such a program, limited availability of Government and/or Council funding can be a major constraint to undertaking Voluntary House Purchases. Typically, only a small number of properties within a floodplain can be considered for Voluntary Purchase, however more can be assisted if funding is available.

The following criteria have been established to identify properties that may merit further investigation for voluntary purchase:

- The property is a residential property;
- Property is located within the 5 Year ARI High Hazard Extent; and
- Overfloor flooding occurs in a 5 Year ARI event.
- Evacuation from flooding is restricted

Twelve (12) properties were identified as potentially fulfilling the criteria for voluntary house purchase.

These properties have been simplistically identified utilising the floor level survey which is obtained from the street frontage of the house. The validity of this information and the suitability of the subject properties for voluntary purchase would need to be verified by Council prior to proceeding with applications for voluntary purchase of these properties.

For the purposes of the multi-criteria assessment, it has been assumed that 1 property would be purchased approximately every 5 years. This assessment has targeted the worst affected properties, with an average of $150,000 in structural damages incurred in a 5 Year ARI event on each property. The outcomes of the 2013 social assessment (**Section 7 and Appendix B**) have been used in this assessment, assuming an average property purchase price of $800,000 (2013) has been applied.

12.3.7 PM7 – Voluntary House Raising

Voluntary house raising (VHR) involves elevating an existing house by progressively raising the piers and associated floor area to a level above the flood planning level. The construction sequence to achieve required raising will be dependent on the individual dwelling. This option is not applicable for properties which are "slab on ground" construction.

This option identifies the worst affected properties on the floodplain and, through state government assistance, properties become eligible for voluntary raising so that the flood risk for these properties can be reduced.

The following criteria have been established to identify properties suitable for voluntary house-raising:

- The property is a residential property with pier construction (i.e. not slab on ground);
- Property is located within the 5 Year ARI Low Hazard Extent; and
- Overfloor flooding occurs in a 5 Year ARI event.

Eight (8) properties were identified that potentially fulfilled the criteria above. The inclusion of additional properties was primarily limited by construction type rather than the other criteria. The construction type was sourced from the property survey data collected in 2014 (**Section 3.2.2**).

Noting the broad scale nature of the damages assessment and possible missing construction information for properties, it may be appropriate for Council to assess additional properties against these criteria if additional information becomes available.

The suitability of house raising would be dependent not only on the building construction type, but also on the levels of the surrounding infrastructure and landform. The eight properties identified should be further assessed for their suitability for house raising through on ground inspections.

Voluntary house raising is generally funded by Council with assistance from the State Government. The cost of raising one house is in the order of $40,000.

As discussed in **Section 9.2**, there are no flood related provisions in the DCP for development in heritage conservation areas. Given that some of the heritage conservation areas within the study area are flood affected, it is recommended that Council consider provisions of flood related controls in the DCP for development in heritage conservation areas.

12.3.8 PM8 – Incentives for Flood Compatible Redevelopment

There are more than 400 properties likely to be affected by over floor flooding in a 5 Year ARI event (**Section 6.7**). Most of these properties lie within the low hazard extent and so are not suitable for voluntary house purchase and the majority of those properties within the 5 Year ARI low hazard extent are constructed with a slab on ground.

An alternative to both VP and VHR could be a financial incentive to undertake flood compatible redevelopment. This incentive could be set at a value equal to the VHR incentive, but could be used towards the general construction costs associated with redevelopment. This may encourage redevelopment of those existing properties currently impacted by flooding. Redevelopment would be undertaken in accordance with flood related development controls thereby reducing the flood risk associated with those properties.

This approach also provides a more equitable outcome than voluntary house raising, allowing all significantly flood affected properties an opportunity to apply to Council for the funding, rather than only a few. In addition, the properties with piers identified as possible candidates for VHR may be reaching the end of their design life, redevelopment rather than house raising may be more appropriate in these cases.

An additional benefit of this option is the potential to raise awareness regarding flood risk and flood related development controls.

For the purposes of this assessment it has been assumed that one property per year would receive redevelopment incentives. The incentive has been assumed to be $40,000.

12.3.9 PM9 – Strategic Planning

When Council is developing strategic plans or assessing rezoning proposals in the vicinity of flood prone land, the opportunities for flood mitigation measures should be explored. This could include adopting options from the Flood Risk Management Plan or may also present alternative approaches to flood mitigation that have not previously been identified in this Flood Risk Management Study.

Planning proposals or large scale redevelopment strategies such as the State Government's Parramatta Road Urban Transformation Strategy present an opportunity for flood prone land to be divided into appropriate land use zones. This is an effective and long term means of limiting danger to personal safety and flood damage to future communities. Options could include converting or embellishing creekline corridors and local depressions as open space, incorporating recreational uses and/or transport corridors.

If Council is looking to increase open space provision or develop pedestrian and cycle facilities within a locality, flood prone land should be the first place to explore. Such land uses are highly compatible with use as overland flowpaths or to install or upgrade stormwater pipelines and infrastructure.

12.3.10 PM10 – Foreshore Management

To assist Council in planning and assessing future planning works, several management options have been identified with regards to protection of foreshore assets and increasing safety in foreshore areas likely to be impacted by inundation during an ocean storm event.

- Several factors were considered when identifying management options:
- Seawall condition;
- Overland flow;
- LEP Zoning;
- Visual amenity;
- Proposed seawall height;
- Property type (commercial, residential, public space etc.); and
- Inundation with sea level rise (both still-water and estuary planning level).

The details of the foreshore management assessment are provided in **Appendix E**.

The purpose of the foreshore management assessment is to support Council's planning around foreshore risk alongside consideration of existing foreshore works to remediate failing or poor condition seawalls and other foreshore structures, development controls, future foreshore development planning.

Considering the uncertainty associated with sea level rise predictions and the timeframes over which sea level rise will occur. It is recommended that Council approach management of foreshore risk on public and private property through the following:

- Application of Estuarine Planning Levels and associated development controls;
- When works are planned on existing foreshore structures for maintenance or remediation, consideration be given to modifying or raising seawalls to provide additional protection for inundation.
- Monitoring of sea level rise and identification of trigger values for different locations with regards to the inundation risk summarised in the Estuary planning Levels Study and this FRMS.

12.4 Emergency Response Modification Options

Emergency response modifications options have been developed as an outcome of the review of existing emergency response arrangement outlined in **Section 8** and additional flood risk issues identified in the assessment of True Hazard (**Section 5.4.2**).

12.4.1 EM1 – Information Transfer to SES

The findings of the Flood Study (Cardno, 2014) and the Flood Risk Management Study and Plan provide a useful data source for the State Emergency Service. It is recommended that this information be transferred to the local SES command centre at Haberfield, as well as the Local and District Emergency Operations Controllers.

The Floodplain Risk Management Guideline - SES Requirements from the FRM Process (DECC, 2007) outlines the SES data requirements from the Floodplain Risk Management Study. These requirements have been tabulated below along with reference to the source of the data within the FRMS.

Table 12-3 The Floodplain Risk Management Guideline - SES Requirements

SES Requirements	Data Provided
Summary of historic information and other intelligence collected as part of data collection.	Section 3 provides details of the data utilised in this study. This data can be made available to the SES.
Plans indicating cross section location or chainages as per the river long section, for ease of data interpretation.	Flooding is not contained only to main channels, with the majority of flooding occurring via overland flows. As such, cross sectional data is not relevant to the interpretation of this study.
Plans showing the base digital terrain/elevation model to AHD where appropriate and available.	Developed as part of the Flood Study (Cardno, 2014).
Plans showing river long sections with flood level variations for historical and design events related directly to the key warning gauge heights.	Flooding is not contained only to main channels, with the majority of flooding occurring via overland flows. As such, cross sectional data is not relevant to the interpretation of this study.
Separate plans should be provided for historical and design floods. Confidence banding should be added to the planning flood long sections based upon calibration and sensitivity analyses.	Developed as part of the Flood Study (Cardno, 2014).
Provision of a description of physical flood behaviour in plain English terms for a layman audience. This is to include a description of the development and pattern of flood behaviour.	Section 5 provides a comprehensive overview of the existing flood behaviour in the study area.
Describe specific risk areas in the context of the potential consequences of flooding from more frequent, major and extreme events. The descriptive criteria in the FRM Guideline on Flood Emergency Response Classification of Communities should be used to delineate areas of the floodplain for different scale events.	Flood risks have been further assessed as part of the review of factors affecting true hazard (Section 5.4.2). Flood emergency response classifications are provided in Section 9.
A spreadsheet of ground and floor levels for houses and flood levels for design and historic events, relative to the key flood warning gauge height is to be provided. This can be based upon the information developed for the damage assessment. The source of the base information should be included.	A spreadsheet of ground and flood levels for all properties within the PMF extent was developed as part of the damages assessment (Section 6). This also includes the design flood levels for all events assessed in the Flood Study (Cardno, 2015). No historical flood levels are provided for individual properties.

SES Requirements	Data Provided
Plans indicating a minimum of flood extents, floodways, flood storage areas and flood fringe areas. Definition of flood hazards should be included (where assessed) based upon the categorisation in the Floodplain Development Manual or similar approach as agreed with DECC.	Plans showing flood extents, flood hazard and hydraulic categories are provided in the Flood study (Cardno, 2014).
Modelling of flood behaviour that defines the variation over time of flood levels, extents and velocities for each of the critical design events. This may require modelling of shorter duration 100 year ARI and PMF or equivalent extreme events to provide advice in relation to the potential differences in time available for response.	A discussion of the critical duration events and available warning time is provided in the Flood Study (Cardno, 2014) and a review of how this relates to emergency response arrangement is provided in Section 8.

12.4.2 EM2 – Prepare a Local Flood Plan

It is recommended that the Inner West Council prepare a local flood plan in conjunction with the SES to outline the following details:

- Evacuation centres in close proximity to the floodplain which allow flood free access to the centres and are flood free sites.
- Inclusion of a description of local flooding conditions.
- Identification of potentially flood affected vulnerable facilities.
- Identification of key access roadssubject to flooding.

Further details of evacuation centres, access road flooding and recommended inclusions for the flood plan are provided in **Section 8** of this document.

12.4.3 EM3 – Public Awareness and Education

Flood awareness is an essential component of flood risk management for people residing in the floodplain. The affected community must be made aware, and remain aware, of their role in the overall floodplain management strategy for the area. This includes the defence of their property and their evacuation, if required, during the flood event.

The study area can be affected by both catchment flooding and foreshore inundation due to ocean storm events. Catchment flooding is generally defined as flash flooding due to the short period of time between when rainfall begins and flooding occurs. Foreshore inundation may occur concurrently or separately from catchment flooding. Public awareness and education campaigns need to address both types of flooding.

Flood warnings for areas impacted by flash flooding are limited (this is discussed further in **Section 8**). In order to get the most benefit from flood warnings that are available, people in flood prone areas will need to know what, if any, effect the flood will have on their property and access routes within the local area and some knowledge of how best to deal with a flood situation.

Flood awareness campaigns should be an ongoing process and requires the continuous effort of related organisations (e.g. Council and SES). The major factor determining the degree of awareness within the community is the frequency of moderate to large floods in the recent history of the area.

For effective flood emergency planning, it is important to maintain an adequate level of flood awareness during the extended periods when flooding does not occur. A continuous awareness program needs to be undertaken to ensure new residents are informed, the level of awareness of long-term residents is maintained, and to cater for changing circumstances of flood behaviour and new developments. An effective awareness program requires ongoing commitment.

The major flood events occurred in the catchment were in February 1993 which was roughly equivalent to a 50 Year ARI event, January 1991 which is approximately 20 Year ARI event and April 1998 which is approximately 10 Year ARI event. Based on the responses from the resident survey conducted for the

Leichhardt Flood Study (Cardno, 2014), approximately 28% of respondents have been living in the catchment at the time of the 1993 flood event.

The responses from the resident survey suggest that around 33% of the respondents were not aware of flooding in the catchment. This can be both a function of the misconception of overland flooding, which is commonly associated with stormwater flooding. Furthermore, the short duration of flooding in the catchment may mean that the flooding occurs when the residents are not at home or during the night and so the flooding is not observed.

The results of the community survey suggest that the flood events that have occurred in the catchment since the 1990s can be used effectively for flood education purposes

It is recommended that the following awareness campaigns be considered for the floodplain. These should be prepared together with the SES, as they have a joint responsibility for community awareness under the DISPLAN.

- Preparation of a FloodSafe brochure relevant to the study area for both residential and business premises. Such a brochure with a fridge magnet may prove to be a more effective means of ensuring people retain information. Once prepared, the FloodSafe brochure can then be uploaded to the Council and SES websites in a suitable format, where it would be made available under the flood information sections of the website. The brochures could also be made available at Council offices and community halls. The brochure should address both catchment flooding and foreshore inundation or separate brochures be prepared.
- Development of a Schools Package from existing material developed by the SES and distribution to schools accordingly. Education is not only useful in educating the students, but can be useful in dissemination of information to the wider community.
- A regular (annual) meeting of local community groups to arrange flood awareness programs on a regular basis. Engaging with long term residents who have memories of past flood events can be useful to share this knowledge with other residents at these events.
- Information dissemination is recommended to be included in Council rates notices for all affected properties on a regular basis.

12.4.4 EM4 – Early Warning Alert System

The critical duration and response times for the study area floodplain limit the implementation of a flood warning system. The short duration flooding experienced in local systems is not well suited to flood warning systems. Severe weather warnings are likely to be the only assistance for these areas.

Council may wish to consider developing an early warning alert system to provide registered residents and business owners with free severe weather alerts. By monitoring BoM weather warnings and other sources, Council could send alerts based on potentially dangerous weather events. The alerts would likely cover weather events such as:

- hail and severe thunderstorms;
- destructive winds and cyclones; and
- floods from a number of different sources including king tide, storm surge and tsunamis.

Alerts could be sent by:

- email;
- SMS; and
- recorded message to a landline.

Council could also look at partnering with a service provider to develop and manage such a system.

12.4.5 EM5 – Flood Warning Signs at Critical Locations

A number of public places in the catchment experience high hazard flooding and many roads are inundated beyond a depth at which cars remain stable. It is therefore important that appropriate flood warning signs are posted at these locations. These signs may contain information on flooding issues or be depth gauges to inform residents of the flooding depth over roads and paths.

It is recommended that depth gauges be installed at road crossings which are subject to inundation in frequent events. Key locations are provided in **Table 8-1**. This option has provided provisional costs associated with installing depth gauges at locations where flood depths exceed 0.3m in a 5 Year ARI event (55 locations).

The use of depth markers at these locations may not be appropriate for several reasons. The road flooding is likely to occur whilst intense rainfall is still occurring. As such, it is unlikely that drivers will notice or even be able to read the depth markers. Further, home owners adjacent to depth markers may object to the placement of these markers for fear that there would be a perception that their properties are flood affected and that this may impact future property purchase.

A larger flood warning or infographic sign may be more appropriate, identifying that the road may be subject to flooding during extreme rainfall events. This information could be supported through public education programs relating to driving through flood waters (Option EM3).

12.4.6 EM6 – Establish Evacuation Centres

Due to the flash flooding nature of catchment flooding within the study area evacuation may not always be possible or the best response. However, evacuation centres may be required for residents affected by foreshore inundation or immediately after a flood event if significant damage is incurred on a property. In other situations residents may not be able to return to the homes due to road flooding and may need temporary refuge until the floodwaters recede.

Several flood free locations have been identified in **Table 8-2** that may be suitable to function as evacuation centres during and following a flood event in the study area. Council and the SES should review the venues including the facilities, indoor area available and flood free access to the sites and liaise with the owners and / or managers of the venues to identify appropriate evacuation centres.

Those venues that are deemed suitable to function as evacuation centres during a flood event should be identified in the Local Flood Plan (**Section 12.4.2**) and FloodSafe brochures (**Section 12.4.3**)

12.4.7 EM7 – Improved Flood Access

Improved access can be comprised of various components, including improved vehicular access via public roads, improved pedestrian access to flood refuge areas or improved regional access to key emergency facilities such as hospitals, ambulance services and evacuation centres.

Flooding of access roads was identified in **Section 8** of this document. Roads identified as key access roads are shown in pink. Most of these roads are Classified Roads (Zone SP2). The locations of notable flooding along these roads are listed in **Table 12-4.** Suggested works to improve access have been provided at each location. Detailed investigation and design of works at these locations could be incorporated into current and future works programs for Council and RMS.

Any design and funding of improvements to access along these roads (e.g. road level raising or improved drainage) could be done in partnership with RMS.

Some locations may have flooding improvements as a result of the structural options outlined in the preliminary options reports (Appendix D) and this will need to be considered with regards to undertaking more than one proposed set of works in the same location.

Table 12-4 Locations for Access Improvements

Location ID	Road	5 Year ARI (m depth)	100 Year ARI m depth)	Suggested Improvements / Works
1	Parramatta Road / Flood Street	1.20	1.70	Significant road raising and associated cross drainage works to ensure conveyance of flows and no impacts on flood levels upstream or downstream.

Location ID	Road	5 Year ARI (m depth)	100 Year ARI m depth)	Suggested Improvements / Works
2	Tebbutt Street	0.55	0.88	Moderate road raising and associated cross drainage works to ensure conveyance of flows and no impacts on flood levels upstream or downstream.
6	Foster Street	0.26	0.41	Improved cross drainage and possible resurfacing of road to slightly increase road height.
14	Norton Street	0.21	0.28	Improved cross drainage with minor increase in road surface level. Or retain flows in Pioneers Memorial Park to reduce overtopping of Norton Street.
18	Charles Street	0.52	0.76	Moderate road raising and associated cross drainage works to ensure conveyance of flows and no impacts on flood levels upstream or downstream.
19	Darley Road	0.64	1.15	Significant road raising and associated cross drainage works to ensure conveyance of flows and no impacts on flood levels upstream or downstream.
20	Norton Street	0.31	0.39	Improved cross drainage and possible resurfacing of road to slightly increase road height.
21	Balmain Road	0.54	0.76	Moderate road raising and associated cross drainage works to ensure conveyance of flows and no impacts on flood levels upstream or downstream.
45	Johnston Street	0.43	0.50	Moderate road raising and associated cross drainage works to ensure conveyance of flows and no impacts on flood levels upstream or downstream.
46	The Crescent / Trafalgar Street	0.59	0.80	Moderate road raising and associated cross drainage works to ensure conveyance of flows and no impacts on flood levels upstream or downstream.
47	Brenan Street	0.38	1.13	Significant increases in road levels are unlikely to be able to be accommodated at these locations due to driveway access and property frontages. The feasibility of increasing the road height by 0.5m will be investigated. This would provide flood free access in more frequent events and reduced flood depths in larger events.
48	Railway parade	0.47	1.40	
63	Robert Street	0.58	0.80	Moderate road raising and associated cross drainage works to ensure conveyance of flows and no impacts on flood levels upstream or downstream.
72	Canal Road	0.64	0.82	The ability to raise road levels at this location is limited due to the rail overpass. Increased drainage capacity is likely to be limited by flow rates into Hawthorne Canal downstream. A more detailed investigation of this site is recommended as a priority. A short term solution may involve the use of a pump out system to clear this location following rainfall.

12.5 Design Practices in Flood Affected Areas

In addition to the flood modification, planning and emergency response measures identified in this study, improvements to flood behaviour can often be achieved at a particular location as part of otherwise unrelated works, such as road resurfacing, kerb and gutter reconstruction, park improvements, etc. To the contrary, such works also have the potential to create or worsen existing flooding problems if not designed carefully.

Following are typical examples of common works undertaken by Council, whether generated by Capital Improvement or Renewal programs, which have the potential to cause positive or negative impacts on existing flooding behaviour:

- Road resurfacing should be undertaken in a manner that does not reduce flow capacity in the kerb and gutter. In flood affected areas, the existing road profile should be assessed to determine whether the flow capacity can actually be improved.
- When considering changes to on street parking arrangements, such as introducing angled parking, measures should be considered to reduce the potential for car tyres obstructing gutter flow; such as wheel stops.
- When introducing traffic devices or landscaping elements into a roadway, the impacts on flow capacity should be considered, particularly in flood affected areas.
- Kerb and gutter construction or renewal provides an opportunity to increase flow capacity when it is feasible to increase the kerb height.
- When undertaking works within parks and reserves, the implications of any redirection of surface waters should be carefully considered. In flood affected areas, there may be potential to positively modify flood behaviour by redirecting flows.

Council should review relevant policies and design practices to ensure that such issues are considered during the concept development and design stages of capital and renewal projects.

12.6 Data Collection Strategies

Though it does not fall within any of the three modification categories that are explored as options above, the collection of post-flood data is recommended as part of this FRMS. In addition to this, it is recommended that the data collection be expanded to create information that will help the community to better understand the flood event and general catchment flood behaviour. This may include the collection / determination of data such as:

- The approximate recurrence interval of the rainfall intensity and peak river / creek flows;
- The approximate recurrence interval of any major over ground flooding;
- A comparison of the storm event with previous historical events and design events. Comparison could be made against rainfall, flows or depths;
- Timings of peak flows or levels; and,
- The timing and duration of road overtopping / closures.
- Photographic evidence of peak depths based on debris markings or reported sightings (for example, “the water came up to the top of this step”)

Following the development of the post-flood collection strategy, a post-flood information mail-out should be developed to pass this information on to the community. The purpose of presenting this data to the community is to allow them to relate their recent flood experience to other historical events and to design events.

Being able to compare their recent flood experience with predicted flows and levels from a 100 Year ARI or PMF event, would give them a greater understanding of what such an event would look like, and what would be required for them to be safe in such an event.

It is particularly difficult to assign tangible economic, social and environmental benefits as the benefits are in the form of various flow on effects. Therefore, data collection has not been assessed as part of the Multi-Criteria-Assessment.

13 Multi Criteria Assessment

13.1 Overview

To assist Council in identifying the flood mitigation options that provide the most benefits for the community, all options across the entire study area need to be compared against each other based on factors including but not limited to the reduction in flood risk and economic flood damages.

Evaluating what constitutes an appropriate strategy for floodplain management is a significant analytical and policy challenge. Impacts associated with flooding include risk to assets and also risk to life. Urban areas impacted by flooding are valued in a number of ways by communities, organisations and individuals. Such challenges have led to the exploration of alternative policy analysis tools, one being Multi Criteria Assessments (MCA). The goal of MCA is to attempt to directly incorporate multiple values held by stakeholders into the analysis of management alternatives while avoiding the reduction of those values into a standard monetary unit. In so doing, one can consider different floodplain management options in the context of economic criteria as well as other criteria such as social, political or environmental aspects. Stakeholders can also assign explicit weights to those values to reflect their preferences and priorities. Therefore, MCA provides opportunities for the direct participation of stakeholders in the analysis.

A Multi Criteria Assessment approach has been developed for the comparative assessment of all floodplain management options identified within the study area using a similar approach to that recommended in the Floodplain Development Manual (2005) as well as using concepts established by the Sydney Coastal Councils Group (SCCG) as discussed in **Section 2.1**. This approach uses a subjective scoring system to assess the merits of various options. The principal merits of such a system are that it allows comparisons to be made between alternatives using a common index. In addition, it makes the assessment of alternatives “transparent” (i.e. all important factors are included in the analysis). However, this approach does not provide an absolute “right” answer as to what should be included in the plan and what should be omitted. Rather, it provides a method by which stakeholders can re-examine options and, if necessary, debate the relative scoring assigned.

Each option is given a score according to how well the option meets specific considerations. A framework for scoring has been developed for each criterion.

13.2 Scoring System

A scoring system was devised to subjectively rank each measure for a range of criteria considering the background information on the nature of the catchment and floodplain. The scoring is based on a triple bottom line approach incorporating economic, social and environmental criterion.

Each of the criteria has been given a weighting to reflect its importance with regards to floodplain management. This weighting was developed in discussion with Council and the Flood Management Advisory Committee and will also be reviewed with regards to submissions received from the public during the public exhibition period (see **Section 4.1**).

Scoring systems were developed separately for *Flood Modification Options* and *Emergency Management and Property Modification* works. The criteria adopted, scoring system applied and the relevant weightings for both of these systems are shown in **Tables 13-1 and 13-2**.

Table 13-1 Multi-criteria Matrix Scoring System – Flood Modification Options

Category	Category Weighting	Category Factor	Criteria	Criteria Weighting	Metric	-4	-3	-2	-1	0	1	2	3	4
Economic	4	1.3	Benefit Cost Ratio	5	Comparison of economic benefits against the capital and operating costs.	< -2	-1 to -2	-0.5 to -1	0 to -0.5	0	0 to 0.5	0.5 to 1	1 to 2	> 2
			Implementation Complexity	3	Implementation or construction timeframe and challenges	Implementation timeframe greater than 1 year with major constraints, challenges and uncertainties which may render the option unfeasible	Implementation timeframe greater than 1 year with significant constraints, challenges and uncertainties which may increase costs or timeframes significantly	Implementation timeframe 6 months to 1 year with some significant constraints and challenges which may increase costs or timeframes significantly	Implementation timeframe 6 months to 1 year with some significant constraints and challenges which may increase costs or timeframes slightly	NA	Implementation timeframe less than 6 months with significant constraints, challenges and uncertainties which may increase costs or timeframes significantly	Implementation timeframe less than 6 months with constraints, challenges and uncertainties which may increase costs or timeframes slightly	Implementation timeframe less than 6 months. No constraints or challenges.	No construction requirements (e.g. planning related option)
			Staging of Works	3	Ability to stage proposed works	NA	NA	NA	NA	Works cannot be staged	Some minor components of the works may be staged	Significant components of the works can be staged	NA	NA
Social	4	1.0	Reduction in risk to life and social impacts	5	Change in number of properties with over floor flooding in 100 Year ARI event	Increase greater than 1 property	NA	NA	NA	No change	Reduction: 1 to 5 properties	Reduction: 6 to 10 properties	Reduction: 11 to 15 properties	Reduction: Greater than 15 properties
			Emergency Access and Social Disruption	4	Flood depth and duration changes for critical transport routes in 100 Year ARI event	Key access roads become flooded that were previously flood free	Significant increase in main road flooding	Moderate increase in local or main road flooding	Minor increase local or main road flooding	No Change	Minor decrease local or main road flooding	Moderate decrease in local or main road flooding	Significant decrease in main road flooding	All roads flood free in vicinity of option
			Compatibility of proposed works / option with Council Plans & Policies	3	Level of compatibility	Conflicts directly with objectives of several plans and policies	Some conflicts with several objectives or direct conflicts with one or few objectives	Some conflicts with one or few objectives	Minor conflicts with one or very few objectives	Not relevant to objectives	Minor support for one or very few objectives	Some support for one or few objectives	Some support for several objectives or achieving one or few objectives	Achieving objectives of several plans and policies
			Community and Stakeholder Support	3	Level of agreement	NA	Strong opposition by numerous submissions	Moderate opposition in several submissions	Individual submissions with opposition	No responses	Individual submissions with support	Moderate support in several submissions	Strong support by numerous submissions	NA
Environmental	3	0.5	Heritage Conservation Areas and Heritage Items	3	Impacts to heritage items identified in the FRMS	Likely Impact on State, National or Aboriginal heritage Item	Likely impact on local heritage item	Likely impact on contributory item within a heritage conservation area	Minor impact on a contributory item within a heritage conservation area	No impact	Reduces impact of flooding on heritage item or heritage conservation area	Positive contribution to heritage item or heritage conservation area	NA	NA
			Flora / Fauna Impacts – including Street Trees	3	Impacts or benefits to flora / fauna	Likely impacts on threatened species	Likely broad-scale vegetation / habitat impacts	Likely isolated vegetation / habitat impacts	Removal of isolated trees, minor landscaping	No impact or unknown	Planting of isolated trees or minor landscaping	Likely isolated vegetation / habitat benefits	Likely broad-scale vegetation / habitat benefits	Broad-scale vegetation / habitat benefits and benefits for threatened species

Category	Category Weighting	Category Factor	Criteria	Criteria Weighting	Metric	-4	-3	-2	-1	0	1	2	3	4
			Acid Sulfate Soils	3	Disruption of PASS	NA	NA	Any work within Class 1 ASS area. Any excavation work within Class 2 ASS area. Excavation >1m within Class 3 ASS area. Excavation >2m within Class 4 ASS area.	Surface works within Class 2 ASS area. Excavation <1m or surface works within Class 3 ASS area. Excavation <2m or surface works within Class 4 ASS area.	Works not within areas identified as PASS	NA	NA	NA	NA
			Contaminated Land	3	Disruption of Contaminated Land	NA	Excavation works at contaminated land site	Surface works at contaminated land site	Works adjacent to contaminated land sites	Works not near contaminated land sites	NA	NA	NA	NA
			Visual Impact	3	Impact of completed works on visual amenity	Complete loss of existing valued visual amenity	NA	Partial loss of existing valued visual amenity	NA	No Change	NA	Moderate improvement to visual amenity	NA	Significant improvement to visual amenity
			Recreation Space	3	Impact on passive/active recreational areas	NA	Significant reduction in recreational space	Minor reduction in recreational space	Loss of recreational opportunity	No impact	Embellishment of existing recreational space	Opportunities for additional recreational space/uses within	Minor increase in recreational space	Significant creation of additional recreational space

Table 13-2 Multi-criteria Matrix Scoring System – Emergency Response and Property Modification Options

Category	Category Weighting	Category Factor	Criteria	Criteria Weighting	Metric	-4	-3	-2	-1	0	1	2	3	4
Economic	4	0.8	Likely Reduction in Flood Damages	5	Change in Annual Average Damage	> $2M	$1M to $2M	$500,000 to $1M	< $500,000	No Change	> -$500,000	-$500,000 to -$1M	-$1M to -$2M	< -$2 M
			Capital Cost	4	Capital Cost of Option	Greater than $1M	$500,000-$1M	$50,000-$500,000	$0-$50,000	Existing infrastructure or council policy continued	NA	NA	NA	NA
			Operating and Maintenance Cost	4	Annual Operating Cost of Option	Greater than $500,000	$50,000-$500,000	$5,000-$50,000	Less than $5,000	No additional ongoing costs	NA	NA	NA	NA
			Implementation Complexity	3	Implementation or construction timeframe and challenges	Implementation timeframe greater than 1 year with major constraints, challenges and uncertainties which may render the option unfeasible	Implementation timeframe greater than 1 year with significant constraints, challenges and uncertainties which may increase costs or timeframes significantly	Implementation timeframe 6 months to 1 year with some significant constraints and challenges which may increase costs or timeframes significantly	Implementation timeframe 6 months to 1 year with some significant constraints and challenges which may increase costs or timeframes slightly	NA	Implementation timeframe less than 6 months with significant constraints, challenges and uncertainties which may increase costs or timeframes significantly	Implementation timeframe less than 6 months with constraints, challenges and uncertainties which may increase costs or timeframes slightly	Implementation timeframe less than 6 months. No constraints or challenges.	No construction requirements (e.g. planning related option)
			Staging of Works	3	Ability to stage proposed works	NA	NA	NA	NA	Works can not be staged	Some minor components of the works may be staged	Significant components of the works can be staged	NA	NA
Social	4	1	Increased Awareness	5	Level of likely increased awareness	NA	NA	NA	NA	No increased awareness of flooding and appropriate response	NA	NA	Increased awareness likely to protect property	Increased awareness likely to protect life
			Improved Response	5	NA	NA	NA	NA	NA	No change	NA	NA	Additional flood data available to response agencies	Improved flood response arrangements
			Emergency Access	4	Flood depth and duration changes for critical transport routes in 100 Year ARI event	Key access roads become flooded that were previously flood free	Significant increase in main road flooding	Moderate increase in local or main road flooding	Minor increase local or main road flooding	No Change	Minor decrease local or main road flooding	Moderate decrease in local or main road flooding	Significant decrease in main road flooding	All roads flood free in vicinity of option
			Reduction in risk to life	5	NA	NA	NA	NA	NA	No Change	May indirectly Reduce Risk to Life	NA	Likely to reduce injury.	Likely to save lives
			Compatibility of proposed works / option with Council Plans & Policies	3	Level of compatibility	Conflicts directly with objectives of several plans and policies	Some conflicts with several objectives or direct conflicts with one or few objectives	Some conflicts with one or few objectives	Minor conflicts with one or very few objectives	Not relevant to objectives	Minor support for one or very few objectives	Some support for one or few objectives	Some support for several objectives or achieving one or few objectives	Achieving objectives of several plans and policies
			Community and Stakeholder Support	3	Level of agreement	NA	Strong opposition by numerous submissions	Moderate opposition in several submissions	Individual submissions with opposition	No responses	Individual submissions with support	Moderate support in several submissions	Strong support by numerous submissions	NA

Category	Category Weighting	Category Factor	Criteria	Criteria Weighting	Metric	-4	-3	-2	-1	0	1	2	3	4
Environmental	3	0.5	Heritage Conservation Areas and Heritage Items	3	Impacts to heritage items identified in the FRMS	Likely Impact on State, National or Aboriginal heritage Item	Likely impact on local heritage item	Likely impact on contributory item within a heritage conservation area	Minor impact on a contributory item within a heritage conservation area	No impact	Reduces impact of flooding on heritage item or heritage conservation area	Positive contribution to heritage item or heritage conservation area	NA	NA
			Flora / Fauna Impacts – including Street Trees	3	Impacts or benefits to flora / fauna	Likely impacts on threatened species	Likely broad-scale vegetation / habitat impacts	Likely isolated vegetation / habitat impacts	Removal of isolated trees, minor landscaping	No impact	Planting of isolated trees or minor landscaping	Likely isolated vegetation / habitat benefits	Likely broad-scale vegetation / habitat benefits	Broad-scale vegetation / habitat benefits and benefits for threatened species
			Acid Sulfate Soils	3	Disruption of PASS	NA	NA	Any work within Class 1 ASS area. Any excavation work within Class 2 ASS area. Excavation >1m within Class 3 ASS area. Excavation >2m within Class 4 ASS area.	Surface works within Class 2 ASS area. Excavation <1m or surface works within Class 3 ASS area. Excavation <2m or surface works within Class 4 ASS area.	Works not within areas identified as PASS	NA	NA	NA	NA
			Contaminated Land	3	Disruption of Contaminated Land	NA	Excavation works at contaminated land site	Surface works at contaminated land site	Works adjacent to contaminated land sites	Works not near contaminated land sites	NA	NA	NA	NA
			Visual Impact	3	Impact of completed works on visual amenity	Complete loss of existing valued visual amenity	NA	Partial loss of existing valued visual amenity	NA	No Change	NA	Moderate improvement to visual amenity	NA	Significant improvement to visual amenity
			Recreation Space	3	Impact on passive/active recreational areas	NA	Significant reduction in recreational space	Minor reduction in recreational space	Loss of recreational opportunity	No impact	Embellishment of existing recreational space	Opportunities for additional recreational space/uses	Minor increase in recreational space	Significant creation of additional recreational space

13.3 Outcomes

The scores and rankings of each of the options is provided in **Appendix F**.

The top five ranking flood modification options are listed in **Table 13-3**. These options all obtained total scores above 50 (of a possible 154.7).

Table 13-3 Top Ranking Flood Modification Options

ID	Description	MCA Score	BCR
WC-FM3	Balmain Road Flow Path – Additional pipe from the low point on Norton St to the existing pipe network (towards Parramatta Rd). Duplication of existing pipe network or extra pipes from Balmain Rd to Whites Creek Culvert at Hearn St.	64.0	1.59
HC_FM1	Additional pipes /culverts from Parramatta Road to Hawthorne Canal via Beeson Street.	58.8	0.71
WC-FM5	Detention Basin at Mackenzie Street (upstream at the intersection of Mackenzie and Milton St)	58.5	1.85
HC_FM3	Additional pipes/culverts from Elswick Street to Hawthorne Canal (via Regent Street and Darley Road). Also extra pipes at Darley Road to reduce flood depths on the Road.	52.2	0.13
WC-FM1	Whites Creek Culvert – Proposing additional culvert or duplication of existing Whites Creek culvert from Parramatta Rd to the open channel downstream of Moore St (at Wisdom Street). WC-FM2 is included in this option.	50.7	0.21

The outcomes of the multicriteria assessment for property and emergency response modification options are summarised in **Table 13-4 and Table 13-5**.

Table 13-4 Ranked Property Modification Options

Option	MCA Score	MCA Rank
PM9 – Strategic Planning	64.6	1
PM2 – DCP Review for Effective Flood Access	42.8	2
PM3 – DCP 2013 Review for Car Parking Controls	41.8	3
PM1 – Review of LEP Wording	38.3	4
PM4 – Onsite Detention Requirements	36.3	5
PM5 – Flood Planning Level	33.8	6
PM8 – Incentives for Flood Compatible Redevelopment	27.8	7
PM7 – Voluntary House Raising	12.8	8
PM6 – Voluntary House Purchase	11.9	9

Table 13-5 Top Ranking Emergency Response Modification Options

Option	MCA Score	MCA Rank
EM2 – Prepare a Local Flood Plan	65.8	1
EM3 – Public Awareness and Education	49.1	2
EM1 – Information Transfer to SES	40.8	3
EM4 – Early Warning Alert System	22.7	4
EM5 – Flood Warning Signs at Critical Locations	20.1	5
EM6 – Establish Evacuation Centres	11.8	6
EM7 – Improved Flood Access	-3	7
EM2 – Prepare a Local Flood Plan	65.8	1

14 Conclusions and Recommendations

This report presents the findings of the Floodplain Risk Management Study stage of the Flood Risk Management Process for the former Leichhardt LGA (the study area), in accordance with the Floodplain Development Manual (NSW Government, 2005). The investigations undertaken as part of this process identified a number of issues within the floodplain. Based on these issues, a series of floodplain management options were developed and recommended.

The outcomes of the multi-criteria assessment provide a sound basis upon which Council can make decisions about undertaking works, making planning decisions and developing response arrangement to reduce the impact of flooding on property and life. The implementation strategy may not necessarily approach the options from “highest ranking to lowest ranking” but will also need to incorporate various other considerations such as existing works programs, availability of funding and other opportunities to combine floodplain works with other activities.

The options identified as having significant flood risk reductions that also do not have adverse social or environmental impacts will be incorporated into the *Leichhardt Floodplain Risk Management Plan* as proposed management actions. This document will recommend a cost-effective plan to manage flood risk and will outline the process of implementation for recommended management actions within the floodplain.

15 References

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Water Board (1990) *Whites Creek SWC No: 95 Catchment Management Study*, August.

Leichhardt Floodplain Risk Management Study and Plan

FIGURES

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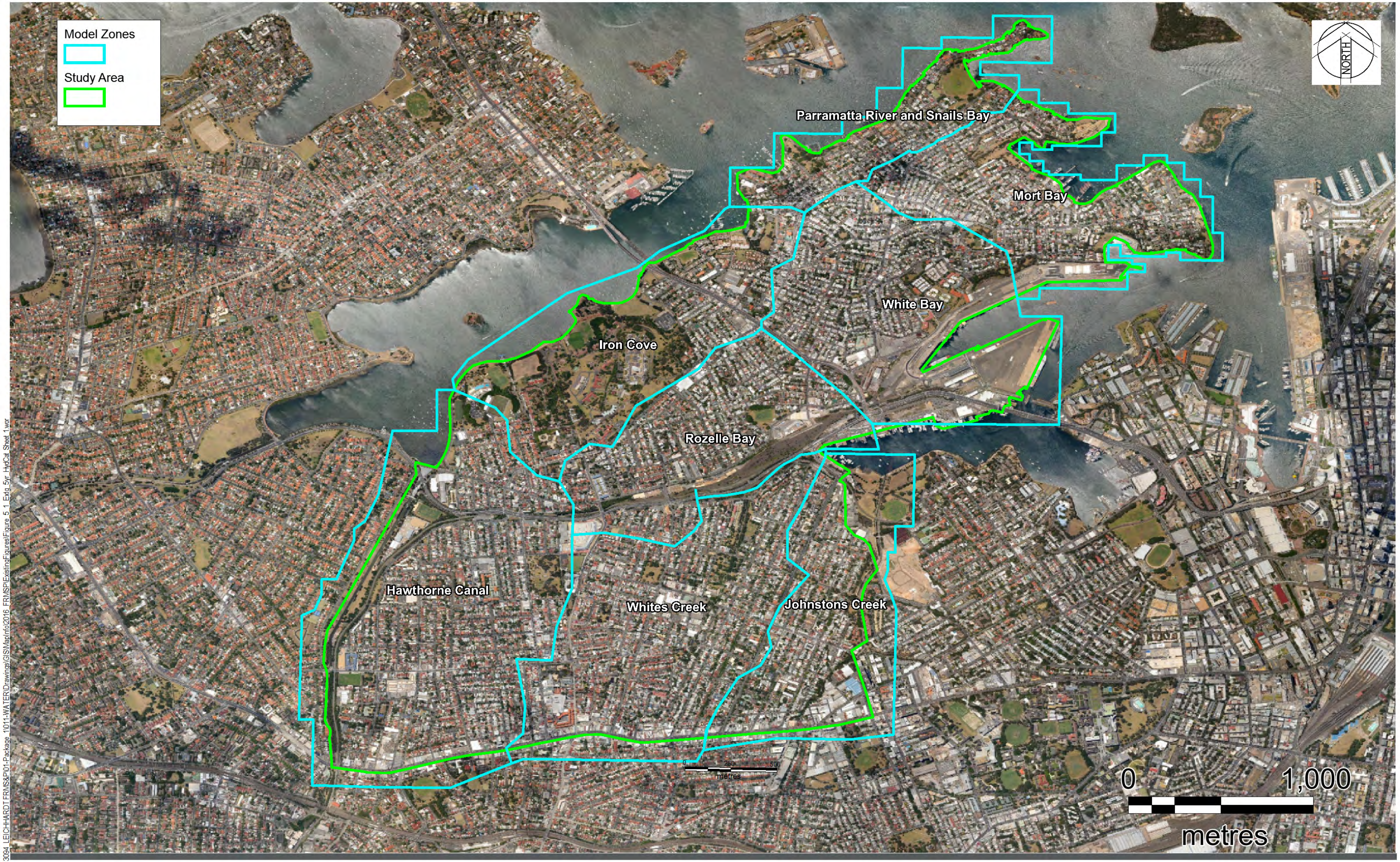

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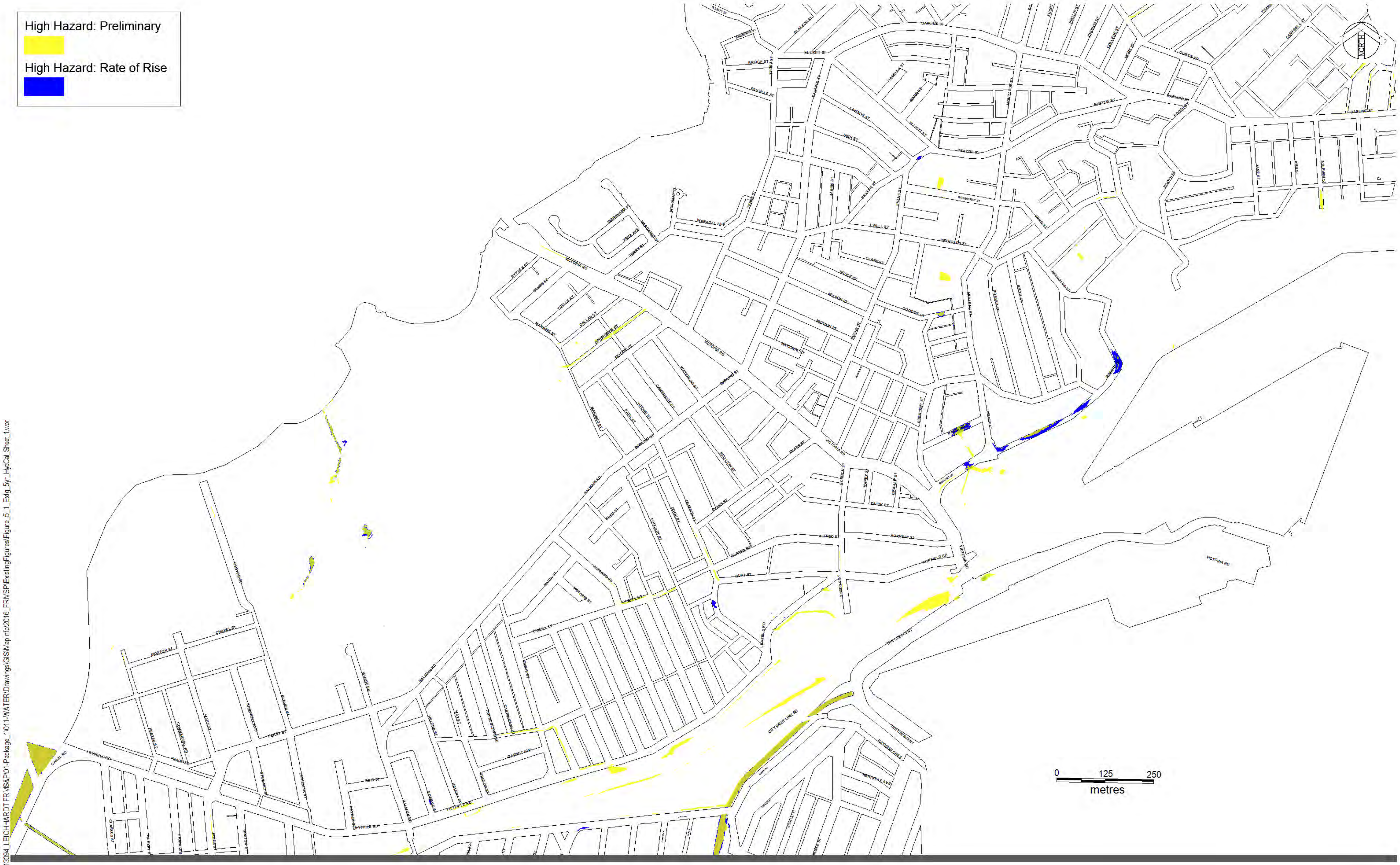

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Leichhardt FRMS&P
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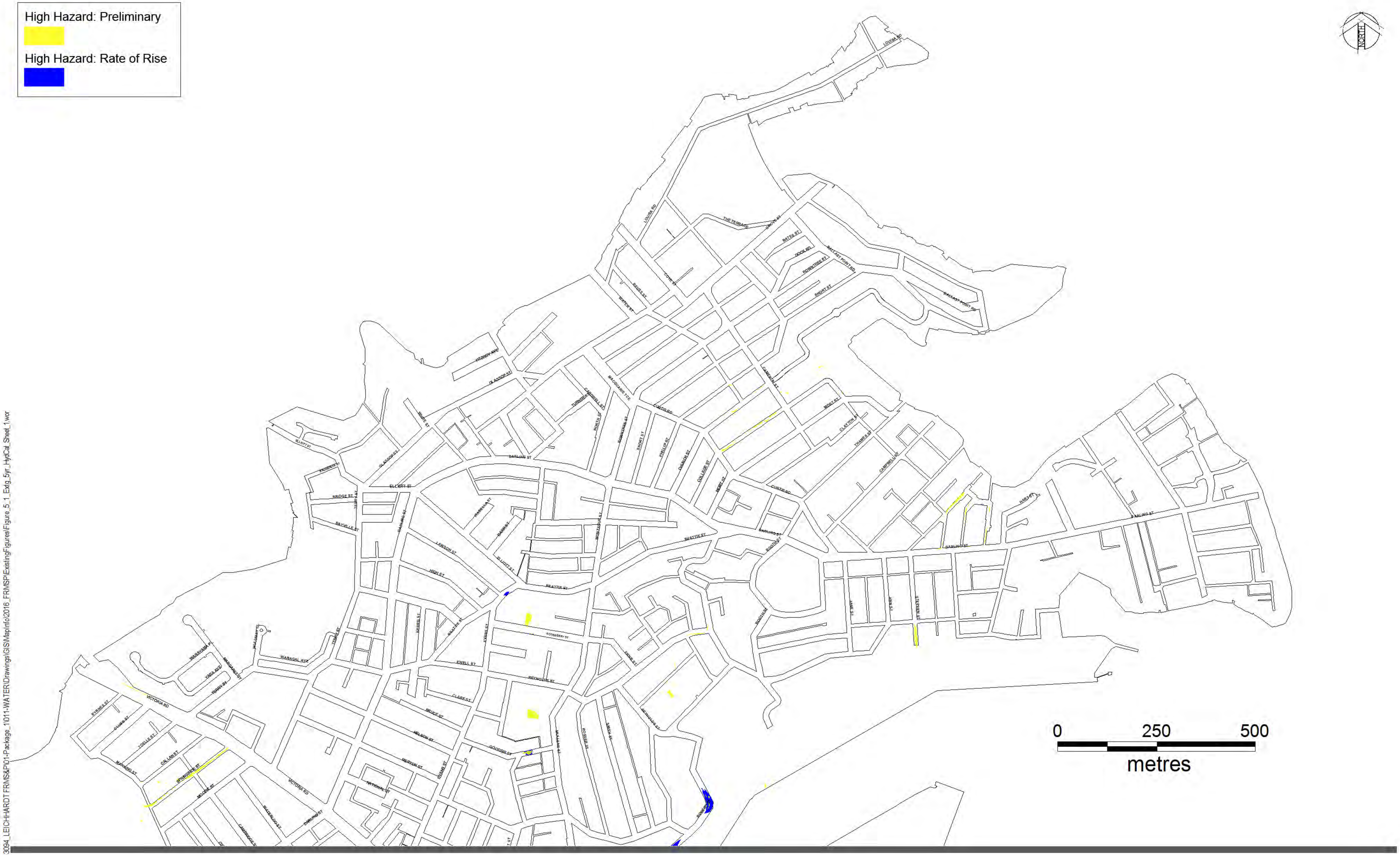

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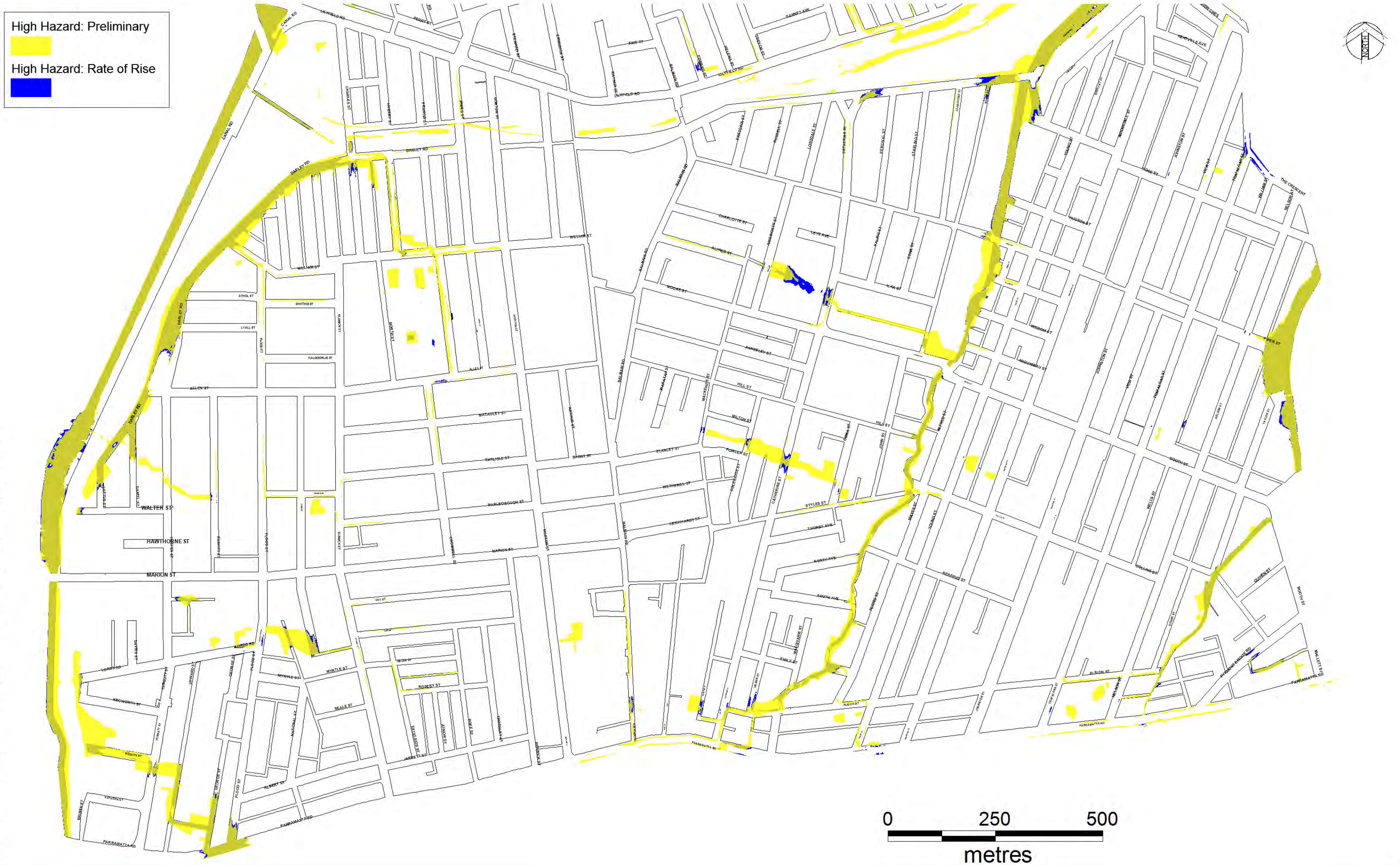

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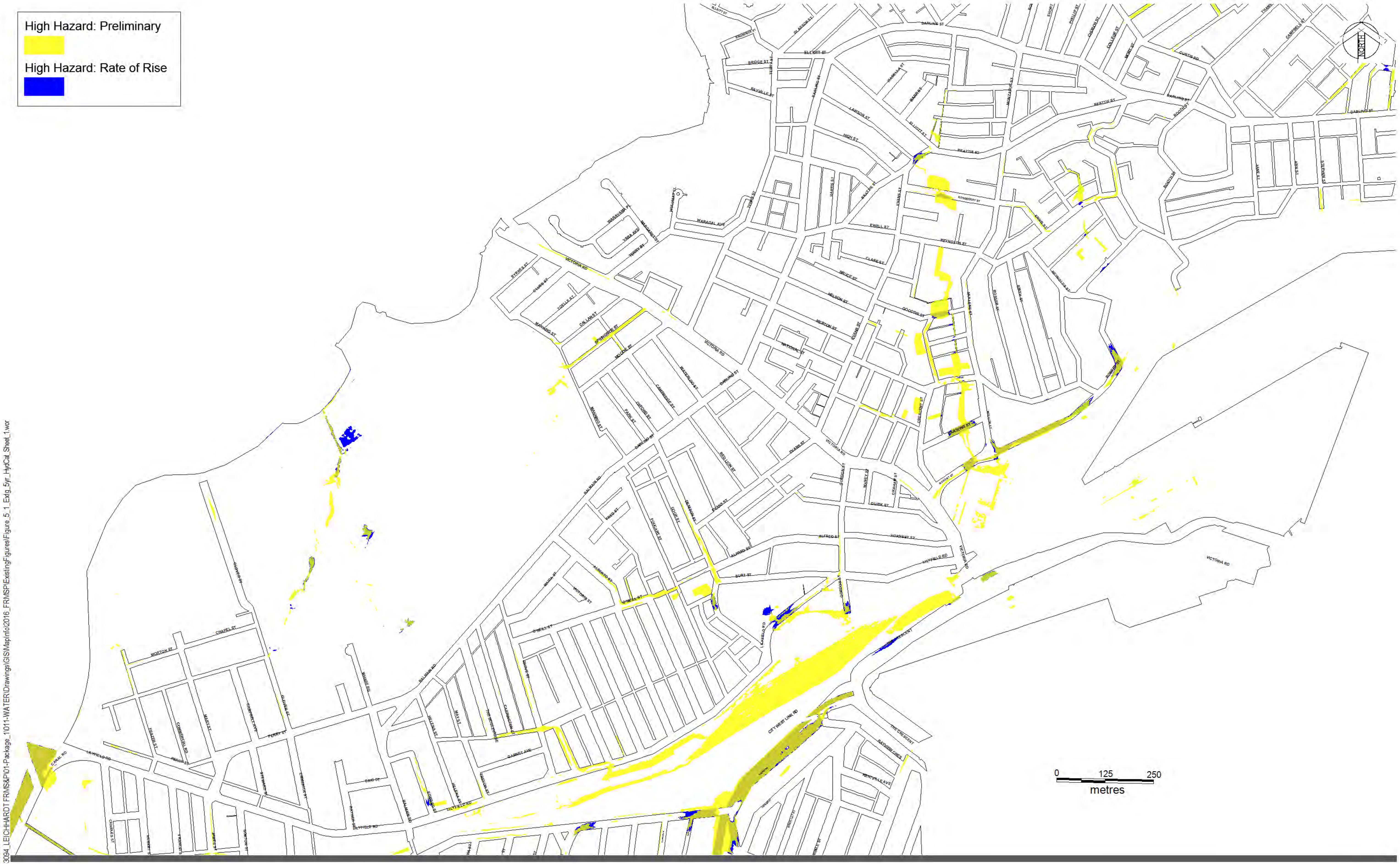

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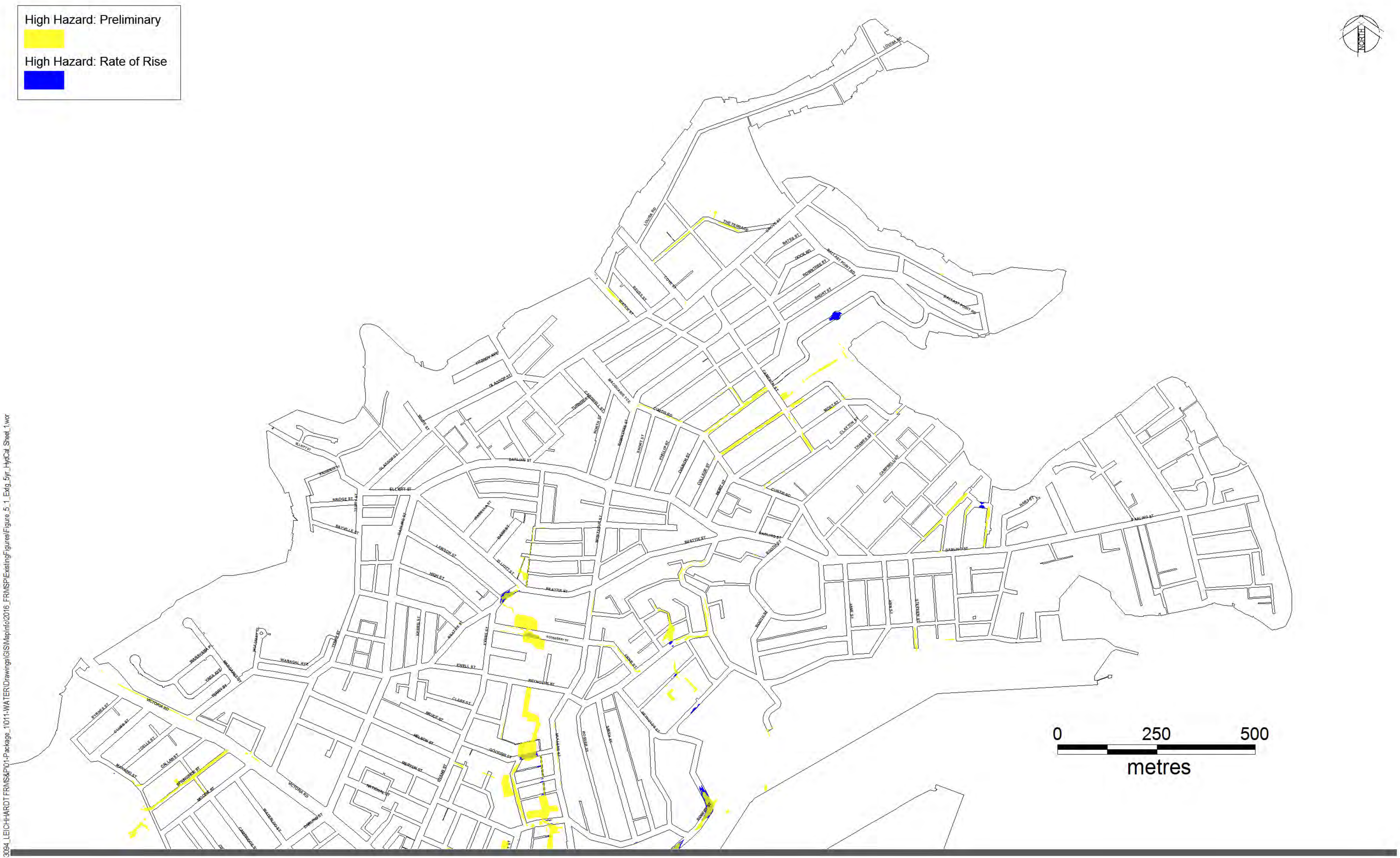

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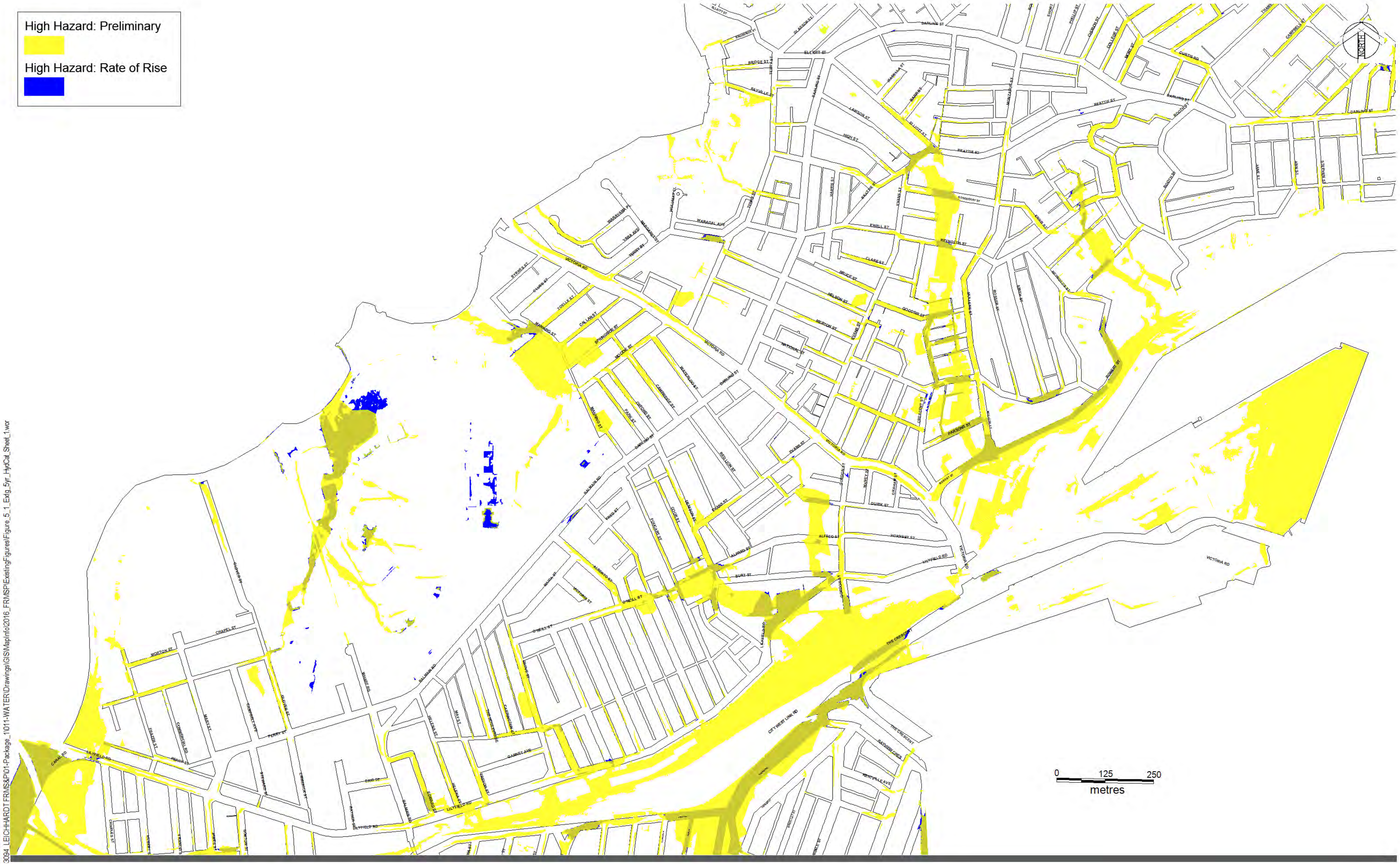

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PMF EVENT RATE OF RISE

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5YR ARI NO EFFECTIVE FLOOD ACCESS
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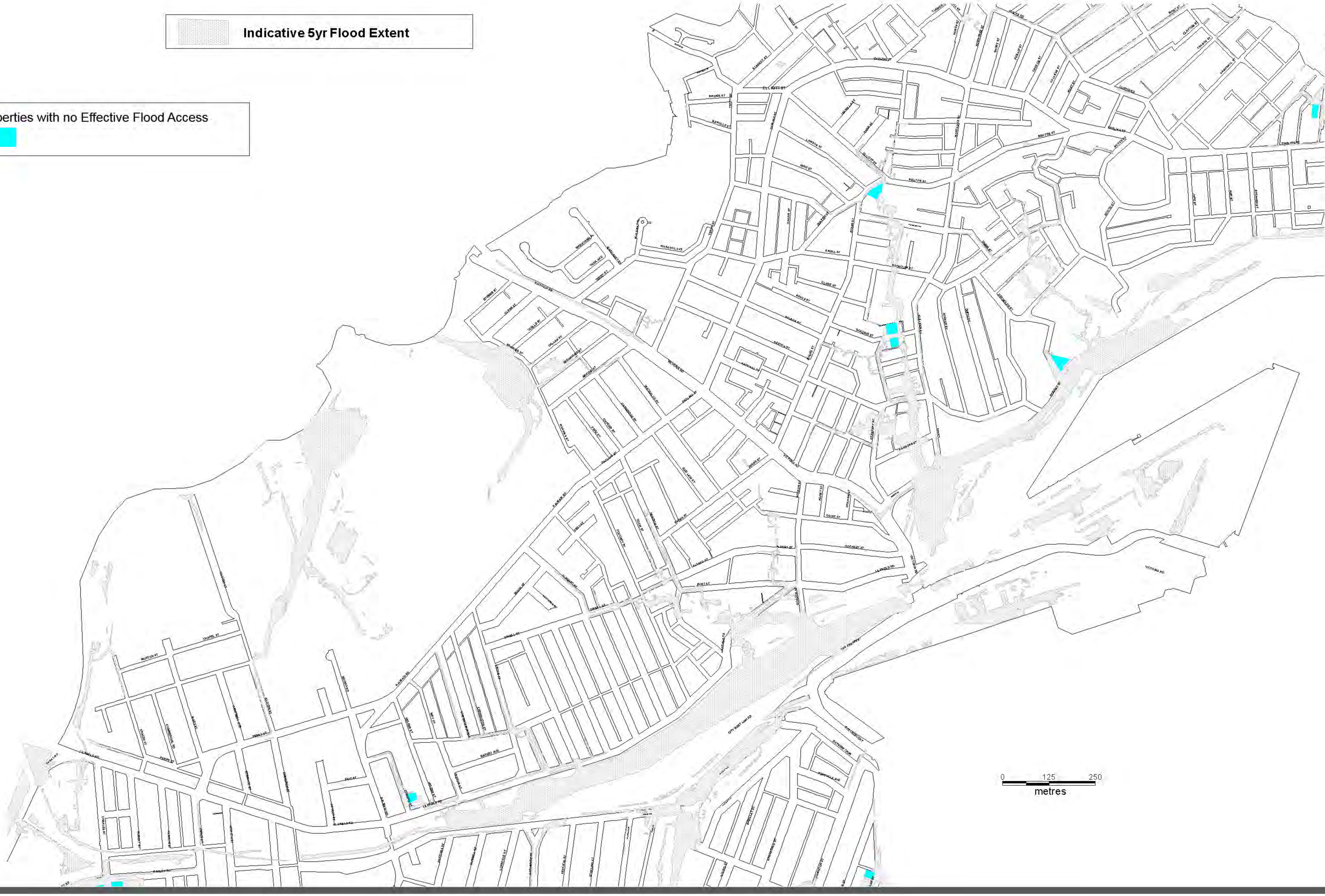

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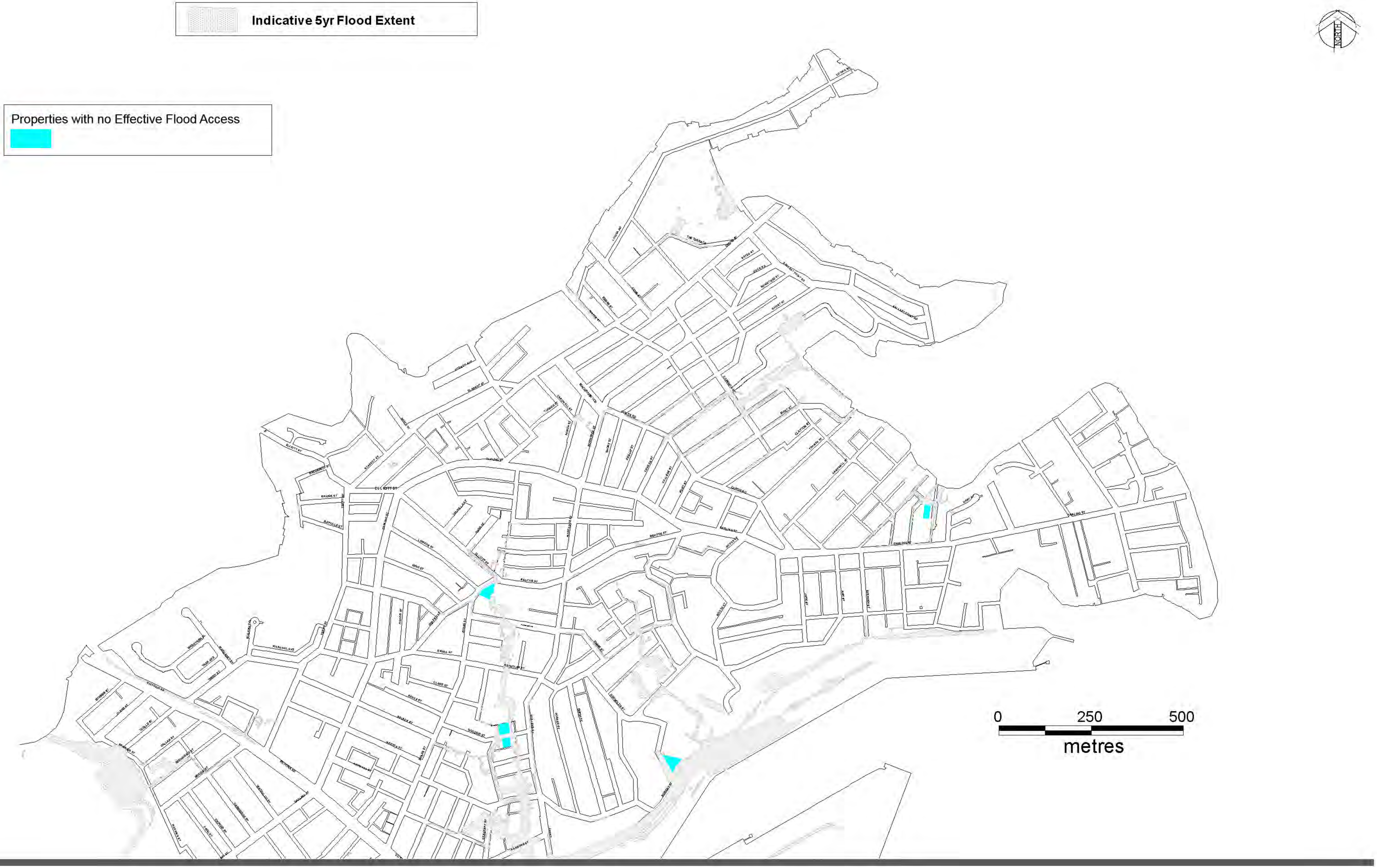

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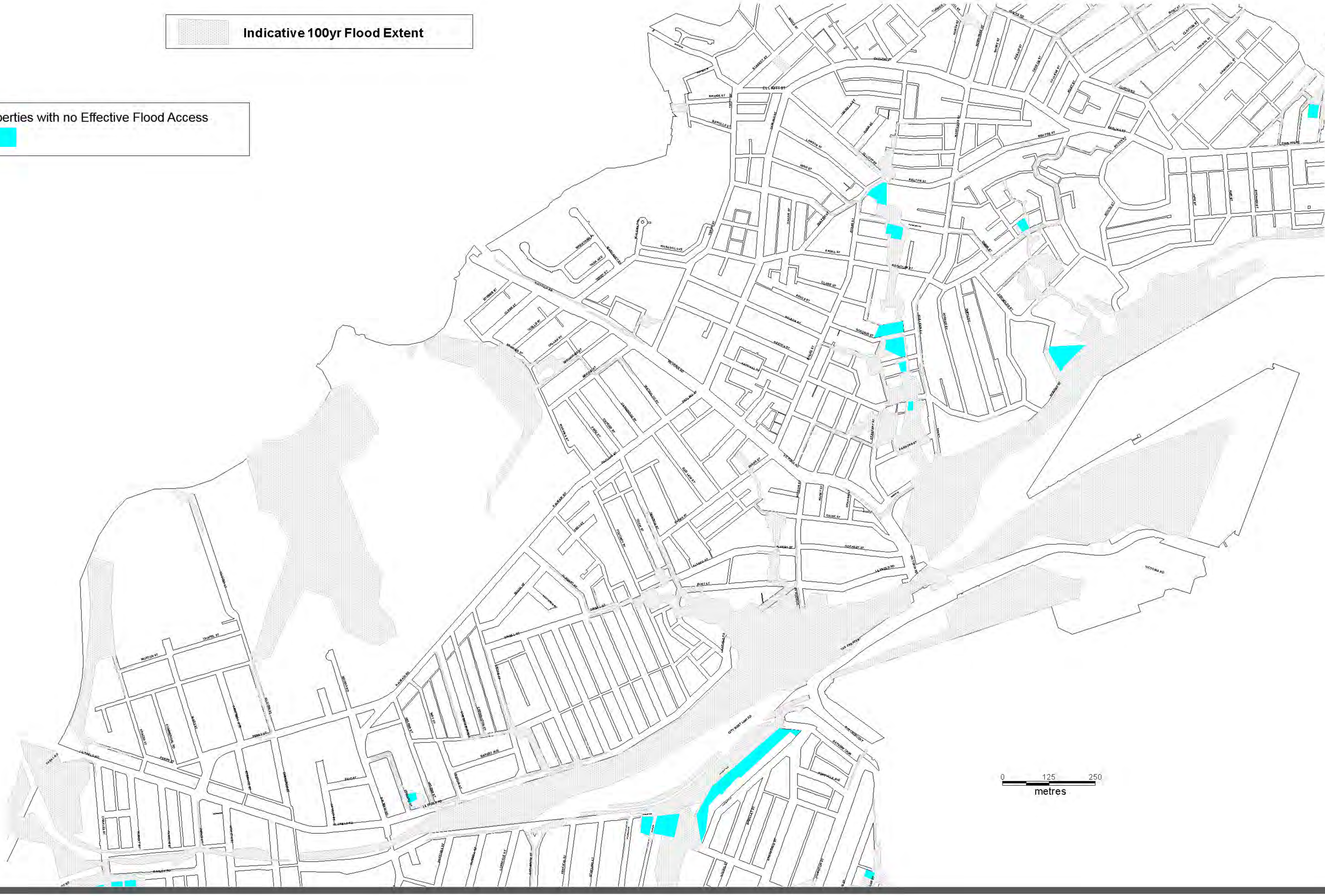

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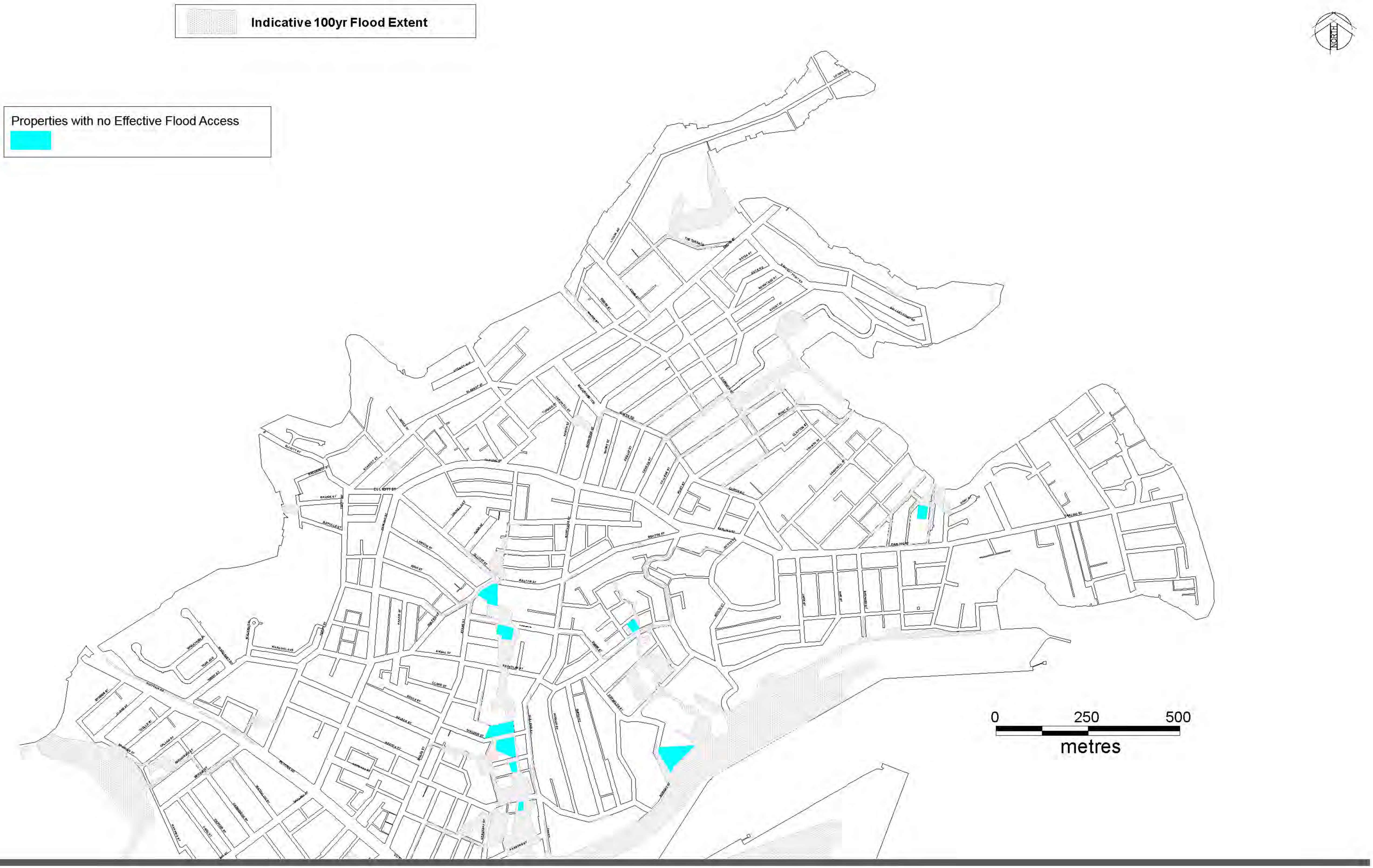

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Inner West Council Leichhardt FRMS&P	Date 2017		Size A3
100YR ARI NO EFFECTIVE FLOOD ACCESS SHEET 3 FIG_5_6_SHEET_3	_100yrARIEffectiveFloodAccess Drawing Number		01 Revision

Inner West Council

Leichhardt FRMS&P

PMF EVENT NO EFFECTIVE FLOOD ACCESS
SHEET 1

FIG_5_7_SHEET_1

Date
2017

_PMFEffectiveFloodAccess
Drawing Number

Size
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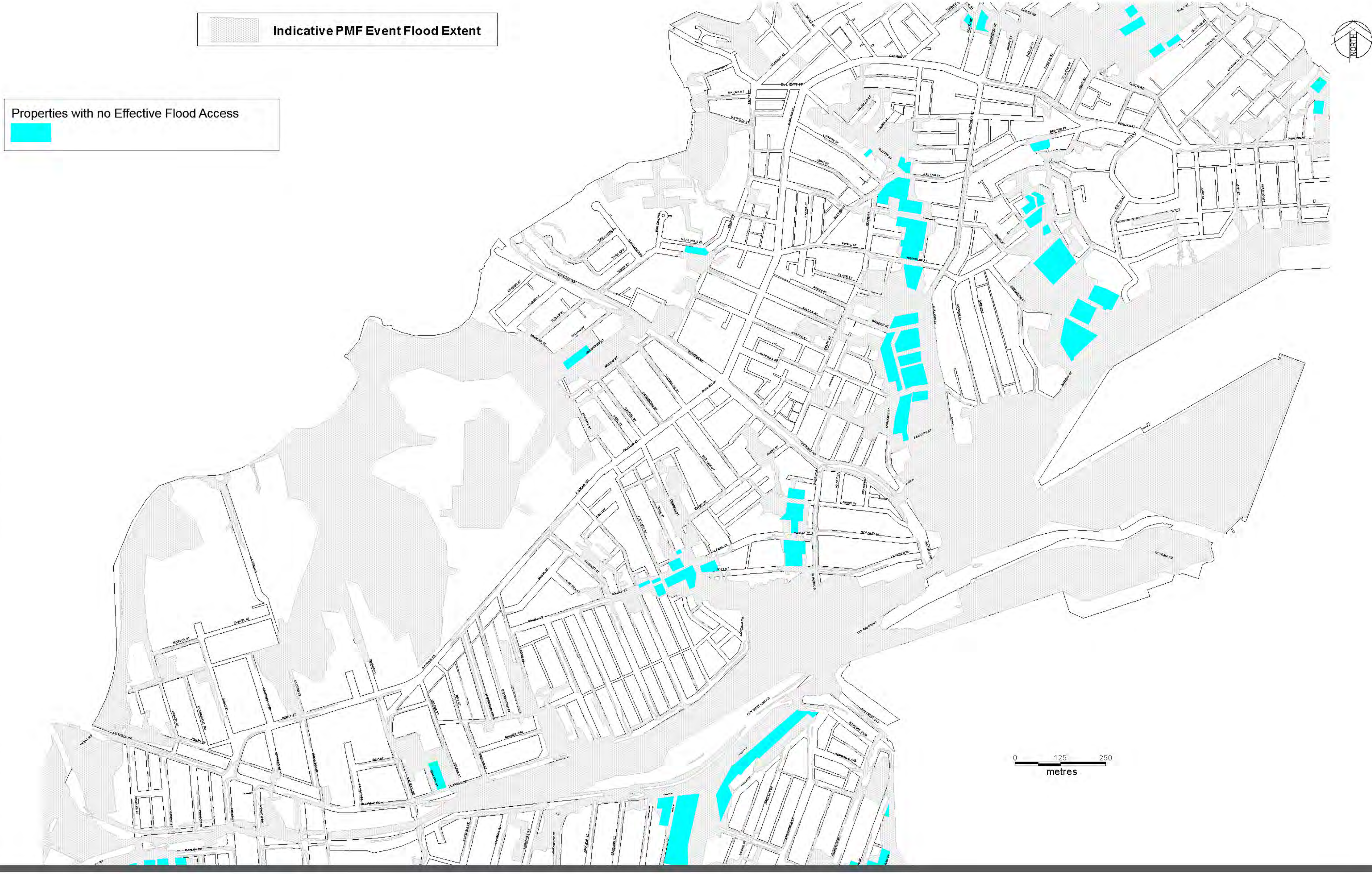

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Leichhardt FRMS&P

PMF EVENT NO EFFECTIVE FLOOD ACCESS
SHEET 2

FIG_5_7_SHEET_2

Date
2017

_PMFEffectiveFloodAccess
Drawing Number

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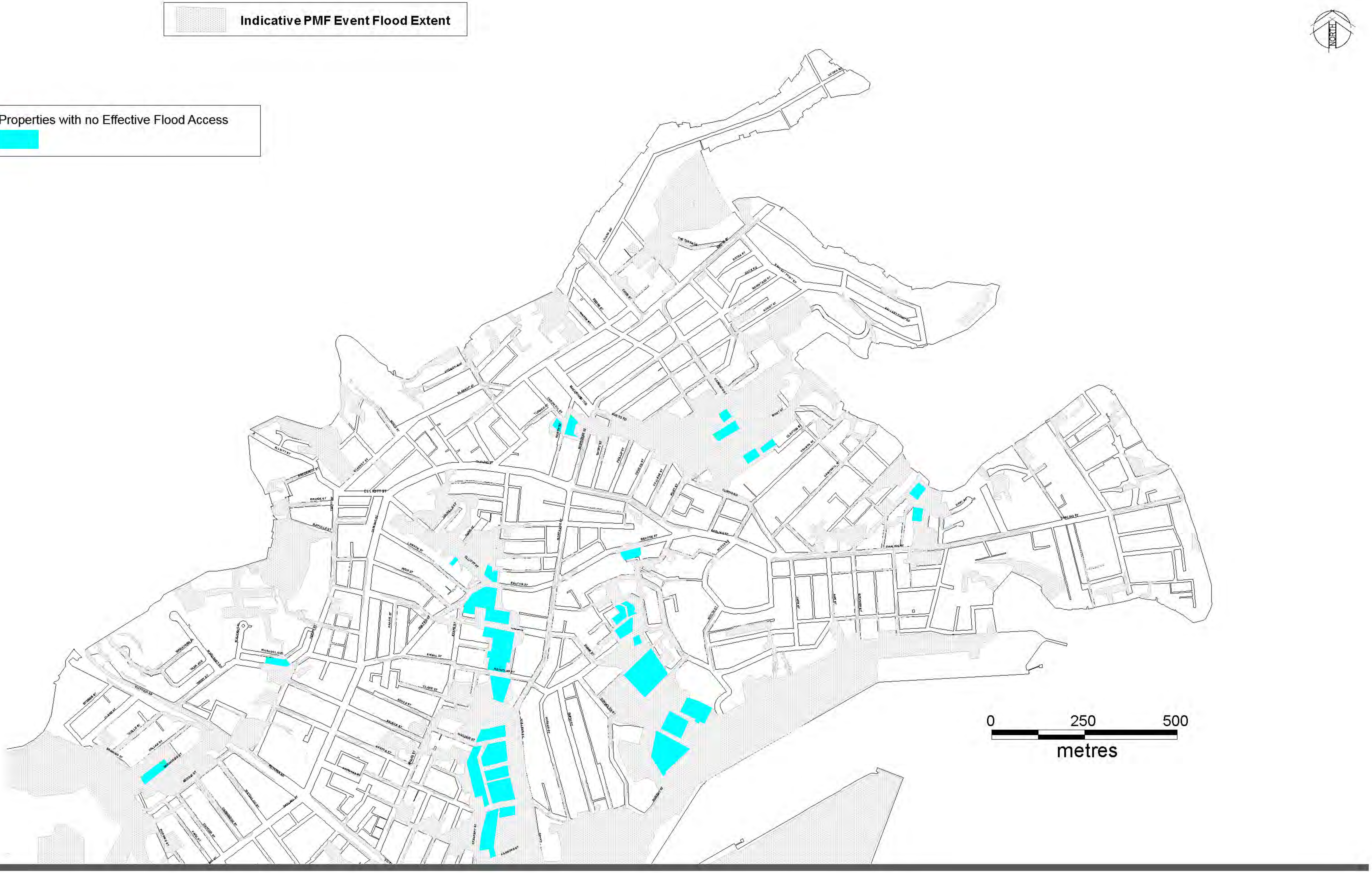

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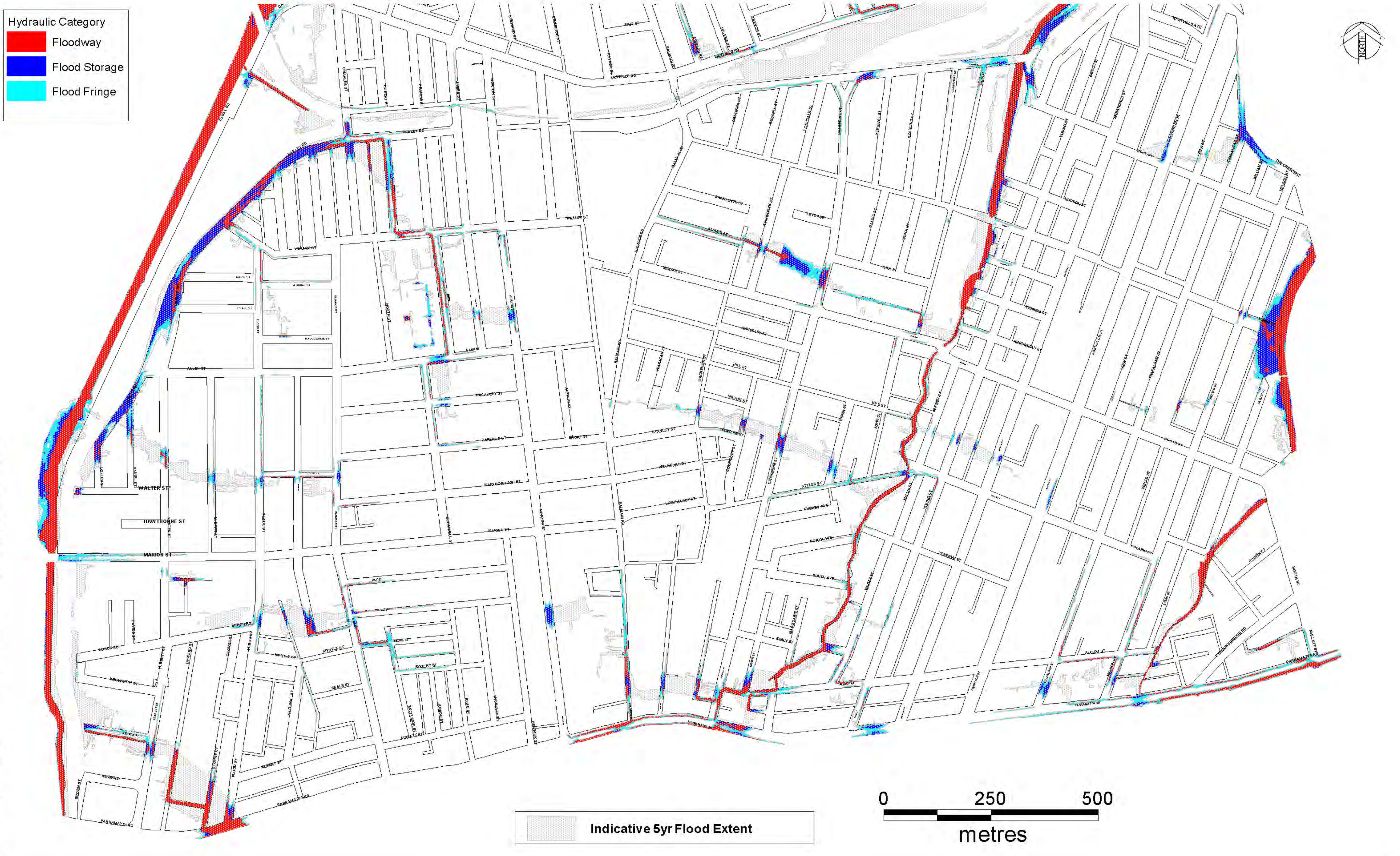
Leichhardt FRMS&P
PMF EVENT NO EFFECTIVE FLOOD ACCESS
SHEET 3
FIG_5_7_SHEET_3

Date
2017

_PMFEffectiveFloodAccess
Drawing Number

Size
A3

01
Revision



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Leichhardt FRMS&P
5YR ARI HYDRAULIC CATEGORIES
SHEET 1
FIG_5_8_SHEET_1

Date
2017

Size
A3

Extg_5yr_HydCat
Drawing Number

01
Revision

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Inner West Council

Leichhardt FRMS&P

5YR ARI HYDRAULIC CATEGORIES
SHEET 2

FIG_5_8_SHEET_2

Date
2017

Size
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Extg_5yr_HydCat
Drawing Number

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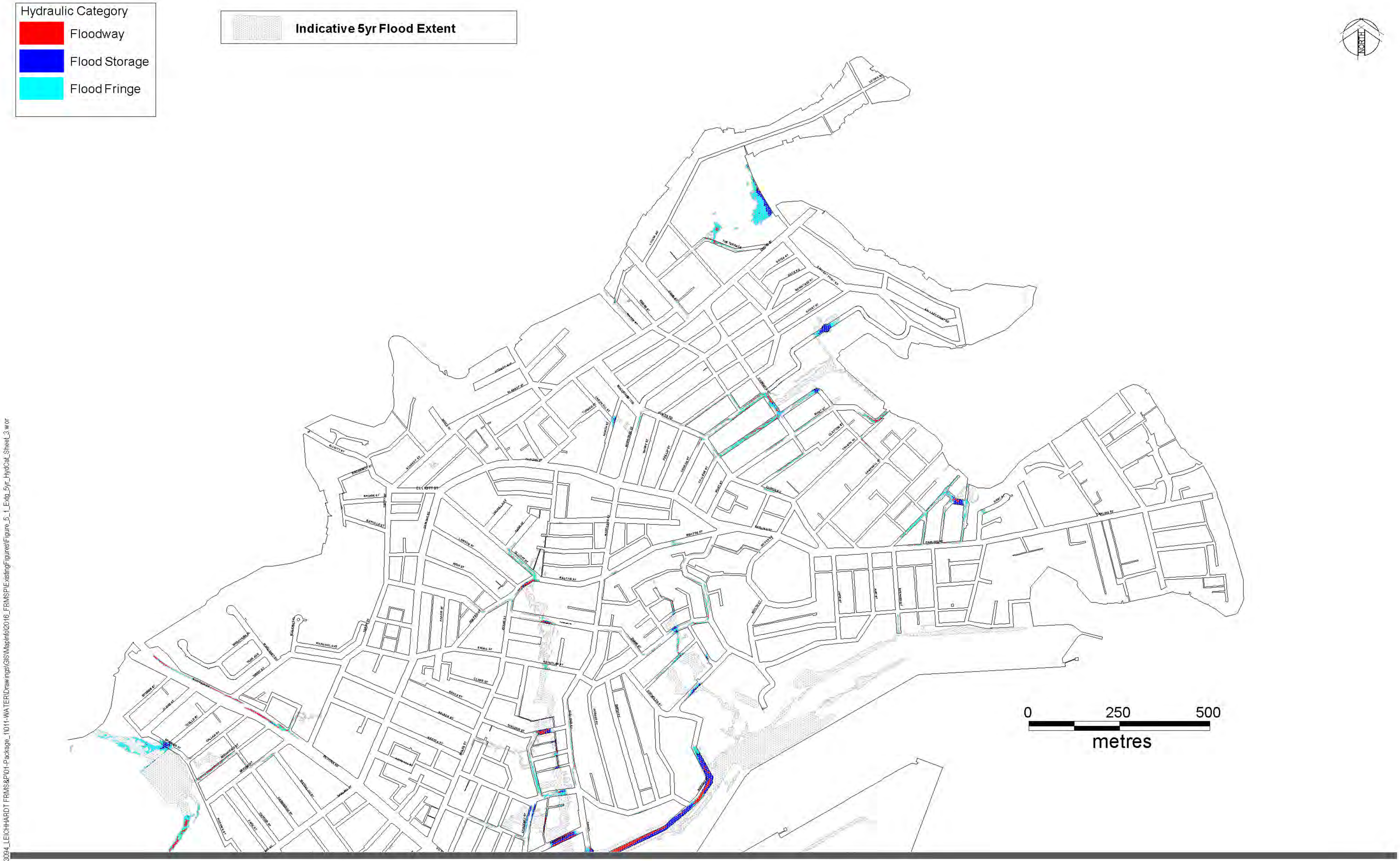

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5YR ARI HYDRAULIC CATEGORIES
SHEET 3
FIG_5_8_SHEET_3

Date
2017

Size
A3

Extg_5yr_HydCat
Drawing Number

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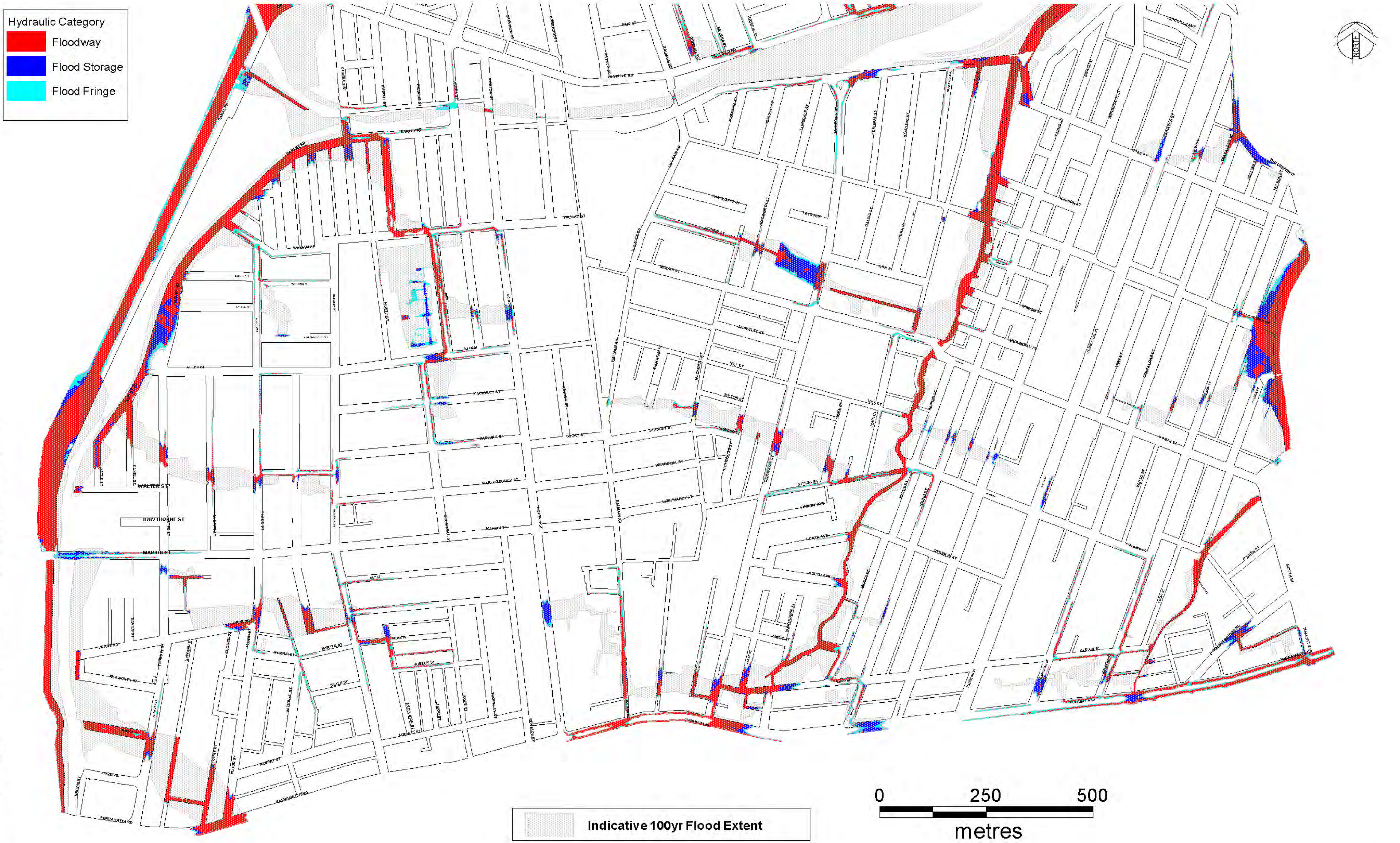

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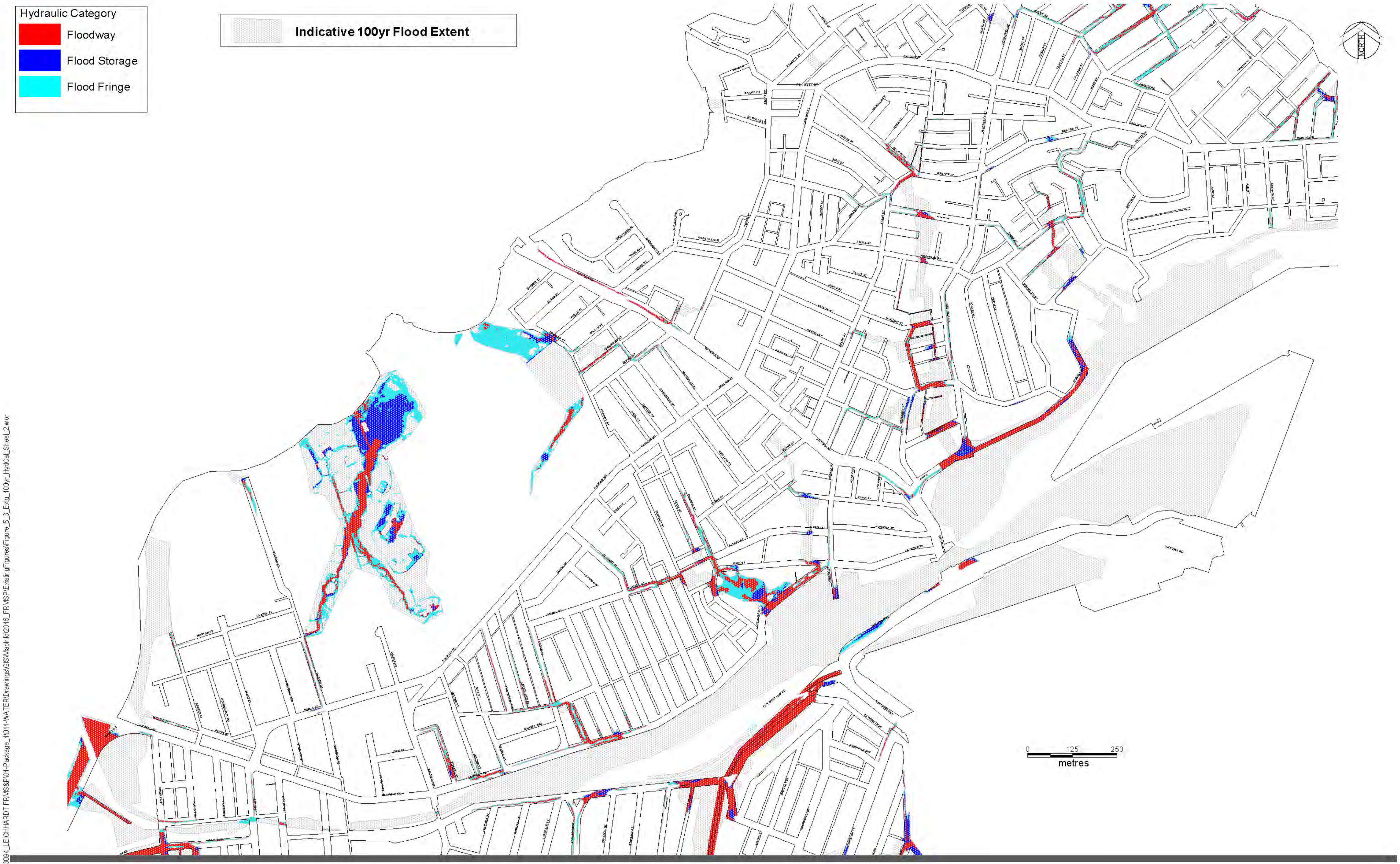
Inner West Council
Leichhardt FRMS&P
100YR ARI HYDRAULIC CATEGORIES
SHEET 1
FIG_5_9_SHEET_1

Date	Size
2017	A3
Extg_100yr_HydCat	01
Drawing Number	Revision



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100YR ARI HYDRAULIC CATEGORIES
SHEET 2
FIG_5_9_SHEET_2

Date
2017

Size
A3

Extg_100yr_HydCat
Drawing Number

01
Revision

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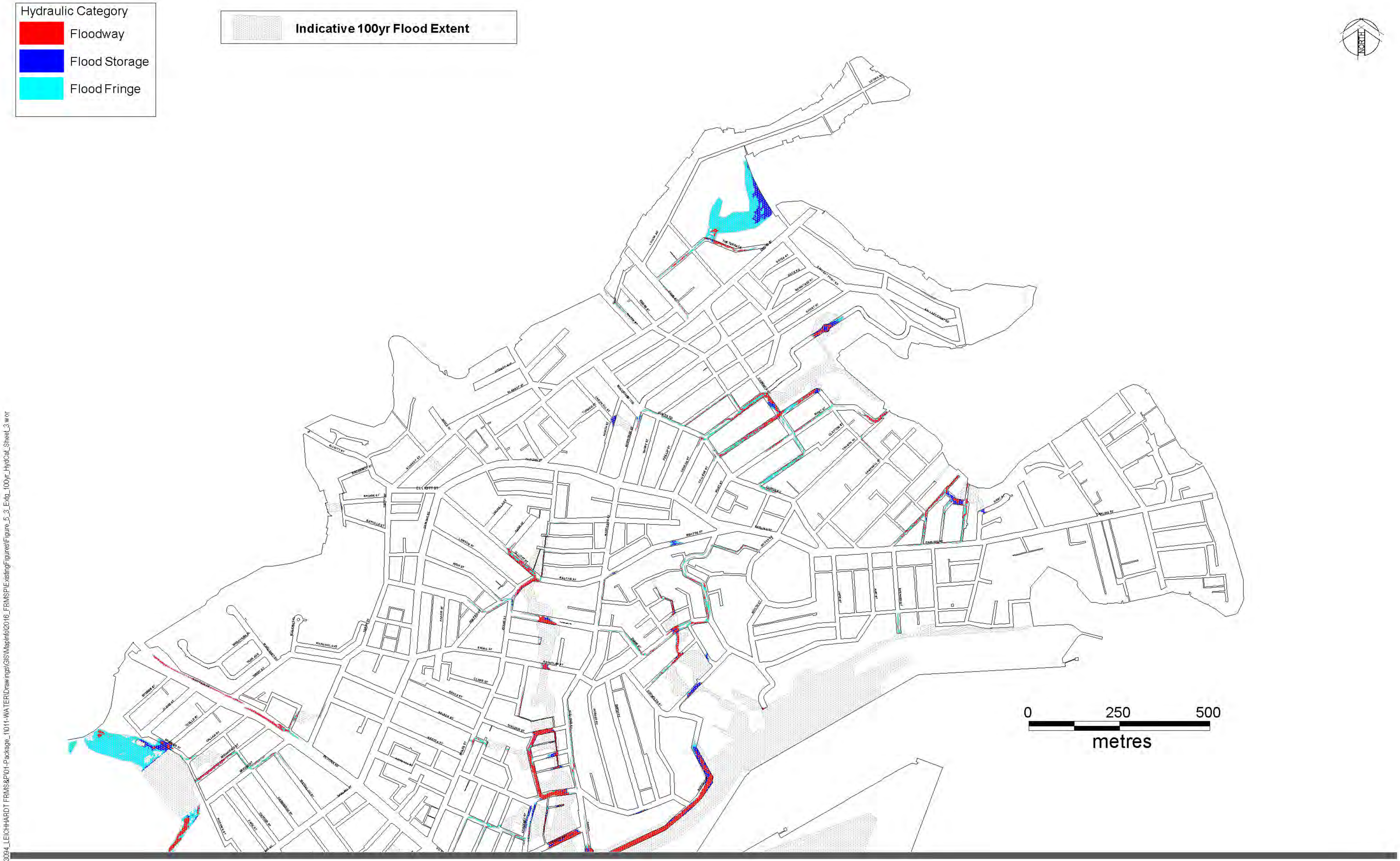

Inner West Council

Leichhardt FRMS&P

100YR ARI HYDRAULIC CATEGORIES

SHEET 3

FIG_5_9_SHEET_3

Date

2017

Size

A3

Extg_100yr_HydCat

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Leichhardt FRMS&P
PMF ARI HYDRAULIC CATEGORIES
SHEET 1
FIG_5_10_SHEET_1

Date
2017

Extg_PMF_HydCat
Drawing Number

Size
A3

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Revision

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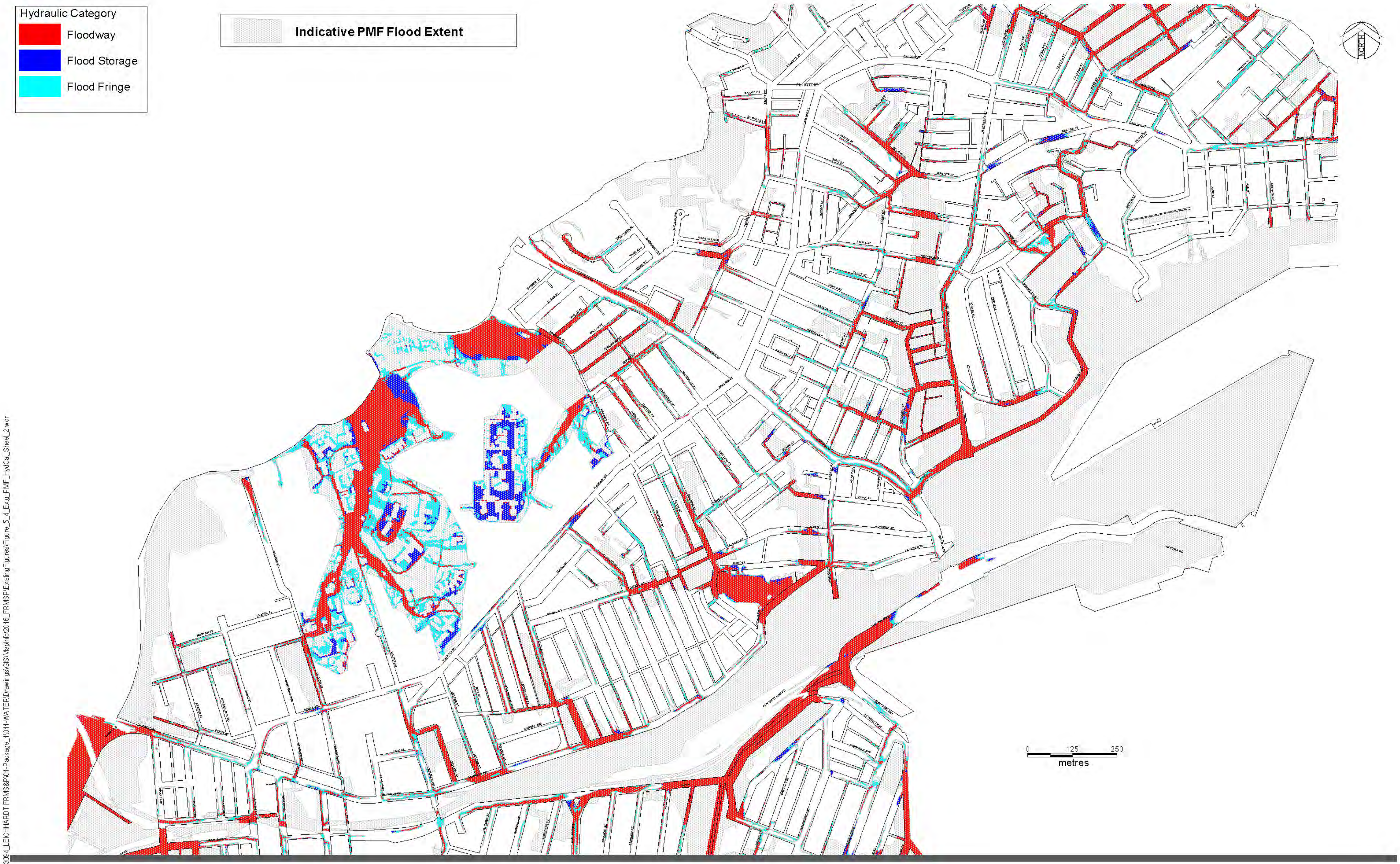

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PMF ARI HYDRAULIC CATEGORIES
SHEET 2
FIG_5_10_SHEET_2

Date	Size
2017	A3
Extg_PMF_HydCat	01
Drawing Number	Revision

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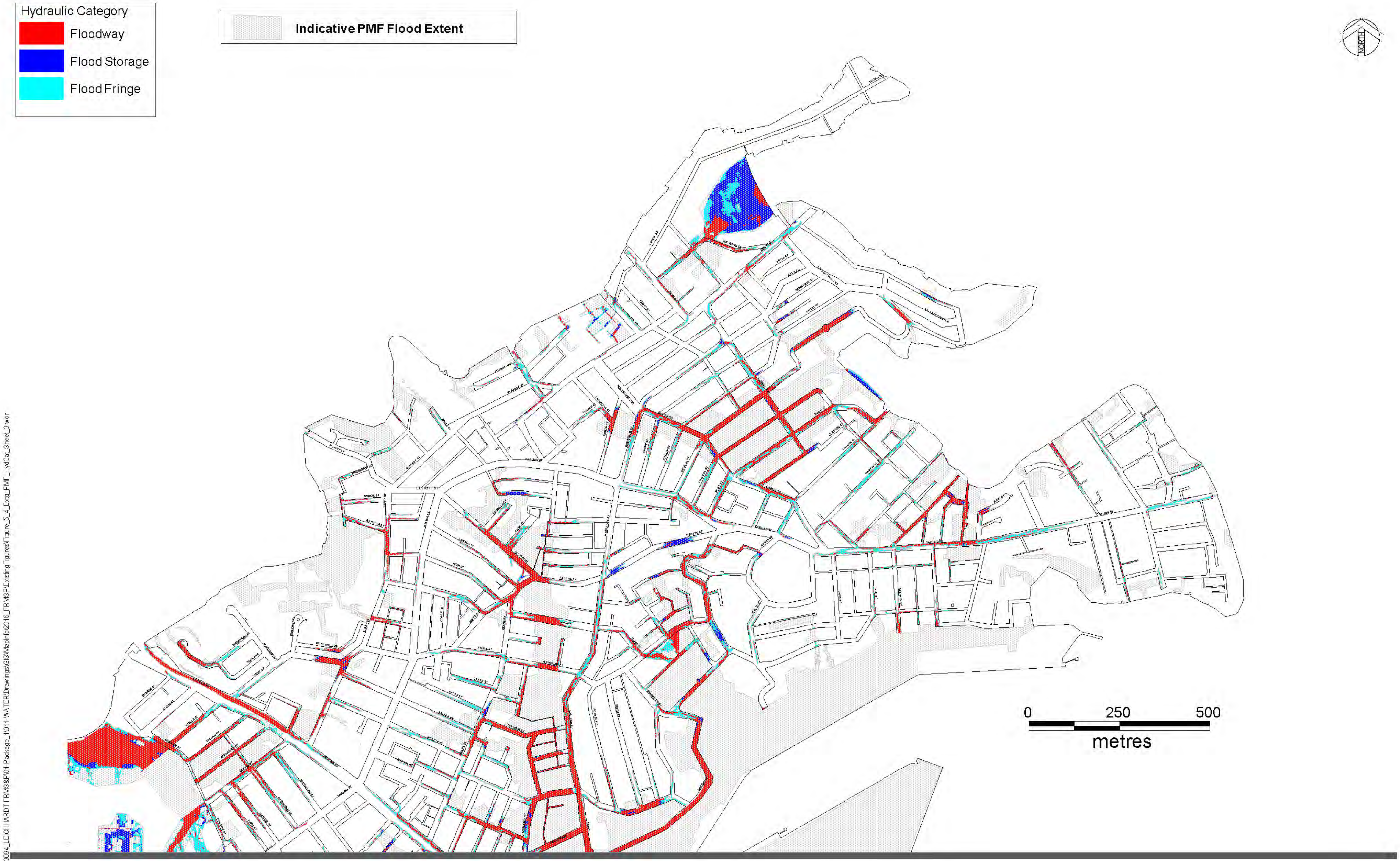

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PMF ARI HYDRAULIC CATEGORIES
SHEET 3

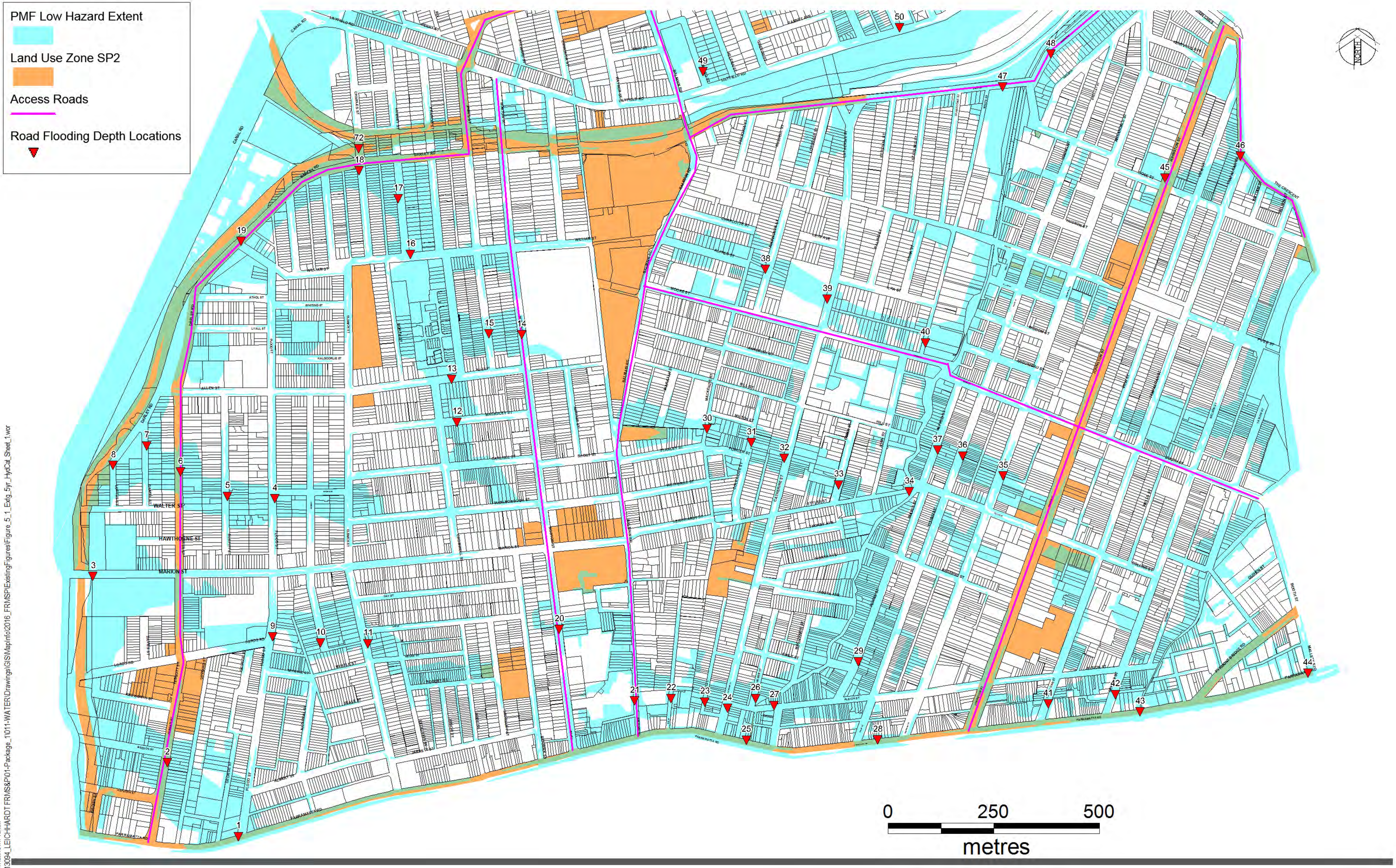
FIG_5_10_SHEET_3

Date
2017

Size
A3

Extg_PMF_HydCat
Drawing Number

01
Revision



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PMF MAJOR ACCESS ROAD FLOODING
SHEET 1

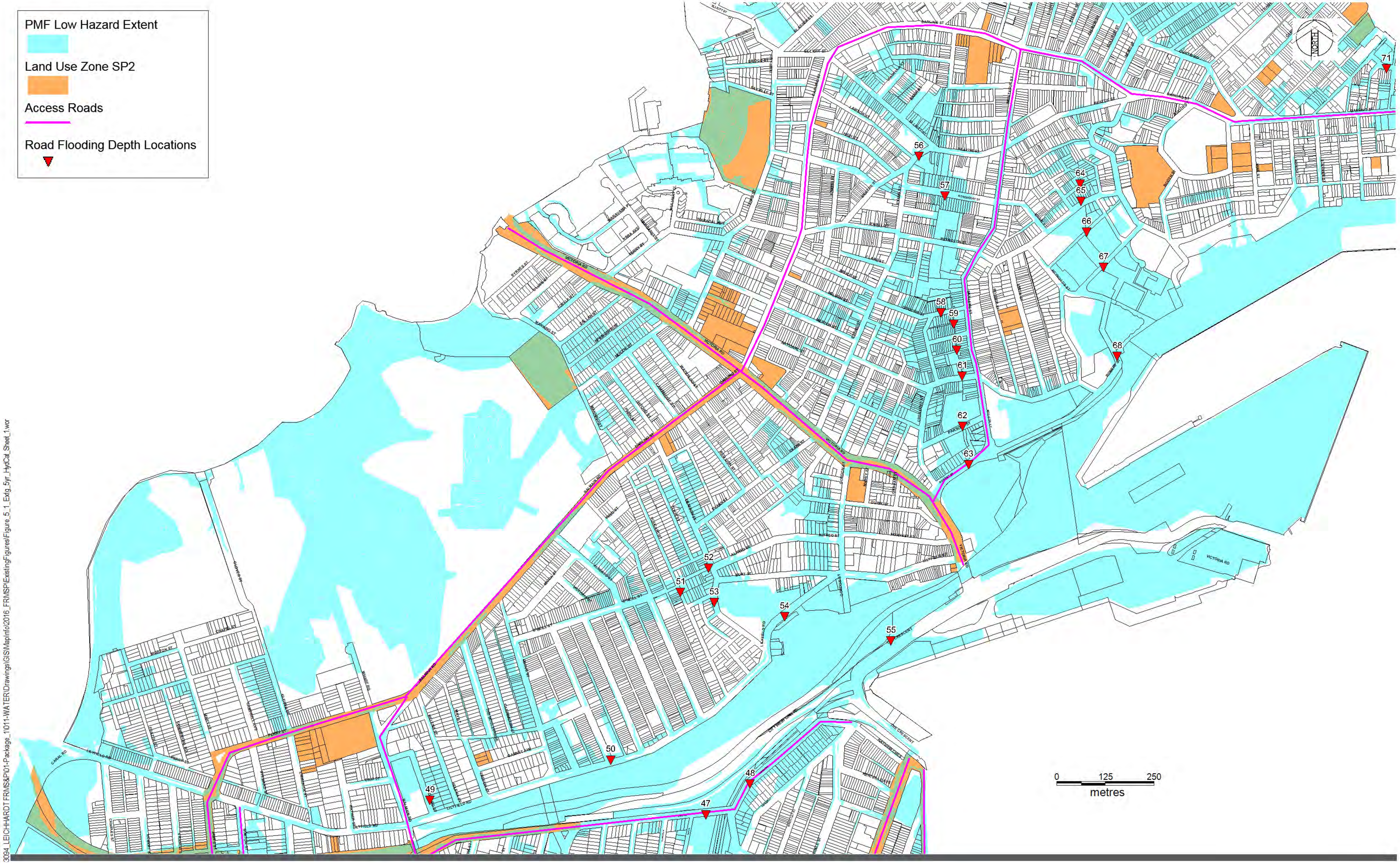
FIG_8_1_SHEET_1

Date
2017

Major_Access_Road_Flooding_V1
Drawing Number

Size
A3

01
Revision



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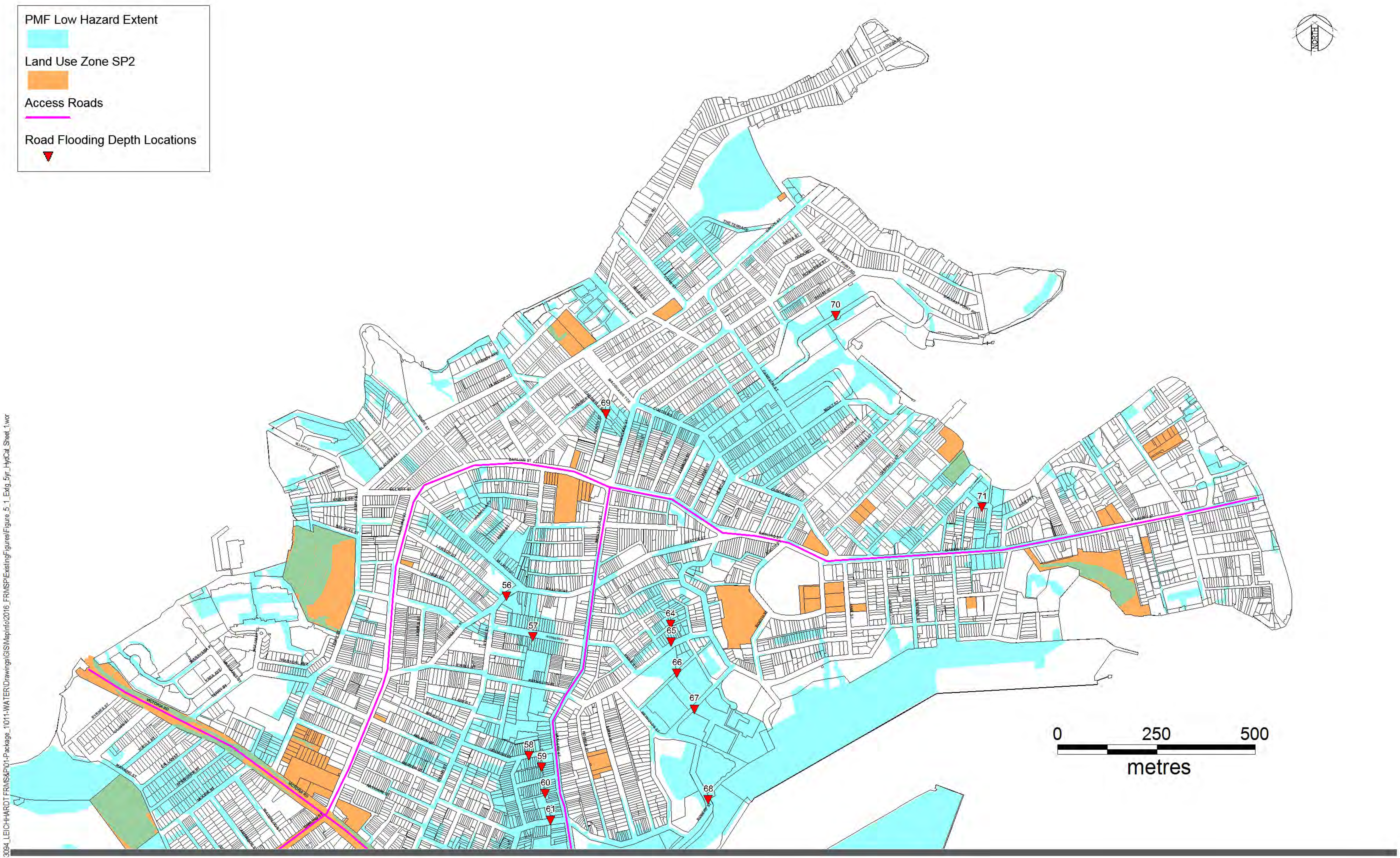
PMF MAJOR ACCESS ROAD FLOODING
SHEET 2
FIG_8_1_SHEET_2

Date	Size
2017	A3

Major_Access_Road_Flooding_V1
Drawing Number

01
Revision



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Inner West Council
Leichhardt FRMS&P
PMF MAJOR ACCESS ROAD FLOODING
SHEET 3
FIG_8_1_SHEET_3

Date
2017

Major_Access_Road_Flooding_V1
Drawing Number

Size
A3

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Revision

Inner West Council
Leichhardt FRMS&P
EVACUATION LOCATIONS
SHEET 1
FIG_8_2_SHEET_1

Date
2017

Size
A3

Evacuation_Locations
Drawing Number

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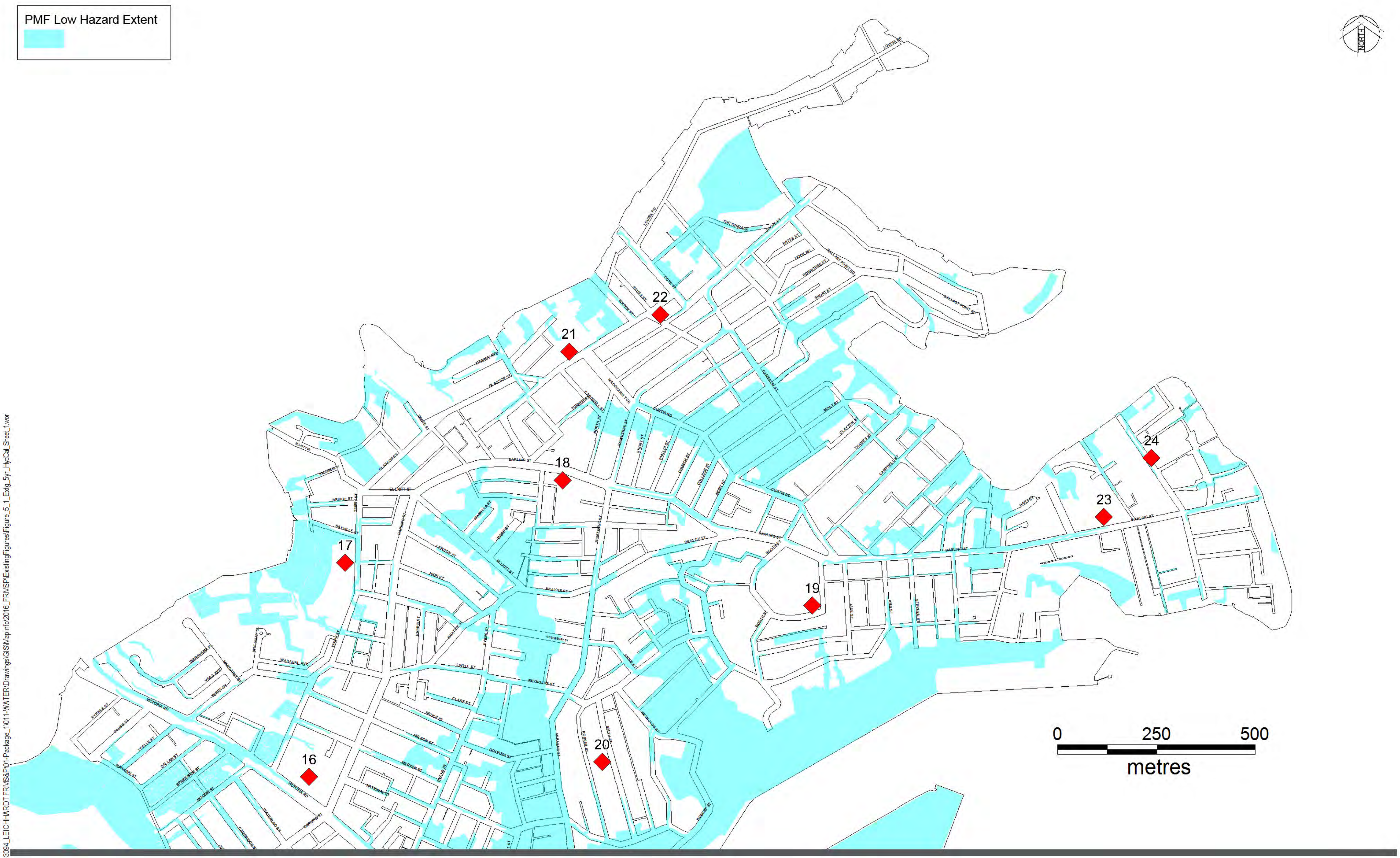
Inner West Council
Leichhardt FRMS&P
EVACUATION LOCATIONS
SHEET 2
FIG_8_2_SHEET_2

Date
2017

Evacuation_Locations
Drawing Number

Size
A3

01
Revision



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Inner West Council
Leichhardt FRMS&P
EVACUATION LOCATIONS
SHEET 3
FIG_8_2_SHEET_3

Date
2017

Evacuation_Locations
Drawing Number

Size
A3

01
Revision

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Leichhardt FRMS&P
EMERGENCY RESPONSE CLASSIFICATION
SHEET 1
FIG_8_3_SHEET_1

Date
2017

Emergency_Response
Drawing Number

Size
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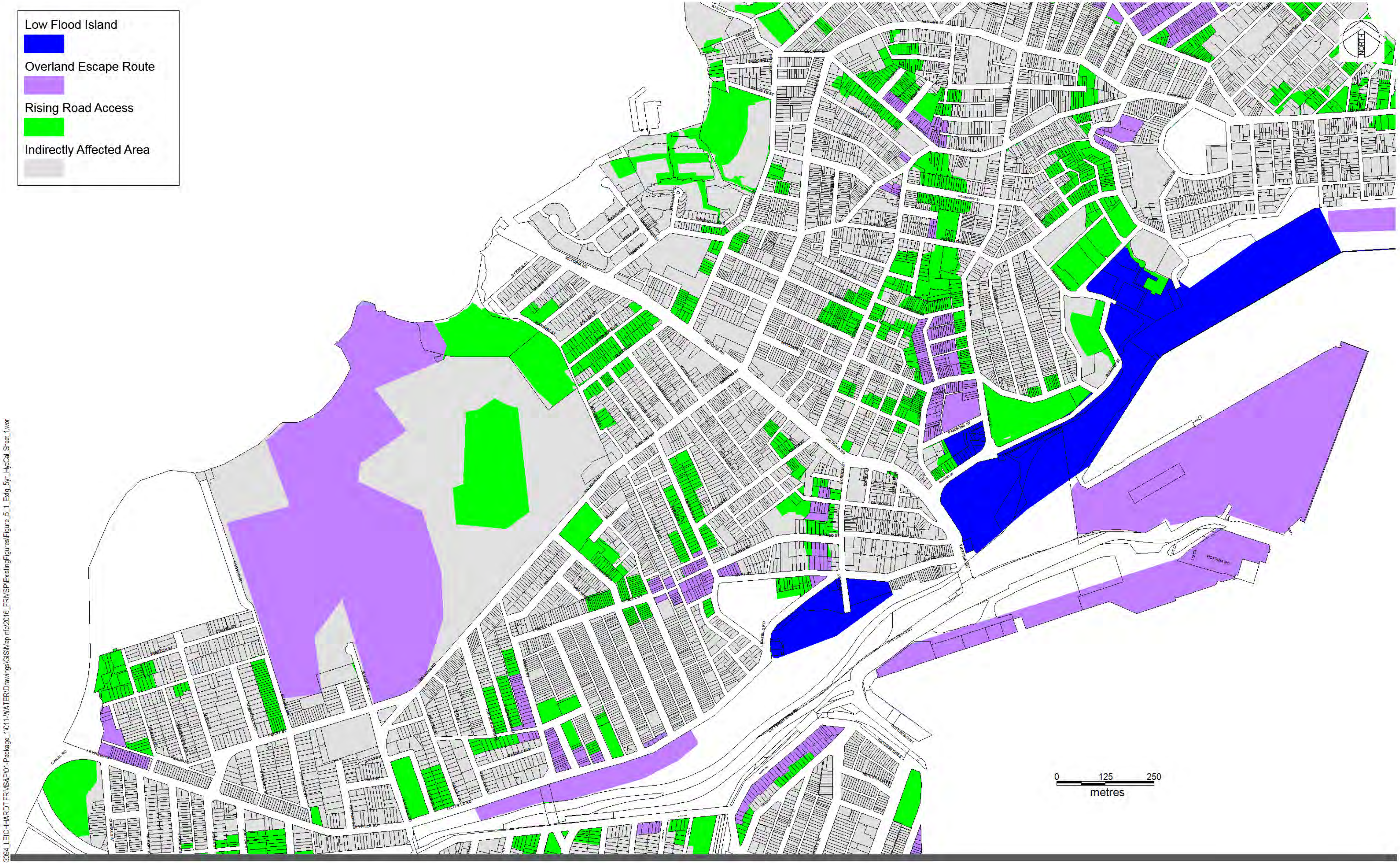
01
Revision



Inner West Council
Leichhardt FRMS&P
EMERGENCY RESPONSE CLASSIFICATION
SHEET 2
FIG_8_3_SHEET_2

Date
2017

Size
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Emergency_Response
Drawing Number

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Revision

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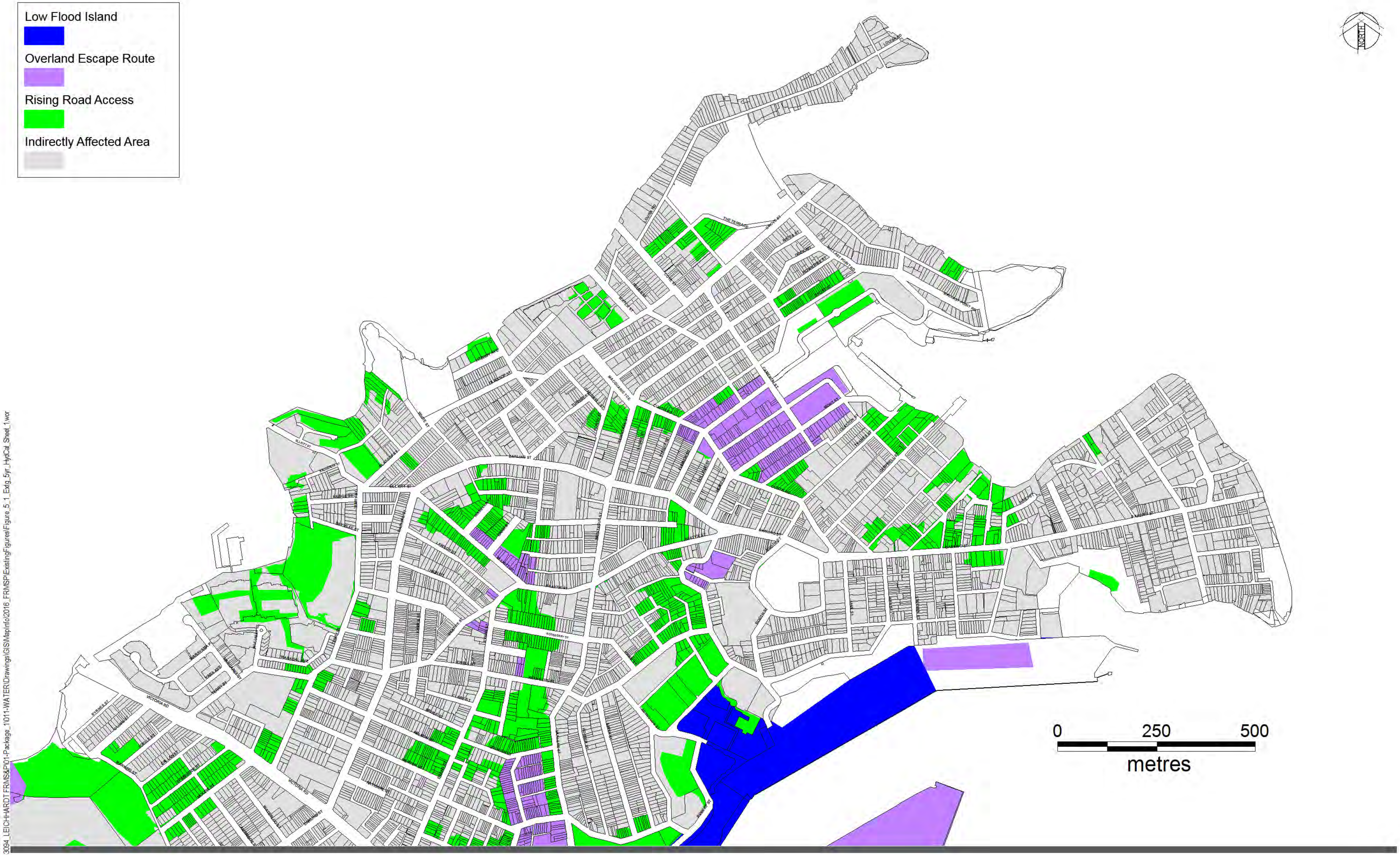

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EMERGENCY RESPONSE CLASSIFICATION
SHEET 3
FIG_8_3_SHEET_3

Date
2017

Emergency_Response
Drawing Number

Size
A3

01
Revision

Leichhardt Floodplain Risk Management Study and Plan

APPENDIX A
FLOOD STUDY ADDENDUM

Leichhardt Floodplain Risk
Management Study and Plan

APPENDIX B
ENVIRONMENTAL AND SOCIAL CHARACTERISTICS

Cardno
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Leichhardt Floodplain Risk Management Study and Plan

APPENDIX C
ONSITE DETENTION ASSESSMENT

Leichhardt Floodplain Risk Management Study and Plan

APPENDIX D

MITIGATION OPTION ASSESSMENTS SUB-CATCHMENT REPORTS

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Leichhardt Floodplain Risk Management Study and Plan

APPENDIX E
FORESHORE MANAGEMENT

Leichhardt Floodplain Risk Management Study and Plan

APPENDIX F

MULTI-CRIERIA ASSESSMENT

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