Leichhardt Floodplain Risk Management Plan

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 Plan is developed from the previous Flood Study (Cardno, 2014).

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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 and prepare a Floodplain Risk Management Draft Plan 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.

The Floodplain Risk Management Study was undertaken to define the existing flooding behaviour and associated hazards, and to investigate possible mitigation options to reduce flood damage and risk.

The overall objective of the Floodplain Risk Management Study was to develop this FRMP that addresses 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).

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.

The Leichhardt LGA Flood Study was prepared by Cardno in 2014 to define the flood behaviour in the study area, including both mainstream and overland flooding.

Flood mitigation options for the management of flooding within the study area were examined as part of the Leichhardt Floodplain Risk Management Study. 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).

This report addresses Stage 5 of the Floodplain Management Process and provide the outcomes of the Floodplain Risk Management Study including implementation considerations.

1.2 Strategic Context

The purpose of the Leichhardt Floodplain Risk Management Study and Plan documents is to assist Inner West Council (Council) mitigate and manage the risk and impacts of flooding in the study area. This is achieved by:

- Providing flood risk context to inform planning and emergency response decision making;
- Identifying specific works or actions that mitigate flood risk to varying degrees and making recommendations regarding priority of works or actions based on a triple bottom line assessment;
- To allow incorporation of flood mitigation works into private and public infrastructure development within the study area; and
- To provide input to the development of strategic plans or assessing rezoning proposals in the vicinity of flood prone land. For example, planning proposals or large scale redevelopment strategies present an opportunity for flood prone land to be divided into appropriate land use zones. In addition, 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.

1.3 Study Area

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 1-1**.

2 Existing Flood Risk

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 of Hawthorne 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. However, 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, the only overland flowpath then available is directly through actual dwellings.

2.1.1 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.

2.1.2 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 of the *Floodplain Risk Management Study*.

Modifications to the hydraulic model were only required in four of the nine model zones (as shown in Figure 5-1 of the Floodplain Risk Management Study and 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 Leichhardt Flood Study (Cardno,2014).

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

2.1.3 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, the only overland flowpath then available is directly through actual dwellings.

The 100 Year ARI and PMF extents are shown in **Figure 2-1**. Further discussion of the flood behaviour is provided in the Leichhardt Flood Study (Cardno,2014).

2.1.4 Flood Hazard

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.

Table 2-1 True Hazard Assessment Outcomes

True Hazard Factor	Outcome of Assessment	Floodplain Risk Management Study Actions
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.

True Hazard Factor	Outcome of Assessment	Floodplain Risk Management Study Actions
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.
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 of the Floodplain Risk Management Study, 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 provided in the Floodplain Risk Management Study.
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 the Floodplain Risk Management Study. The controls applied to different development types have been considered in this review.

True Hazard Factor	Outcome of Assessment	Floodplain Risk Management Study Actions
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 of the Floodplain Risk Management Study 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 in the Floodplain Risk Management Study.
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 the Floodplain Risk Management Study. The controls applied to different development types have been considered in this review.

2.2 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 Floodplain Risk Management Study using the data from the 2010 study.

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.

2.3 Current Economic Impact of Flooding

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 2-2.**

Table 2-2 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.

Assessment of the tangible flood damages is based on a relationship between the depths of flooding on a property and the likely damage within the property.

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 the Floodplain Risk Management Study**.** The total damage for a design event is determined by adding all the individual property damages for that event.

Figure 2-2 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 the Floodplain Risk Management 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).

The results of the flood damage assessment are provided for the entire study area in **Table 2-3** and for each of the sub-catchments of the study area in **Table 2-4**.

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 2-3** are not simply the sum of the values in **Table 2-4**.

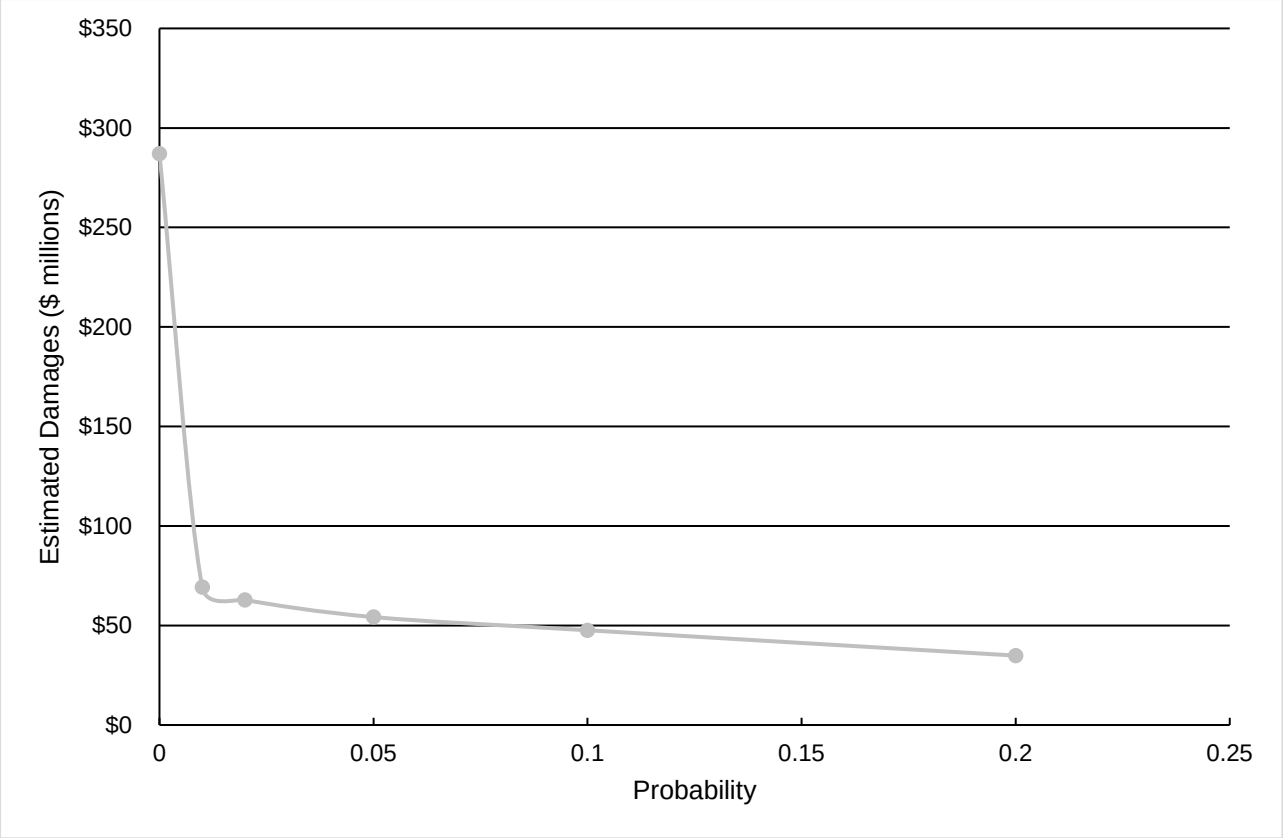

Figure 2-2 Average Annual Damage Curve for the Leichhardt Study Area

Table 2-3 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 2-4 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

3 Community Consultation

The community consultation undertaken as part of the Floodplain Risk Management Study and Plan 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 community's experience with historical flooding in the catchment.

The purpose of the consultation undertaken as part of the Floodplain Risk Management Study and Flood Risk Management Plan 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.

The draft Floodplain Risk Management Study and Plan documents were updated based on the feedback received during the public exhibition period. The final Floodplain Risk Management Study and Plan documents contain a chapter outlining the community consultation activities and outcomes.

3.1.1 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 submitted 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. Council also received approximately 40 queries via telephone and, 10 feedback emails.

A summary of submissions received and responses to those submissions are provided in the Leichhardt Floodplain Risk Management Study. 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.

3.1.2 Website

Council's website has a dedicated page providing information relating to this study.

The webpage provides 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 involved in the study;
- Relevant development controls; and

3.2 Floodplain Risk Management Committee

3.2.1 Floodplain Risk Management Committee

At its meeting on 23 July 2013 Leichhardt 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 Inner West Council 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 Flood Management Advisory Committee 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.

4 Floodplain Risk Management Options

4.1 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 4-1**.

Table 4-1 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.

4.2 Assessing Potential Floodplain Risk Management Options

4.2.1 Preliminary Options Assessment

The Leichhardt Floodplain Risk Management Study assessed a range of potential options for the management of flood risk. Potential options were identified through an evaluation of the flood risk identified in the Leichhardt LGA Flood Study (Cardno 2014), field investigations and at meetings between Leichhardt Council engineers and Cardno.

The process first identified the areas subject to flooding in the 100 year ARI event in the Leichhardt Flood Study (Cardno 2010). Once these areas were identified consideration was given to what structural options might be available to modify the flood behaviour and reduce the flooding in these areas (for example, detention basins, levees, diverting water away from properties and increasing the pipe capacity).

All parks and reserves along the path of the flooding were considered and reviewed in relation to their position in the catchment and their suitability for use as a detention basin or for construction of a levee. Preliminary modelling of the potential detention basin sites was undertaken to determine whether they achieved any improvement to downstream flooding. Where the detention basins did not achieve am appreciable improvement, the option was recorded as being considered but discarded from further modelling. This was the case for Evan Jones Playground, Leichhardt and Gladstone Park, Balmain. The proposed levee in Hogan Park/Smith Park, Annandale was discarded after modelling showed the option worsened the effect of flooding on properties upstream of the levee.

Pipeline upgrades were considered where areas affected by flooding followed the alignment of an existing pipeline or culvert (this could be a Council or Sydney Water pipeline/culvert). Consideration was given to whether the pipeline or culvert could be upgraded and, if so, what was the most cost effective and practical way to do so. Where the existing pipeline and associated flooding generally followed a roadway, upgrade of the pipeline along the existing alignment was modelled. Where the existing pipeline passed through private property and there was no drainage easement, consideration was given to whether the pipeline could be diverted to other roads or public land. Where this was not possible, modelling proceeded with the pipeline upgrade following the existing alignment.

4.2.2 Detailed Options Assessment

Based on the outcomes of the preliminary options assessment, the options with the greatest likely flood benefit were selected for more detailed assessment.

Each of the options was then evaluated for its ability to reduce flood risk. This was then assessed against the costs associated with the option and any other issues, impacts or benefits. This assessment process involved hydraulic modelling, economical assessments and a multi-criteria assessment. An overview of these assessment are provided in the following sections, with further details provided in the Floodplain Risk Management study.

4.2.2.1 Hydraulic Modelling of Options

The hydraulic model (Sobek) developed for the Leichhardt 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 of the Floodplain Risk Management Study.

4.2.2.2 Economic Assessment of Options

The capital and recurrent costs were estimated for each flood modification option.

An assessment of the damages for the existing condition in the study area and each sub-catchment is presented in **Section 2.2**. The reduction in damages resulting from the Flood Modification Options was assessed in a similar manner using the model results for each option.

The economic flood damage results for each of the option is presented in Appendix D of the Floodplain Risk Management Study. The reduction in AAD, which effectively represent the reduction in flood damage costs per year as a result of the option, was provided for each option.

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 of the Floodplain Risk Management Study, the resulting BCR for each option is provided in **Table 4-2**.

4.2.3 Multi-criteria Assessment

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). 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.

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.

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 the Floodplain Risk Management Study.

4.2.4 Outcomes of Options Assessment

The primary outcome of the options assessment is a score and ranking for each option, providing Council with an understanding of the most effective options for managing flood risk, while also considering the other contributing factors to successful floodplain management works.

Overall, the majority of structural options did not achieve high benefit cost ratios due to the high costs of implementation and the relatively minor reduction to flood risk to properties. Therefore, consideration of other factors outlined in the multi-criteria assessment became critical such as reduction in risk to life and improved access during a flood event.

The scores, weighting and ranking of all options are provided in the Floodplain Risk Management Study.

The hydraulic modelling, economic assessment and multi-criteria assessment identified those options that have merit for future implementation in the study area. These options are discussed in **Sections 4.3, 4.4 and 4.4.2**.

Other options outlined in the Floodplain Risk Management Study may be considered for implementation for reasons other than flood risk management. The options assessment details will be useful for future planning regarding those works.

4.3 Flood Modification Measures

Possible flood modification measures (i.e. structural measures) for the study area were identified based on the flood model results (Cardno, 2014), historical information and engineering judgement.

The various management options were identified taking into consideration the flood behaviour, existing stormwater infrastructure and the availability and location of easements.

Flood modification measures for the study area have also 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 4-1**.

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

Details of all options identified and assessed are provided in the Floodplain Risk Management Study, including the model results and economic assessments.

The options identified as having merit for implementation in the study area were those options with a mulit-criteria assessment rank of 1 to 25. These options are summarised in Table 4-2 and **Figures 4-2 to 4-26** with further details provided in the Floodplain Risk Management Study.

Table 4-2 Recommended Flood Modification Options

Option ID	Option Description	Capital Cost	Annual Costs	BCR	MCA Score	MCA Rank	Figure Ref
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.	$7,047,700	$7,300	1.59	64.0	1	4-2
HC_FM1	Additional pipes /culverts from Parramatta Road to Hawthorne Canal via Beeson Street.	$11,482,900	$7,600	0.71	58.8	2	4-3
WC-FM5	Detention Basin at Mackenzie Street (upstream at the intersection of Mackenzie and Milton St)	$933,800	$5,000	1.85	58.5	3	4-4
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.	$17,044,600	$10,800	0.13	52.2	4	4-5
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). Also combining WC-FM2 along with this option.	$20,455,400	$15,800	0.21	50.7	5	4-6
WC-FM6	Styles Street Flow Path – Additional pipes from Mackenzie St to Whites Creek Culvert.	$9,398,500	$6,100	0.28	49.2	6	4-7
HC_FM4	Additional pipes/ culverts from William Street to Hawthorne Canal via Hubert Street and Darley Road.	$8,300,000	$7,100	0.17	43.2	7	4-8
WC-FM13	Whites Creek Culvert/Open Channel – Proposing 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)	$28,519,800	$15,800	0.23	42.7	8	4-9
HC_FM2	Additional pipes or duplication of existing network from Reuss Street to Hawthorne Canal via Elswick Street, Flood Street and Marion Street.	$10,479,300	$11,200	0.20	41.7	9	4-10
WB-FM1	Beattie Street Branch – Proposing 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.	$25,686,400	$27,300	0.17	41.7	9	4-11
WC-FM11	Moore Street Flow Path – Additional Pipes from Catherine St to Whites Creek along Moore Lane.	$3,653,100	$4,800	0.13	35.7	11	4-12

Option ID	Option Description	Capital Cost	Annual Costs	BCR	MCA Score	MCA Rank	Figure Ref
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	$12,600	0.25	34.2	12	4-13
HC_FM5	Proposed culverts through the rail embankment to drain flood waters from Darley Road to Hawthorne Canal.	$2,689,100	$2,900	0.41	33.7	13	4-14
WB-FM2	Wortley Street Branch – Proposing 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.	$8,513,100	$11,700	0.17	33.7	13	4-15
WC-FM10	Detention Basin at Catherine Street (War Memorial Park)	$2,151,880	$5,000	0.21	31.2	15	4-16
JC-FM2	Pyrmont Bridge Road Flow Path – Additional pipes or duplication of existing network from Parramatta Rd to Johnstons Creek via Pyrmont Bridge Rd.	$6,120,900	$4,400	0.37	30.7	16	4-17
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	$5,500	0.32	30.7	16	4-18
RB-FM1	Lilyfield Road Flow Path – Proposing 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.	$18,284,200	$16,900	0.10	30.7	16	4-19
WC-FM8	Annandale Street Flow Path – Duplication of existing pipe network or additional pipes from Annandale St to Whites Creek culvert.	$3,927,200	$3,000	0.14	30.2	19	4-20
MB_FM5	McKell Street Branch – Additional pipe from Short St that crosses McKell St and drain into Mort Bay	$630,800	$1,100	0.08	29.2	20	4-21
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.	$3,036,300	$5,200	0.04	27.7	21	4-22
WC-FM2	Young Street Flow Path – Proposing 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	$5,100	0.13	26.7	22	4-23

Option ID	Option Description	Capital Cost	Annual Costs	BCR	MCA Score	MCA Rank	Figure Ref
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.	$3,413,400	$5,600	0.21	26.2	23	4-24
WC-FM14	Whites Creek Bridge Upgrades –Upgrade Bridges at Piper Street and Brenan Street.	$5,816,800	$58,168	0.03	26.2	23	4-25
WB-FM4	Montague Street Branch and additional pipes – Proposing additional pipes from Montague St that connect into the existing network.	$2,131,600	$4,200	0.15	25.2	25	4-26

4.4 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 recommendations provided within these options have been developed from the review undertaken of the existing policies and plans, the Flood Planning Level and onsite detention requirements. Details of this review are provided in the Floodplain Risk Management Study.

All property modification options scored well as an outcome of the multi-criteria assessment. An overview of the scores and ranks are provided below (in order of rank).

Table 4-3 Property Modification Options

Option	Capital Cost	Recurrent Cost	Responsibility / Possible Funding Sources	MCA Score	MCA Rank
PM9 – Strategic Planning	-	-	Council	64.6	1
PM2 – DCP Review for Effective Flood Access	-	-	Council	42.8	2
PM3 – DCP 2013 Review for Car Parking Controls	-	-	Council	41.8	3
PM1 – Review of LEP Wording	-	-	Council	38.3	4
PM4 – Onsite Detention Requirements	-	-	Council	36.3	5
PM5 – Flood Planning Level	-	-	Council	33.8	6
PM8 – Incentives for Flood Compatible Redevelopment	$40,000	$40,000	Council / OEH	27.8	7
PM7 – Voluntary House Raising	$320,000	-	Council / OEH	12.8	8
PM6 – Voluntary House Purchase	$800,000	$126,000	Council / OEH	11.9	9

A description of each of the recommended options is provided in the following sections.

4.4.2 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.

4.4.3 PM2 – DCP Review for Effective Flood Access

The emergency management review (Floodplain Risk Management Study) 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.

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.

4.4.4 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 the Floodplain Risk Management Study. This should be reviewed by Council to ensure consistency.

4.4.5 PM4 – Onsite Detention Requirements

The OSD assessments undertaken as part of the Floodplain Risk Management Study 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.

4.4.5.1 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 x 80%) / 10,000 x 300 = 24 m^3

PSD = (1,000 x 80%) / 10,000 x 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.

4.4.5.2 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

4.4.5.3 Onsite Retention Offsets

In addition to the rainwater tank size requirements outline in the Floodplain Risk Management Study 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 of the Floodplain Risk Management Study.

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.

4.4.5.4 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.

4.4.6 PM5 – Flood Planning Level

The Flood Planning Level review (Floodplain Risk Management Study) 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 in the Floodplain Risk Management Study.

4.4.7 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 (Floodplain Risk Management Study) have been used in this assessment, assuming an average property purchase price of $800,000 (2013).

4.4.8 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 (Floodplain Risk Management Study).

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 4.4.3**, 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.

4.4.9 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 2.3**). 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.

4.4.10 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 the 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.

4.5 Emergency Response Modification Options

Emergency response modifications options have been developed as an outcome of the review of existing emergency response arrangement and additional flood risk issues identified in the assessment of True Hazard in the Flood Risk Management Study.

Most emergency response modification options scored well as an outcome of the multi-criteria assessment. With the exception of EM7 (Improved Flood Access), where the score was impacted by the high cost. However, these works could be looked to be undertaken with road upgrades undertaken by RMS as they are scheduled.

An overview of the scores and ranks are provided below (in order of rank).

Table 4-4 Emergency Response Modification Options

Option	Capital Cost	Recurrent Cost	Responsibility / Possible Funding Sources	MCA Score	MCA Rank
EM2 – Prepare a Local Flood Plan	-	-	SES	65.8	1
EM3 – Public Awareness and Education	$30,000	$5,000	SES / Council	49.1	2
EM1 – Information Transfer to SES	-	-	SES / Council	40.8	3
EM4 – Early Warning Alert System	$60,000	$10,000	SES / Council / BoM	22.7	4
EM5 – Flood Warning Signs at Critical Locations	$165,000	$33,000	SES / Council	20.1	5
EM6 – Establish Evacuation Centres	$100,000	$20,000	SES / Council	11.8	6
EM7 – Improved Flood Access	$3,000,000	$50,000	Council / RMS	-3	7

4.5.2 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 Floodplain Risk Management Study.

Table 4-5 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 of the FRMS 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 of the Floodplain Risk Management Study provides a comprehensive overview of the existing flood behaviour in the study area.

SES Requirements	Data Provided
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 of the Floodplain Risk Management Study). Flood emergency response classifications are provided in Section 9 of the Floodplain Risk Management Study.
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 of the Floodplain Risk Management Study). 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.
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 of the Floodplain Risk Management Study.

4.5.3 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 roads subject to flooding.

Further details of evacuation centres, access road flooding and recommended inclusions for the flood plan are provided in Section 8 of the Flood Risk Management Study.

4.5.4 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. 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.

4.5.5 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.

4.5.6 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 the Floodplain Risk Management Study. 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).

4.5.7 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 the Floodplain Risk Management Study 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 and FloodSafe brochures

4.5.8 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 the Flood Risk Management Study. 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 4-6.** 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 of the Flood Risk Management Study) and this will need to be considered with regards to undertaking more than one proposed set of works in the same location.

Table 4-6 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.
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

Location ID	Road	5 Year ARI (m depth)	100 Year ARI (m depth)	Suggested Improvements / Works
48	Railway parade	0.47	1.40	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.
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.

4.6 Design Practices in Flood Affected Areas

In addition to the flood modification, planning and emergency response measures identified in the Flood Risk Management 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.

4.7 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 Floodplain Risk Management

Study. 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;
- The timing and duration of road overtopping / closures; and.
- 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.

4.8 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 the Floodplain Risk Management Study.

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 the Flood Risk Management Study.

5 Implementation

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 have been incorporated into this Floodplain Risk Management Plan as proposed management actions.

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.

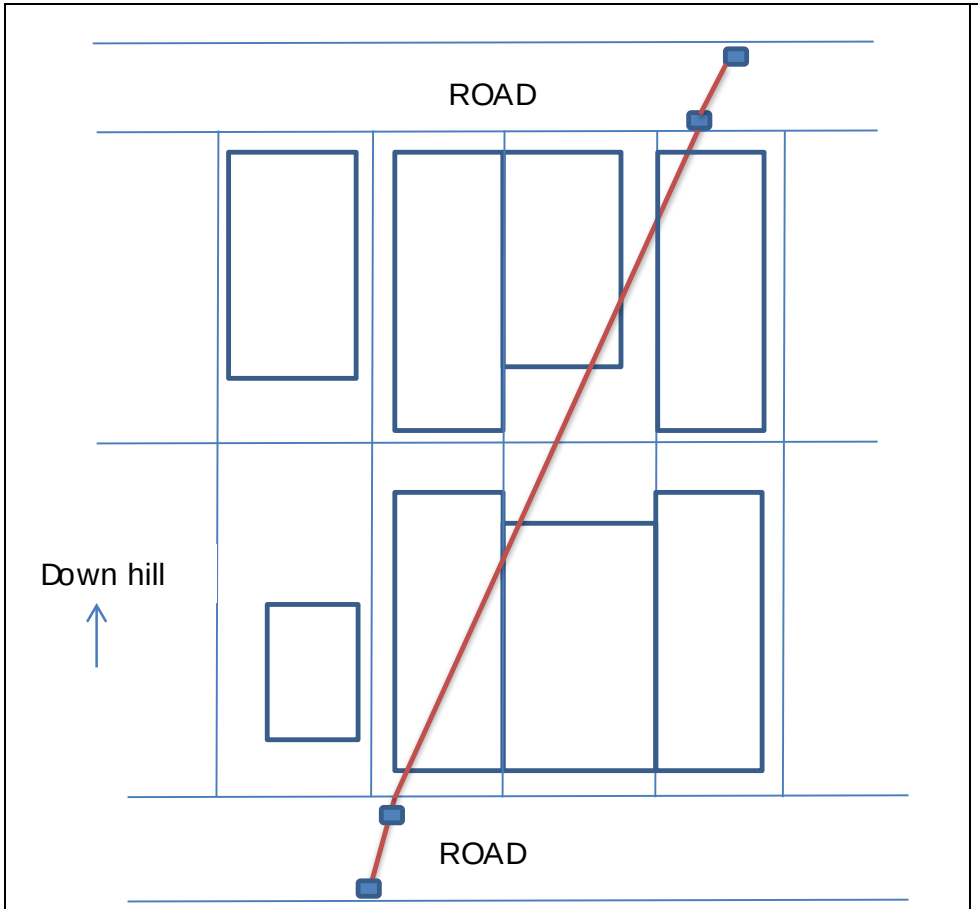

Plate A Pipeline passes beneath multiple properties and on a diagonal to the property boundaries

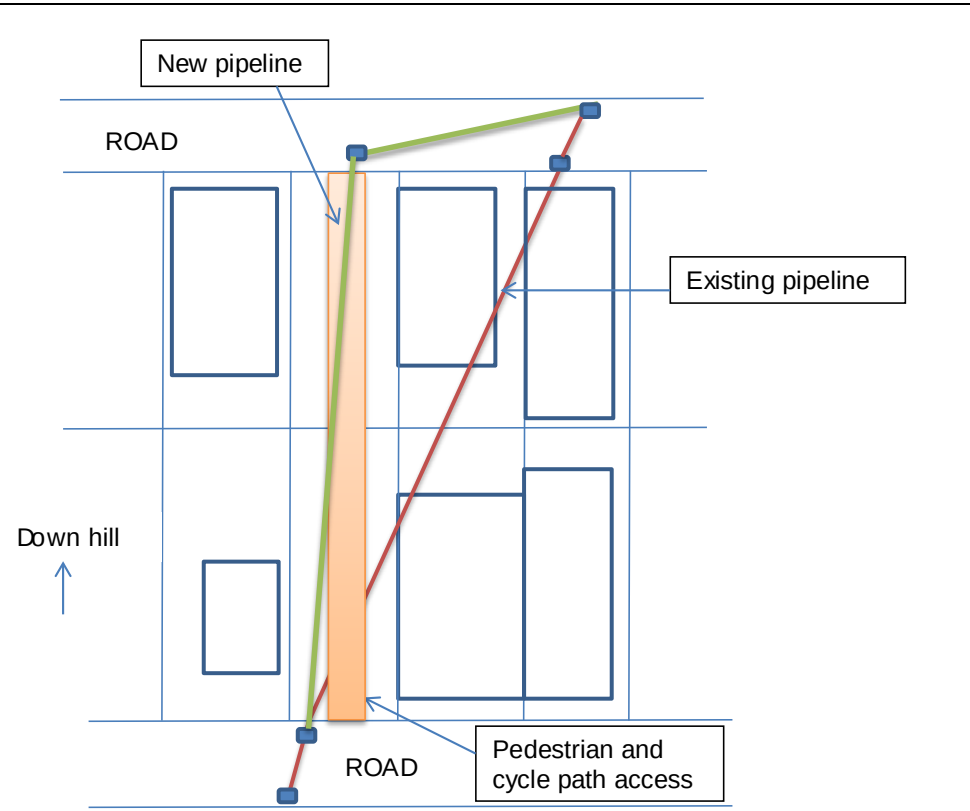

Plate B Demolition of existing dwellings and construction of pedestrian/cycle access

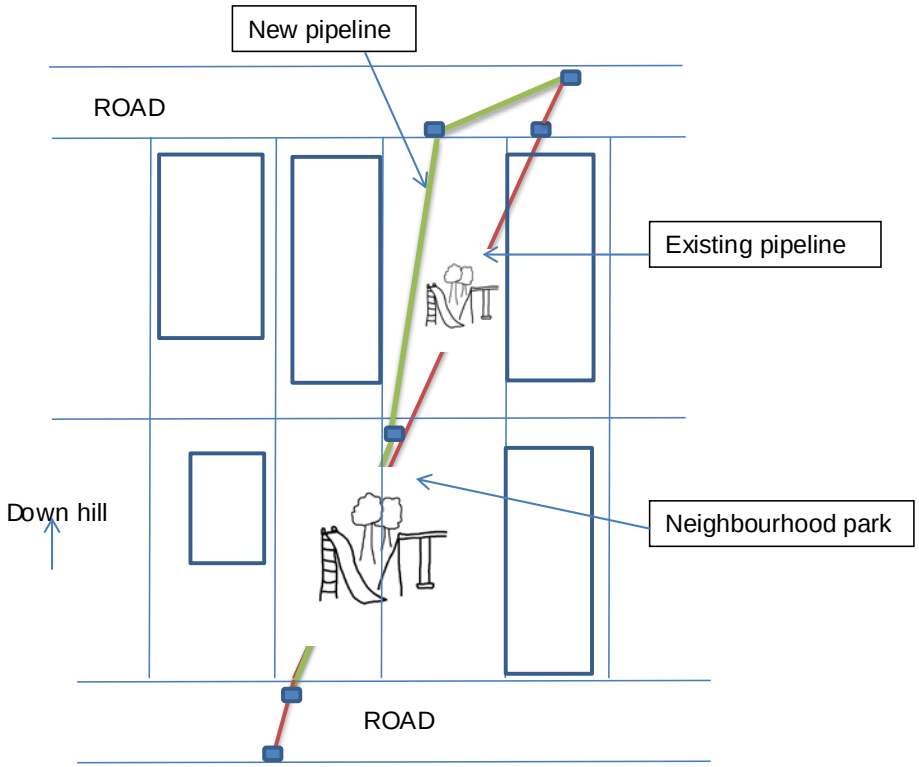

Plate C Demolition of existing dwellings and construction of a park

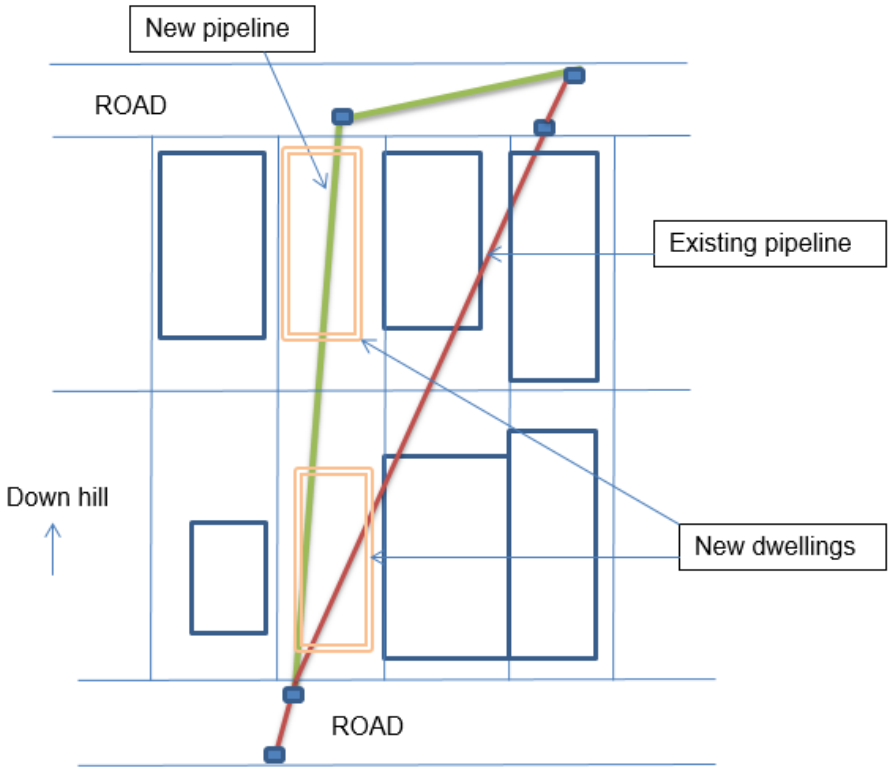

Plate D Demolition of existing buildings. Construction of pipeline and easement then resale of the land for development

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

6 Conclusions and Recommendations

This report presents the findings of the Floodplain Risk Management Study 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.

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, Property modification measures Emergency response modification measures. As a means of directly incorporating the non-economic social and environmental values held by stakeholders into the analysis and prioritisation of the flood management alternatives, all of the viable flood risk management options (property modification, emergency response and flood modification) were assessed using a Multi-Criteria Assessment. All property modification options scored well as an outcome of the multi-criteria assessment as did most emergency response modification options. The assessment identified those structural flood modification options that have merit for implementation.

The assessment does not recommend a specific works plan for implementation. Instead the assessment identifies a series of structural flood modification measures and property modification measures that have merit for implementation when the opportunity arises. Of importance to note is that many of the structural measures are dependent upon coordinated actions by the other asset owners, for example Sydney Water and Road and Maritime Services. Property modifications are dependent upon the development decisions made by property owners. Acquisition of premises for renewal or improvement of drainage structures requires the combination of site availability and project funding. Each of these measures are tabulated in **Sections 4.3, 4.4 and 4.5** of this document. Emergency response measures should be implemented as the first planned risk management action.

7 References

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Leichhardt Floodplain Risk Management Study and Plan

FIGURES

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Inner West Council
Leichhardt FRMS&P
STUDY AREA

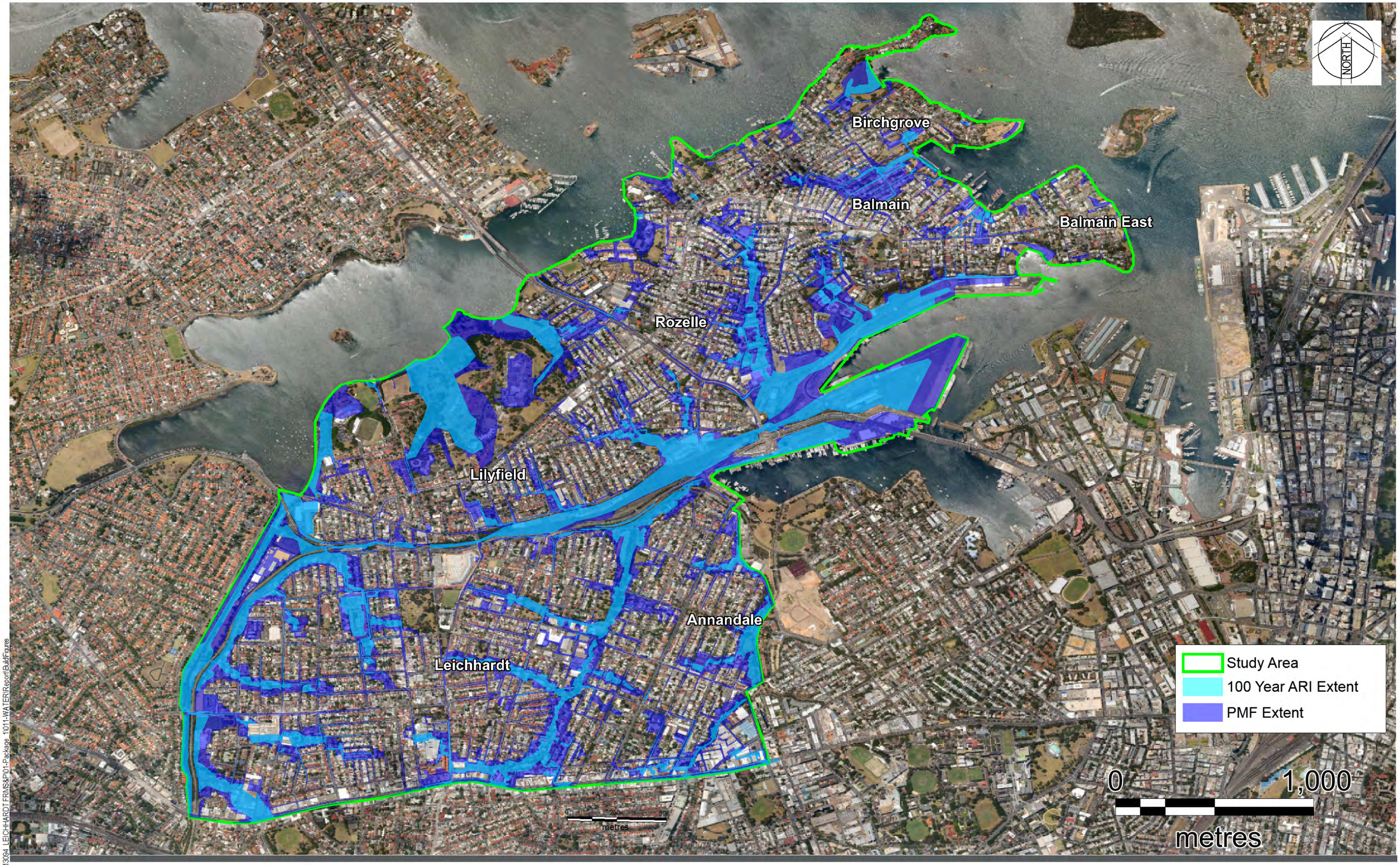
FIG_1_1

Date
MAY 2017

Size
A3

Leichhardt_Study_Area
Drawing Number

01
Revision



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Inner West Council
Leichhardt FRMS&P
PMF AND 100 YEAR ARI FLOOD EXTENT

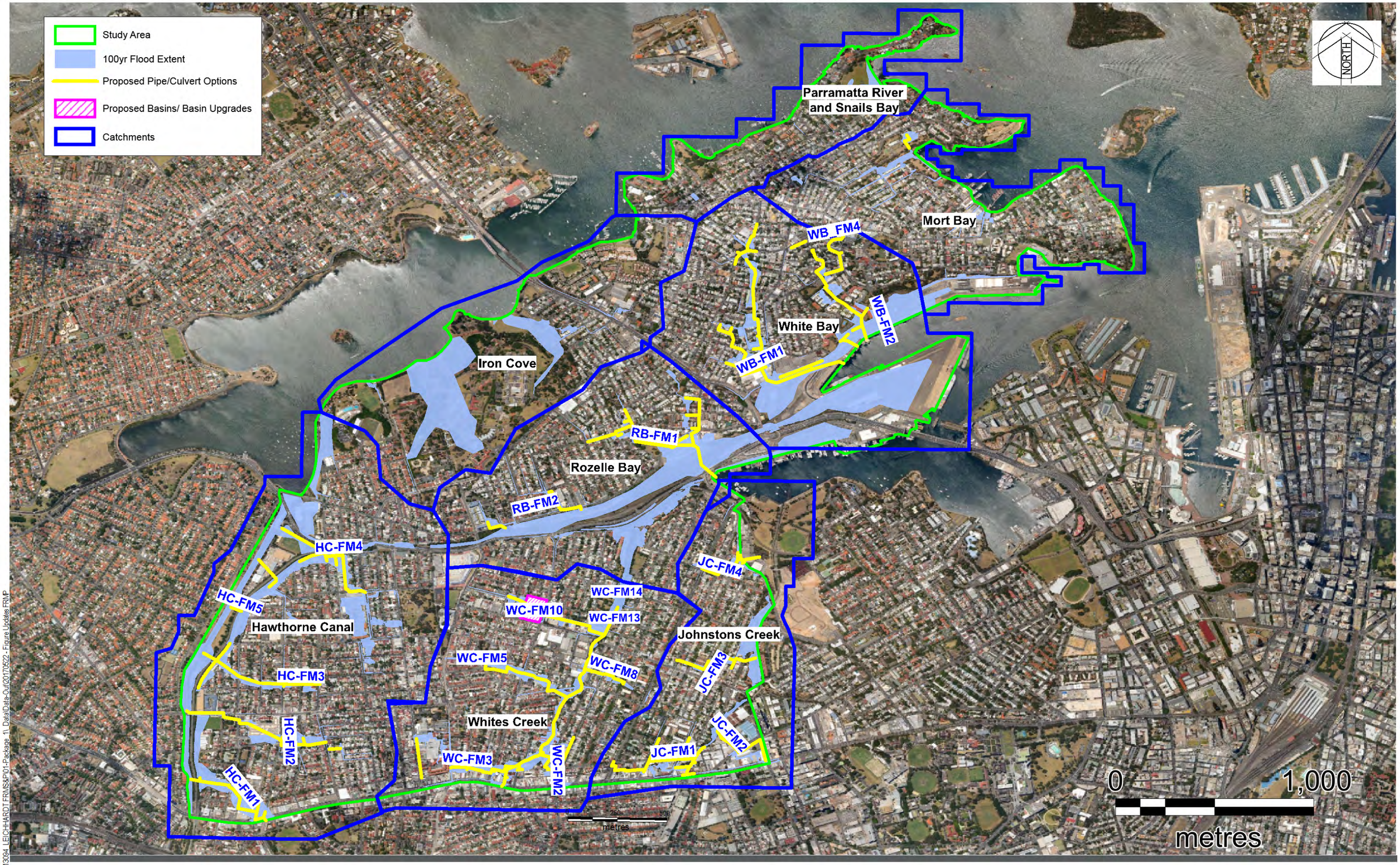
FIG_2_1

Date
MAY 2017

Size
A3

Leichhardt_Study_Area
Drawing Number

01
Revision



DATE PLOTTED:May 2017 BY: Matthew Prumm
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Inner West Council
Leichhardt FRMS&P
FLOOD MODIFICATION OPTIONS

FIG_4_1

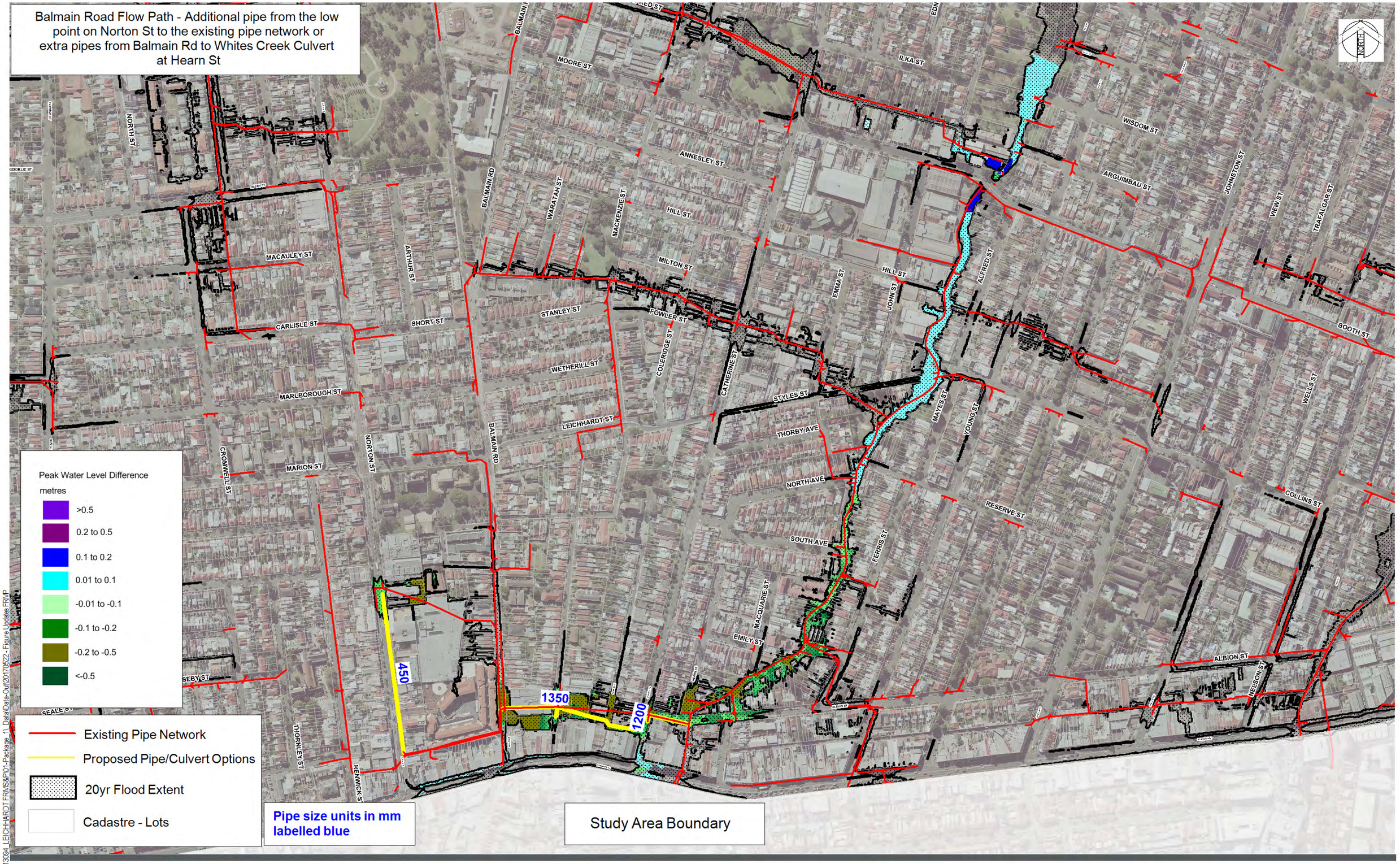
Date
05/2017

Size
A3

Leichhardt_Proposed_Option_Locations
Drawing Number

01
Revision

Balmain Road Flow Path - Additional pipe from the low point on Norton St to the existing pipe network or extra pipes from Balmain Rd to Whites Creek Culvert at Hearn St



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INNER WEST COUNCIL
LEICHHARDT FRMS&P
WC_FM3 20YR ARI WL DIFF MITIGATION LESS EXISTING
FIG_4_2

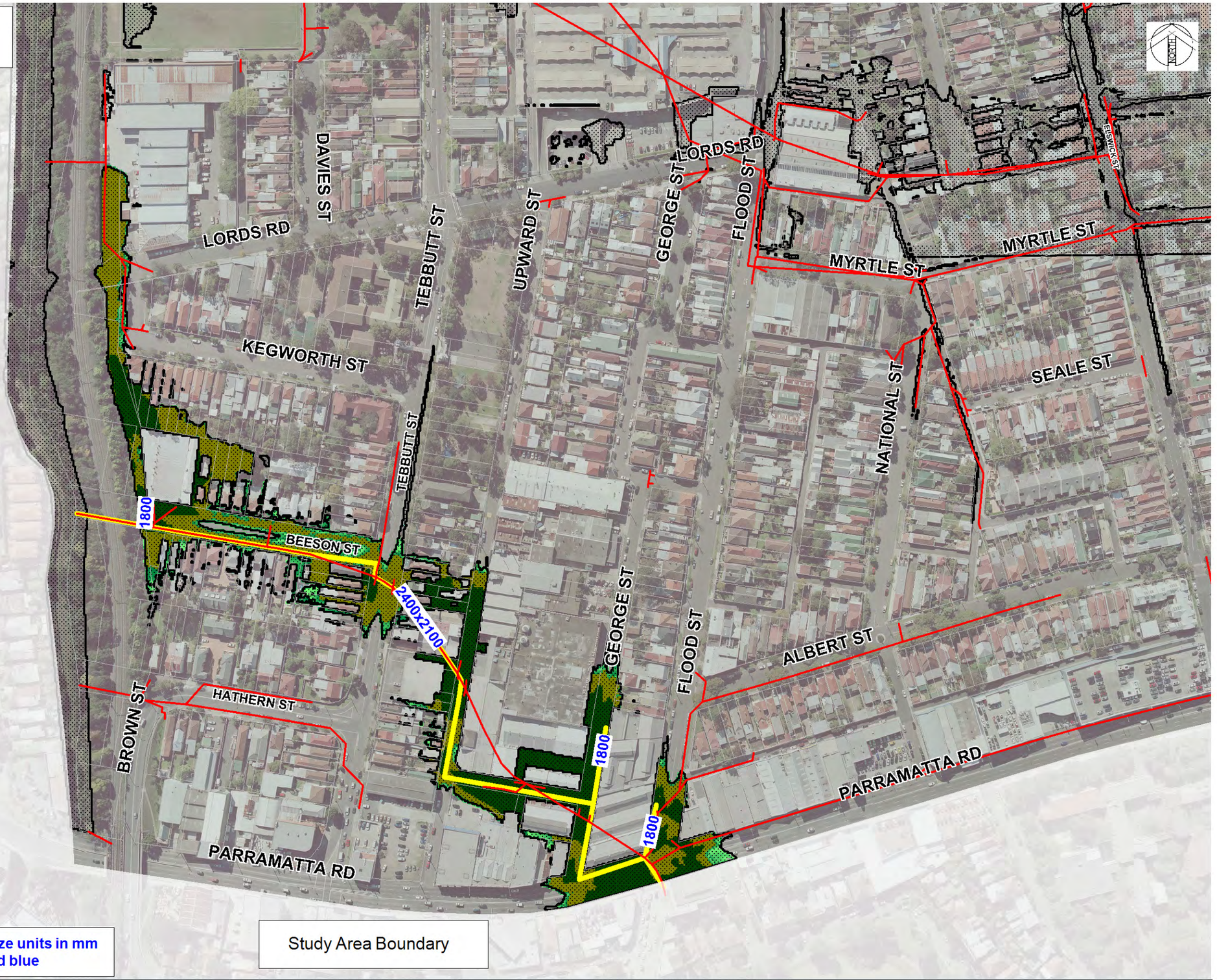
Date
05/2017

Size
A3

WC_FM3_20yr_WlDiff
Drawing Number

01
Revision

Additional pipes / culverts from Parramatta Road to Hawthorne Canal via Beeson St



Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Existing Pipe Network

Proposed Pipe/Culvert Options

20yr Flood Extent

Cadastre - Lots

Pipe size units in mm labelled blue

Study Area Boundary

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INNER WEST COUNCIL
LEICHHARDT FRMS&P
HC_FM1 20YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_4_3

Date
05/2017

Size
A3

HC_FM1_20yr_WlDiff
Drawing Number

01
Revision

Detention Basin at Mackenzie St (upstream at the intersection of Mackenzie and Milton St)

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INNER WEST COUNCIL
LEICHHARDT FRMS&P
WC_FM5 20YR ARI WL DIFF MITIGATION LESS EXISTING
FIG_4_4

Date
05/2017

Size
A3

WC_FM5_20yr_WlDiff
Drawing Number

01
Revision

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.

Study Area Boundary

Existing Pipe Network

Proposed Pipe/Culvert Options

20yr Flood Extent

Cadastre - Lots

Pipe size units in mm labelled blue

Peak Water Level Difference metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

NORTH

1800X1200

1800X1500

1500X900

1200

900

900

WILLIAM ST

ATHOL ST

WHITING ST

LYALL ST

FLOOD ST

KALGOORLIE ST

ELSWICK ST

NORTH ST

NORTON ST

ALLEN ST

MACAULEY ST

CARLISLE ST

MARLBOROUGH ST

MARION ST

DARLEY RD

LOFTUS ST

DANIEL ST

WALTER ST

HAWTHORNE ST

FOSTER

BURFITT

FLOOD ST

ELSWICK ST

DATE PLOTTED: May 2017
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INNER WEST COUNCIL
LEICHHARDT FRMS&P
HC_FM3 20YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_4_5

Date
05/2017

Size
A3

HC_FM3_20yr_WlDiff
Drawing Number

01
Revision

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). Also combining WC-FM2 along with this option.

NORTH

BALMAIN RD
LILYFIELD RD
PRETORIA ST
RUSSELL ST
LONSDALE ST
CATHERINE ST
PERCIVAL ST
STARLING ST
YOUNG ST
ANNANDALE ST
KENTVILLE AVE
JOHNSTON ST
VIEW ST
ROSE ST
CHARLOTTE ST
AINSWORTH ST
LEYS AVE
PALING ST
EDNA ST
HUDSON ST
ALFRED ST
MOORE ST
ILKA ST
WISDOM ST
ANNESLEY ST
ARGUIMBAU ST
TRAFALGAR ST
WARATAH ST
MACKENZIE ST
HILL ST
MILTON ST
EMMA ST
JOHN ST
BOOTH ST
STANLEY ST
FOWLER ST
COLERIDGE ST
WETHERILL ST
CATHERINE ST
STYLES ST
MAYES ST
LEICHHARDT ST
THORBY AVE
NORTH AVE
RESERVE ST
SOUTH AVE
FERRIS ST
MACQUARIE ST
EMILY ST
ALBION ST

3100X2100
2700X2100
2400X1800
1200
1650
1200
1200

Peak Water Level Difference
metres
- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Pipe size units in mm labelled blue

- Existing Pipe Network
- Proposed Pipe/Culvert Options
- Proposed Basin
- 20yr Flood Extent
- Cadastre - Lots

Study Area Boundary

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INNER WEST COUNCIL
LEICHHARDT FRMS&P
WC_FM1 20YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_4_6

Date
05/2017

Size
A3

WC_FM1_20yr_WlDiff
Drawing Number

01
Revision

Styles Street Flow Path - Additional pipes from Mackenzie St to Whites Creek Culvert

MILTON ST
STANLEY ST
FOWLER ST
COLERIDGE ST
WETHERILL ST
CATHERINE ST
EMMA ST
HILL ST
JOHN ST
ALFRED ST
STYLES ST
MAYES ST
YOUNG ST
LEICHHARDT ST
THORBY AVE
NORTH AVE
SOUTH AVE
FERRIS ST
RESERVE ST

900
1500
1650
2700X2100
1050
1050
2400X1800
750

Peak Water Level Difference
metres
- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

- Existing Pipe Network
- Proposed Pipe/Culvert Options
- 20yr Flood Extent
- Cadastre - Lots

Pipe size units in mm labelled blue

DATE PLOTTED: May 2017
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INNER WEST COUNCIL
LEICHHARDT FRMS&P
WC_FM6 20YR ARI WL DIFF MITIGATION LESS EXISTING
FIG_4_7

Date
05/2017

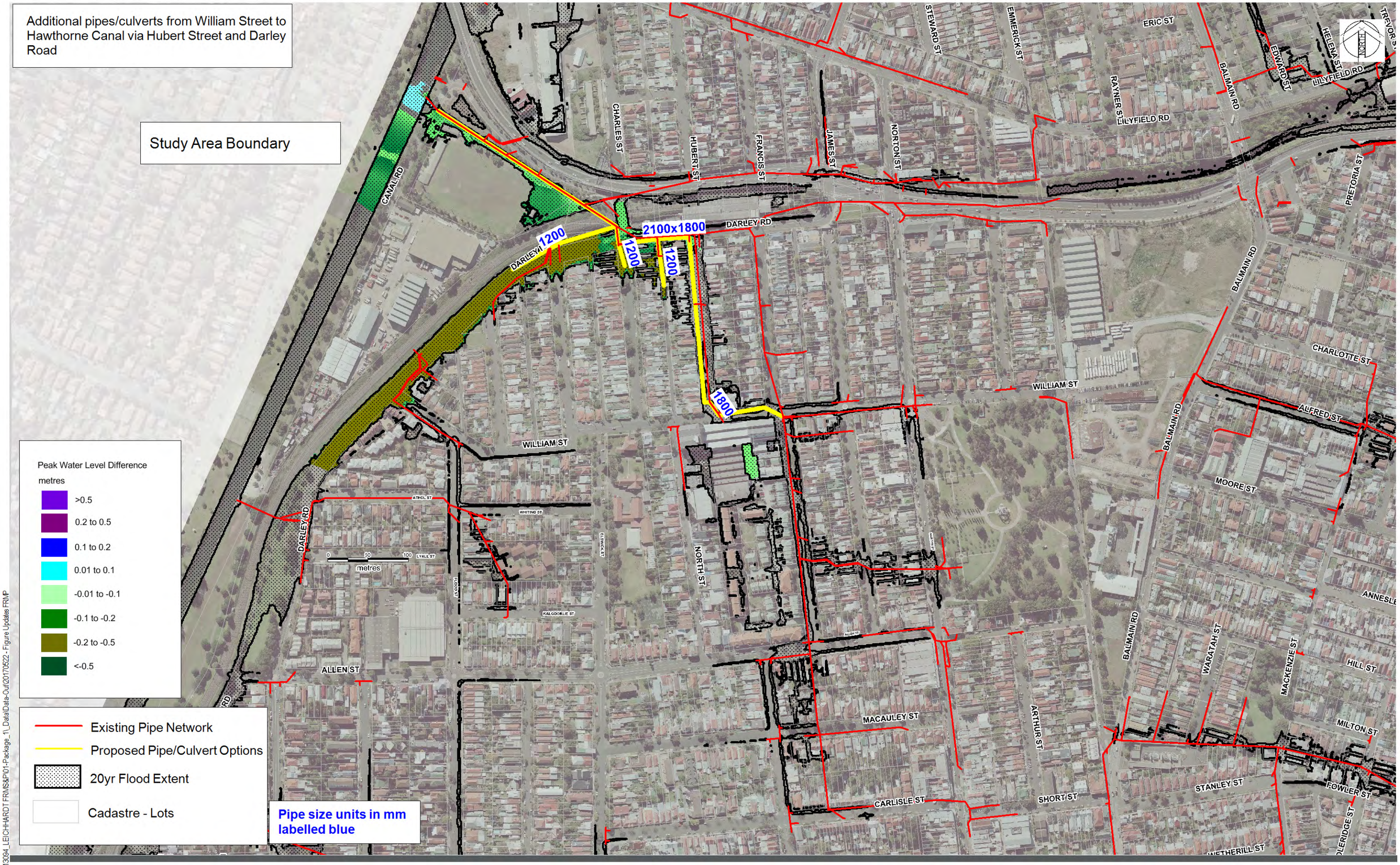
Size
A3

WC_FM6_20yr_WlDiff
Drawing Number

01
Revision

Additional pipes/culverts from William Street to Hawthorne Canal via Hubert Street and Darley Road

Study Area Boundary



Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

- Existing Pipe Network
- Proposed Pipe/Culvert Options
- 20yr Flood Extent
- Cadastre - Lots

Pipe size units in mm labelled blue

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INNER WEST COUNCIL
LEICHHARDT FRMS&P
HC_FM4 20YR ARI WL DIFF MITIGATION LESS EXISTING
FIG_4_8

Date
05/2017

Size
A3

HC_FM4_20yr_WlDiff
Drawing Number

01
Revision

Whites Creek Culvert/Open Channel - Proposing 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)

900
3100X2100
2700X2100
1050
1200
750
1650
1200
1500X900
1200

Pipe size units in mm labelled blue

Peak Water Level Difference metres
- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Existing Pipe Network
Proposed Pipe/Culvert Options
Bridge Upgrades
20yr Flood Extent
Cadastre - Lots

Kilometres

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INNER WEST COUNCIL
LEICHHARDT FRMS&P

WC_FM13 20YR ARI WL DIFF MITIGATION LESS EXISTING
FIG_4_9

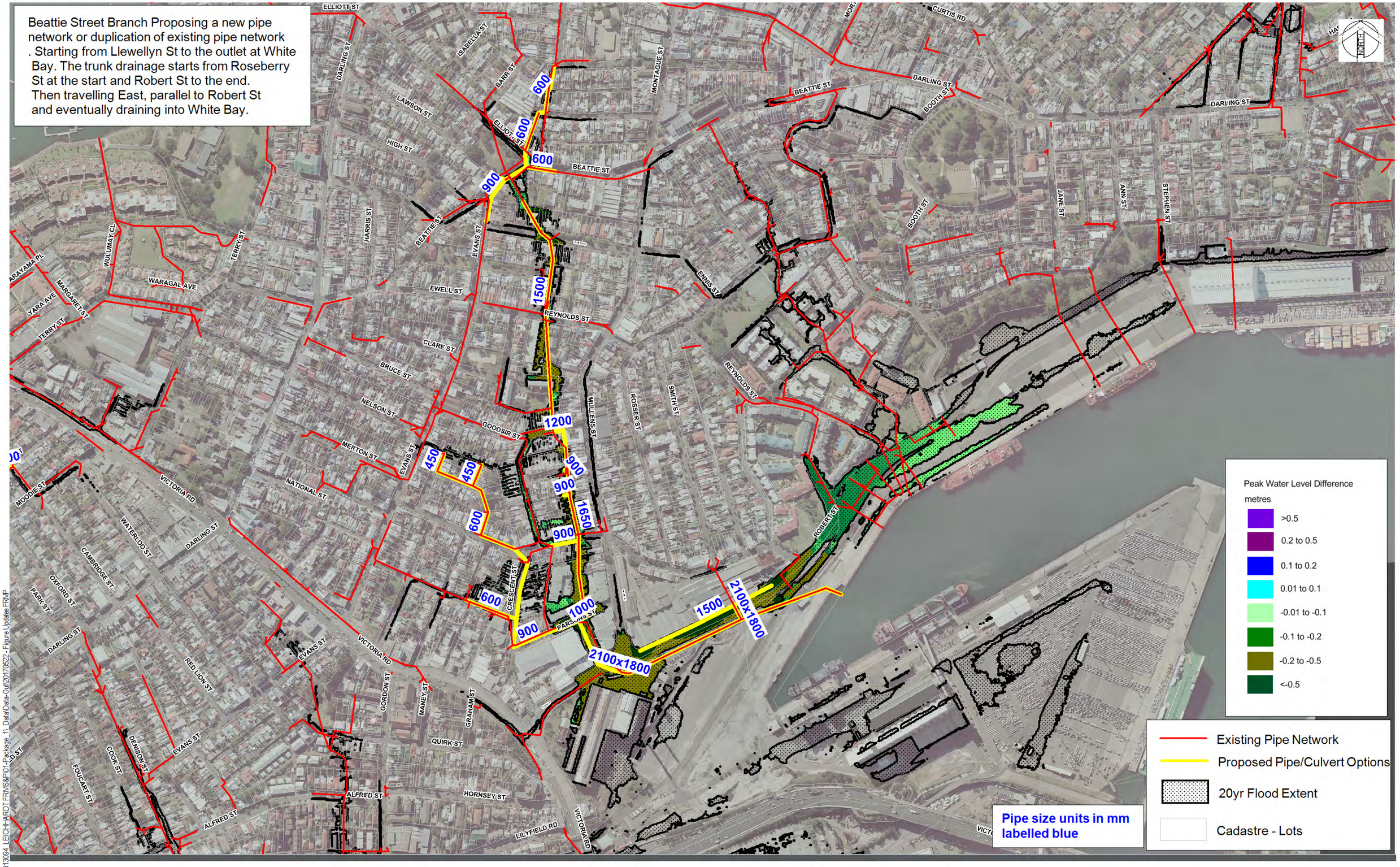
Date
05/2017

Size
A3

WC_FM13_20yr_WlDiff
Drawing Number

01
Revision

Beattie Street Branch Proposing 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.



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INNER WEST COUNCIL
LEICHHARDT FRMS&P
WB_FM1 20YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_4_10

Date
05/2017

Size
A3

WB_FM1_20yr_WlDiff
Drawing Number

01
Revision

Additional pipes or duplication of existing network from Reuss Street to Hawthorne Canal via Elswick Street, Flood Street and Marion Street.

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INNER WEST COUNCIL
LEICHHARDT FRMS&P
HC_FM2 20YR ARI WL DIFF MITIGATION LESS EXISTING
FIG_4_11

Date
05/2017

Size
A3

HC_FM2_20yr_WlDiff
Drawing Number

01
Revision

Moore Street Flow Path Additional Pipes from Catherine St to Whites Creek along Moore Lane.

AINSWORTH ST
LEYS AVE
PALING ST
EDNA ST
ILKA ST
ALFRED ST
PIPER ST
SMITH ST
GILLIES ST
YOUNG ST
ANNESLEY ST
MOORE ST
BOOTH ST
1200
1500
3100X2100
2700X2100

Peak Water Level Difference
metres
- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

- Existing Pipe Network
- Proposed Pipe/Culvert Options
- 20yr Flood Extent
- Cadastre - Lots

Pipe size units in mm labelled blue

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INNER WEST COUNCIL
LEICHHARDT FRMS&P
WC_FM11 20YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_4_12

Date
05/2017

Size
A3

WC_FM11_20yr_WlDiff
Drawing Number

01
Revision

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.

NORTH

WISDOM ST
ANNESLEY ST
ARGUIMBAU ST
JOHNSTON ST
VIEW ST
TRAFALGAR ST
PIPER ST
HILL ST
EMMA ST
JOHN ST
ALFRED ST
BOOTH ST
WELLS ST
CATHERINE ST
STYLES ST
MAYES ST
YOUNG ST
THORBY AVE
NORTH AVE
RESERVE ST
COLLINS ST
GUIHEN ST
SOUTH ST
SOUTH AVE
FERRIS ST
MACQUARIE ST
EMILY ST
PYRMONT BRIDGE RD
PARRAMATTA RD
ALBION ST
NELSON ST
600
750
1800X1200
1200

Peak Water Level Difference
metres
- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Study Area Boundary

Existing Pipe Network
Proposed Pipe/Culvert Options
20yr Flood Extent
Cadastre - Lots

Pipe size units in mm labelled blue

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INNER WEST COUNCIL
LEICHHARDT FRMS&P
JC_FM1 20YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_4_13

Date
05/2017

Size
A3

JC_FM1_20yr_WlDiff
Drawing Number

01
Revision

Wortley Street Branch Proposing 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.

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INNER WEST COUNCIL
LEICHHARDT FRMS&P
WB_FM2 20YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_4_14

Date
05/2017

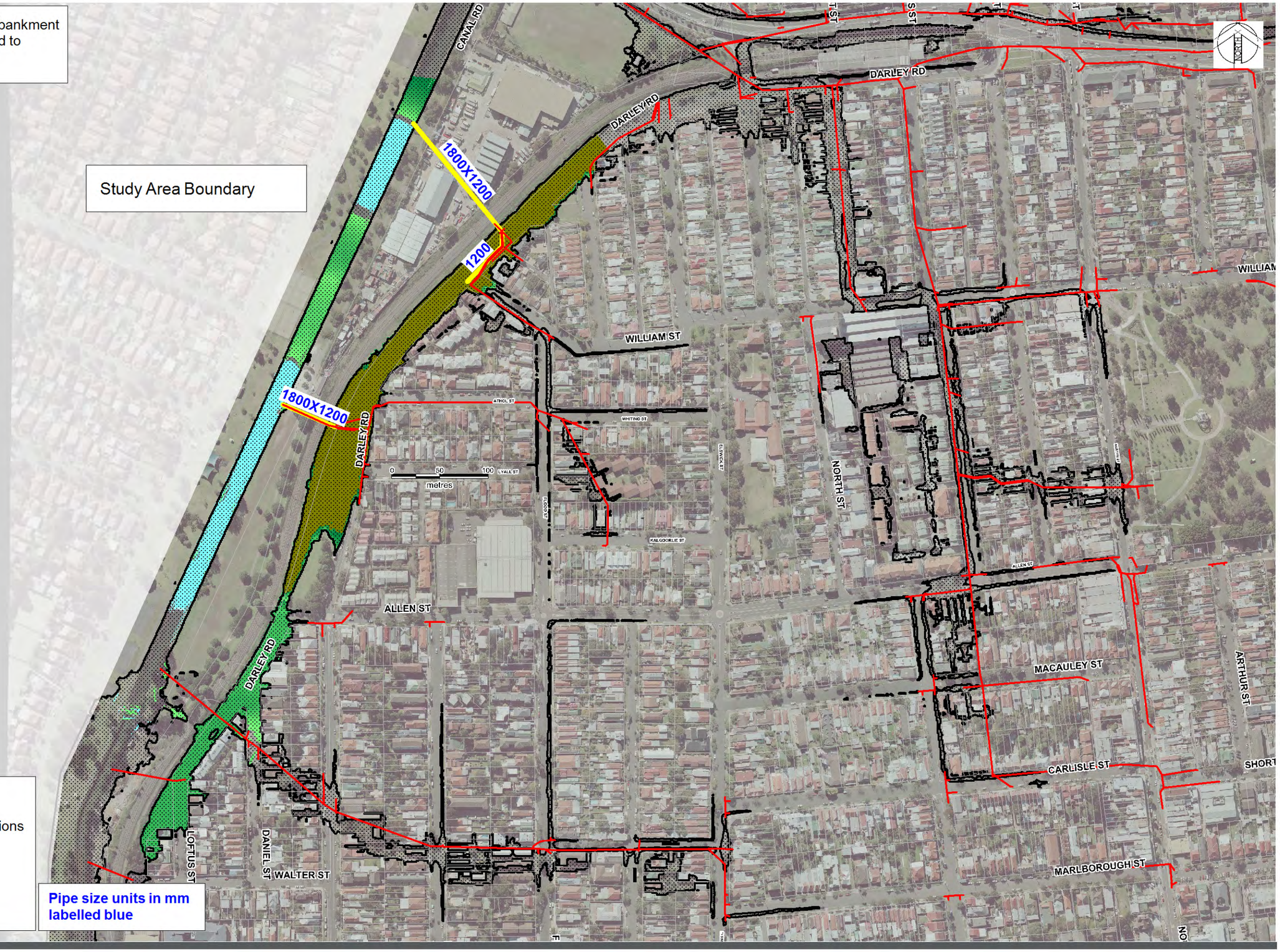
Size
A3

WB_FM2_20yr_WlDiff
Drawing Number

01
Revision

Proposed culverts through the rail embankment to drain flood waters from Darley Road to Hawthorne Canal.

Study Area Boundary



Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

- Existing Pipe Network
- Proposed Pipe/Culvert Options
- 20yr Flood Extent
- Cadastre - Lots

Pipe size units in mm labelled blue

DATE PLOTTED: May 2017
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INNER WEST COUNCIL
LEICHHARDT FRMS&P
HC_FM5 20YR ARI WL DIFF MITIGATION LESS EXISTING
FIG_4_15

Date
05/2017

Size
A3

HC_FM5_20yr_WlDiff
Drawing Number

01
Revision

Detention Basin at Catherine St (War Memorial Park)

OTTE ST

AINSWORTH

LEYS AVE

PALING ST

EDNA ST

ALFRED ST

ORE ST

14413 m2

ILKA ST

ANNESLEY ST

MOORE ST

NORTH

Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

- Existing Pipe Network
- Proposed Basin
- 20yr Flood Extent
- Cadastre - Lots

Pipe size units in mm labelled blue

DATE PLOTTED: May 2017
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INNER WEST COUNCIL
LEICHHARDT FRMS&P
WC_FM10 20YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_4_16

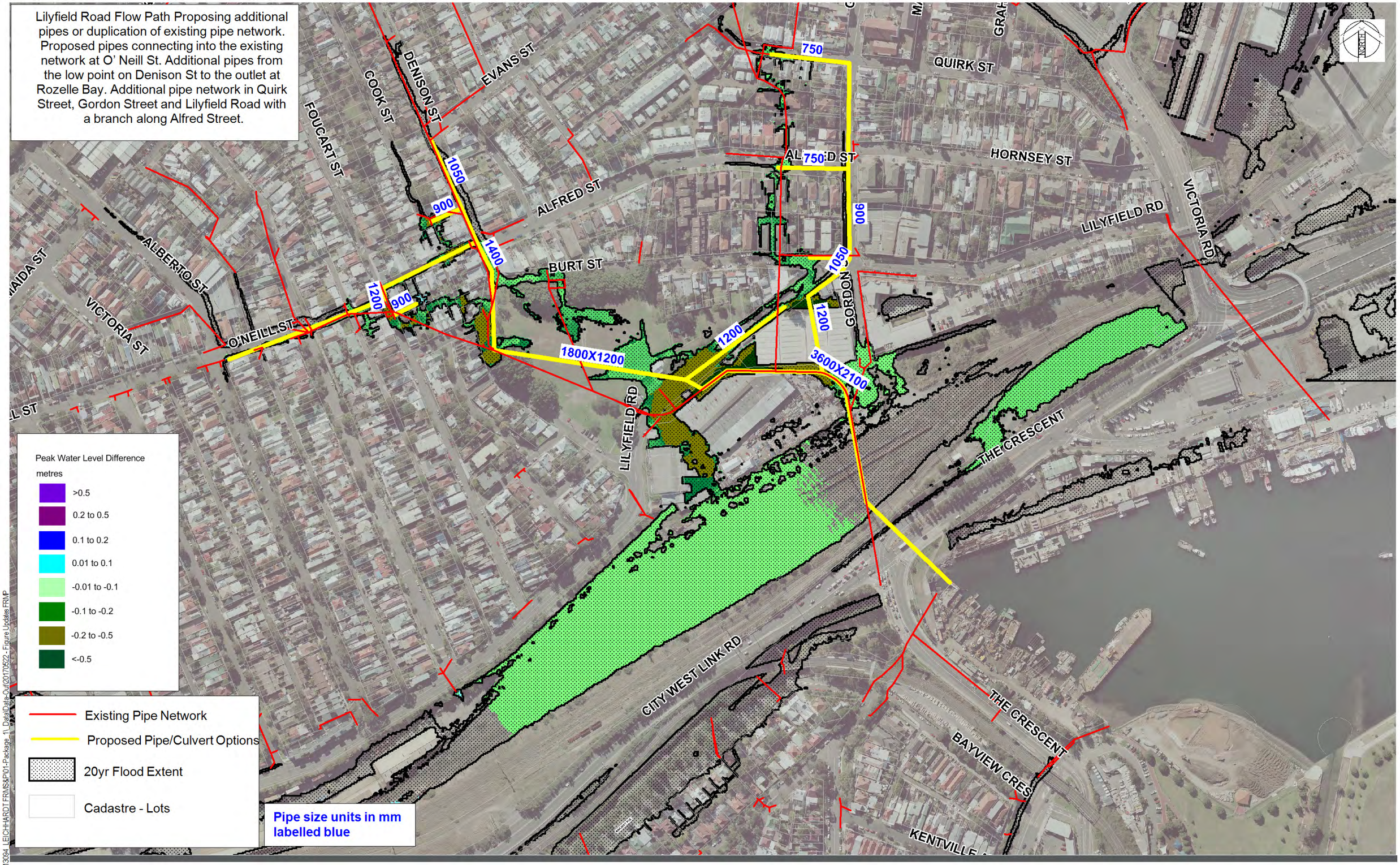
Date
05/2017

Size
A3

WC_FM10_20yr_WlDiff
Drawing Number

01
Revision

Lilyfield Road Flow Path Proposing 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.



Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Existing Pipe Network

Proposed Pipe/Culvert Options

20yr Flood Extent

Cadastre - Lots

Pipe size units in mm labelled blue

DATE PLOTTED: May 2017
FILE: N:\Projects\499\FY13\NA49913094_LEICHHARDT FRMS&P\01-Package_1_Data\Data-Out\20170522 - Figure Updates FRMP

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INNER WEST COUNCIL
LEICHHARDT FRMS&P
RB_FM1 20YR ARI WL DIFF MITIGATION LESS EXISTING
FIG_4_17

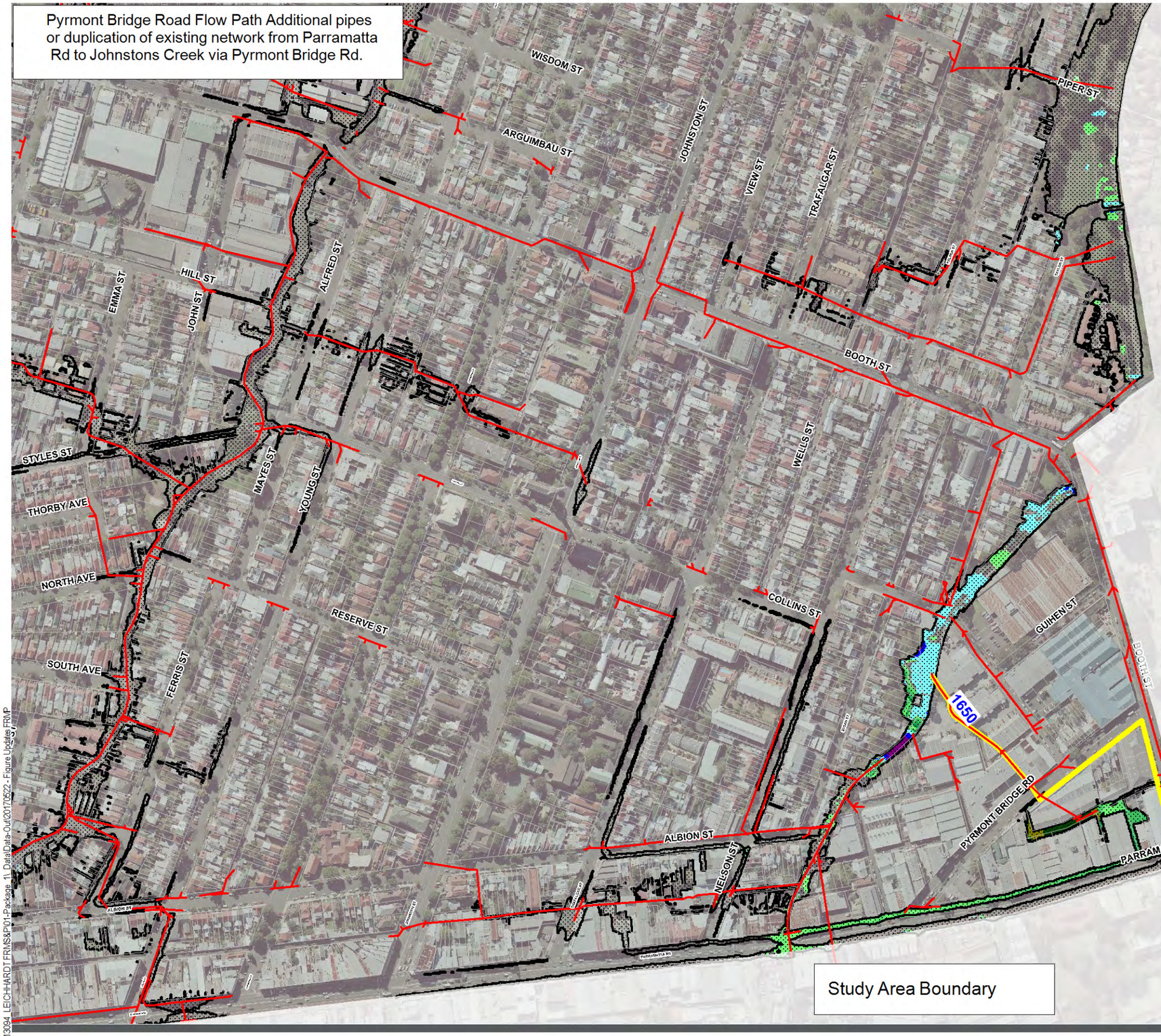
Date
05/2017

Size
A3

RB_FM1_20yr_WlDiff
Drawing Number

01
Revision

Pyrmont Bridge Road Flow Path Additional pipes or duplication of existing network from Parramatta Rd to Johnstons Creek via Pyrmont Bridge Rd.



Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Existing Pipe Network

Proposed Pipe/Culvert Options

20yr Flood Extent

Cadastre - Lots

Study Area Boundary

Pipe size units in mm labelled blue

DATE PLOTTED: May 2017
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INNER WEST COUNCIL
LEICHHARDT FRMS&P
JC_FM2 20YR ARI WL DIFF MITIGATION LESS EXISTING
FIG_4_18

Date
05/2017

Size
A3

JC_FM2_20yr_WlDiff
Drawing Number

01
Revision

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).

Study Area Boundary

VIEW S

TRAFALGAR ST

NELSON ST

TAYLOR ST

BOOTH ST

900

600

900

900

Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Existing Pipe Network

Proposed Pipe/Culvert Options

20yr Flood Extent

Cadastre - Lots

Pipe size units in mm labelled blue

DATE PLOTTED: May 2017
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INNER WEST COUNCIL
LEICHHARDT FRMS&P
JC_FM3 20YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_4_19

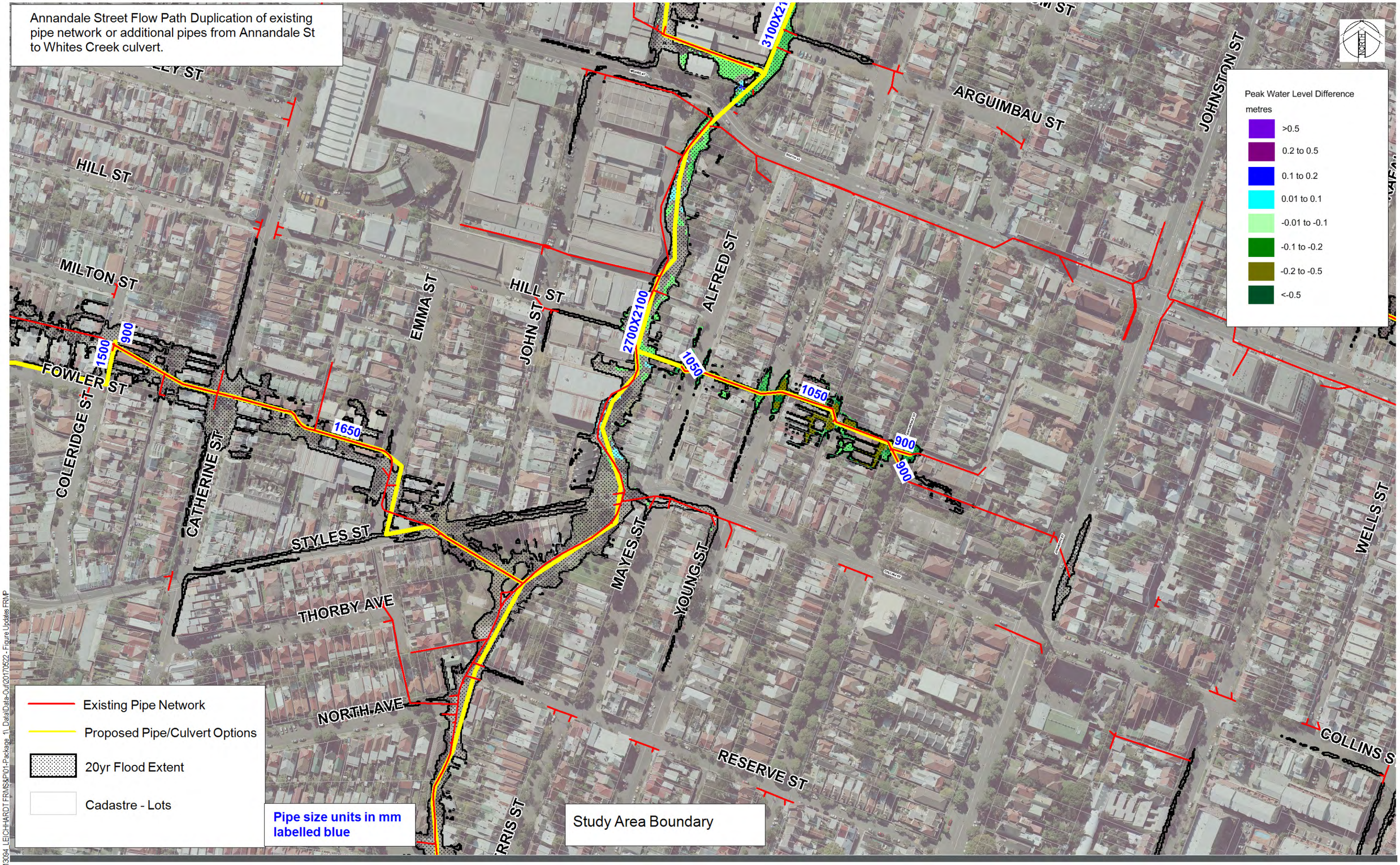
Date
05/2017

Size
A3

JC_FM3_20yr_WlDiff
Drawing Number

01
Revision

Annandale Street Flow Path Duplication of existing pipe network or additional pipes from Annandale St to Whites Creek culvert.



DATE PLOTTED: May 2017
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INNER WEST COUNCIL
LEICHHARDT FRMS&P
WC_FM8 20YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_4_20

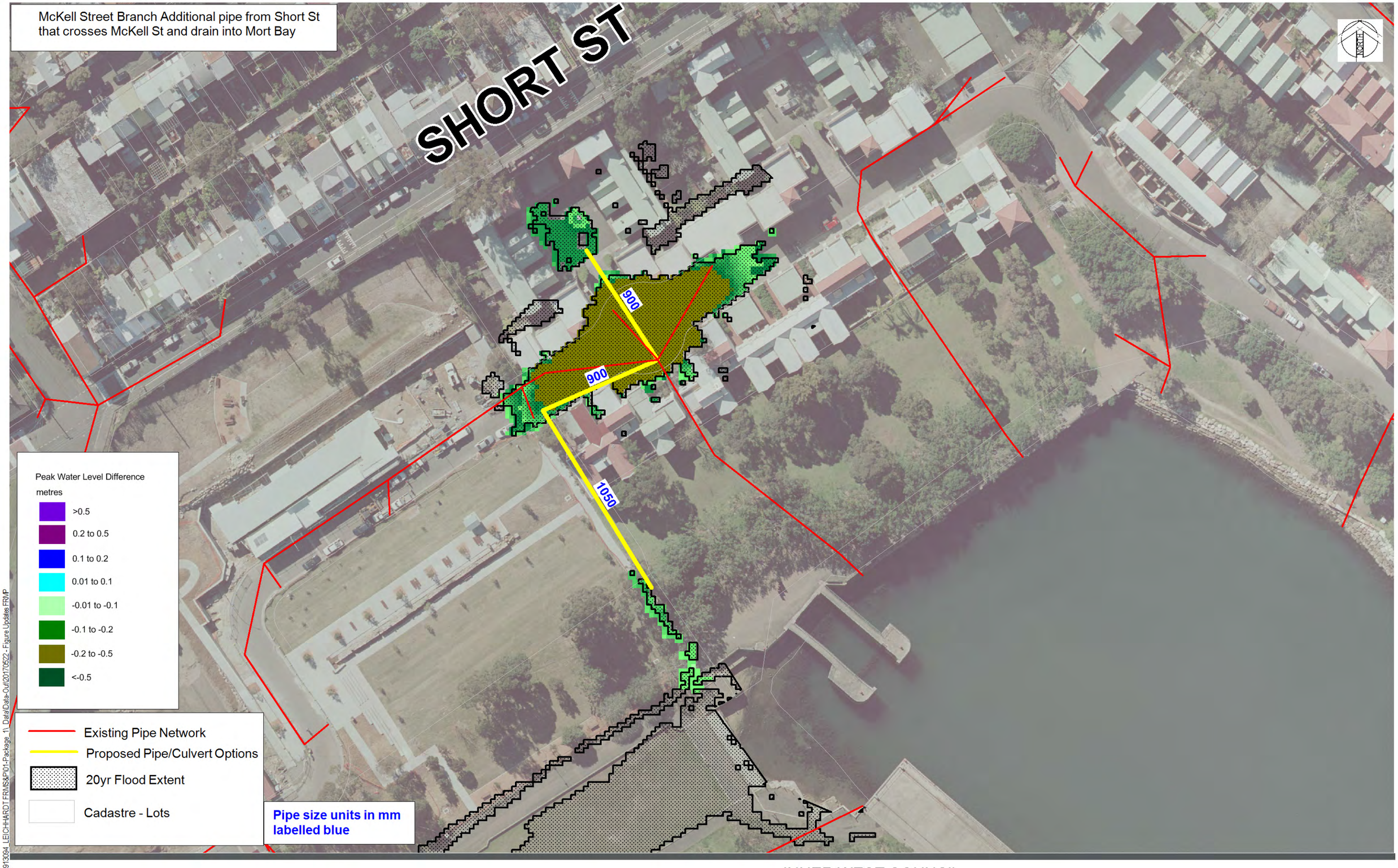
Date
05/2017

Size
A3

WC_FM8_20yr_WlDiff
Drawing Number

03
Revision

McKell Street Branch Additional pipe from Short St that crosses McKell St and drain into Mort Bay



Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Existing Pipe Network

Proposed Pipe/Culvert Options

20yr Flood Extent

Cadastre - Lots

Pipe size units in mm labelled blue

DATE PLOTTED: May 2017
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INNER WEST COUNCIL
LEICHHARDT FRMS&P
MB_FM5 20YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_4_21

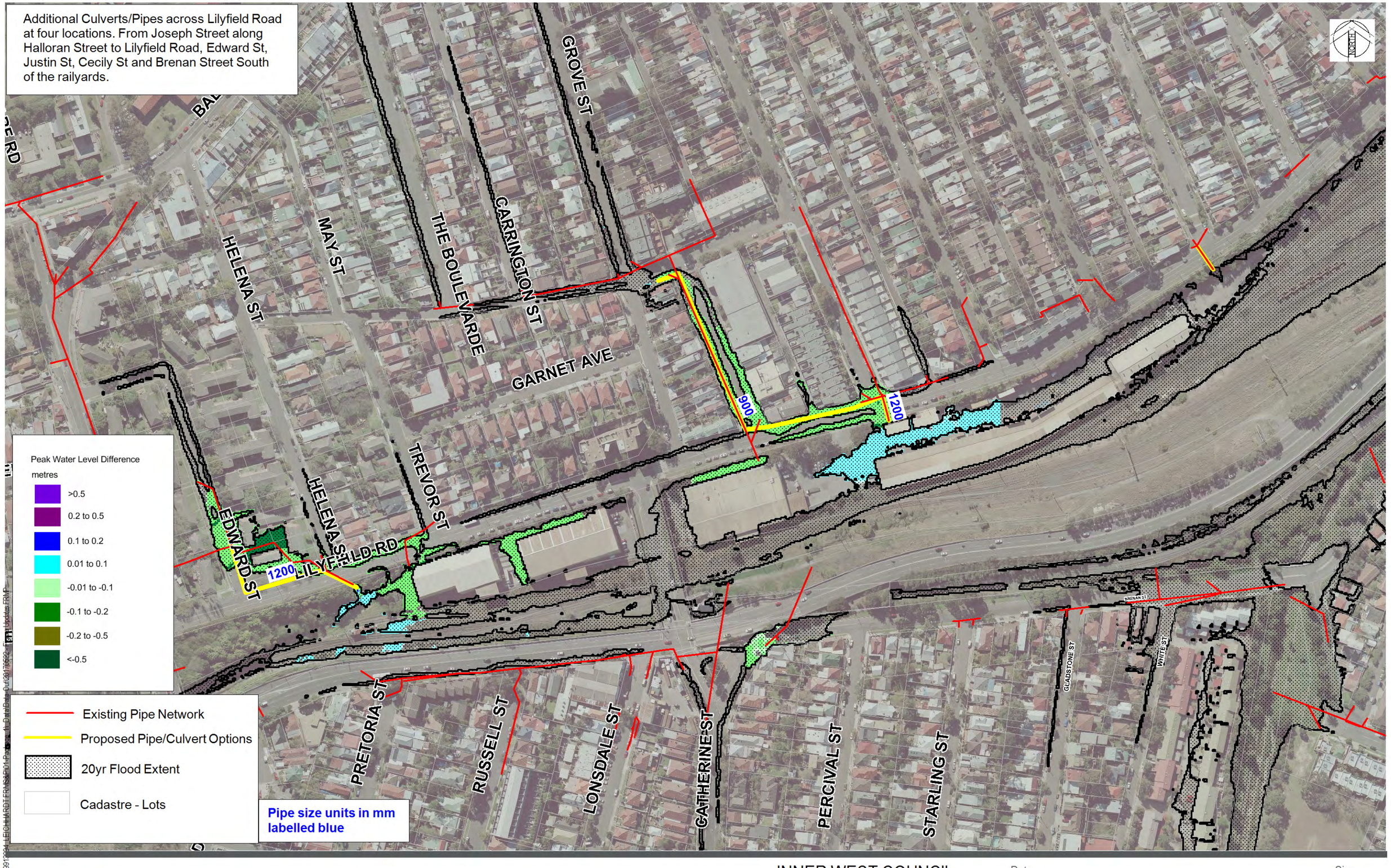
Date
05/2017

Size
A3

MB_FM5_20yr_WlDiff
Drawing Number

01
Revision

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.



Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Existing Pipe Network

Proposed Pipe/Culvert Options

20yr Flood Extent

Cadastre - Lots

Pipe size units in mm labelled blue

DATE PLOTTED: May 2017
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INNER WEST COUNCIL
LEICHHARDT FRMS&P
RB_FM2 20YR ARI WL DIFF
MITIGATION LESS EXISTING
FM_4_22

Date
05/2017

Size
A3

RB_FM2_20yr_WlDiff
Drawing Number

01
Revision

Young Street Flow Path Proposing 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.

NORTH

PALING ST
EDNA ST
ILKA ST
WISDOM ST
ANNESLEY ST
ARGUIMBAU ST
MACKENZIE ST
HILL ST
MILTON ST
EMMA ST
JOHN ST
ALFRED ST
FOWLER ST
COLERIDGE ST
CATHERINE ST
STYLES ST
MAYES ST
YOUNG ST
THORBY AVE
NORTH AVE
RESERVE ST
SOUTH AVE
FERRIS ST
MACQUARIE ST
EMILY ST
HEARN ST
ALBION ST
PARRAMATTA RD
1200
1500X900
750

Pipe size units in mm labelled blue

Peak Water Level Difference
metres
- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Existing Pipe Network
Proposed Pipe/Culvert Options
20yr Flood Extent
Cadastre - Lots

Study Area Boundary

DATE PLOTTED: May 2017
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INNER WEST COUNCIL
LEICHHARDT FRMS&P
WC_FM2 20YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_4_23

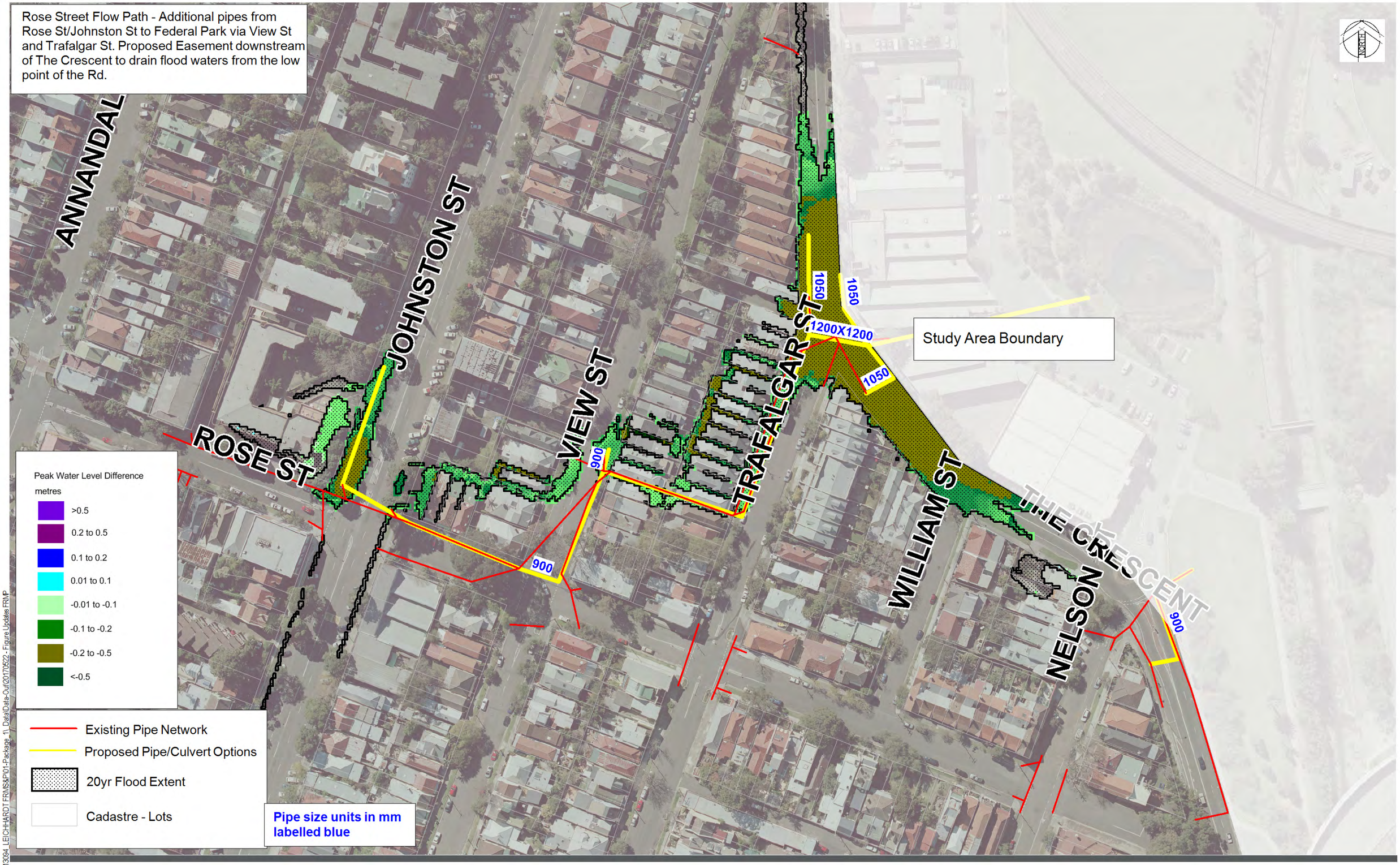
Date
05/2017

Size
A3

WC_FM2_20yr_WlDiff
Drawing Number

03
Revision

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.



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INNER WEST COUNCIL
LEICHHARDT FRMS&P
JC_FM4 20YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_4_24

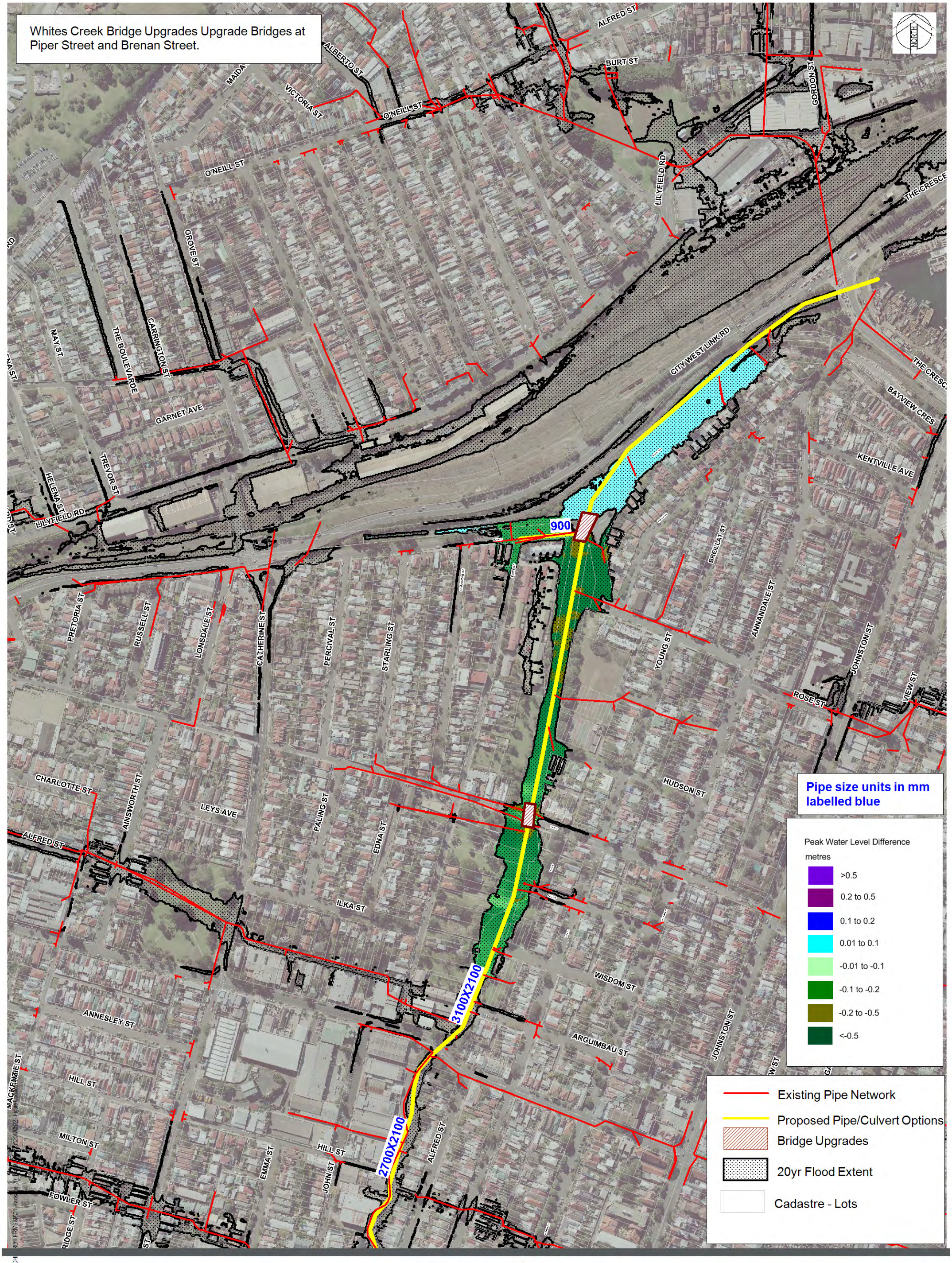
Date
05/2017

Size
A3

JC_FM4_20yr_WlDiff
Drawing Number

01
Revision

Whites Creek Bridge Upgrades Upgrade Bridges at Piper Street and Brenan Street.



Pipe size units in mm labelled blue

Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

- Existing Pipe Network
- Proposed Pipe/Culvert Options
- Bridge Upgrades
- 20yr Flood Extent
- Cadastre - Lots

DATE PLOTTED: May 2017
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INNER WEST COUNCIL
LEICHHARDT FRMS&P

WC_FM14 20YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_4_25

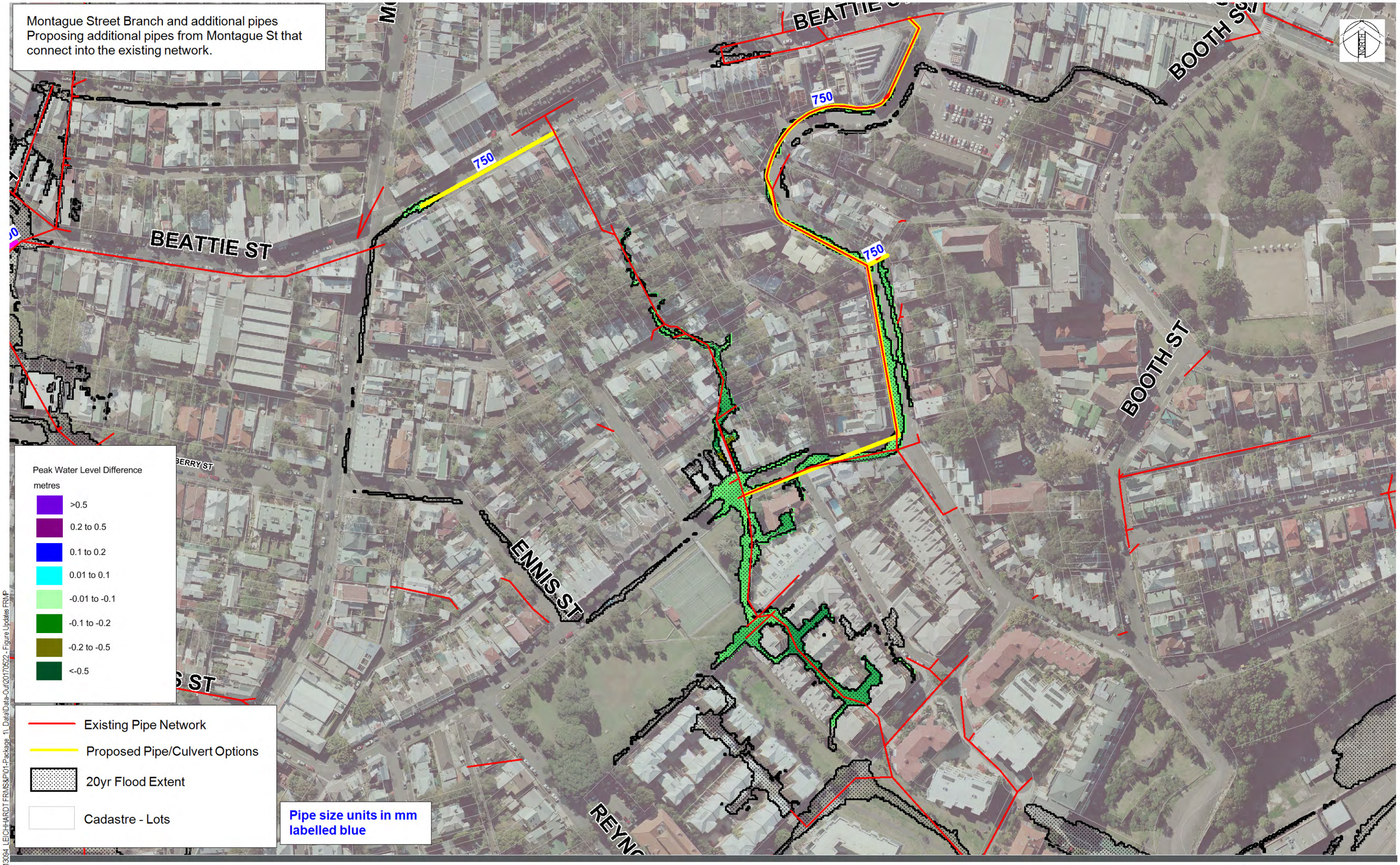
Date
05/2017

Size
A3

WC_FM14_20yr_WlDiff
Drawing Number

01
Revision

Montague Street Branch and additional pipes
Proposing additional pipes from Montague St that connect into the existing network.



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INNER WEST COUNCIL
LEICHHARDT FRMS&P
WB_FM4 20YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_4_26

Date
05/2017

Size
A3

WB_FM4_20yr_WlDiff
Drawing Number

01
Revision