Leichhardt Floodplain Risk Management Study and Plan

APPENDIX D

MITIGATION OPTION ASSESSMENTS SUB-CATCHMENT REPORTS - DRAFT

Cardno
Shaping the Future

Area 1 - Hawthorne Canal Options Assessment

Leichhardt Flood Risk Management Study and Plan - DRAFT

NA49913094

Prepared for
Inner West Council

Cardno
Shaping the Future

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1 Hawthorne Canal Catchment Description

The catchment for Hawthorne Canal is in the order of 670 hectares in size, and is the single largest catchment in the study area. A large portion of the catchment, greater than 400 hectares, is located outside of the study area.

The majority of the flooding issues within the Hawthorne Canal catchment occur upstream of the rail line that runs generally parallel to the canal. In this area, there are no formalised creeks or channels, and when the capacity of the existing pipe system is exceeded overland flow proceeds down streets and through properties.

There are a number of tributaries of the Canal in this area, the largest of which originates from upstream of Parramatta Road (outside of the study area).

The rail line itself forms a major hydraulic control in the study area, and significant ponding occurs upstream of this location. The ponding is largely influenced by the capacity of the culverts under the rail line connecting to Hawthorne Canal. The high hazard classification in this area is depth governed.

Flooding from the main Canal itself is limited to the west of the rail line, and does not affect a significant number of properties within the Study Area. However, flood levels within the Canal can affect the conveyance of flows from the culverts originating on the eastern side of the rail line.

The options proposed for assessment in the report are located within the study area portion of the Hawthorne Canal Catchment.

The location of the Hawthorne Canal Catchment within the Study Area is shown in Figure 1-1.

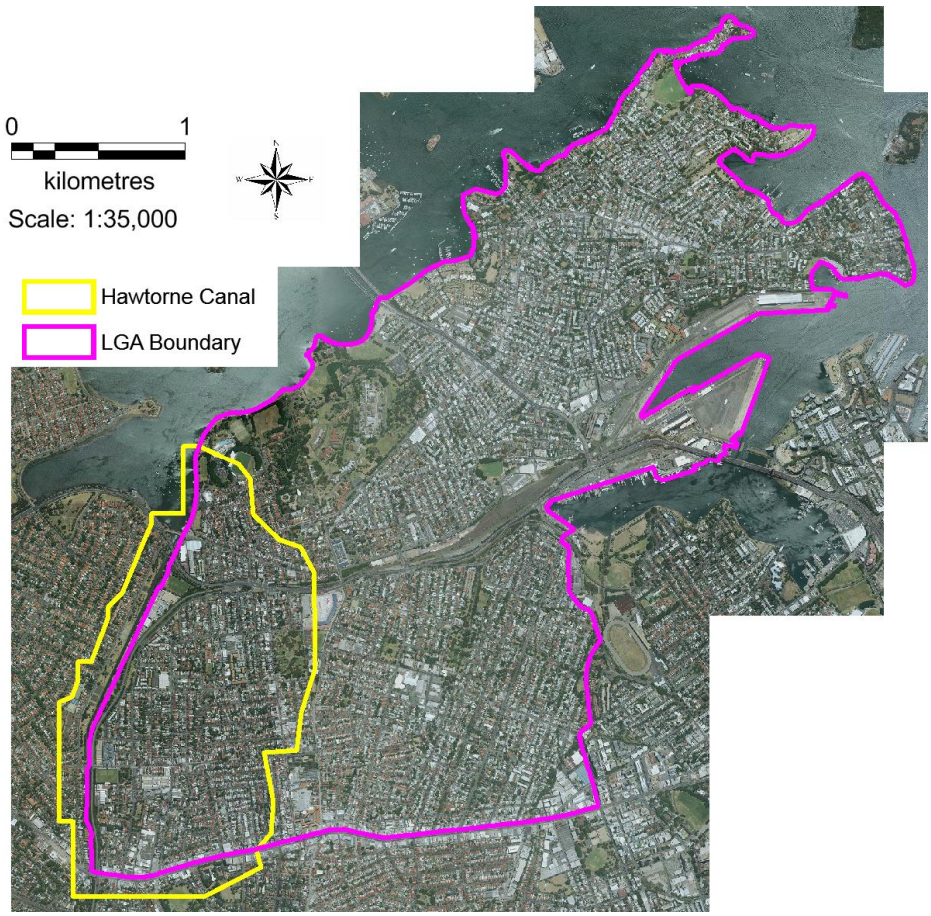


Figure 1-1 Hawthorne Canal Catchment Location

2 Flood Mitigation Options Identification

2.1 Flood Modification Measures for Hawthorne Canal

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

The various management options were identified taking into consideration the:

- flood behaviour and flow in the 20 year ARI event;
- grade of pipe (upstream and downstream); and
- preliminary availability and location of easements.

It should also be noted that Sydney Water and RMS may also play a major role in regards to fund allocation for the options recommended. Sydney Water's approach to flood-related improvement works on its assets is that Sydney Water will work with Councils to deliver the works (typically on a 50:50 cost-sharing basis) and provided Sydney Water has funding available within its Flood Risk Program. It is assumed that RMS will provide all the funding for the transverse pipe sections across State roads. Currently no allocation of RMS funding has been assigned for infrastructure travelling longitudinally along State Roads. It is likely that some contribution would be required from RMS for these upgrades in State Road easements. The total cost for HC-FM5 was allocated to RMS.

Flood modification measures for the Hawthorne Canal Catchment have been identified based on opportunities to connect with future upgrades and improvements.

2.2 Hawthorne Canal Flood Mitigation Options

Within the Hawthorne Canal catchment five (5) sets of options were modelled. These are shown in **Table 2-1** and **Figure 2-1**. The 100yr, 20yr and 5yr ARI peak water level difference plots for each mitigation option are attached at the end of this appendix report.

Table 2-1 Hawthorne Canal Mitigation Options

Option Description	Option Name	ID
Beeson Street Flow Path - Additional pipes /culverts from Parramatta Road to Hawthorne Canal via Beeson Street.	Beeson Street Flow Path HC-FM1	HC-FM1
Marion Street Flow Path – Additional pipes or duplication of existing network from Reuss Street to Hawthorne Canal via Elswick Street, Flood Street and Marion Street.	Marion Street Branch HC-FM2	HC-FM2
Regent Street Flow Path – 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.	Regent Street Branch HC-FM3	HC-FM3
Hubert Street Flow Path - Additional pipes/ culverts from William Street to Hawthorne Canal via Hubert Street and Darley Road.	Hubert Street Branch HC-FM4	HC-FM4
Darley Road - Proposed culverts through the rail embankment to drain flood waters from Darley Road to Hawthorne Canal.	Darley Road Branch HC-FM5	HC-FM5

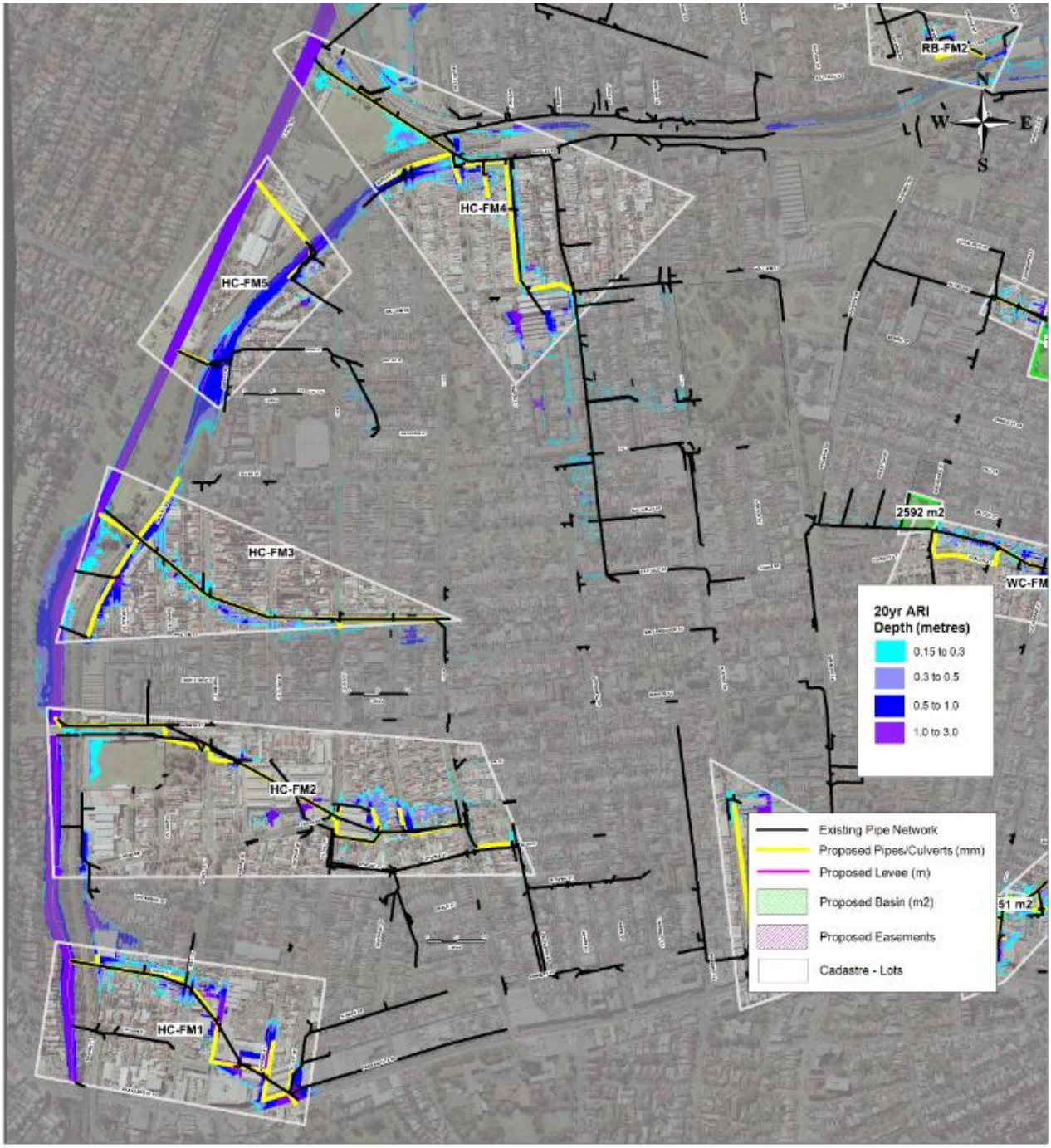


Figure 2-1 Hawthorne Canal Mitigation Options Locations

2.2.1 Beeson Street Flow Path HC-FM1

HC-FM1 consists of additional pipes and culverts from Parramatta Road to Hawthorne Canal via Beeson Street. This option aims to mitigate flood inundation due to the 20 year ARI flood event. The option is expected to mitigate the inundation experienced along the sections of Flood Street, George Street, Upward Street and Tebbutt Street that are located between Parramatta Road and Kegworth Street. Flooding on Beeson Street is also expected to reduce.

Under existing conditions, the worst flooding due to the 20 year ARI event takes place on Flood Street, George Street, Upward Street and Parramatta Road with depths up to 1.9m.

The main branch of the option comprises of a box culvert (2.4m x 2.1m) that is 625m in length. There are also 1800mm diameter pipes connecting to the culverts at Parramatta Road, Flood Street and George Street as well as a pipe at the western end of Beeson Street.

There is a new development currently underway at 22 George Street, Leichhardt. This development has incorporated re-routing and upgrading if the existing trunk drainage pipeline passing through the property, consistent with the recommendations of this mitigation option. The development is also required to make provision for a future overland flow path between McAleer and Upward Streets to cater for larger storm events, consistent with the objectives of this mitigation option.

Construction of the culvert from Flood Street to George Street along Parramatta Road will be difficult, as there are challenges with the grade and there are likely to be significant services in this area. If any re-development is scheduled to occur in the industrial block between Flood Street and George Street, the proposed culvert could be incorporated into the development which would simplify the design. It should be noted that this option would also rely on drainage upgrade on the Southern side of Parramatta Road, within Petersham.

Potential constraints for this measure also include construction of a pipeline under the rail corridor and pipe crossings of major roads, especially Parramatta Road, with associated costs due to construction, services and traffic management requirements. Any pipeline upgrade between Upward Street and Tebbutt Street will most likely be reliant upon future development of these properties and being able to incorporate the upgraded pipeline and overland flow path into the development.

In regards to cost allocation between the primary asset owners, both RMS and Sydney Water could potentially share a majority of the cost alongside Council. The transverse drainage across Tebbutt Street and Parramatta Road would ideally be allocated to RMS while the remaining major trunk drainage upgrades will potentially be the responsibility of Sydney Water.

2.2.2 Marion Street Branch HC-FM2

HC-FM2 on Marion Street contains new pipes and modifications to the existing network. The option begins from Reuss Street and ends at Hawthorne Canal via Elswick Street, Flood Street and Marion Street. The aim of the option is to mitigate flood inundation due to the 20 year ARI event which produces flooding at the car park adjacent to Lord Street.

The main branch of the option comprises of a 1500mm diameter pipe that is 900m in length. Pipes, 900mm in diameter, connect to the main branch on Edith Lane, Ivory Lane and Flood Street and a 600mm diameter pipe is used on Reuss Street.

The final alignment of the upgrades would be subject to ongoing liaison with Sydney Water to look at potential opportunities to upgrade Sydney Water pipelines located nearby in lieu of additional pipelines through 1A Lords Road.

There will be costs associated due to construction, services and traffic management requirements. There is potential for RMS (Foster Road transverse crossing) and Sydney Water (Main trunk drainage) to share some of the cost.

2.2.3 Regent Street Branch HC-FM3

This option consists of two major branches. One branch is along Darley Road between Walter Street and Allen Street. The Darley Road branch consists of a Culvert (1.5mx0.9m) that is 350m in length. This culvert targets the ponding which occurs behind the rail line on Darley Road.

The other branch starts from Elswick Street and ends at Hawthorne Canal and consists of 900mm and 1200mm diameter pipes with a combined length of 650m plus a box culvert (1.8m x 1.5m) with a length of 80m. This branch travels through Regent Street and crosses Edith Street, Flood Street, Burfitt Street, Foster Street and Daniel Street and finally Darley Road and then beneath the railway track and into Hawthorne Canal. Heavy flooding as a result of the 20 year ARI storm event is expected at the intersection of Darley Road and Loftus Street with depths in this location of around 1.1m.

A major constraint for this measure consists of the tunnelling under the railway line plus other construction costs that maybe required for pipe crossings beneath the railways line. To reduce these costs and construction constraints the viability of construction of a new pipeline from Darley Road via the existing pedestrian subway between Darley Road and Hawthorne Canal instead of tunnelling beneath the railway line could also be investigated.

In addition to the tunnelling constraint the pipeline has to be upgraded through substantial lengths of private property, which may require the buyback of 4 properties. It is likely to be more feasible to continue the pipeline through the four properties, because an alternative alignment to reduce the property buy-backs will require pits at a depth of 3m below the current road level.

In regards to the primary asset owners in the area (RMS, Sydney Water and Council), RMS could possibly be apportioned part of the upgrade cost. The cost applicable to RMS would involve the transverse drainage in Foster Street.

It is noted that an alternative is to split this option into two components, being those works upstream and downstream of Darley Road . Construction of the Darley Road culvert and crossing under the rail line would assist in alleviating the flooding in this area, without construction of the longer pipe up to Elswick Street which has a number of constraints.

2.2.4 Hubert Street Branch HC-FM4

HC-FM4 consists of pipes and culverts from William Street to Hawthorne Canal via Hubert Street and Darley Road. There are two types of culverts. One is a 2.4mx2.1m culvert 300m in length that begins from the Charles Street/Darley Road Intersection and drains onto Hawthorne Canal after crossing Canal Road. The other culvert (2.1mx1.8m) is 90m in length and travels along Darley Road between Hubert Street and Charles Street. The proposed pipes consist of a 1800mm diameter line and a separate 1200mm diameter line. The 1800mm diameter pipe is 320m in length and starts on Francis Street, travels along William Street and then onto Hubert Street, finally ending at Darley Road. The 1200mm diameter pipes are located on an Un-Named Lane between Hubert Street and Charles Street, Charles Street and Darley Road.

The worst of the flooding is predominantly on Darley Road with depths approaching the 1m level during the 20 year ARI storm event. Potential constraints include costs due to construction, services and traffic management requirements on Darley Road.

An alternative is split this option into two components, being initially the construction of the works at Darley Road , with a long term aim to construct the other upstream sections. This would assist in addressing the flooding issues on Darley Road.

RMS funding could be investigated for works that involve transverse drainage in Darley Road.

2.2.5 Darley Road Branch HC-FM5

The Darley Road branch consists two sections of proposed culverts that cross through the rail embankment to drain flood waters from Darley Road to Hawthorne Canal. One section consists of a culvert (1.8m x 1.2m) with a length of 60m and is on Darley Road between Athol Street and Lyall Street. The other section consists of a 1200mm diameter pipe starting from the William Street/ Darley Road intersection then connecting to a 1.8m x 1.2m culvert on Darley road that crosses beneath the rail embankment.

Major flooding due to the 20 year ARI storm event is on Darley Road with depths to around 1.25m. A major constraint for this measure consist of the tunnelling plus other construction costs that maybe required for pipe crossing at the railways line.

RMS funding could be investigated to contribute for most of the costs related with this option. This includes the sections that are upgraded on Darley Road.

3 Mitigation Option Modelling Outcomes

The Hawthorne Canal flood mitigation options were assed for the 5, 10, 20, 50 and 100 Year ARI design flood events, along with the PMF event.

The outcomes of the modelling are shown in the 5, 20, and 100 Year ARI water level difference plots attached at the end of this catchment report.

A summary of the impacts on flood behaviour for each option is provided below.

3.1 Beeson Street Flow Path HC-FM1

The proposed increase in drainage capacity of mitigation option HC-FM1 is shown to reduce overland flows along the Beeson Street flow path. The mitigation strategy shows water level decreases of 0.2m – 0.5m along sections of Parramatta Road, Flood Street, George Street, Upward Street and McAleer Street, and Beeson Street leading into Hawthorne Canal.

Significant reductions are apparent at properties located on Upward Street, Tebbutt Street, Beeson Street and Kegworth Street. Modelling of this mitigation strategy indicates that 63 properties would have a decrease in water level of more than 0.15m in the 20 Year ARI event.

3.2 Marion Street Branch HC-FM2

The increase in drainage capacity at the Marion Street Branch proposed in HC-FM2 is shown to decrease flood levels by 0.2m – 0.5m in the vicinity of Ivory Street, Edith Street and Edith Lane in the 20 Year ARI event. Significant water level decreases of more than 0.5m are also apparent at the car park adjacent to Lord Street in this event. A 0.2m – 0.5m water level decrease is also visible in properties between Edith Street and Flood Street in the 20 Year ARI event. Results indicate that 21 properties would experience a decrease in water level of more than 0.15m in the 20 Year ARI event due to this mitigation strategy.

3.3 Regent Street Branch HC-FM3

Mitigation option FM3 shows significant water level decreases of more than 0.5m in some areas of Darley Road between Walter Street and Allen Street in the 20 Year ARI event. Decreases are also observable upstream, along Regent Street at Elswick Street, Edith Street and Flood Street, as well as Burfitt Street, Forster Street and Daniel Street towards Hawthorne Canal. The increased conveyance under the railway to Hawthorne Canal reduces flood levels on a number of residential properties, with 22 properties showing a water level decrease of more than 0.15m in the 20 Year ARI event.

3.4 Hubert Street Branch HC-FM4

Mitigation option HC-FM4 shows significant decrease in water levels either side of the railway at Darley Road and Charles Street. The most significant reductions are seen at the intersections of Darley Road and Falls Street, Elswick Street and Charles Street. These reductions are between 0.2m and 0.5m in the 20 Year ARI event. Water level decreases of 0.01m to 0.2m are also observable at Blackmore Park and along Canal Road in the 20 Year ARI event. Results indicate that 26 properties would experience a decrease in water level of more than 0.15m in the 20 Year ARI event due to this mitigation strategy.

3.5 Darley Road Branch HC-FM5

Mitigation option HC-FM5 shows a decrease in ponding along Darley Road between Walter Street and Falls Street due to an increase in conveyance beneath the railway embankment to Hawthorne Canal. The majority of this water level decrease in the 20 Year ARI is between 0.2m and 0.5m. Results indicate that 9 properties would experience a decrease in water level of more than 0.15m in the 20 Year ARI event due to this mitigation strategy.

4 Economic Assessment of Flood Damages in the Hawthorne Canal Catchment

4.1 Hawthorne Canal Mitigation Options Damages Assessment

An assessment of damages for the existing condition in the Hawthorne Canal Catchment is presented in the Floodplain Risk Management Study. The approach adopted for calculating the existing damages has been repeated for the modelling results from the mitigation options proposed for the Hawthorne Canal catchment.

The economic flood damage results for each of the options and the existing scenarios are presented in **Table 4-1** to **Table 4-6**. The reductions in properties affected by overground and overfloor flooding, total damages and AAD are provided.

The total reduction in damaged properties and the associated reduction in damage costs for each mitigation strategy is summarised in **Table 4-6**. This table represents a summary of differences between existing and Mitigation scenarios presented in **Table 4-1** to **Table 4-5**.

The flood damages assessment is a useful tool for comparing the merits of various options, it is not a precise flood risk analysis tool and the limitation associated with the assessment should be considered when interpreting the results.

The following information should be considered when interpreting the damages data:

- Negative property or dollar values represent increases from the existing scenario.
- Where an option results in a reduction in flood depths there may not be any reduction in the flood damages where:
    - The reduction in flood depths or extent occur in open space or roadways; or
    - The reduction in flood depths occurs on properties that were not impacted by over floor flooding (i.e. the flooding on the property grounds is shallower but still exists).
- The flood damages are calculated at a discrete location on each property. This location is where the floor level and ground level survey was obtained from. As such, if the flooding occurs at another location on the property other than the survey point, this property will not register any damages with regards to this damages assessment.
- Commercial and industrial damages are only incurred when over floor flooding exists.
- The reduction in the number of properties impacted as a result of an option may vary between different flood events due to the performance of the proposed work under the different flow behaviour of each flood event.

Table 4-1 HC_FM1 Flood Damage Assessment Summary

Event / Property type	Properties with Overfloor Flooding		Properties with Overground Flooding		Estimated Total Damage ($ June 2016)	
	Existing Case	*Mitigation Case*	*Existing Case*	*Mitigation Case*	*Existing Case*	*Mitigation Case*
PMF Event						
Residential	91	82	109	109	$ 7,774,777	$ 6,821,243
Commercial	3	3	4	4	$ 1,302,890	$ 1,290,785
Industrial	38	32	38	36	$ 7,811,077	$ 6,991,709
PMF Total	**132**	**117**	**151**	**149**	**$ 16,888,744**	**$ 15,103,737**
100yr ARI						
Residential	18	7	40	36	$ 1,009,407	$ 364,898
Commercial	2	0	2	2	$ 110,694	$ -
Industrial	24	9	26	22	$ 3,648,873	$ 1,623,131
100yr ARI Total	**44**	**19**	**68**	**61**	**$ 4,768,973**	**$ 1,988,029**
50yr ARI						
Residential	18	7	39	35	$ 960,444	$ 315,935
Commercial	2	0	2	2	$ 104,434	$ -
Industrial	24	9	25	21	$ 3,310,125	$ 1,284,383
50yr ARI Total	**44**	**16**	**66**	**58**	**$ 4,375,003**	**$ 1,600,318**
20yr ARI						
Residential	13	4	32	28	$ 704,390	$ 246,953
Commercial	1	0	2	2	$ 84,980	$ -
Industrial	20	8	22	20	$ 2,604,302	$ 1,039,801
20yr ARI Total	**34**	**12**	**56**	**50**	**$ 3,393,671**	**$ 1,286,754**
10yr ARI						
Residential	11	4	23	19	$ 569,359	$ 231,269
Commercial	1	0	2	2	$ 79,321	$ -
Industrial	20	6	20	18	$ 2,224,903	$ 865,964
10yr ARI Total	**32**	**10**	**45**	**39**	**$ 2,873,583**	**$ 1,097,233**
5yr ARI						
Residential	4	2	11	8	$ 237,109	$ 95,268
Commercial	1	0	2	2	$ 70,209	$ -
Industrial	18	4	19	16	$ 1,667,896	$ 480,795
5yr ARI Total	**23**	**6**	**32**	**26**	**$ 1,975,215**	**$ 576,063**
Total Annual Average Damage					**$ 965,931**	**$ 376,372**

Table 4-2 HC_FM2 Flood Damage Assessment Summary

Event / Property type	Properties with Overfloor Flooding		Properties with Overground Flooding		Estimated Total Damage ($ June 2016)	
	Existing Case	*Mitigation Case*	*Existing Case*	*Mitigation Case*	*Existing Case*	*Mitigation Case*
PMF Event						
Residential	131	116	223	222	$ 8,039,935	$ 7,185,828
Commercial	6	6	6	6	$ 695,940	$ 680,626
Industrial	2	2	2	2	$ 2,628,273	$ 2,442,588
PMF Total	**139**	**124**	**231**	**230**	**$ 11,364,148**	**$ 10,309,043**
100yr ARI						
Residential	26	16	55	53	$ 1,956,331	$ 1,123,743
Commercial	5	4	5	4	$ 361,630	$ 146,889
Industrial	0	0	1	1	$ -	$ -
100yr ARI Total	**31**	**20**	**61**	**58**	**$ 2,317,961**	**$ 1,270,632**
50yr ARI						
Residential	19	16	49	48	$ 1,601,238	$ 1,119,109
Commercial	5	4	5	4	$ 282,991	$ 142,482
Industrial	0	0	1	1	$ -	$ -
50yr ARI Total	**24**	**20**	**55**	**53**	**$ 1,884,229**	**$ 1,261,591**
20yr ARI						
Residential	18	15	43	42	$ 1,498,207	$ 985,487
Commercial	4	3	4	4	$ 109,477	$ 106,782
Industrial	0	0	0	0	$ -	$ -
20yr ARI Total	**22**	**18**	**47**	**46**	**$ 1,607,684**	**$ 1,092,270**
10yr ARI						
Residential	17	11	39	39	$ 1,344,886	$ 859,912
Commercial	3	2	4	4	$ 104,526	$ 100,790
Industrial	0	0	0	0	$ -	$ -
10yr ARI Total	**20**	**13**	**43**	**43**	**$ 1,449,412**	**$ 960,702**
5yr ARI						
Residential	13	10	32	31	$ 1,023,686	$ 798,536
Commercial	2	2	4	4	$ 99,131	$ 99,082
Industrial	0	0	0	0	$ -	$ -
5yr ARI Total	**15**	**12**	**36**	**35**	**$ 1,122,817**	**$ 897,618**
Total Annual Average Damage					**$ 515,255**	**$ 384,745**

Table 4-3 HC_FM3 Flood Damage Assessment Summary

Event / Property type	Properties with Overfloor Flooding		Properties with Overground Flooding		Estimated Total Damage ($ June 2016)	
	Existing Case	*Mitigation Case*	*Existing Case*	*Mitigation Case*	*Existing Case*	*Mitigation Case*
PMF Event						
Residential	113	111	180	178	$ 6,977,319	$ 6,663,452
Commercial	0	0	0	0	$ -	$ -
Industrial	1	1	1	1	$ 203,585	$ 204,891
PMF Total	**114**	**112**	**181**	**179**	**$ 7,180,904**	**$ 6,868,343**
100yr ARI						
Residential	42	24	78	75	$ 2,204,349	$ 1,297,488
Commercial	0	0	0	0	$ -	$ -
Industrial	1	1	1	1	$ 92,138	$ 484
100yr ARI Total	**43**	**25**	**79**	**76**	**$ 2,296,487**	**$ 1,297,972**
50yr ARI						
Residential	36	18	75	70	$ 1,884,444	$ 1,003,401
Commercial	0	0	0	0	$ -	$ -
Industrial	1	0	1	1	$ 83,715	$ -
50yr ARI Total	**37**	**18**	**76**	**71**	**$ 1,968,159**	**$ 1,003,401**
20yr ARI						
Residential	28	13	64	56	$ 1,395,539	$ 729,808
Commercial	0	0	0	0	$ -	$ -
Industrial	1	0	1	1	$ 80,480	$ -
20yr ARI Total	**29**	**13**	**65**	**57**	**$ 1,476,018**	**$ 729,808**
10yr ARI						
Residential	18	11	52	46	$ 1,062,192	$ 639,099
Commercial	0	0	0	0	$ -	$ -
Industrial	1	0	1	1	$ 74,296	$ -
10yr ARI Total	**19**	**11**	**53**	**47**	**$ 1,136,488**	**$ 639,099**
5yr ARI						
Residential	14	10	42	39	$ 854,526	$ 600,027
Commercial	0	0	0	0	$ -	$ -
Industrial	1	0	1	1	$ 66,071	$ -
5yr ARI Total	**15**	**10**	**43**	**40**	**$ 920,598**	**$ 600,027**
Total Annual Average Damage					**$ 426,625**	**$ 264,516**

Table 4-4 HC_FM4 Flood Damage Assessment Summary

Event / Property type	Properties with Overfloor Flooding		Properties with Overground Flooding		Estimated Total Damage ($ June 2016)	
	Existing Case	*Mitigation Case*	*Existing Case*	*Mitigation Case*	*Existing Case*	*Mitigation Case*
PMF Event						
Residential	216	221	372	373	$ 15,099,829	$ 15,406,768
Commercial	23	23	24	24	$ 749,167	$ 760,372
Industrial	0	0	0	0	$ -	$ -
PMF Total	**239**	**244**	**396**	**397**	**$ 15,848,996**	**$ 16,167,140**
100yr ARI						
Residential	82	71	178	177	$ 5,885,739	$ 5,516,880
Commercial	7	7	11	11	$ 127,183	$ 127,194
Industrial	0	0	0	0	$ -	$ -
100yr ARI Total	**89**	**78**	**189**	**188**	**$ 6,012,923**	**$ 5,644,074**
50yr ARI						
Residential	74	63	169	169	$ 5,395,138	$ 4,962,925
Commercial	7	7	10	10	$ 126,664	$ 126,654
Industrial	0	0	0	0	$ -	$ -
50yr ARI Total	**81**	**70**	**179**	**179**	**$ 5,521,802**	**$ 5,089,578**
20yr ARI						
Residential	62	55	155	152	$ 4,744,297	$ 4,342,642
Commercial	7	5	10	10	$ 126,245	$ 85,826
Industrial	0	0	0	0	$ -	$ -
20yr ARI Total	**69**	**60**	**165**	**162**	**$ 4,870,542**	**$ 4,428,468**
10yr ARI						
Residential	57	49	146	141	$ 4,218,891	$ 3,893,819
Commercial	7	5	10	10	$ 125,738	$ 85,315
Industrial	0	0	0	0	$ -	$ -
10yr ARI Total	**64**	**54**	**156**	**151**	**$ 4,344,629**	**$ 3,979,134**
5yr ARI						
Residential	46	42	112	108	$ 3,445,695	$ 3,445,695
Commercial	7	5	9	9	$ 124,934	$ 124,934
Industrial	0	0	0	0	$ -	$ -
5yr ARI Total	**53**	**47**	**121**	**117**	**$ 3,570,629**	**$ 3,570,629**
Total Annual Average Damage					**$ 1,484,594**	**$ 1,428,757**

Table 4-5 HC_FM5 Flood Damage Assessment Summary

Event / Property type	Properties with Overfloor Flooding		Properties with Overground Flooding		Estimated Total Damage ($ June 2016)	
	Existing Case	*Mitigation Case*	*Existing Case*	*Mitigation Case*	*Existing Case*	*Mitigation Case*
PMF Event						
Residential	64	63	83	83	$ 4,001,594	$ 4,002,015
Commercial	0	0	0	0	$ -	$ -
Industrial	3	3	3	3	$ 267,663	$ 265,222
PMF Total	**67**	**66**	**86**	**86**	**$ 4,269,257**	**$ 4,267,238**
100yr ARI						
Residential	24	15	47	47	$ 1,164,144	$ 732,444
Commercial	0	0	0	0	$ -	$ -
Industrial	1	1	1	1	$ 92,138	$ 84,869
100yr ARI Total	**25**	**16**	**48**	**48**	**$ 1,256,281**	**$ 817,312**
50yr ARI						
Residential	17	12	47	47	$ 893,077	$ 612,722
Commercial	0	0	0	0	$ -	$ -
Industrial	1	1	1	1	$ 83,715	$ 82,774
50yr ARI Total	**18**	**13**	**48**	**48**	**$ 976,792**	**$ 695,496**
20yr ARI						
Residential	12	10	40	39	$ 578,480	$ 426,423
Commercial	0	0	0	0	$ -	$ -
Industrial	1	1	1	1	$ 80,480	$ 80,527
20yr ARI Total	**13**	**11**	**41**	**40**	**$ 658,959**	**$ 506,949**
10yr ARI						
Residential	8	6	34	33	$ 413,894	$ 295,650
Commercial	0	0	0	0	$ -	$ -
Industrial	1	1	1	1	$ 74,296	$ 74,316
10yr ARI Total	**9**	**7**	**35**	**34**	**$ 488,189**	**$ 369,966**
5yr ARI						
Residential	2	2	21	20	$ 175,441	$ 129,619
Commercial	0	0	0	0	$ -	$ -
Industrial	1	1	1	1	$ 66,071	$ 66,091
5yr ARI Total	**3**	**3**	**22**	**21**	**$ 241,513**	**$ 195,711**
Total Annual Average Damage					**$ 164,717**	**$ 130,584**

Table 4-6 Reduction in Damages Associated with Each Option

	Overfloor flooding properties reduction	Overground flooding properties reduction	Total Damage Reduction ($)	AAD Reduction ($)
HC-FM1				
PMF event	15	2	$ 1,785,006	$25,193
100yr ARI event	25	7	$ 3,254,059	$30,144
50yr ARI event	28	8	$ 2,774,685	$73,224
20yr ARI event	22	6	$ 2,106,918	$97,082
10yr ARI event	22	6	$ 1,776,349	$158,775
5yr ARI event	17	6	$ 1,399,152	$209,873
Total				**$594,290**
HC-FM2				
PMF event	15	1	$ 1,055,105	$10,511
100yr ARI event	11	3	$ 1,047,329	$8,350
50yr ARI event	4	2	$ 622,639	$17,071
20yr ARI event	4	1	$ 515,414	$25,103
10yr ARI event	7	0	$ 488,710	$35,695
5yr ARI event	3	1	$ 225,199	$33,780
Total				**$130,510**
HC-FM3				
PMF event	2	2	$ 312,561	$6,555
100yr ARI event	18	3	$ 998,515	$9,816
50yr ARI event	19	5	$ 964,759	$25,665
20yr ARI event	16	8	$ 746,211	$31,090
10yr ARI event	8	6	$ 497,388	$40,898
5yr ARI event	5	3	$ 320,570	$48,086
Total				**$162,109**
HC-FM4				
PMF event	Assumed to be equal to the existing case damages[1]			
100yr ARI event	11	1	$ 368,849	$4,005
50yr ARI event	11	0	$ 432,224	$13,114
20yr ARI event	9	3	$ 442,074	$20,189
10yr ARI event	10	5	$ 365,494	$18,275
5yr ARI event	6	4	$ -	$0
Total				**$55,584**
HC-FM5				
PMF event	1	0	$ 2,020	$2,205
100yr ARI event	9	0	$ 438,969	$3,601
50yr ARI event	5	0	$ 281,297	$6,500
20yr ARI event	2	1	$ 152,010	$6,756
10yr ARI event	2	1	$ 118,223	$8,201
5yr ARI event	0	1	$ 45,802	$6,870
Total				**$34,133**

[1] A modelling instability produced unreliable results for the PMF design event for FM4. The results available, would suggest the flow behaviour would not be impacted significantly in the PMF as a result of this option.

4.2 Benefit to Cost Ratio of Options

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

Table 4-7 summarises the results of the economic assessment of each of the flood management options. The indicator adopted to rank these measures on economic merit is the benefit-cost ratio (B/C), 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:

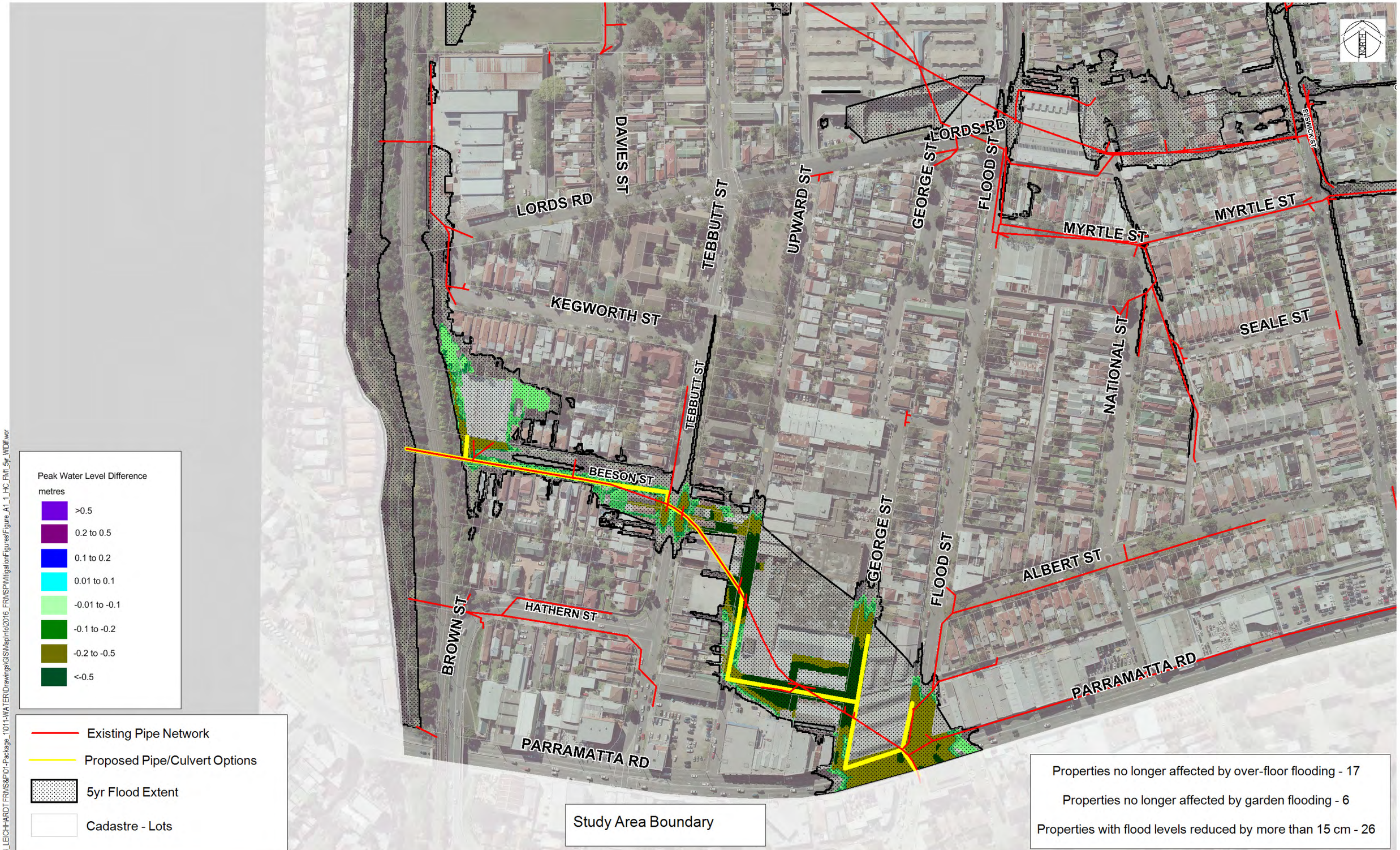
- Where the benefit-cost is greater than 1 the economic benefits are greater than the cost of implementing the measure;
- Where the benefit-cost is less than 1 but greater than 0, there is still an economic benefit from implementing the measure but the cost of implementing the measure is greater than 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.

Table 4-7 Summary of Economic Assessment of Flood Management Options

Option ID	Option Description	NPW of Reduction in AAD	NPW of Cost of Implementation	B/C Ratio	Economic Ranking
HC_FM1	Additional pipes /culverts from Parramatta Road to Hawthorne Canal via Beeson Street.	$8,202,000	$11,588,000	0.71	1
HC_FM2	Additional pipes or duplication of existing network from Reuss Street to Hawthorne Canal via Elswick Street, Flood Street and Marion Street.	$1,801,000	$10,634,000	0.17	3
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.	$2,237,000	$17,194,000	0.13	5
HC_FM4	Additional pipes/ culverts from William Street to Hawthorne Canal via Hubert Street and Darley Road.	$1,400,000	$8,398,000	0.17	4
HC_FM5	Proposed culverts through the rail embankment to drain flood waters from Darley Road to Hawthorne Canal.	$471,000	$2,729,000	0.17	2

Hawthorne Canal Mitigation Option Figures

Figure HC_FM1_5yr_WlDiff
Figure HC_FM1_20yr_WlDiff
Figure HC_FM1_100yr_WlDiff
Figure HC_FM2_5yr_WlDiff
Figure HC_FM2_20yr_WlDiff
Figure HC_FM2_100yr_WlDiff
Figure HC_FM3_5yr_WlDiff
Figure HC_FM3_20yr_WlDiff
Figure HC_FM3_100yr_WlDiff
Figure HC_FM4_5yr_WlDiff
Figure HC_FM4_20yr_WlDiff
Figure HC_FM4_100yr_WlDiff
Figure HC_FM5_5yr_WlDiff
Figure HC_FM5_20yr_WlDiff
Figure HC_FM5_100yr_WlDiff



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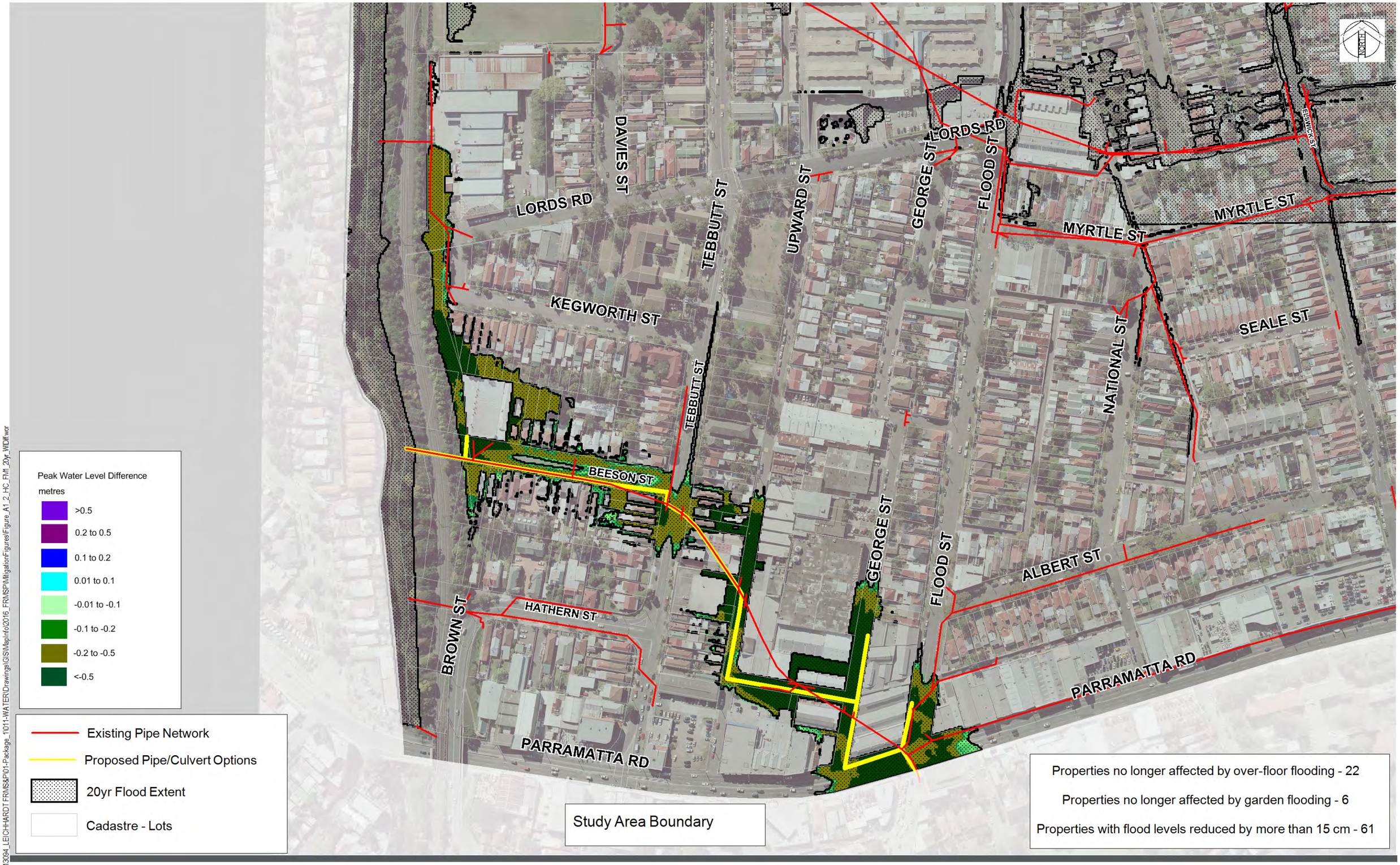
INNER WEST COUNCIL
LEICHHARDT FRMS&P
HC_FM1 5YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_A1_1

Date
03/2017

Size
A3

HC_FM1_5yr_WlDiff
Drawing Number

03
Revision



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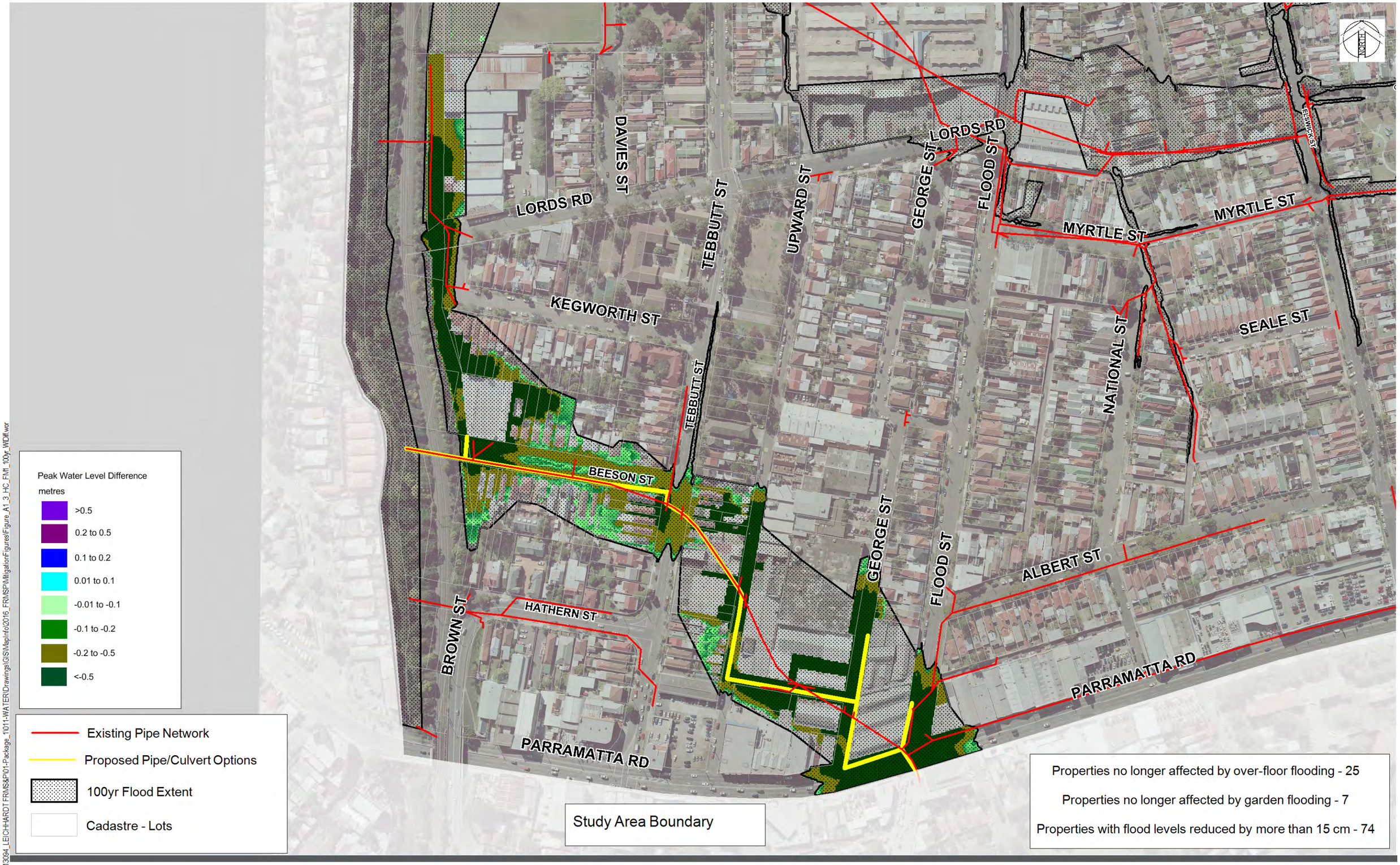
INNER WEST COUNCIL
LEICHHARDT FRMS&P
HC_FM1 20YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_A1_2

Date
03/2017

Size
A3

HC_FM1_20yr_WIDiff
Drawing Number

03
Revision



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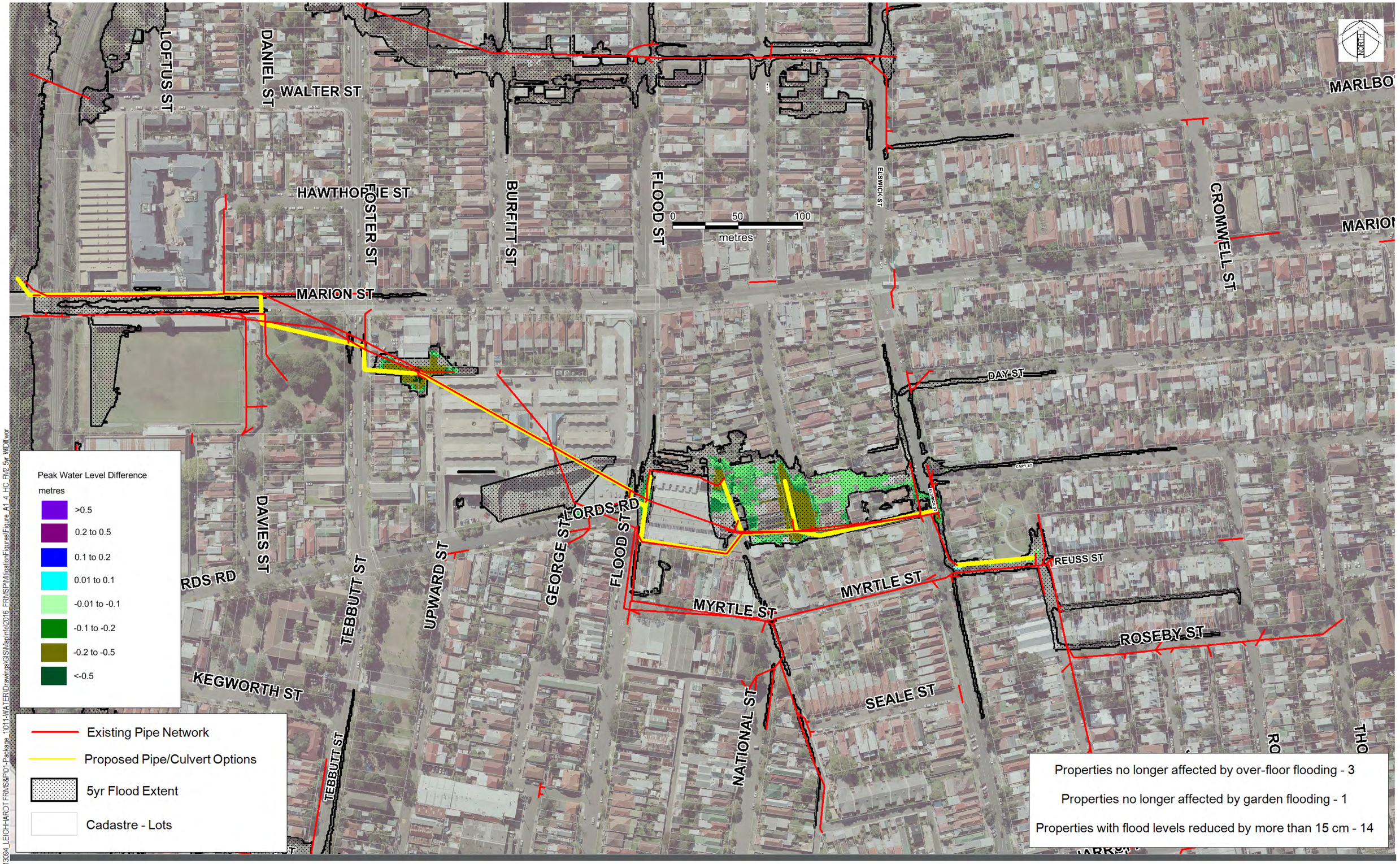
INNER WEST COUNCIL
LEICHHARDT FRMS&P
HC_FM1 100YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_A1_3

Date
03/2017

Size
A3

HC_FM1_100yr_WlDiff
Drawing Number

03
Revision



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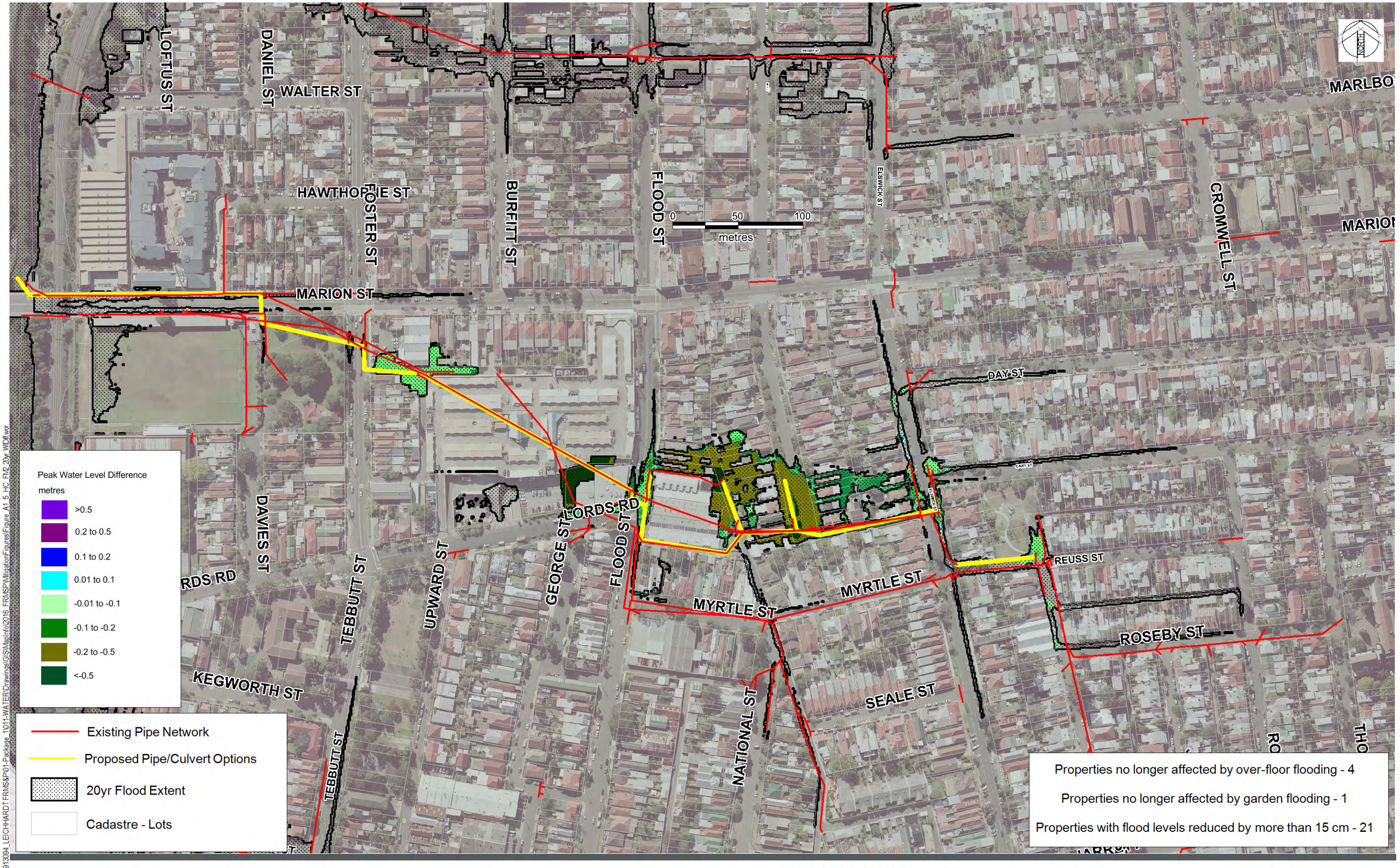
INNER WEST COUNCIL
LEICHHARDT FRMS&P
HC_FM2 5YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_A1_4

Date
03/2017

Size
A3

HC_FM2_5yr_WlDiff
Drawing Number

03
Revision



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INNER WEST COUNCIL
LEICHHARDT FRMS&P
HC_FM2 20YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_A1_5

Date
03/2017

Size
A3

HC_FM2_20yr_WIDiff
Drawing Number

03
Revision

LOFTUS ST
DANIEL ST
WALTER ST
HAWTHORNE ST
FOSTER ST
BURFITT ST
FLOOD ST
REGENT ST
ELSWICK ST
CROMWELL ST
MARLBO
MARION
MARION ST
DAY ST
0 50 100
metres
NORTH
DAVIES ST
LORDS RD
GEORGE ST
FLOOD ST
UPWARD ST
TEBBUTT ST
KEGWORTH ST
MYRTLE ST
REUSS ST
ROSEBY ST
SEALE ST
NATIONAL 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
100yr Flood Extent
Cadastre - Lots

Properties no longer affected by over-floor flooding - 11

Properties no longer affected by garden flooding - 3

Properties with flood levels reduced by more than 15 cm - 27

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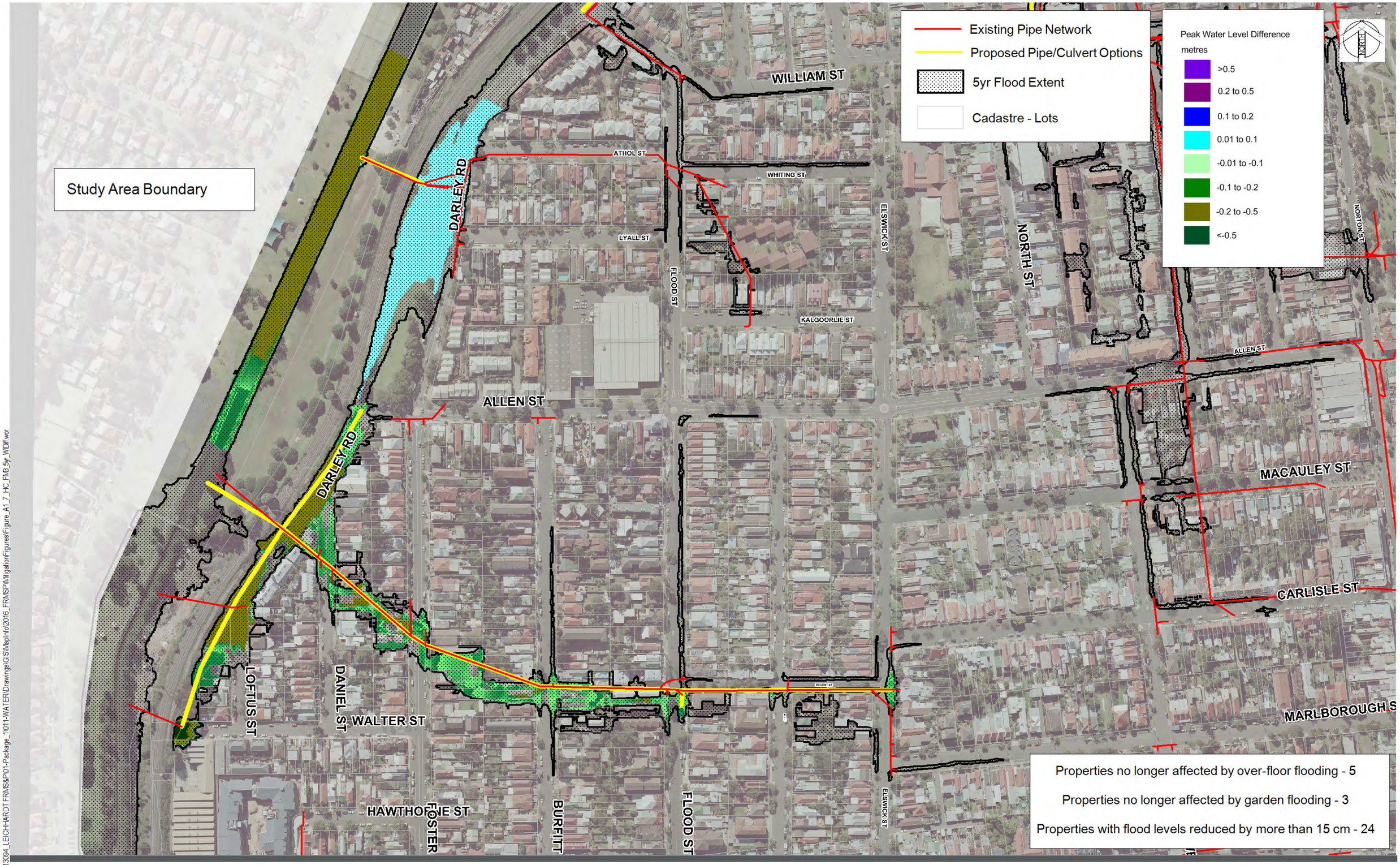
INNER WEST COUNCIL
LEICHHARDT FRMS&P
HC_FM2 100YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_A1_6

Date
03/2017

Size
A3

HC_FM2_100yr_WlDiff
Drawing Number

03
Revision



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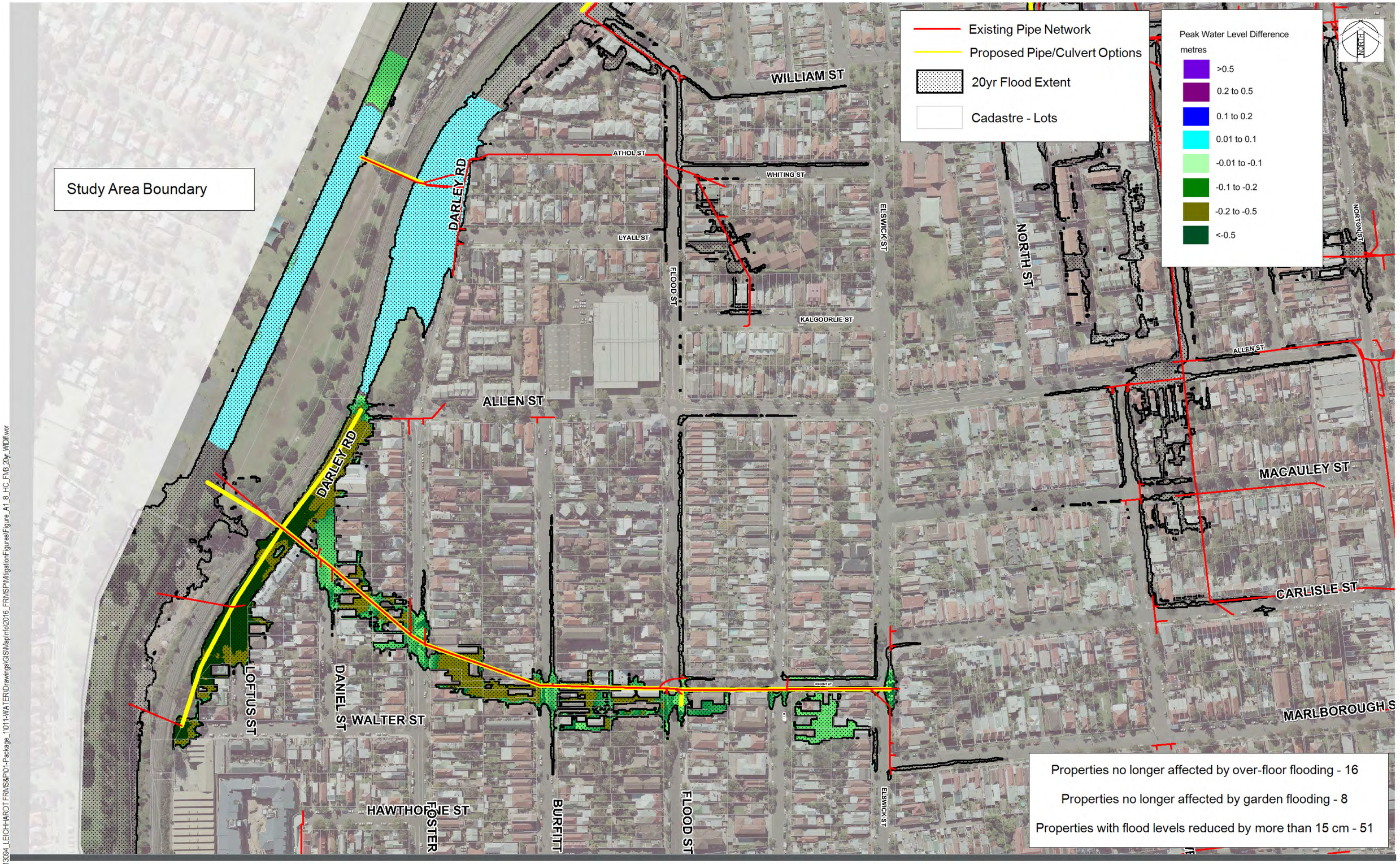
INNER WEST COUNCIL
LEICHHARDT FRMS&P
HC_FM3 5YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_A1_7

Date
03/2017

Size
A3

HC_FM3_5yr_WIDiff
Drawing Number

03
Revision



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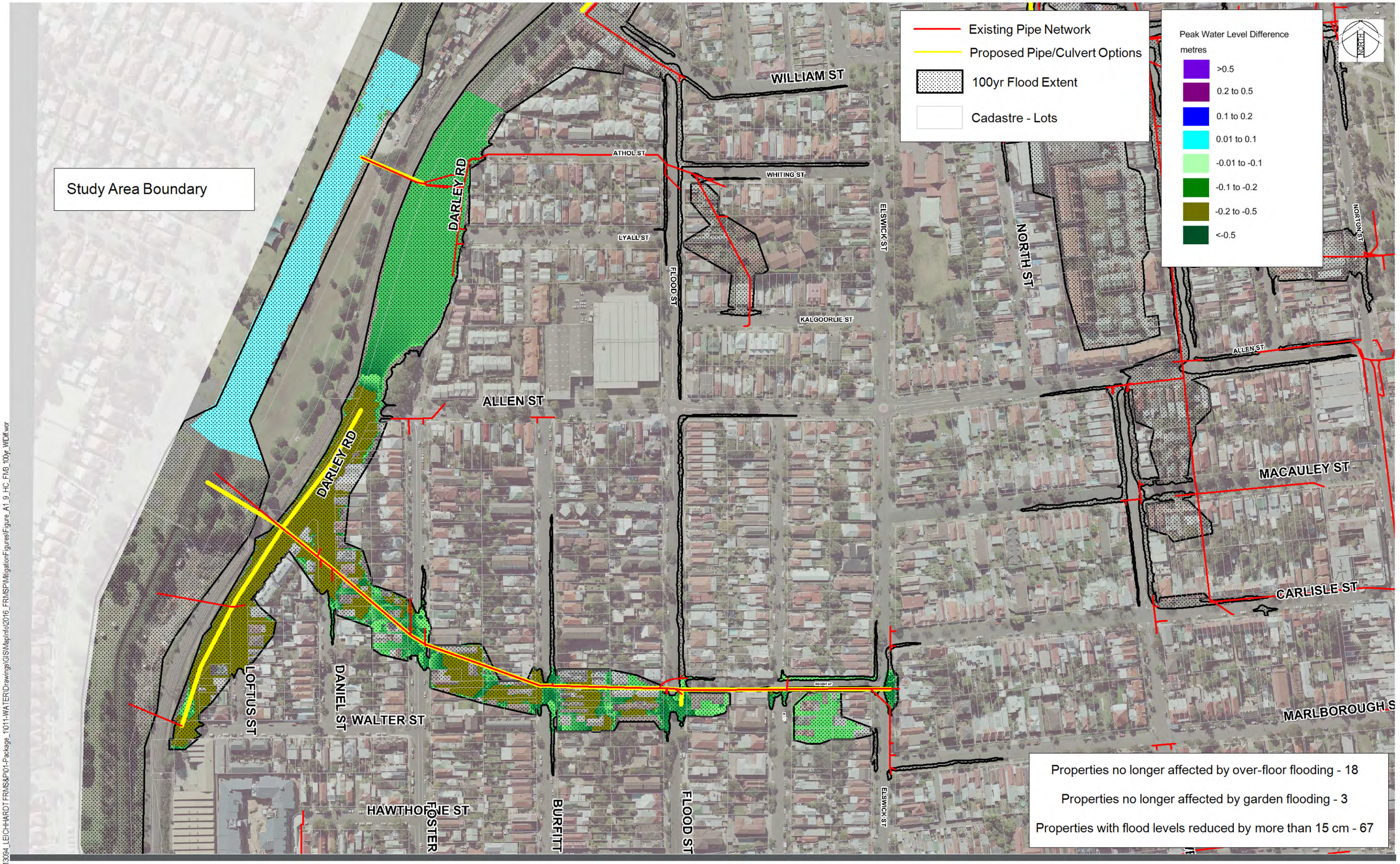
LEICHHARDT FRMS&P
HC_FM3 20YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_A1_8

Date
03/2017

Size
A3

HC_FM3_20yr_WIDiff
Drawing Number

03
Revision



Properties no longer affected by over-floor flooding - 18

Properties no longer affected by garden flooding - 3

Properties with flood levels reduced by more than 15 cm - 67

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INNER WEST COUNCIL
LEICHHARDT FRMS&P
HC_FM3 100YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_A1_9

Date
03/2017

Size
A3

HC_FM3_100yr_WlDiff
Drawing Number

03
Revision

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
- 5yr Flood Extent
- Cadastre - Lots

Properties no longer affected by over-floor flooding - 6

Properties no longer affected by garden flooding - 4

Properties with flood levels reduced by more than 15 cm - 29

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INNER WEST COUNCIL
LEICHHARDT FRMS&P
HC_FM4 5YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_A1_10

Date
03/2017

Size
A3

HC_FM4_5yr_WlDiff
Drawing Number

03
Revision

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

Properties no longer affected by over-floor flooding - 9

Properties no longer affected by garden flooding - 3

Properties with flood levels reduced by more than 15 cm - 35

0 50 100 metres

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INNER WEST COUNCIL
LEICHHARDT FRMS&P
HC_FM4 20YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_A1_11

Date
03/2017

Size
A3

HC_FM4_20yr_WIDiff
Drawing Number

03
Revision

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
- 100yr Flood Extent
- Cadastre - Lots

Properties no longer affected by over-floor flooding - 11

Properties no longer affected by garden flooding - 1

Properties with flood levels reduced by more than 15 cm - 38

0 50 100 metres

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INNER WEST COUNCIL
LEICHHARDT FRMS&P
HC_FM4 100YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_A1_12

Date
03/2017

Size
A3

HC_FM4_100yr_WIDiff
Drawing Number

03
Revision

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
- 5yr Flood Extent
- Cadastre - Lots

0 50 100 metres

Properties no longer affected by over-floor flooding - 0

Properties no longer affected by garden flooding - 1

Properties with flood levels reduced by more than 15 cm - 8

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INNER WEST COUNCIL
LEICHHARDT FRMS&P
HC_FM5 5YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_A1_13

Date
03/2017

Size
A3

HC_FM5_5yr_WlDiff
Drawing Number

03
Revision

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

0 50 100 metres

Properties no longer affected by over-floor flooding - 2

Properties no longer affected by garden flooding - 1

Properties with flood levels reduced by more than 15 cm - 9

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INNER WEST COUNCIL
LEICHHARDT FRMS&P
HC_FM5 20YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_A1_14

Date
03/2017

Size
A3

HC_FM5_20yr_WIDiff
Drawing Number

03
Revision

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
- 100yr Flood Extent
- Cadastre - Lots

0 50 100 metres

Properties no longer affected by over-floor flooding - 9

Properties no longer affected by garden flooding - 0

Properties with flood levels reduced by more than 15 cm - 45

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INNER WEST COUNCIL
LEICHHARDT FRMS&P
HC_FM5 100YR ARI WL DIFF
MITIGATION LESS EXISTING
FIG_A1_15

Date
03/2017

Size
A3

HC_FM5_100yr_WlDiff
Drawing Number

03
Revision