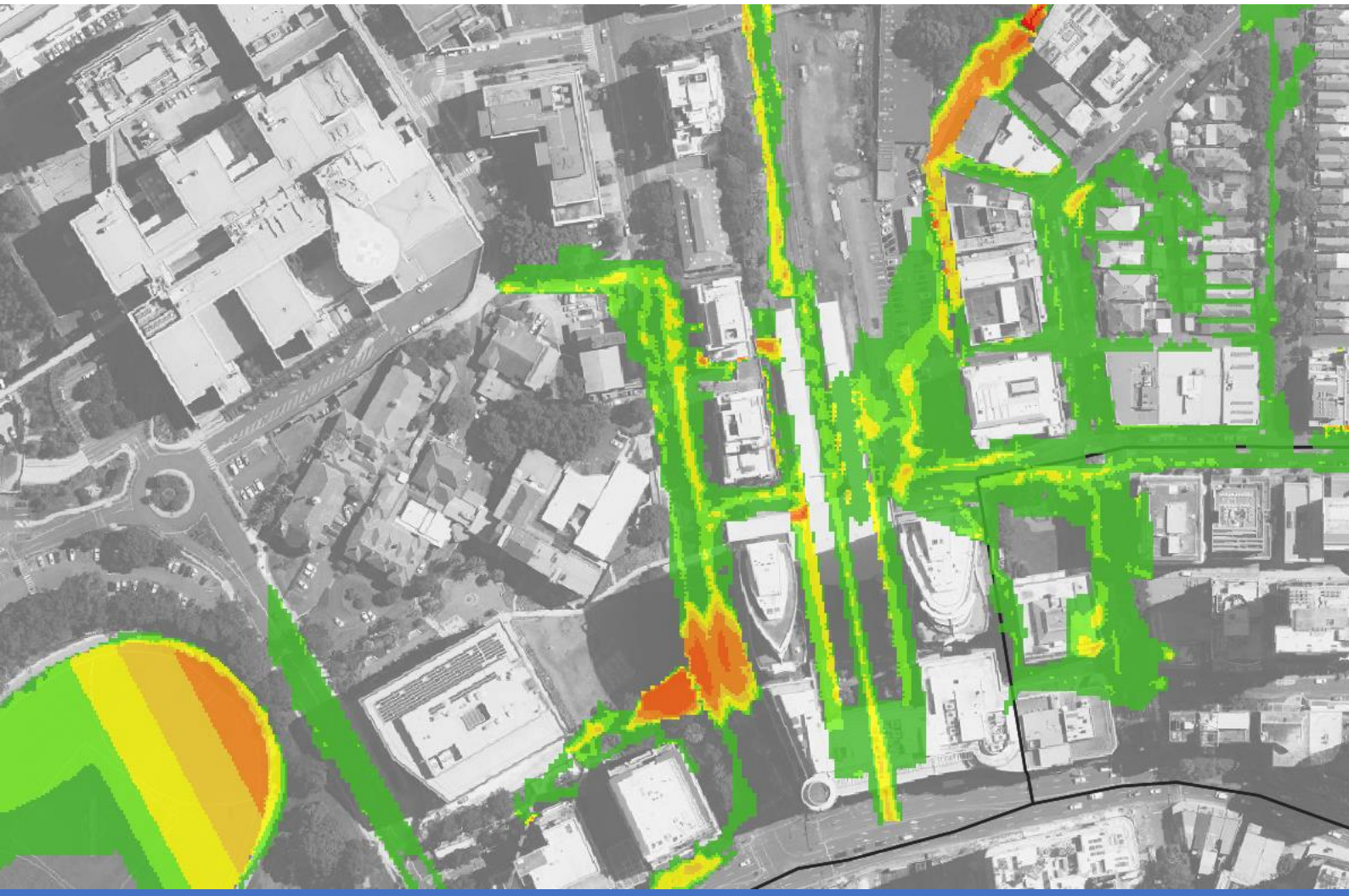
Department of Planning, Housing and Infrastructure

State Led Rezoning Crows Nest – Flooding and Stormwater Study

Draft Report



June 2024

grc HYDRO

State Led Rezoning Crows Nest – Flooding and Stormwater Study Draft Report

Project:	State Led Rezoning Crows Nest – Flooding and Stormwater Study
Project Number:	240008
Client:	NSW Department of Planning, Housing and Infrastructure
Client Contact:	Charlene Nelson
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Date:	6 June 2024
Verified By:	

Date	Version	Description
26-Mar-2023	1	Preliminary Findings
23-Apr-2024	2	Draft report
23-May-2024	3	Draft report
6-Jun-2024	4	Draft report for Public Exhibition

Filepath: J:\240008\Admin\Report\SLRCN_FloodingSW_060624.docx

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EXECUTIVE SUMMARY

This report sets out a Flood Risk Assessment undertaken by GRC Hydro on behalf of NSW Department of Planning, Housing and Infrastructure, for the State Led Rezoning Crows Nest project. The project consists of rezoning in the St Leonards and Crows Nest area, aimed at providing additional residential dwellings in the area. Per the background documentation, "rezonings will provide planning support to optimise investment in transport infrastructure and unlock housing supply close to existing transport hubs and new metro lines. This will involve reviewing existing planning controls (including controls for height and floor space ratio) around identified transport hubs to ensure development is feasible and deliver increased density.". The study area spans North Sydney and Willoughby Council areas, as well as a small portion of Lane Cove Council.

The assessment used a series of previously established hydrologic and hydraulic models to assess flooding in the precinct, which span multiple catchments that drain to Sydney Harbour. Models were adjusted and expanded in some areas to reflect current catchment conditions. Design flood behaviour has been assessed with regard to depths and level, flood hazard categories and hydraulic categories, while rate of rise, duration and other factors have also been considered. As an overview, flooding in the precinct consists of:

- Focus Area: Very minimal overland flow with the area lying on a natural ridge. Shallow overland flow occurs in some areas with around 0.1 m depth in the 1% AEP event. Area is not affected by creek flooding.
- Entire Precinct: While the precinct is generally aligned with a prominent topographic ridge through St Leonards/Crows Nest, significant overland occurs in several locations and mainstream flooding occurs in one park area. Overland flow is typically shallow and confined to roadways but in various locations passes through private property, and has significant flood hazard. The recently built detention basin under Gore Hill Oval, as well as the oval itself, provide significant benefit in reducing flooding downstream in the vicinity of St Leonards station.

The assessment found that proposed intensification of the Focus Area is suitable from a flood risk perspective as the areas has low or negligible flood risk. More broadly across the precinct, potential other rezoning is generally suitable from a flood risk perspective but intensification would not be suitable for some areas of high flood hazard, and some types of rezoning of the limited areas of FPA would be constrained. Councils' DCP and LEP, and relevant state government policies have been considered with respect to development of flood-prone areas. The report sets out relevant planning controls that are currently in the DCPs that will manage flood risk, but notes that their application could be formalised as part of the rezoning and updated planning controls. These controls will ensure flood risk is incorporated into the design of new buildings and associated development, and that flooding outside of the precinct is not impacted as a result of the development.

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1. INTRODUCTION

The State Led Rezoning Crows Nest is a large-scale upzoning in the Crows Nest and St Leonards areas across the Local Government Areas (LGAs) of Willoughby, North Sydney and Lane Cove. The broad objective is to provide more residential dwellings while utilising the central location and current and future transport links. The project is one in a series of similar rezonings across Sydney being led by the state government, aimed at providing more housing.

The study area consists of a focus area within a larger precinct. The focus area is where the proposed rezoning and intensification will occur while the larger precinct has been considered as where possible future rezoning and intensification will occur.

The precinct is located across multiple catchments and is affected by both mainstream and overland flow flooding. The current study assesses design flood behaviour in the area for a range of design flood events, using hydrologic and hydraulic models. The study then assesses future development and intensification of the area, including its impact on flood behaviour. The study then reviews and recommends necessary flood mitigation measures including planning controls.

2. BACKGROUND

2.1 Study Area

The study area consists of the Crows Nest precinct and the focus area in the centre of the precinct. The study area is split across a series of small catchments that generally flow either north to Middle Harbour or south to Sydney Harbour. The divide is shown in Image 1 below and the main flowpaths have been numbered for reference in this report. Flowpaths 1, 2 and 3 all drain north to Flat Rock Creek, which is downstream of the precinct, while Flowpath 4 flows to Berrys Creek, also downstream of the precinct.

The area broadly consists of fully-developed medium to high density urban areas with a mix of residential, commercial and industrial land, centred on Crows Nest and St Leonards. Current urban development dates from the late 19th century including St Leonards train station opening in 1890.

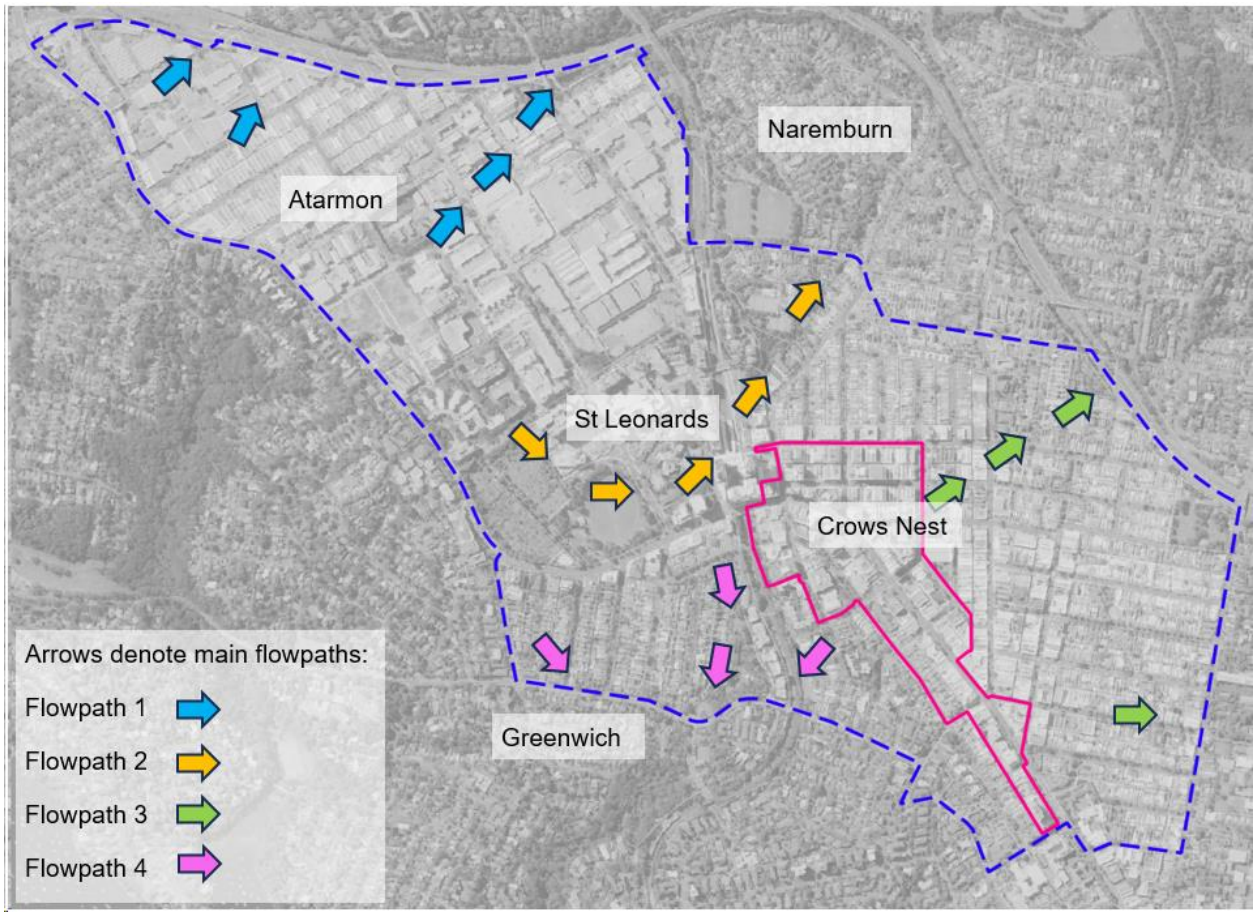


Image 1: Overview of flowpaths locations. Note: flood extents are shown on Figure 6 and onwards at rear of report

2.1.1 Flowpath 1

Flowpath 1 is located in Atarmon in the north of the precinct, in an area of commercial and industrial lots. The majority of the area drains to a low point near the Hampden Road overpass of the freeway, while the area to the west drains beneath the freeway near McLachlan Avenue.

The combined catchment area is in the order of 80 ha, and forms a subcatchment to the much larger Flat Rock Creek catchment. Flooding consists of overland flow with no creeks or channels present.

The area is not affected by sea level rise associated with climate change, as it is well above sea level. As set out in the subsequent report sections, flooding in the area contains significant depths where roadways are not aligned with the topographic low point, causing runoff to pond against buildings, in some areas. As with the other flowpaths, topography is steep in the area, which concentrates runoff to the low points and generally allows for efficient discharge of flow to the downstream areas. Site visit photos are shown in Image 2.

The previous study which has been utilised for this flowpath is the Flat Rock Creek Floodplain Risk Management Study and Plan.

Image 2: Examples of low points in the Flowpath 1 area

2.1.2 Flowpath 2

Flowpath 2 is located in St Leonards and Naremburn in the middle of the precinct, in an area of commercial and residential lots. The area drains to a low point near Dalleys Road through an unnamed channel.

The catchment area is in the order of 105 ha, and forms a subcatchment to the much larger Flat Rock Creek catchment. Flooding mostly consists of overland flow with a channel present at the downstream. The area is not affected by sea level rise associated with climate change, as it is well above sea level. As with the other flowpaths, topography is steep in the area, which concentrates runoff to the stormwater channel and generally allows for efficient discharge of flow to the downstream areas. The flowpath is discontinuous in most events between Gore Hill Oval and the downstream/northeast side of St Leonards Station. This is due to a combination of the very large stormwater tank installed under the oval, as well as the oval itself, detaining significant volumes of flow, and then a wall and very large drainage pit just west of Herbert Street also capturing runoff and draining it beneath the railway line. Site visit photos are shown in Image 3.

The previous study which has been utilised for this flowpath is the Flat Rock Creek Floodplain Risk Management Study and Plan.

Image 3: Flood-affected locations in the Flowpath 2 area, Herbert Street (left) and Evans Lane (right)

2.1.3 Flowpath 3

Flowpath 3 is located in Crows Nest in the east part of the precinct, in an area of commercial and residential lots. The majority of the area drains to a low point near the Brook Street underpass of Gore Hill Freeway, while the area to the south-east drains to a low point on West street.

The combined catchment area is in the order of 95 ha, and forms a subcatchment to the much larger Flat Rock Creek catchment. Flooding consists of overland flow with no creeks or channels present. The area is not affected by sea level rise associated with climate change, as it is well above sea level. As with Flowpath 1, flooding in the area contains significant depths where roadways have trapped low points, causing runoff to pond against buildings (see example below on Hume Lane). As with the other flowpaths, topography is steep in the area, which concentrates runoff to the low points and generally allows for efficient discharge of flow to the downstream areas. Site visit photos are shown in Image 4.

The previous study which has been utilised for this flowpath is the North Sydney LGA-Wide Floodplain Risk Management Study and Plan.

Image 4: Examples of low points in the Flowpath 3 area, Hume Lane (left) and Brook Street underpass (right)

2.1.4 Flowpath 4

Flowpath 1 is located in St Leonards and Greenwich in the south of the precinct, in an area of commercial and residential lots. The area drains to a low point near Russell Street and River Road.

The catchment area is in the order of 50 ha, and forms a subcatchment to the larger Berrys Creek catchment. The area is not affected by sea level rise associated with climate change, as it is well above sea level. The area consists of one overland flowpath to the west, generally parallel to River Road, that has minimal depths of flooding, and a second overland flowpath to the east, which has a similar catchment area but has localised flooding at Lithgow Street and Christie Street on the road low points. Site visit photos are shown in Image 5.

The previous study which has been utilised for this flowpath is the North Sydney LGA-Wide Floodplain Risk Management Study and Plan, of which the model was expanded (see Section 4.1 Model Updates).

Image 5: Examples of low points in the Flowpath 4 area

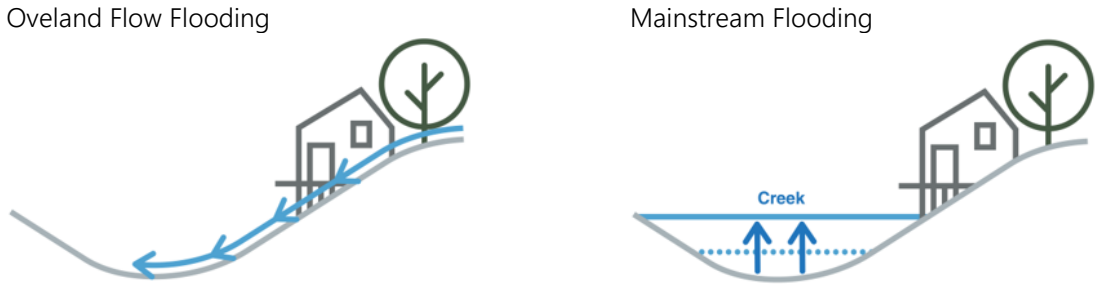
2.2 Flooding Mechanisms

The catchment overviews provided above refer to mainstream and overland flow flooding. These are types of flooding as set out in the NSW Flood Risk Management Manual (2023) and earlier guidelines.

Mainstream flooding occurs from rising water on a defined watercourse causing the watercourse to break its banks and inundate areas that are usually dry. This mechanism typically occurs over a long period of time and generally results in deep, slow moving floodwaters. Image 6 (right hand side) depicts this mechanism. In the three LGAs of interest, mainstream flooding occurs when the stormwater channels and natural creek channels flood the adjacent land.

Overland flow flooding occurs when runoff has not yet reached the creek or channel. In urban areas it most commonly occurs along topographic sags which are typically serviced by a pit and pipe network. When the pipes' capacity is exceeded, above-ground flowpaths form. Overland flow is typically shallower and faster moving than mainstream flooding and occurs with less warning. NSW guidelines note that the two types of flooding can be indistinguishable to people experiencing flooding and that overland flow can cause significant property damage and flood risk, despite not originating from a major watercourse.

Image 6: Flood Mechanisms in the Study Area



3. AVAILABLE DATA

3.1 Overview

The current study utilised a number of data sets in defining and assessing existing flood behaviour in the study area. This data largely consists of previous studies and Council GIS data. The study then assessed future development based on the proposed intensification area. A summary of each data set is provided below.

3.2 Previous Studies

3.2.1 North Sydney Floodplain Risk Management Study and Plan (GRC Hydro, 2022)

The study investigated flood risk across the North Sydney LGA, which consists of a series of eighteen catchments draining to Sydney Harbour. Flood risk was assessed for a range of events up to the Probable Maximum Flood (PMF) using DRAINS and WBNM hydrologic models, and a TUFLOW hydraulic model. With an average catchment size of 60 hectares across the 18 catchments, and a fully urbanised catchment, overland flow flooding is prevalent in many areas. Both modelling and resident/Council's experiences of flooding showed many areas where flooding causes significant property and road inundation, including above-floor flooding. Modelling was based on the ARR2019 methodology and model parameters, while IFD data was based on an at-site gauge analysis (Observatory Hill). The study defined a Flood Planning Area consisting of the 722 lots that had significant flooding on any part of the lot, or directly adjacent to a lot, in a 1% AEP event. The flood risk assessment showed relatively low sensitivity to sea level rise and increased rainfall due to climate change, for the large majority of the catchment.

3.2.2 Flat Rock Creek Floodplain Risk Management Study and Plan (WMAwater, 2020)

The study was undertaken on behalf of Willoughby Council and, similarly to the North Sydney study, investigated flooding for events up to the PMF. The study area was the portion of the Flat Rock Creek catchment in Willoughby LGA, with modelling including the upper areas well away from the creek

itself, where overland flow is present. The study used a DRAINS hydrologic model and TUFLOW hydraulic model. Hydrologic modelling was based on the ARR2019 methodology and model parameters, including IFD. The study defined a Flood Planning Area consisting of the area covered by the mainstream flood extent of a flood at the 1% AEP + 0.5 m level. The assessment of climate change was carried out in the earlier flood study and found relatively low sensitivity of flood levels to increased rainfall intensity, with 0.1-0.3 m increase along the creek itself (outside of the current study's study area) and 0.02-0.1 m increase in areas of overland flow.

3.2.3 St Leonards and Crows Nest 2036 (NSW Department of Planning, Industry and Environment, 2020)

The plan sets out future development of the St Leonards and Crows Nest area with the aim of carrying out urban renewal and expanding the area as an employment centre and residential area. The plan itself sets out a strategy for the area intended to guide future development. The strategy sets out potential future zonings and requires that planning proposals that rezone land be consistent with the plan.

With regards to flooding, the 2036 plan does not contain a flood risk assessment, but does contain an objective for the area of "Planning Priority N22: Adapting to the impacts of urban and natural hazards and climate change" which would include flood hazard.

The plan sets out potential future zoning of the area on page 65's "Land Zoning" map.

3.3 GIS Data

GIS data was provided as part of the two sets of models (North Sydney, and Flat Rock Creek) including the pit and pipe network, road centrelines, kerb lines and building outlines. GIS layers showing the study area precinct and sub-areas was provided by NSW Department of Planning, Housing and Infrastructure.

3.4 Site Visit

Site visit was undertaken in March 2024 to confirm above-ground features along each of the flowpaths, and to familiarise with the broader catchments. Photos of typical features observed are provided in Section 2.1.

4. DESIGN FLOOD BEHAVIOUR

4.1Model Updates

The North Sydney and Flat Rock Creek models covering the precinct catchment were updated as part of the study to refine the flood mapping in the areas of interest. The changes are set out in Table 2 and broadly consisted of:

1. The North Sydney model was expanded to cover the portion of land in Lane Cove LGA but was otherwise used as is. The North Sydney model is made up of the 'North' and 'West' models ('East' and 'South' models are located outside the precinct)
2. The Flat Rock Creek model results were trimmed in some areas of overlap (see table below)

The models were then re-ran for the design events of interest and the updated results were reviewed.

Table 1: Model Updates

Model	Model Update	Explanation
North Sydney	Refined subcatchment definition in added Lane Cove LGA area	The Lane Cove LGA portion was previously not modelled in TUFLOW, while DRAINS treated the area as a single subcatchment. This subcatchment was then split into smaller subcatchments of approximately 1 ha size to be consistent with the North Sydney LGA modelling.
North Sydney	Expanded TUFLOW layers (building outlines, hydraulic roughness, kerb lines etc) in Lane Cove LGA area	As above, the Lane Cove LGA portion was not previously modelled. New inflows from DRAINS were applied at a series of inflow locations which then form overland flowpaths in TUFLOW. A pipe size of 0.6 m diameter was observed during site visit, while all other pipe sizes and locations were conservatively estimated. Model results for the area are considered indicative and are not suitable for site-specific flood modelling. The culvert estimated to be located beneath the railway line at approximately -33.825, 151.195 has been conservatively estimated as 0.6 m diameter and the actual size has been requested from TfNSW.
Flat Rock Creek	Pit and pipe network updated	A trunk pipe at Chandos/Willoughby Rd was changed based on data used in the North Sydney model.
Flat Rock Creek	Gore Hill Oval detention basin included	The recently built detention basin under Gore Hill Oval was included in the model provided by Council and was noted as a proposed development. The model kept the basin, which has since been built. The modelling itself in the area is unchanged with the only change being it

		is no longer referred to as proposed in the model files.
Both Models	Results Trimming	The two models overlap in the Crows Nest area and so produce two sets of results. Due to differences in model schematisation, particularly representation of buildings (high roughness in Flat Rock model, vs. coded out in North Sydney model) results were slightly different. To ensure mapping of results was clear and consistent, and did not jump between the two sets of results, Flowpaths 1 and 2 were mapped using the Flat Rock Creek model results, and Flowpaths 3 and 4 were mapped using the North Sydney model results.

4.2 Design Events

The design events of interest were the 5% AEP, 1% AEP and Probable Maximum Flood, representing a range of design flood behaviour. The following design model events were run:

- Flat Rock Creek
  - 5% AEP 25 minute storm
  - 1% AEP 25 minute storm
  - PMF 15 minute storm
- North Sydney West
  - 5% AEP 60 minute storm (Storm 10 temporal pattern)
  - 1% AEP 45 minute storm (Storm 3 temporal pattern) and 120 minute storm (Storm 2 temporal pattern)
  - PMF 15, 30 and 120 minute storm
- North Sydney North
  - 5% AEP 60 minute storm (Storm 10 temporal pattern)
  - 1% AEP 45 minute storm (Storm 2 temporal pattern) and 90 minute storm (Storm 8 temporal pattern)
  - PMF 15, 60 and 120 minute storm

The critical duration for each catchment was determined in the previous studies and does not change as a result of the model updates.

4.2.1 Climate Change

The hydrologic and hydraulic models were adjusted to assess the effect of climate change on design flood behaviour. Climate change is expected to worsen flood risk over time as higher greenhouse gas concentrations lead to increases in high intensity rainfall and sea levels. The assessment used the IPCC (Intergovernmental Panel on Climate Change) greenhouse gas concentration scenarios and subsequent modelling estimating each scenario's effect on rare rainfall events. There are four IPCC greenhouse gas concentration projections named RCP 2.5, 4.5, 6.0 and 8.5, with the RCP 2.5 being the most optimistic (emissions plateau and then decline) and 8.5 the least optimistic (emissions

continue to grow). For the RCP4.5 and 8.5 scenarios, the projected increase in precipitation intensity were obtained from the ARR Data Hub and shown in Table 2 for the 2090 estimate, which were then modelled for the 1% AEP event for the North Sydney model. For the Flat Rock Creek model, only the 10% and 30% rainfall increase scenarios were available, so the latter was used as a proxy for the 20% rainfall increase, given the results will be similar.

Table 2: Climate Change Factors – Percentage Increase in Rainfall Intensity in 2090

Year	RCP 4.5	RCP 8.5
2090	+9.5 %	+19.7%

Sea level rise as a result of climate change affects the catchment's tailwater conditions at the catchment outlets in Sydney Harbour and can affect flood behaviour in the lower catchment. An estimate of sea level rise is 0.4 m by 2050 and 0.9 m by 2100, as set out in the NSW government Practical Consideration of Climate Change guideline (2007). Because the lowest part of the precinct is around 45 mAHD, and therefore entirely unaffected by sea level rise, sea level rise was not modelled for the current assessment.

For each scenario the peak flood levels were then tabulated and compared to the base case (i.e., no climate change), as presented in Section 4.3.3..

4.3 Model Results – Existing Case

4.3.1 Flood Behaviour – Depths and Levels

The models were used to present produce flood mapping for a range of outputs and design events, for the study area. Peak flood depth maps with levels contours for the design events are shown on Figure 6 (5% AEP), Figure 7 (1% AEP) and Figure 8 (PMF) Table 2 summarises design flood levels for a number of locations in the study area. Flood hazard is shown on Figures 9 to 11. The locations in Table 2 are shown on each figure.

Table 3: Design Flood Levels

ID	Location	Ground Level (mAHD)	Peak Flood Level (mAHD) per design event		
			5% AEP	1% AEP	PMF
1	Marden St	70.95	71.06	71.34	72.36
2	Longueville Rd near Reserve Rd	61.92	62.47	62.58	63.38
3	Hotham Parade	77.67	77.89	77.92	78.31
4	Sawyer Ln/Ashers Ln	82.63	83.18	83.30	84.11
5	Campbell St/Clarendon St	76.14	76.54	76.59	76.93
6	Campbell St/Lanceley Pl	69.90	70.41	70.44	70.87
7	Reserve Rd/Cleg St	67.99	68.39	68.45	69.04
8	Cleg St near Waltham St	66.04	66.67	66.73	67.58
9	Waltham St near Taylor Ln	64.13	65.57	65.91	67.56
10	Taylor Ln near Herbert St	61.78	61.87	61.94	62.29
11	Driveway near Frederick St	72.57	73.53	73.92	75.04

ID	Location	Ground Level (mAHD)	Peak Flood Level (mAHD) per design event		
			5% AEP	1% AEP	PMF
12	Frederick St Near Herbert St	74.32	74.45	74.48	75.12
13	Reserve Rd near Frederick St	87.36	87.55	87.61	87.90
14	Herbert St near Westbourne St	75.80	76.37	76.56	77.13
15	Drainage point near Herbert St near Pacific Hwy	73.98	74.35	74.86	76.86
16	Waters Rd near Northcote St	60.49	60.85	60.90	61.69
17	Chandos St near Plunkett St	83.13	83.16	83.17	83.18
18	Brook St near Gore Hill Fwy	66.95	67.84	67.97	68.96
19	Wheatleigh St near Chandos St	72.67	73.26	73.35	74.18
20	Willoughby Rd/Chandos St	77.10	77.19	77.22	77.84
21	River Rd/Canberra Ave	44.87	45.64	45.69	46.26
22	Lithgow St near Oxley St	67.94	69.12	69.43	69.91

The flood levels in Table 2 can be used to calculate the equivalent flood depth, for example, the flood depth at location 22 is 1.18 m (69.12 flood level – 67.94 ground level = 1.18 m). The table shows:

- In a relatively common flood such as the 5% AEP, most areas have around 0.2-0.5 m depth which is typical of overland flowpaths with limited catchment area. Some locations have more severe flooding, with the greatest depths of flooding being at locations 9 (1.4 m), 11 (1.0 m), 18 (0.9 m) and 22 (1.2 m). These are:
    - The main Atarmon flowpath (Flowpath 1) where significant depths accumulate on trapped low points, at Cleg Street and to the north
    - The downstream end of Flowpath 3, where flow accumulates at the freeway underpass on Brook Street
    - The low point on Lithgow Street just south of Christie Lane and the Pacific Highway, where the rail embankment blocks runoff from a small catchment to the east. Results at this location are indicative only as the pipe size under the railway has been assumed.
- In a 1% AEP event, commonly used as the design event, nearly all locations have only 0-0.3 m increase in depth, relative to the 5% AEP, and 16 of the locations are only 0-0.1 m higher. This shows most locations do not scale significantly between flood events. The exception is the property driveway at location 11 in Atarmon (0.4 m higher in 1% AEP) and the low area west of Herbert Street (location 15) where significant depths build up behind the wall between the drainage point and the footpath/road.
- PMF depths are high with many locations having around 1 m depth or more.

Flood depth mapping shows the Focus Area is located away from the four main flowpaths with the few areas of inundation having shallow depths confined to roads. The one exception is depths of 0.3-0.5 m at Christie Street, due to runoff from a very limited upstream catchment collecting at a low point on the road.

4.3.2 Flood Behaviour – Flow Rates

Peak flow rates were also tabulated in each precinct in Table 4, with a breakdown of the above-ground and piped flow, in each design event.

Table 4: Peak Flow Rates

	5% AEP (m^3/s)			1% AEP (m^3/s)			PMF (m^3/s)		
Location	Pipes Peak Flow	Overland Peak Flow	Total	Pipes Peak Flow	Overland Peak Flow	Total	Pipes Peak Flow	Overland Peak Flow	Total
A	3.8	4.5	8.6	4.2	5.5	9.4	4.7	24.5	29.2
B	0.2	0.1	0.3	0.2	0.2	0.4	0.2	1.3	1.5
C	0.9	2.2	3.1	0.9	2.9	3.9	1.0	13.7	14.7
D	2.2	3.0	5.2	2.4	4.7	7.1	2.7	34.0	36.8
E	1.3	2.4	3.8	1.5	3.7	5.2	1.7	23.3	25.0
F	0.5	3.9	4.3	0.6	5.3	5.9	1.0	26.2	27.2
G	0.6	3.7	4.4	0.7	4.7	5.3	0.8	38.8	39.5

The table shows that as with flood depths, there is minimal scaling between events at most locations, with similar flow in the 5% AEP and 1% AEP events. Locations with relatively small upstream catchments such as locations B, C, E, F and G have around 1-4 m3/s total flow in a 5% AEP event. Even with small upstream catchments, the majority of flow is above ground, i.e. the pipes are at capacity. Higher flows are at location A, the main flowpath through Atarmon, and D, the main Flowpath 3 area, through the Crows Nest area. The table shows the trunk drain at location A takes a significant portion of flow (just under half of total flow in the 1% AEP) whereas at D more than two-thirds is overland flow. The flow rates are typical of urban areas with overland flow and are small enough that trunk drainage upgrades may be considered for mitigating flood risk. The main constraint is likely to be the long length of any such upgrade and the associated cost.

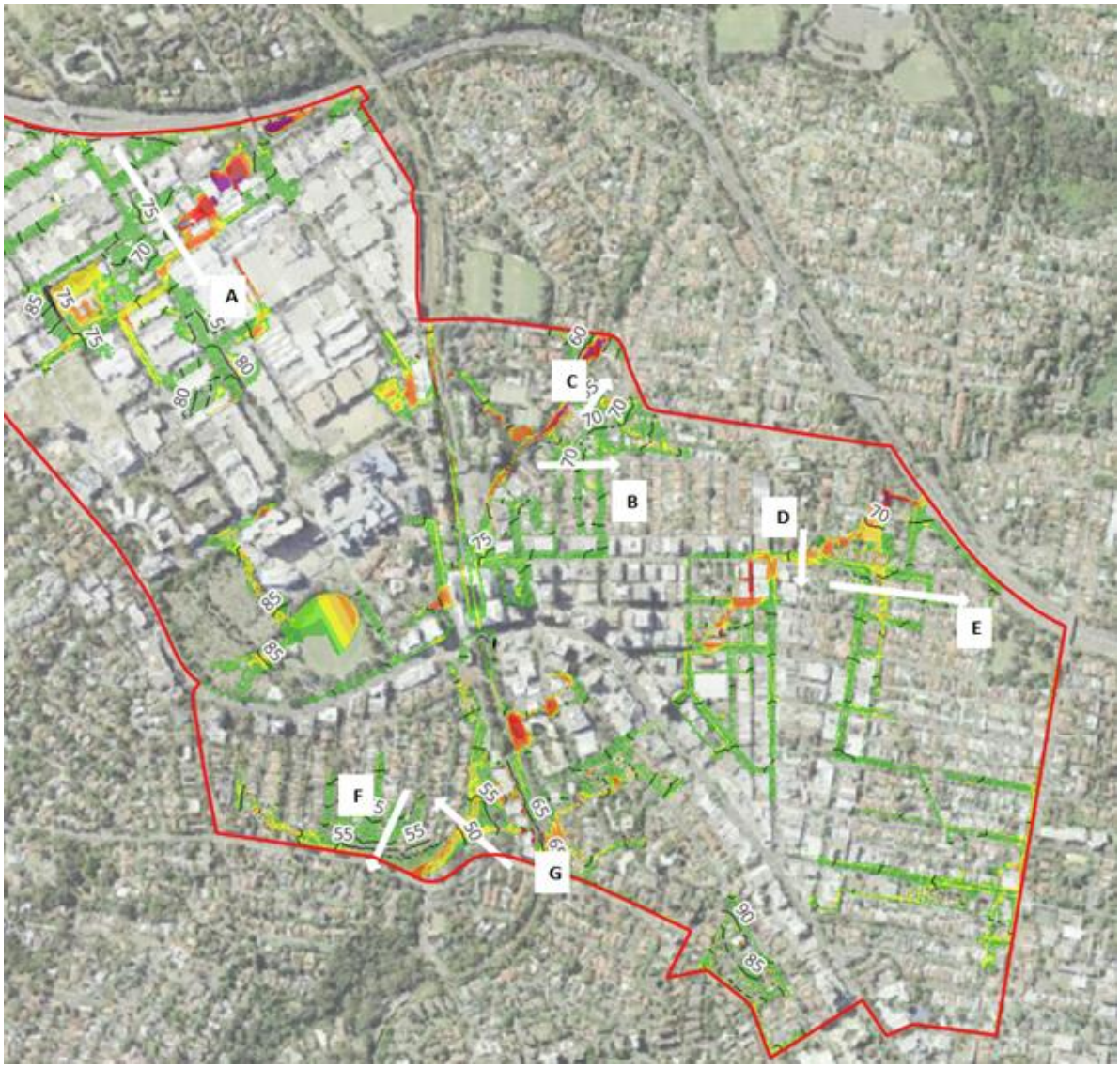


Image 7: Flow Measurement Locations

4.3.3 Flood Behaviour – Hazard

Flood hazard mapping has been developed through application of ARR2019 and Australian Emergency Management Institute (AEMI) flood hazard guidelines. The guidelines consider the threat to people, vehicles and buildings based on flood depth and velocity at a specific location. The AEMI flood hazard mapping can be used to assess the flood hazard for site occupants and proposed site usage, as well as for the community surrounding the site.

Chart 1 and Table 5 present the relationship between the velocity and depth of floodwaters and the corresponding classification.

Chart 1: Flood Hazard Curves (Australian Emergency Management Handbook 7)

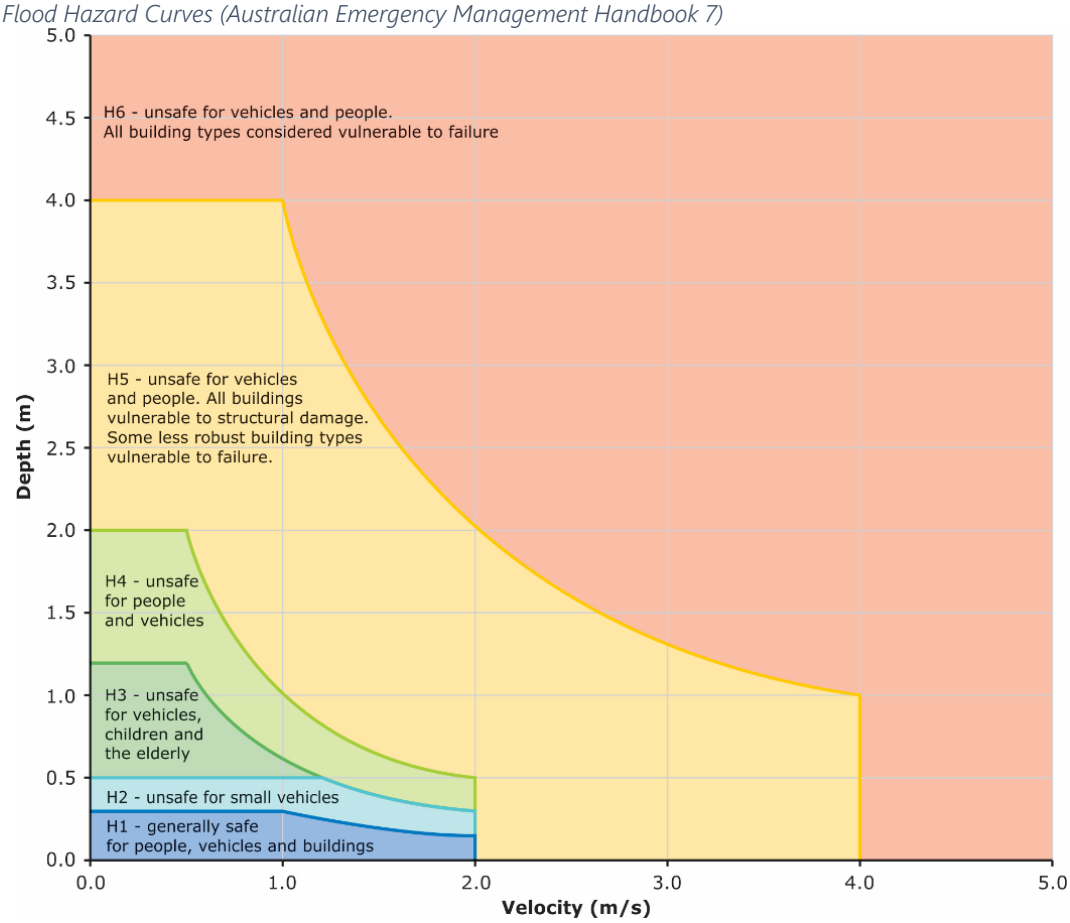


Table 5: Flood Hazard – Vulnerability Thresholds

Hazard Classification	Description
H1	Generally safe for vehicles, people and buildings.
H2	Unsafe for small vehicles.
H3	Unsafe for vehicles, children and the elderly.
H4	Unsafe for vehicles and people.
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

The hazard is shown on Figures 9, 10 and 11 for the 5% AEP, 1% AEP and PMF. The figures show:

- Across all flowpaths, the large majority of flow is categorised H1 in the 5% AEP and 1% AEP, which is mostly the sheet flow and gutter flow in the upper catchment.
- On Flowpath 1, the trapped low point north of Cleg Street is H3-H5 hazard.
- On Flowpath 2, aside from two low points on Herbert Street with H3 hazard, the first hazardous flow is Evans Lane (H5 due to the high velocity) and then through the park to the north. Virtually all other areas including around St Leonards station are H1.
- On Flowpath 3, flow is generally H1 with the exception of H3-H5 hazard in the vicinity of Hume Lane at the trapped low point, and the areas of H3-H5 to the northeast along the flowpath, approaching the freeway underpass.

- On Flowpath 4, flow is generally H1 including through the residential area south of Gore Hill Oval. Two lowpoints on Lithgow Street however have H3-H4 hazard in a 1% AEP event and the Christie Street low point has H3.

With regards to the focus area, it only has H1 hazard in a 1% AEP event, apart from the low point on Christie Street which has H3.

4.3.4 Flood Behaviour – Flood Function/Hydraulic Categories

Flood Function (also referred to as 'Hydraulic Categories') refers to the classification of floodwaters into three categories: floodway/flow conveyance, flood storage and flood fringe. These categories help to describe the nature of flooding across the floodplain and aid planning when assessing developable areas. According to the Australian Emergency Management Handbook 7, these three categories can be defined as:

- Floodway – the areas where a significant proportion of the floodwaters flow and typically align with defined channels. If these areas are blocked or developed, there will be significant redistribution of flow and increased flood levels across the floodplain. Generally, floodways have deep and/or fast moving floodwaters.
- Flood storage – areas where, during a flood, a significant proportion of floodwaters extend into, water is stored and then recedes after a flood. Significant filing or development in these areas may increase flood levels nearby; and
- Flood fringe – areas that make up the remainder of the flood extent. Development in these areas are unlikely to alter flood behaviour in the surrounding area.

The large majority of flood-affected land in the study area is overland flow, for which the guideline states:

- Defining flood function is complex
- It is important to define a continuous flowpath or floodway once it has formed
- Conveyance and encroachment techniques are difficult to use, and the indicator technique likely more appropriate (this means using depth and velocity, or similar outputs, to estimate areas of flood function)
- Large flood storage areas are not common and may not be present

On this basis, the flood function criteria in the two previous studies using depth, velocity and depth-velocity thresholds has been adopted for the current assessment. The thresholds are as follows:

1. Floodway = Velocity x Depth > 0.25 m^2/s AND Velocity > 0.25 m/s OR Velocity > 1 m/s
2. Flood Storage = Areas that are not floodway, with depth of >0.5 m (for North Sydney, whereas Flat Rock Creek used >0.3 m).
3. Flood Fringe = All remaining areas

The flood function is shown on Figure 12, 13 and 14 for the 5% AEP, 1% AEP and PMF.

4.3.5 Flood Planning Area

The Flood Planning Area is traditionally the area to which flood planning controls apply. Following recent NSW Ministerial Directions, flood planning controls more specifically now apply up to the

PMF. The Flood Planning Area is still referred to in the policy and guidelines so has been included in this assessment.

The Flood Planning Area (FPA) is typically based on a flood extent equivalent to a flood height 0.5 m above the 1% AEP flood level. In areas of overland flow, this may exaggerate the flood affectation and so often a lot by lot determination is made based on the depth of inundation on each lot in the 1% AEP. The two FPAs in the area, as shown on Figure 13, are:

- North Sydney FPA is a lot by lot selection of all lots that contain or are directly adjacent to a significantly flood depth or flow.
- Flat Rock Creek FPA is reported as the extent of the 1% AEP + 0.5 m flood (and so is not a lot based selection). The report indicates the FPA is only for areas of mainstream (i.e. creek/channel) flooding, but the mapping appears to also cover a portion of overland flow. The exact distinction of mainstream/overland is not particularly consequential, however, it is notable the upper Flat Rock Creek catchment which has overland flow, does not have a mapped FPA.

It is important to note that the FPA does not designate properties with a certain level of flood risk, as lots can have minor affection (e.g. ~0.2 m depth over part of the backyard) and be included in the FPA, or alternatively have very significant affectation (e.g. high hazard flow through the dwelling in frequent floods). Rather than a designation of flood risk, the FPA is simply a determination of where flooding needs to be considered in future development on a particular lot.

4.4 Model Results – Sensitivity Analysis

Sensitivity analysis describes the sensitivity of model results to changes in the modelling parameters. These parameters include structure blockage, hydraulic roughness and climate change (rainfall increase, and sea level rise). Each parameter is estimated based on the available data, but, due to the complexity of the catchment and flood-producing rainfall, the estimate will involve a series of assumptions and therefore has a degree of uncertainty. The sensitivity analysis therefore qualifies the assumptions by measuring their effect on the modelled flood behaviour. Large changes in the flood behaviour indicates a higher degree of uncertainty in the model results.

The sensitivity is tested by varying each parameter within a reasonable estimate range, and then re-running the hydraulic models (and hydrologic model for losses) to determine the peak flood level results for each scenario, for the 1% AEP event. The sensitivity is then quantified by measuring the impact on the peak flood level at a series of reporting locations.

The parameters tested and the results of the sensitivity analysis are presented below in Table 6 for roughness and blockage, and Table 7 for climate change.

Table 6: Sensitivity Analysis - Roughness and Blockage

ID	Location	Change in 1% AEP flood level			
		Roughness Decreased by 20%	Roughness Increased by 20%	Blockage (pipes) by 20%	Blockage (pipes) by 50%
1	Marden St	0.00	0.00	0.19	0.39
2	Longueville Rd near Reserve Rd	-0.03	0.02	0.01	0.12
3	Hotham Parade	-0.01	0.01	0.04	0.10
4	Sawyer Ln/Ashers Ln	-0.05	0.03	0.05	0.12
5	Campbell St/Clarendon St	-0.01	0.01	0.02	0.05
6	Campbell St/Lanceley Pl	-0.02	0.01	0.01	0.03
7	Reserve Rd/Cleg St	-0.01	0.01	0.01	0.03
8	Cleg St near Waltham St	-0.02	0.02	0.01	0.01
9	Waltham St near Taylor Ln	-0.11	0.09	0.06	0.13
10	Taylor Ln near Herbert St	0.03	-0.02	0.02	0.06
11	Driveway near Frederick St	0.01	-0.01	0.16	0.35
12	Frederick St Near Herbert St	-0.01	0.01	0.01	0.03
13	Reserve Rd near Frederick St	-0.03	0.02	0.02	0.04
14	Herbert St near Westbourne St	-0.01	0.01	0.04	0.11
15	Adjacent to Herbert St near Pacific Hwy	0.01	-0.01	0.42	0.92
16	Waters Rd near Northcote St	0.00	0.01	0.08	0.20
17	Chandos St near Plunkett St	0.00	0.00	0.00	0.00
18	Brook St near Gore Hill Fwy	0.00	0.01	0.02	0.07
19	Wheatleigh St near Chandos St	-0.01	0.01	0.02	0.05
20	Willoughby Rd/Chandos St	-0.01	0.01	0.01	0.03
21	River Rd/Canberra Ave	-0.01	0.01	0.00	0.01
22	Lithgow St near Oxley St	-0.01	0.01	0.09	0.13

Table 6 shows that there is very minimal sensitivity to both hydraulic roughness at most locations, with all locations having +-0.1 m change, and many having +-0.01 m or less. Sensitivity to pipe blockage is slightly higher, with several locations showing increases of around 0.1-0.2 m, indicating the pipes take a significant portion of the flow for these overland flow catchments. One locations (location 15) shows higher sensitivity because there is a very large pit at this low point and reduced inflow to the pipe builds up behind the wall separating the pit from Herbert Street.

Table 7: Sensitivity Analysis – Climate Change

ID	Location	Change in 1% AEP flood level		
		RF +10%	RF +20%*	RF + 30%
1	Marden St	0.13	NA	0.23
2	Longueville Rd near Reserve Rd	0.08	NA	0.09
3	Hotham Parade	0.04	NA	0.08
4	Sawyer Ln/Ashers Ln	0.06	NA	0.14
5	Campbell St/Clarendon St	0.03	NA	0.06
6	Campbell St/Lanceley Pl	0.02	NA	0.05
7	Reserve Rd/Cleg St	0.04	NA	0.09
8	Cleg St near Waltham St	0.03	NA	0.07
9	Waltham St near Taylor Ln	0.17	NA	0.38
10	Taylor Ln near Herbert St	0.04	NA	0.08
11	Driveway near Frederick St	0.21	NA	0.37
12	Frederick St Near Herbert St	0.02	NA	0.04
13	Reserve Rd near Frederick St	0.03	NA	0.05
14	Herbert St near Westbourne St	0.05	NA	0.08
15	Herbert St near Pacific Hwy	0.30	NA	0.57
16	Waters Rd near Northcote St	0.08	NA	0.17
17	Chandos St near Plunkett St	0.00	NA	0.00
18	Brook St near Gore Hill Fwy	0.05	0.11	NA
19	Wheatleigh St near Chandos St	0.05	0.10	NA
20	Willoughby Rd/Chandos St	0.02	0.05	NA
21	River Rd/Canberra Ave	0.02	0.04	0.06
22	Lithgow St near Oxley St	0.07	0.11	0.15

*As noted, 20% rainfall increase was not available for Flat Rock Creek modelling so the 30% increase was used as a proxy.

The analysis shows climate change will have a small effect on flood behaviour in the precinct. Around half of the locations have limited upstream catchment and the increased rainfall and runoff does not significantly affected flow depths, with an increase of 0.1 m or less. However, locations with larger catchments show increases of up to 0.2-0.4 m in the higher rainfall increase scenario. As with pipe blockage, the higher increase at Location 15 is due to the low point acting as a small basin and does not represent increased flood risk to roads/property.

5. FLOOD RISK ASSESSMENT OF PROPOSED INTENSIFICATION

The proposed intensification for the State Led Rezoning Crows Nest has been assessed with regards to flooding. The intensification area is the Focus Area shown on the figures. The intensification is expected to occur through a combination of rezoning and updated planning controls.

The intensification is in an area of minimal flooding, situated on or near the Pacific Highway which forms part of a topographic ridge through the area.

This section of the report also provides general advice on potential rezoning and intensification in the wider Crows Nest and St Leonards Precinct, with regards to flooding.

The assessment consists of the following considerations:

- The compatibility of the proposed intensification with the flood hazard of the area. Local and state policies require tailoring a site's land use to fit the flood hazard.
- The impact of the potential building envelopes on flood risk in the area, and whether any flood impacts require specific mitigation measures.
- The suitability of Councils' flood planning controls in mitigating flood risk associated with future development in the precinct, and whether additional planning controls are required.
- The compliance of the proposal with each of the specific requirements of Council policy, specifically the two Local Environmental Plans (LEP) and Development Control Plans, and each of the requirements of state government policy, specifically:
    - March 2022 Local Planning Directions
    - Considering flooding in land use planning (guideline) dated July 2021
    - Considering flooding in land use planning: guidance and statutory requirements (planning circular) dated July 2021
    - NSW Flood Risk Management Manual (2023), which replaces the earlier Floodplain Development Manual

5.1 Flood Hazard Compatibility

A primary consideration in assessing development of flood-affected land is the flood hazard. Flood hazard refers to the threat posed to people, vehicles and buildings in an area of flooding, and is based on the depth and velocity of floodwaters across the range of flood events. Deeper and faster flow has the potential to carry away people or vehicles, causing potential injury, death or financial loss, and similarly, deep and/or fast flow can damage and in some cases destroy buildings. Section 4.3.3 presents the thresholds of depth and velocity that separate the hazard categories from H1 (lowest level) to H6 (highest level).

As set out in Section 4.3.3, flood hazard has been mapped for the Crows Nest precinct, for the 5% AEP, 1% AEP and PMF events. The Focus Area has low hazard (H1 to H3) in all areas in flood events up to and including the 1% AEP event. The low hazard is due to the absence of significant overland

flowpaths through the area. Flood hazard is generally similar in extreme events, with some very localised areas of H4 and H5 hazard in the PMF.

More broadly across the precinct, the flood hazard mapping shows high hazard is limited to locations where either a significant flowpath forms, mostly following roadways but occasionally through property, or where a trapped low point causes a hazardous build-up of depth, again, usually on roads but also occurring on property.

Based on the flood hazard, the large majority of the precinct would be suitable for typical urban land uses, such as residential and commercial development and high-density multi-storey dwellings. However, areas with a significant flooding issue with H4-H6 hazard in the 1% AEP would pose a significant flooding constraint and would not be recommended for intensification of use.

5.2 Effect of Development on Flood Behaviour

Development in a flood-affected area has the potential to result in adverse flooding impacts, arising from diverting, obstructing or otherwise displacing floodwaters relative to current conditions, and creating or worsening a flooding issue for surrounding properties. These adverse impacts are investigated as part of a flood impact assessment, using available flood models. Typically if a new development affects flood behaviour it is due to a change in the building footprint, and/or change in ground levels around the building, both of which can be assessed using a hydraulic model. Flood modelling has not been undertaken by the current assessment, which has only considered the rezoning itself and not future building design.

New development as a result of intensification would generally fall into one of the following scenarios:

- New development located away from an area of flooding, in which case no impact is possible and no assessment is required
- New development located in an area of flooding, but on a lot that is currently flood-free (e.g. the existing building is built to the edge of the lot boundary), in which case impacts are very unlikely but would be reviewed.
- New development located in an area of flooding that may affect flood behaviour, in which case the proposed building footprint, ground level changes, and any relevant stormwater features would be modelled and assessed for flood impacts.

This level of detail is not available at the current stage and so it is recommended that flood impact assessment be carried out for any new developments, as set out in Section 5.5. It is worth noting that the precinct is a fully urbanised area and so future development as a result of rezoning or revised planning controls would not significantly change the catchment characteristics, from a flooding perspective. Furthermore, most sites in the Focus Area are not actually flooded so have very minimal chance of having a flood impact issue, and would likely not actually require flood impact assessment if future development are only within the lot itself.

5.2.1 On-Site Detention

On-site Detention (OSD) refers to the temporary storage of stormwater flows within a lot in a tank or similar feature. OSD requirements are set by Council and are aimed at ensuring new developments

do not increase runoff as a result of increased impermeable areas relative to pre-development conditions. While OSD requirements are typically set out separately to the flood planning controls, OSD can influence flood behaviour. OSD controls will likely lead to some benefit regarding flooding in the area, particularly in the Willoughby LGA, given that there are OSD requirements for sites that already have 80-100% impervious area. For example the Willoughby DCP requires that " All major developments must provide OSD systems designed to capture and detain stormwater runoff for all storm events up to and including the 1% AEP storm event..". OSD features such as tanks will be incorporated into new buildings and will be included in the flood impact assessment at DA stage.

5.3 Compliance with North Sydney, Willoughby and Lane Cove Policy

Development of flood-prone land in the three LGAs the precinct covers must be in accordance with their Local Environmental Plan (North Sydney LEP 2013, Lane Cove LEP 2009 and Willoughby LEP 2012). The Development Control Plans then contains more specific controls to be followed to ensure compliance with the LEP.

The LEP has a standard clause related to flooding. Clause 5.21 applies to all development on flood-prone land while a second clause (5.22) was added in late-2023 to apply additional controls to critical and sensitive land-uses for land between the Flood Planning Area and the PMF flood extent, which are termed Special Flood Considerations, however, only North Sydney and Lane Cove have not adopted clause 5.22.

The objectives of the LEP clauses are to:

- Minimise flood risk to life and to property
- Allow development on flood-affected land that is compatible with the area's flood function and behaviour, including climate change
- To avoid adverse or cumulative impacts on flood behaviour and the environment
- to enable the safe occupation and efficient evacuation of people in the event of a flood

The compliance of the intensification with the LEP is set out in Table 8. The current Focus Area is located in North Sydney and Lane Cove Council areas, however, Willoughby has been included to provide advice for potential other rezoning in the wider precinct.

Table 8: LEP Compliance

LEP Planning Control	Compliance Comment
(1) The objectives of this clause are as follows— (a) to minimise the flood risk to life and property associated with the use of land, (b) to allow development on land that is compatible with the flood function and behaviour on the land, taking into account projected changes as a result of climate change,	Higher density residential/commercial would meet the LEP objectives, provided that new development follows the applicable flood planning controls. The Focus Area does not have high flood risk and the flood risk to life and property is readily managed. The area itself is largely not flooded with some areas of shallow overland flow with significant flowpaths forming on some roads in large floods, as typically occurs in an urban area.

(c) to avoid adverse or cumulative impacts on flood behaviour and the environment, (d) to enable the safe occupation and efficient evacuation of people in the event of a flood.	More broadly across the precinct, in some locations there is a significant depth of high hazard flooding that is localised to a road low point and adjacent property, that would not be suitable for intensification of use via rezoning (see Section 5.1). Climate change has been assessed and found to not significantly impact on flood risk in the catchment. Safe occupation and efficient evacuation of people is generally achievable in the future design of individual buildings.
(2) Development consent must not be granted to development on land the consent authority considers to be within the flood planning area unless the consent authority is satisfied the development— (a) is compatible with the flood function and behaviour on the land, and (b) will not adversely affect flood behaviour in a way that results in detrimental increases in the potential flood affectation of other development or properties, and (c) will not adversely affect the safe occupation and efficient evacuation of people or exceed the capacity of existing evacuation routes for the surrounding area in the event of a flood, and (d) incorporates appropriate measures to manage risk to life in the event of a flood, and (e) will not adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.	a) The flood function consists of flood fringe with some floodway areas on the main flowpaths, and limited flood storage. Intensification is suitable with regards to flood function. b) Flood impact assessment would be required for future development in flood-affected areas (see recommendations). Review of the Focus Area not indicate any areas where catchment characteristics would be significantly modified, that would impact flooding. c) Evacuation is not a significant risk factor for lots in the Focus Area. In the broader precinct, overland flow occasionally passes through properties. Any new buildings can be designed to be safely occupied during a flood event, with a Shelter In Place evacuation strategy. Emergency access during a 1% AEP flood event will generally be achievable, through low hazard flooding on roads. d) At the current stage, risk to life measures consist of appropriate zoning based on the flood risk, and ensuring suitable flood planning controls are to be applied. Rezoning and intensification is suitable for the area and buildings can be designed to ensure risk to life is managed, see Section 5.5 Recommended Measures. e) The only watercourse in the vicinity of the precinct is Flat Rock Creek, which would not be adversely affected by the intensification.
(3) In deciding whether to grant development consent on land to which this clause applies, the consent authority must consider the following matters—	a) Projected changes to flood behaviour as a result of climate change have been assessed, with regards to rainfall increase and sea level rise. Both are shown to have very minimal effect on

(a) the impact of the development on projected changes to flood behaviour as a result of climate change, (b) the intended design and scale of buildings resulting from the development, (c) whether the development incorporates measures to minimise the risk to life and ensure the safe evacuation of people in the event of a flood, (d) the potential to modify, relocate or remove buildings resulting from development if the surrounding area is impacted by flooding or coastal erosion.	flood behaviour in the precinct, which is well above sea level, and has small upstream catchments that tend to be insensitive to future increases in rainfall intensity. b) The intended design and scale of buildings may potentially be, at some locations, a significant increase from what currently exists. The increase is suitable, from a flood risk perspective. c) See above. d) Building relocation would not be required at the location, given the low flood risk under current and future climate scenarios, and the elevated location. There are no low-lying areas.
[Clause 5.22 – Willoughby LEP] (2) This clause applies to— (a) for sensitive and hazardous development—land between the flood planning area and the probable maximum flood, and (b) for development that is not sensitive and hazardous development—land the consent authority considers to be land that, in the event of a flood, may— (i) cause a particular risk to life, and (ii) require the evacuation of people or other safety considerations. (3) Development consent must not be granted to development on land to which this clause applies unless the consent authority has considered whether the development— (a) will affect the safe occupation and efficient evacuation of people in the event of a flood, and (b) incorporates appropriate measures to manage risk to life in the event of a flood, and (c) will adversely affect the environment in the event of a flood.	a) Rezoning or other changes that permit additional sensitive and hazardous development is not proposed. Childcare, schools or aged care are not proposed at the rezoning sites. b) Land is not present in the precinct that has a particular risk to life or require the evacuation of people. On this basis the clause is not relevant to the project

The table overview shows the proposed intensification is compliant with the objectives and requirements of the LEPs.

Table 9 summarises the three Development Control Plan (DCP) flooding sections and the project's compliance with it. The DCP contains objectives, design principles and then a matrix of specific planning controls. Many of the DCP controls pertain to building design and so would apply again

for the design of any individual building. The assessment of the masterplan is a broader review of compliance and to identify the relevant controls to be applied in the future.

Table 9: DCP Compliance

DCP Section	Compliance Comment
Willoughby DCP Objectives a. provide consistent guidelines and criteria for developers and other land users of overland flow/floodprone properties in the City of Willoughby local government area when preparing development applications b. ensure land identified by Willoughby City Council as subject to a flood related development control has a flood impact statement or flood risk study done before approval of new development c. reduce the potential risks to property damage and loss of life arising from the development of overland flow and floodprone land, as well as minimise damage to private property during flooding events d. prevent development intensification on land that is subject to a high risk of flood (H4 to H6) e. ensure development on floodprone properties have to adopt measures to not exacerbate flooding on other properties f. increase public awareness through education of the potential adverse impacts of development on properties adjoining overland flow/floodprone properties	Note: No change is proposed in Willoughby. Compliance comment below pertains to general advice for future rezoning in the precinct. b. This would be carried where appropriate, see Section 5.5 Recommendations c. Future development would reduce risk to property damage via following the LEP and DCP flood planning controls, which will result in flooding being incorporated into the design of each building, for example, higher floor levels in areas that currently suffer above-floor inundation. d. Flood hazard has been assessed in Section 5.1. H4-H6 areas have been recommended to not be intensified, unless large-scale infrastructure works can be carried out in tandem with rezoning that would remove the high hazard flooding. e. This would be achieved by following the LEP and DCP flood planning controls, see Section 5.5. f. This would be achieved through the flood assessment process which would be carried out for each affected lot.
Willoughby Process for Flood Affected Lots For all development that is flood affected, a flood impact statement as a minimum must be provided to Willoughby City Council. This must be prepared by a suitably qualified engineer in line with the NSW Government's Floodplain Development Manual and address the various controls. A detailed flood study is required for sites where Council has no detailed flood study, the footprint of the building is changing or overland flow paths are being altered. All major developments (works other than single dwellings and dual occupancy developments) will require a site specific flood study if the site is a flood affected lot or if the site is adjacent to a major drainage path or mainstream flooding.	This flood impact statement and in some cases a detailed flood study would be carried out for future development arising from rezoning – see Recommendations section.
Willoughby Design requirements for new development in areas subject to local drainage or overland flow a. minimum floor level for buildings = 1% AEP water level + 500mm b. minimum garage floor level = 1% AEP water level + 300mm	

c. minimum crest level for driveway to basement parking = PMF water level or 1% AEP water level + 500mm, whichever is higher d. minimum floor level for carport = 1% AEP water level + 100mm e. underside of any structure to be 300mm above 1% AEP flood level f. construct on high side of property g. flood evacuation route at 1% AEP +500mm level h. flood impact assessment required; a flood study may be required where works potentially impact flood levels.	a-f. These are readily achievable for new buildings. In some instances where flood affectation is significant, it is recommended these requirements be considered early on in the design process. g. Evacuation will likely be shelter in place for new buildings due to the nature of overland flow, which tends to create brief, hazardous conditions on the majority of roads in an area. h. Flood impact assessment will be carried out where required, see Section 5.5
Lane Cove DCP Objectives 1. Where overland flow enters a property due consideration must be given to the effects of stormwater discharges upon neighbouring properties. 2. In situations where there is a known flooding problem, or there is a risk of stormwater inundation, a flood study of the catchment containing the development site will be required. The flood study shall be in accordance with current practice as outlined in Australian Rainfall & Runoff, and subject to the satisfaction of Council's Engineer. 3. Development Applications to undertake any property improvements on land that is subject to overland flow, must give due consideration to the manner in which the proposed work will affect the free passage of overland flow through the property. The development is not to create or aggravate hazardous overland flow conditions. Lane Cove DCP Freeboard Requirements Floor levels of dwellings, including garages, should be at a level that will ensure they are not subject to stormwater inundation or nuisance flooding. To prevent stormwater from entering buildings the finished floor levels must be set at least 150mm above the adjacent ground levels. The entire outside perimeter of all buildings must have overland escape routes which will protect all finished floor levels from flooding in the event of the complete blockage of the surrounding drainage system. Where it is proposed to build in an area known to be affected by overland flow, all spaces are to have a minimum freeboard of 300mm (except parking and storage areas which are to have a freeboard of 150mm), above the calculated top water level for the 1 in 100 year	1. and 3. For the large majority of the Focus Area, there is no overland flow through lots. Areas of overland flow are readily managed as part of the future design stages For the wider precinct, these are readily achievable and overland flow through a property would be considered as part of a flood impact assessment (see Section 5.5. for recommendations). 2. The current assessment contains a broad-scale flood study for the Lane Cove portion of the precinct. More detailed studies can be carried out as part of future development. Freeboard requirements can be incorporated into the design of future development. The DCP section also contains requirements for car parking, fencing and safety that are readily achievable as part of the design of future development.

ARI storm event. Freeboard may need to be increased to 500mm or greater where there are high flowrates, high flow depths or low confidence in the accuracy of the flood model.	
North Sydney DCP – Floodplain Management Policy (Interim) Objectives a) inform the community of this Policy with regard to the use of flood prone land; b) establish guidelines for the development of flood prone land that are consistent with the NSW Flood Policy and NSW Floodplain	
c) control development and activity within the floodplains within the LGA having regard to the characteristics and level of information available for the floodplains;	c) Flooding characteristics of the Focus Area have been assessed in this document
d) minimise the risk to human life and damage to property by controlling development on flood prone land; e) apply a merit based approach to all development decisions taking into account ecological, social and environmental considerations;	d) New development would minimise the risk to life and property damage through the use of flood planning controls which would, in many instances, reduce flood risk from what currently exists
f) ensure that the development or use of floodplains does not adversely impact upon the aesthetic, recreational and ecological values of the waterway corridors;	f) Waterway corridors are not present in the North Sydney portion of the precinct and would not be affected
g) ensure that all land uses and essential services are appropriately sited and designed in recognition of all potential floods;	g) Land use compatibility with the flood behaviour has been assessed
h) ensure that all development on the floodplain complies with Ecologically Sustainable Development (ESD) principles and guidelines; and i) promote building design that considers requirements for the development of flood prone land and to ensure that the development of flood prone land does not have significant impacts upon the amenity of an area.	h) and i) This is readily achievable as part of future design of individual lots
North Sydney Floodplain Management Policy (Interim) Specific Controls The DCP has a table of flood planning levels, requirements for fencing, filling of land, and car parking design.	These requirements are readily achievable as part of the design of future development.
The proposed residential/commercial/industrial building or dwelling should not increase the likelihood of flooding on other developments, properties or infrastructure.	This would be covered as part of the flood impact assessment.

Intensification in the Focus Area is assessed to be in accordance with the design principles in the DCP, with regards to flooding. The relevant planning controls relating to building design are discussed in more detail in Section 5.5.

5.4 Compliance with NSW Policy

Management of flood risk is overseen by the state government in conjunction with local governments, with the state government providing technical guidelines for understanding and managing flood risk, as well as review and consent for state significant developments and planning proposals. These guidelines are collected in the NSW Flood Risk Management Manual (2023) which has superseded the earlier Floodplain Development Manual (2005). The overarching legislation is the NSW Environmental Planning and Assessment Act 1979 (EP&A Act), which tasks Councils with implementing the NSW government's flood prone land policy, with the objectives:

(a) to ensure that development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005, and

(b) to ensure that the provisions of an LEP on flood prone land is commensurate with flood hazard and includes consideration of the potential flood impacts both on and off the subject land.

The policy has requirements prohibiting development in areas of floodway, ensuring development does not adversely impact others, and requirements for development of the FPA. These requirements are then set out in the LEP clauses (see previous report section).

In addition to the two guidelines and overarching policy, three recent policies have been released with specific direction on flooding and land use planning including rezoning. These are:

- Considering flooding in land use planning: guidance and statutory requirements (planning circular) dated July 2021
- Considering flooding in land use planning (guideline) dated July 2021
- March 2022 Local Planning Directions

The first guidance sets out the various statutory requirements including the new LEP clauses (assessed above), and the two other guidelines above.

The second is a 9 page guideline for Councils on how to consider flooding in land use planning, which instructs Councils to:

- Consider flood function, flood hazard, extent and flooding behaviour for the full range of flood events, and risk to life
- Recommends Councils produce a Flood Planning Area for their LGA
- Use a freeboard of 0.5 m when setting Flood Planning Levels, or a lower freeboard in some cases where the consequences of flooding are lower
- Consider Special Flood Considerations (of which the details are set out in LEP Clause 5.22, which was only adopted into LEPs in late 2023).
- Map areas of flooding as part of the assessment

These considerations have all been included in the current assessment.

Lastly, March 2022 Local Planning Directions requirements are set out below in Table 10.

Table 10: March 2022 Local Planning Directions

Planning Directions	Compliance Comment
A planning proposal must include provisions that give effect to and are consistent with the NSW Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005 (including the Guideline on Development Controls on Low Flood Risk Areas).	Consideration of a range of flood events up to the PMF, including flood hazard and flood function classification, has been undertaken. Further, site access and the potential for isolation and emergency vehicle access issues are considered. The analysis and findings are consistent with the objectives of the Floodplain Development Manual 2005 and newer Flood Risk Management Manual.
A planning proposal must not rezone land within the flood planning areas from Special Use, Special Purpose, Recreation, Rural or Environmental Protection Zones to a Residential, Business, Industrial, Special Use or Special Purpose Zone.	No Special Purpose zones and recreation zones are proposed to rezone with in FPA
A planning proposal must not contain provisions that apply to the flood planning areas which: permit development in floodway areas, permit development that will result in significant flood impacts to other properties, permit a significant increase in the development of that land, are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services, or permit development to be carried out without development consent except for the purposes of agriculture (not including dams, drainage canals, levees, buildings or structures in floodways or high hazard areas), roads or exempt development.	There is one area of FPA in the Focus Area, which contains the very upper portion of an overland flowpath of limited catchment in the North Sydney LGA. The limited flood risk and the magnitude flow, which is readily incorporated into future building design, means the intensification is not considered unsuitable. Further discussion is presented below this table. For the precinct more broadly: -The large majority of the precinct's area is flood fringe, with only localised instances of floodway and flood storage. Floodway passes through properties in some locations however is very localised. - Flood impact assessment has not been carried out as part of the current assessment. However, the assessment finds that impacts from future works are readily managed via flood impact assessment as part of future design of individual sites. -Rezoning that allows for intensification of the area would involve a significant increase in the development of the various FPAs across the precinct and would be assessed if that were to occur in an area of FPA. It is worth noting that were rezoning and intensification of use be proposed for the FPA, that the FPA designation is, in some areas, due to 1% AEP depths of around 0.2-0.3 m on part of a lot, which is H1-H2 hazard in the 1% AEP and flood fringe. Given the low flood risk and opportunity to significantly reduce flood risk in the precinct via the design of new

	buildings in the area, the increase in density is considered to be suitable. -No increase in government spending on mitigation, infrastructure or services would be expected. -Development consent would be required for new buildings in the precinct in the FPA.
A planning proposal must not impose flood related development controls above the residential flood planning level for residential development on land, unless a relevant planning authority provides adequate justification for those controls to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General). For the purposes of a planning proposal, a relevant planning authority must not determine a flood planning level that is inconsistent with the Floodplain Development Manual 2005 (including the Guideline on Development Controls on Low Flood Risk Areas) unless a relevant planning authority provides adequate justification for the proposed departure from that Manual to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).	Flood-related development controls above the residential FPL are not proposed. The recommended FPL is provided in Section 5.5 and is consistent with the Floodplain Development Manual and newer Flood Risk Management Manual.

The assessment finds that the re-zoning is generally compliant with the planning directions. One area of consideration would be the several North Sydney FPA lots located in the Focus Area. In this area and also more broadly across the precinct, if rezoning/intensification were proposed in areas of floodway or FPA, it may be not compliant as the directions prohibit changes to a Flood Planning Area that results in "*significant increase in the development of that land*". However, based on GRC Hydro's assessment of flooding and flood risk, the FPA in this area does not necessarily mean the particular lots have high flood risk and based on experience in other areas, future development could be readily designed that ensures protection against flooding and for some lots, reduces the flood risk from what currently exists.

The planning directions do make some allowance for inconsistency with the above requirements, stating that a proposal can be inconsistent if the planning authority is satisfied that "*the planning proposal is supported by a flood and risk impact assessment accepted by the relevant planning authority and is prepared in accordance with the principles of the Floodplain Development Manual 2005 and consistent with the relevant planning authorities' requirements*". The current assessment clearly sets out the low risk at the site with regards to design flood depths, velocities, hazard, flood function, evacuation and also scaling between the 1% AEP and extreme events, and sensitivity to blockage and climate change. At the area in question in the Focus Area, the FPA lots, while having some flood affectation, have quite low flood risk in many regards as there is:

- In the 1% AEP, nearly all hazard is H1 except for a small portion of H2/H3
- Largely flood fringe with some flood storage where depths are greater

- No significant evacuation or access issues
- Flow rates and flood depths that can be incorporated into the design of the building while likely also reducing the site's flood risk relative to the existing conditions

On this basis we would seek the consent of the planning authority that intensification of this particular Flood Planning Area is permitted.

5.5 Focus Area Intensification - Recommended Measures including Flood Planning Controls

The Focus Area is located in an area of low or negligible flood risk. It is located near the catchment ridge (i.e. have very small upstream catchments) and nearly all the lots themselves are not flooded, with shallow flow on the roadways. At some locations there is higher flood affectation, for example, there is some potential inundation on Nicholson Street and Christie Street, that would warrant assessment and management as part of future development. This inundation is unlikely to be captured in Lane Cove Council flood planning controls as the sites have such minimal catchment, and it is more likely to considered a drainage/minor overland flow issue rather than major overland flow.

It is recommended to update in the 2036 plan or a similar masterplan for the state led rezoning:

- Mapping or other description of 1% AEP and PMF flood affectation in the Focus Area, with regards to flood depths, levels and hazard. At locations such as Nicholson Street and Christie Street, there is potential flooding on the road low points (Nicholson Street, Christie Street) which should be incorporated into building design at the ground level.
- Requirement that future development in the area follow the controls in North Sydney DCP and Lane Cove DCP Part O Stormwater Management and in particular O.10 Stormwater Inundation
- A note that as part of future development, flood mapping can be refined via use of ground and stormwater survey at the site, for the existing case.

These measures are sufficient to manage the low flood risk across the Focus Area.

5.6 Potential Other Rezoning Across the Precinct - Recommended Measures including Flood Planning Controls

The current assessment has found that rezoning and intensification in the precinct is broadly suitable in relation to the area's flood behaviour, but has identified various requirements that must be met in subsequent stages in the design of new buildings and associated development. These requirements are captured by the LEP and DCP flood planning controls, which are considered to comprehensively manage flood risk. However, to improve the coverage of the flood planning controls, their application may be formalised, especially for Willoughby LGA that does not map a FPA for most of the precinct, and for Lane Cove LGA which does not appear to have flood mapping for the Lane Cove portion of the precinct.

To formalise the application of the relevant flood planning controls, in the 2036 plan or a similar masterplan for the state led rezoning, it is recommended to:

- Map the existing North Sydney and Willoughby Flood Planning Areas on a single map, and in consultation with Willoughby and Lane Cove Councils, consider expanding the Flood Planning Area to the overland flowpaths in their LGAs. Alternatively, another designation can be used to signify flood planning controls apply to future development. As an example, new buildings with basement car parks located on Herbert Street or Christie Street at the topographic low points may not have flood planning controls applied to them (confirmation is sought from the relevant Councils). The mapping may also be limited to the proposed area of rezoning, once known.
- Set out in the same masterplan the relevant flood planning controls to be applied in the design of future development, namely:
    - North Sydney Council's Floodplain Management Policy (Interim)
    - Lane Cove DCP Part O Stormwater Management and in particular O.10 Stormwater Inundation
    - Willoughby DCP's Part I: Stormwater Management, Attachment 2 - Technical Standard 2 – floodplain management

The assessment identifies the most important controls being:

- Flood impact assessment is to be carried out to ensure no increase in flood risk on adjoining areas as a result of new development.
- Use of Flood Planning Levels for new development.

The other DCP controls such as use of flood compatible materials, structural soundness, car parking and evacuation are also important in managing flood risk. Table 11 lists a selection of the controls that would apply and provides advice on applying the controls to new development in each precinct.

Table 11: Advice on application of DCP Planning Controls

DCP Planning Controls for New Development	Advice on Application
1. Floor levels are to be set at or above the Flood Planning Level, which varies between LGAs and depending on the type of development	Indicative 1% AEP flood depths and levels can be read from the mapping provided in this report, and from Council's FRMS&Ps. The required FPL of buildings in all areas in the Flood Planning Area should be considered early in the building design process. Building entrances cannot sit flush with the footpath level in most locations and will require some level of step up or ramp.
2. Building components are often required to to have flood compatible building components below the 100 year ARI flood level plus freeboard.	Flood compatible building components include common building materials with an example list in North Sydney's Interim Floodplain Management Policy.
3. Flood Impact Assessment requirements vary between the three DCPs but generally impact assessment must show no adverse impacts on adjoining areas in a 1% AEP event.	Flood impacts should be considered early in the design process where a flowpath may be blocked or diverted by a new building and associated works. Lots with existing buildings to the edge of lot boundary are less likely to have flood impacts.

4. Car Parking and Driveway Access requirements vary but as with floor levels, will generally require a step up from the road level.	Car parking requirements particularly for basement car parks should be considered early in the building design process. For some sites, locating the entrance away from the areas of deepest flooding will simplify the design requirements.

Other planning controls are set out in each DCP including evacuation, emergency management, and structural soundness.

6.CONCLUSIONS

Assessment of flood risk has been carried out in relation to the Crows Nest Rezoning project in the North Sydney, Willoughby and Lane Cove LGAs. The assessment has used the available hydrologic and hydraulic models to assess flood risk in each of the catchments.

The assessment found that proposed rezoning and intensification of the Focus Area is suitable from a flood risk perspective. The area has low or negligible flood risk which is readily managed. Standard flood planning controls will be sufficient to manage flood risk.

With regards to potential other rezoning across the precinct, this is broadly suitable although high flood hazard exists in certain locations that would likely preclude rezoning that resulted in intensification of use, and some types of rezoning of the limited areas of FPA would be constrained. The council DCPs and LEPs, and relevant state government policies have been considered with respect to development of flood-prone areas. The report sets out relevant planning controls that are currently in the DCPs that will manage flood risk, but notes that the area the DCP controls apply to should be formalised. These controls will ensure flood risk is incorporated into the design of new buildings and associated development, and that flooding in the area is not impacted as a result of future development.

7.REFERENCES

1. Flat Rock Creek Floodplain Risk Management Study and Plan – WMAwater, 2020

2. North Sydney LGA-Wide Floodplain Risk Management Study and Plan – GRC Hydro, 2022

3. St Leonards and Crows Nest 2036 – NSW Department of Planning, Industry and Environment

4. Australian Rainfall and Runoff 2019 – Commonwealth of Australia

5. Flood Risk Management Manual - NSW Government, 2023

6. Australian Disaster Resilience Handbook 7 – Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia, 2017, Australian Institute for Disaster Resilience.

APPENDIX A

Glossary of Key Terminology (Reference: Floodplain Development Manual 2005)

annual exceedance probability (AEP)	the chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. Eg, if a peak flood discharge of 500 m3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m3/s or larger events occurring in any one year (see ARI).
Australian Height Datum (AHD)	a common national surface level datum approximately corresponding to mean sea level.
average annual damage (AAD)	depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
average recurrence interval (ARI)	the long-term average number of years between the occurrence of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
catchment	the land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	the council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the council, however legislation or an EPI may specify a Minister or public authority (other than a council), or the Director General of DIPNR, as having the function to determine an application.
development	is defined in Part 4 of the EP&A Act infill development: refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development new development: refers to development of a completely different nature to that associated with the former land use. Eg, the urban subdivision of an area previously used for rural purposes. New developments involve re-zoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. redevelopment: refers to rebuilding in an area. Eg, as urban areas age, it may become necessary to demolish and reconstruct buildings on a

	relatively large scale. Redevelopment generally does not require either re-zoning or major extensions to urban services.
disaster plan (DISPLAN)	a step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
discharge	the rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
effective warning time	the time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	a range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage (refer Section C6) before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	Awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves and their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	the remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	is synonymous with flood prone land (ie) land susceptible to flooding by the PMF event. Note that the term flood liable land covers the whole floodplain, not just that part below the FPL (see flood planning area).

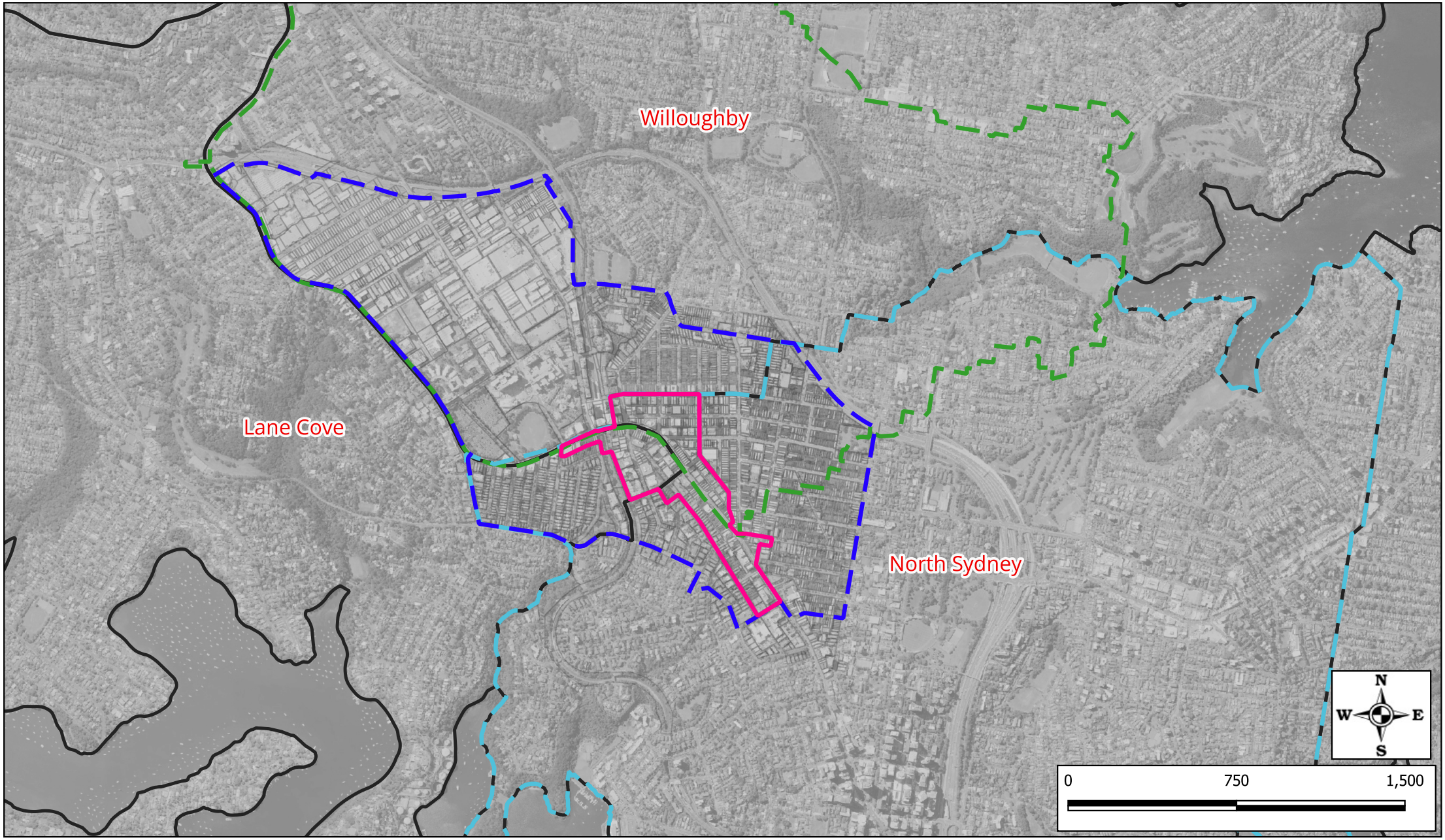
flood mitigation standard	the average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
floodplain risk management options	the measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
floodplain risk management plan	a management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at state, division and local levels. Local flood plans are prepared under the leadership of the SES.
flood planning area	the area of land below the FPL and thus subject to flood related development controls. The concept of flood planning area generally supersedes the "flood liable land" concept in the 1986 Manual.
flood planning levels (FPLs)	are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the "standard flood event" in the 1986 manual.
flood proofing	a combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	land susceptible to flooding by the PMF event. Flood prone land is synonymous with flood liable land.
flood readiness	Readiness is an ability to react within the effective warning time.
flood risk	potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below: existing flood risk: the risk a community is exposed to as a result of its location on the floodplain. future flood risk: the risk a community may be exposed to as a result of new development on the floodplain. continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town

	protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
freeboard	provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. (See Section K5). Freeboard is included in the flood planning level.
habitable room	in a residential situation: a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. in an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	a source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community.
hydraulics	term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	a graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.

mainstream flooding	inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purposes of this manual major drainage involves: • the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or • water depths generally in excess of 0.3m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or • major overland flowpaths through developed areas outside of defined drainage reserves; and/or • the potential to affect a number of buildings along the major flow path.
mathematical/computer models	the mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
merit approach	the merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State's rivers and floodplains. The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into council plans, policy, and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local flood risk management policy and EPIs.
minor, moderate and major flooding	both the SES and the BoM use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood: minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. moderate flooding: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.

	major flooding: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
modification measures	measures that modify either the flood, the property or the response to flooding.
peak discharge	the maximum discharge occurring during a flood event.
probable maximum flood	the PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
probable maximum precipitation	the PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	a statistical measure of the expected chance of flooding (see AEP).
risk	chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	the amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	equivalent to water level (both measured with reference to a specified datum).
stage hydrograph	a graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
survey plan	a plan prepared by a registered surveyor.
water surface profile	a graph showing the flood stage at any given location along a watercourse at a particular time.

FIGURES



Focus Area
Precinct Boundary
LGA Boundary
North Sydney model boundary
Flat Rock Creek model boundary

TITLE: **Study Area and Precinct**		
PROJECT: **State Led Rezoning Crows Nest - Flooding and Stormwater Study**		
PROJECT No. **240008**		
DATE: **06-2024**	SCALE: 1:22,000	FIGURE No. **01**

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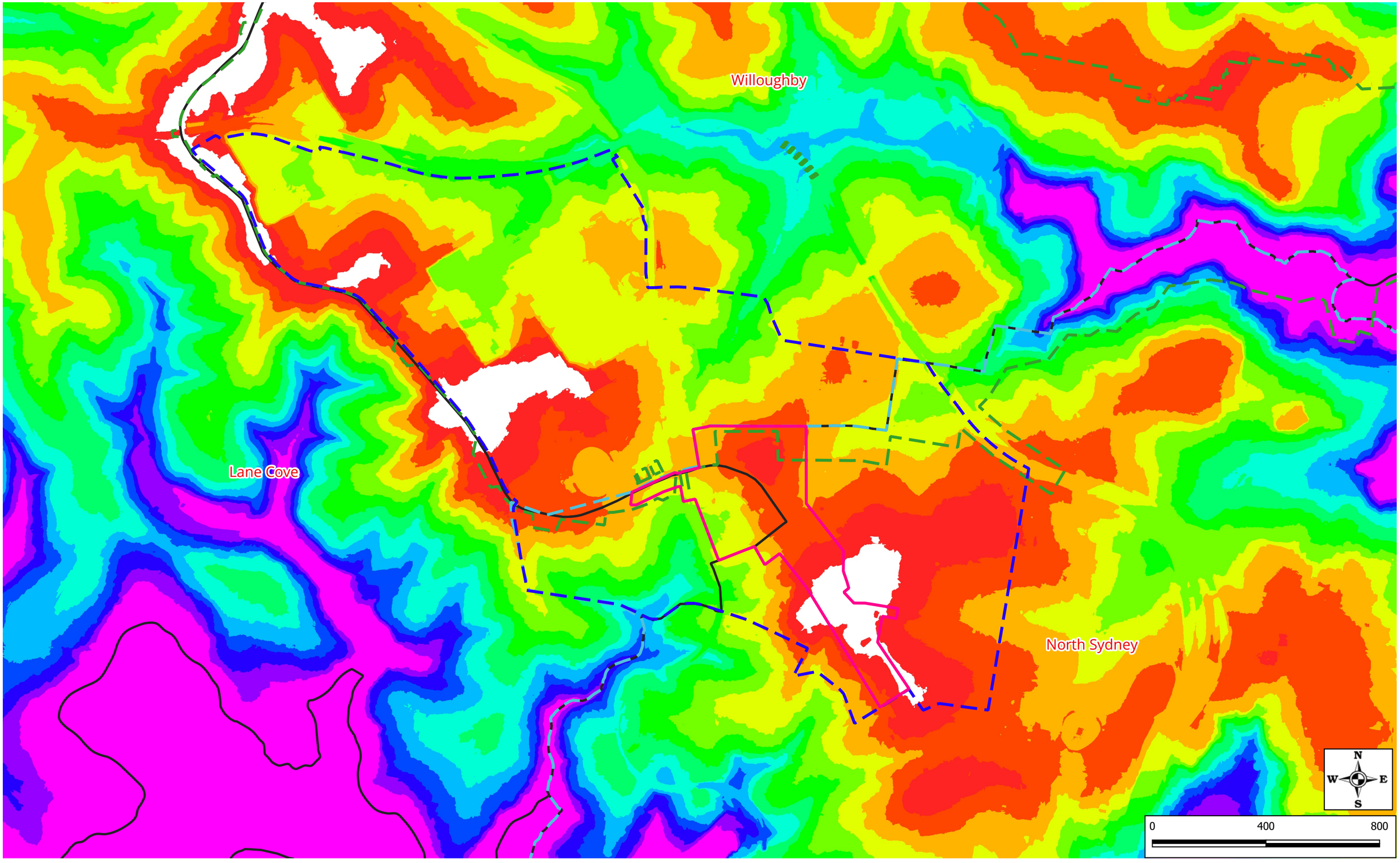

Focus Area
Precinct Boundary
LGA Boundary

Ground Elevation (mAHD)

- <= 30.0
- 30.0 - 35.0
- 35.0 - 40.0
- 40.0 - 45.0
- 45.0 - 50.0
- 50.0 - 55.0
- 55.0 - 60.0
- 60.0 - 65.0
- 65.0 - 70.0
- 70.0 - 75.0
- 75.0 - 80.0
- 80.0 - 85.0
- 85.0 - 90.0
- 90.0 - 95.0
- > 95

TITLE: **Digital Elevation Model**		
PROJECT: **State Led Rezoning Crows Nest - Flooding and Stormwater Study**		
PROJECT No. **240008**		
DATE: **06-2024**	SCALE: 1:12,000	FIGURE No. **02**

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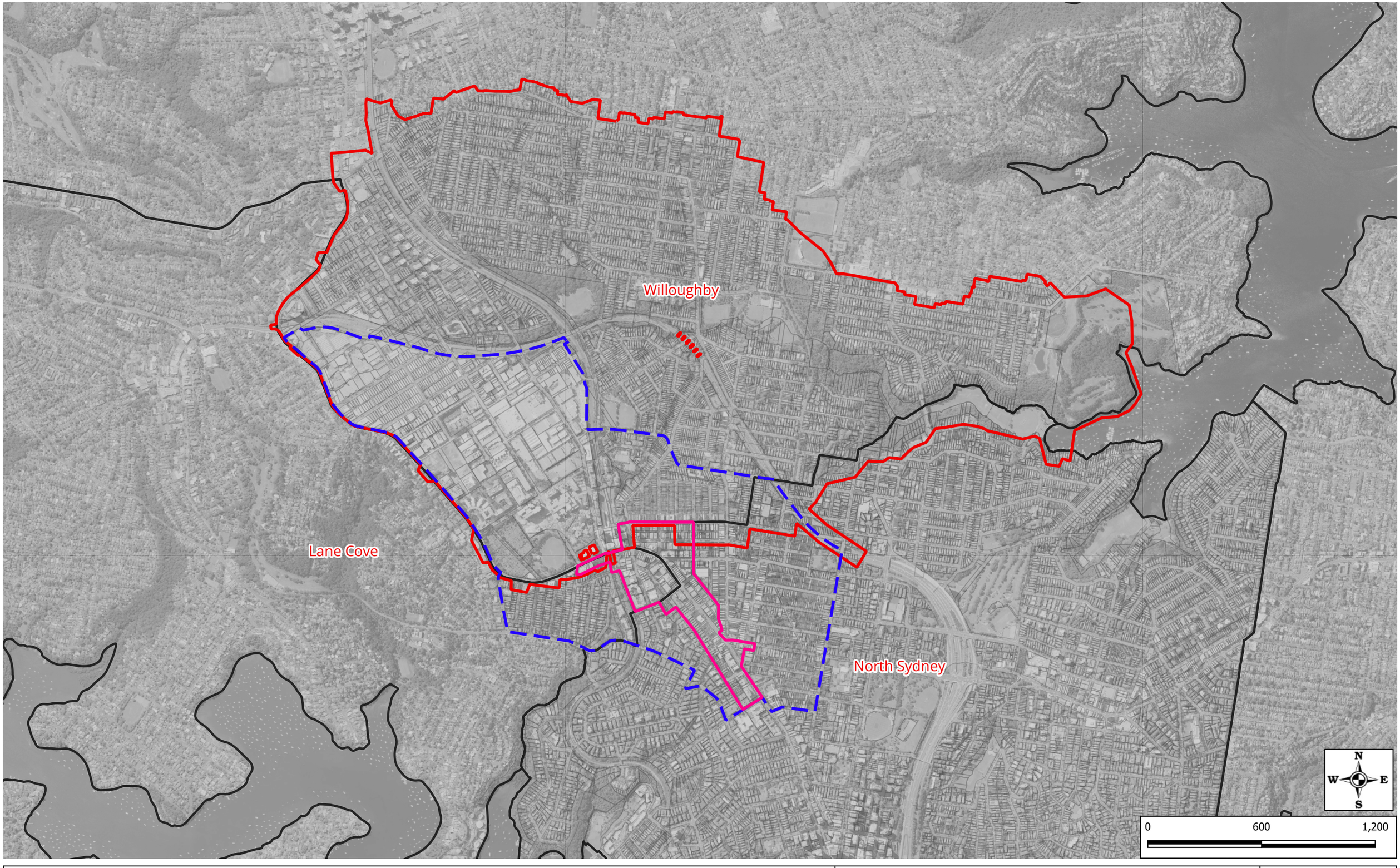

Focus Area
Precinct Boundary
LGA Boundary
LGA Boundary
Hydraulic Model Boundary

TITLE: **Subcatchment Delineation - Flat Rock Creek**		
PROJECT: **State Led Rezoning Crows Nest - Flooding and Stormwater Study**		
PROJECT No. **240008**		
DATE: **06-2024**	SCALE: 1:18,000	FIGURE No. **03A**

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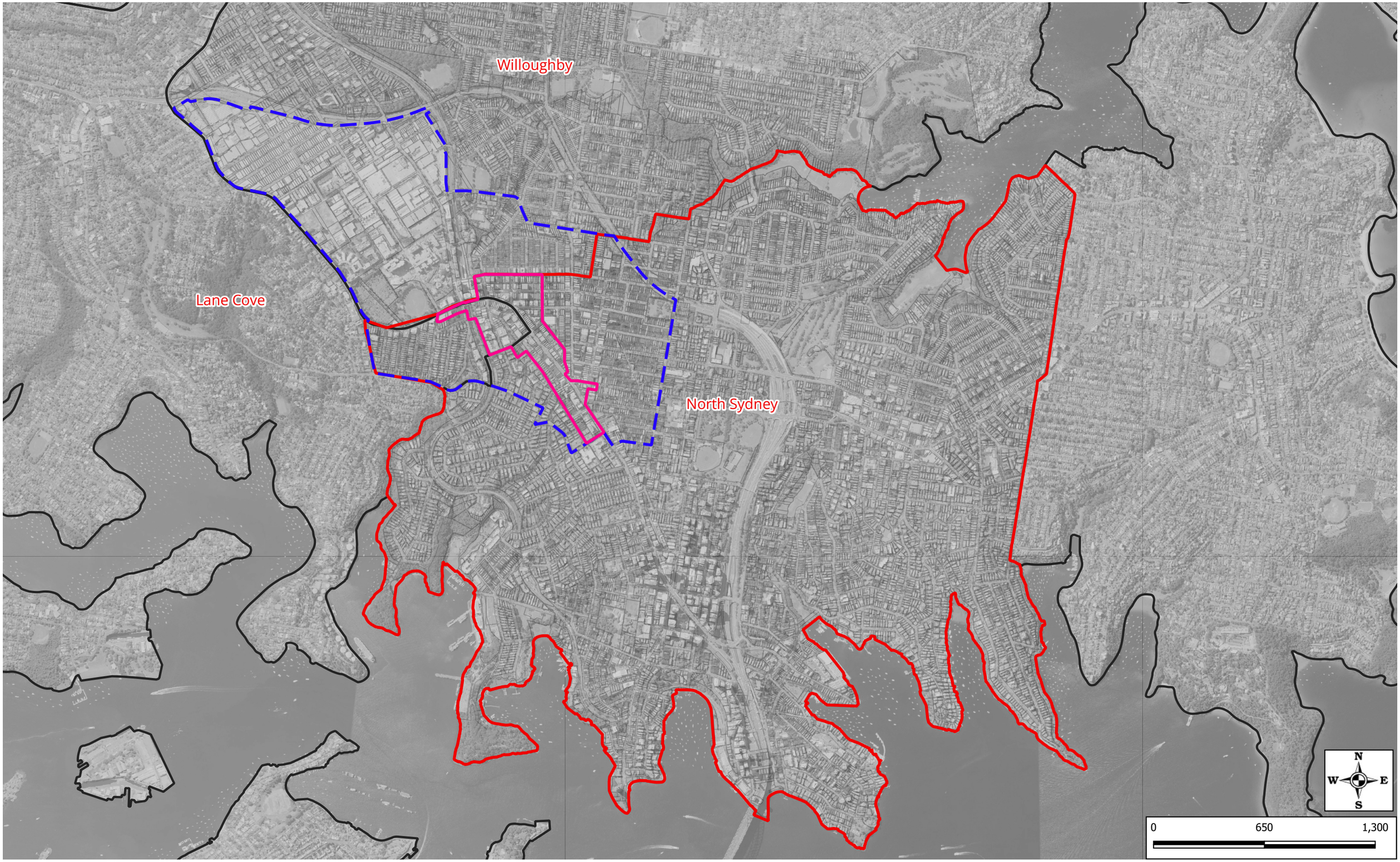

Focus Area
Precinct Boundary
LGA Boundary
LGA Boundary
Hydraulic Model Boundary

TITLE: **Subcatchment Delineation - North Sydney**		
PROJECT: **State Led Rezoning Crows Nest - Flooding and Stormwater Study**		
PROJECT No. **240008**		
DATE: **06-2024**	SCALE: 1:20,000	FIGURE No. **03B**

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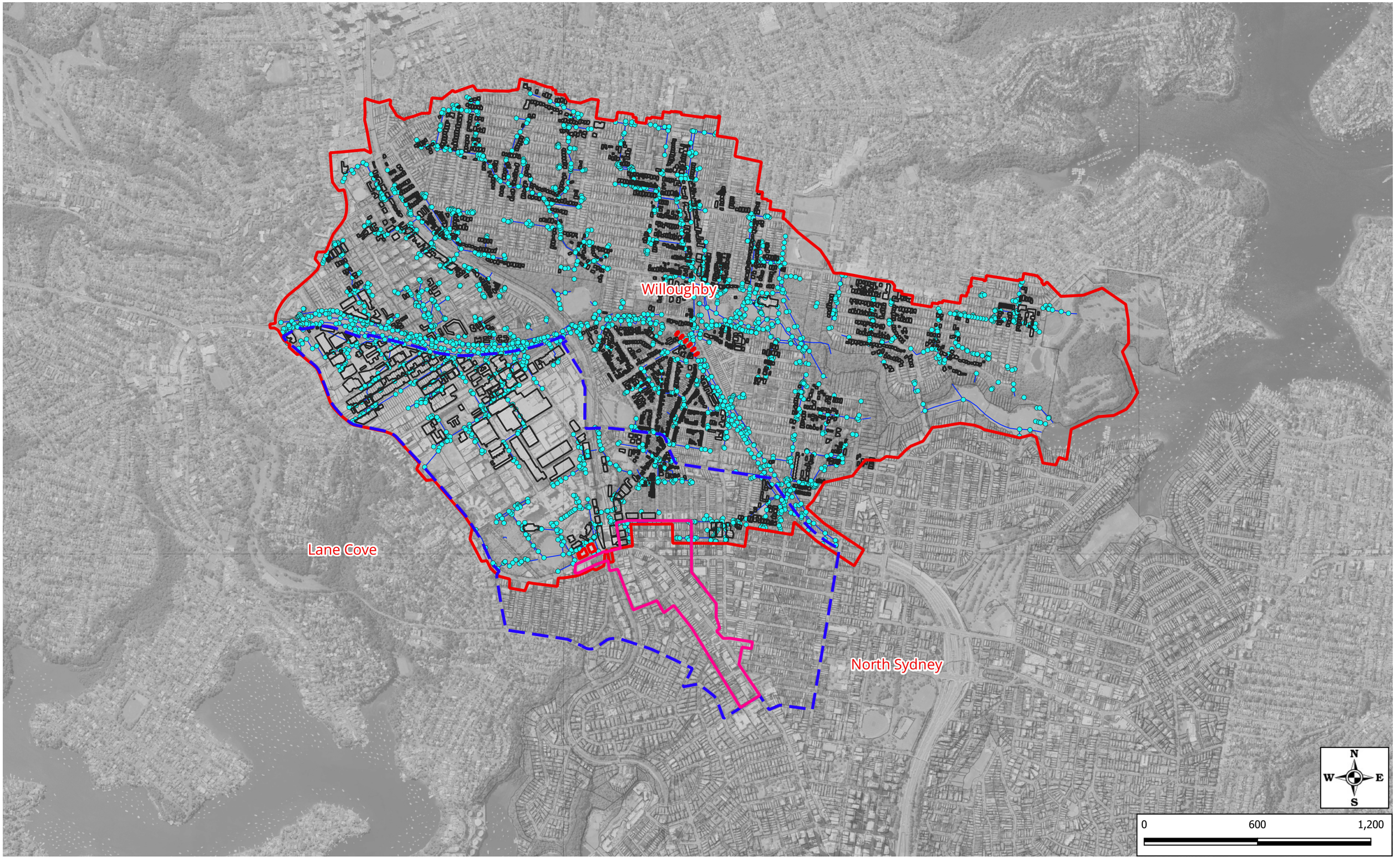

Focus Area
Precinct Boundary
Cadastre
Hydraulic Model Boundary
Buildings
Stormwater Pits
Stormwater Pipes

TITLE: **Hydraulic Model Schematisation - Flat Rock Creek**		
PROJECT: **State Led Rezoning Crows Nest - Flooding and Stormwater Study**		
PROJECT No. **240008**		
DATE: **06-2024**	SCALE: 1:18,000	FIGURE No. **04A**

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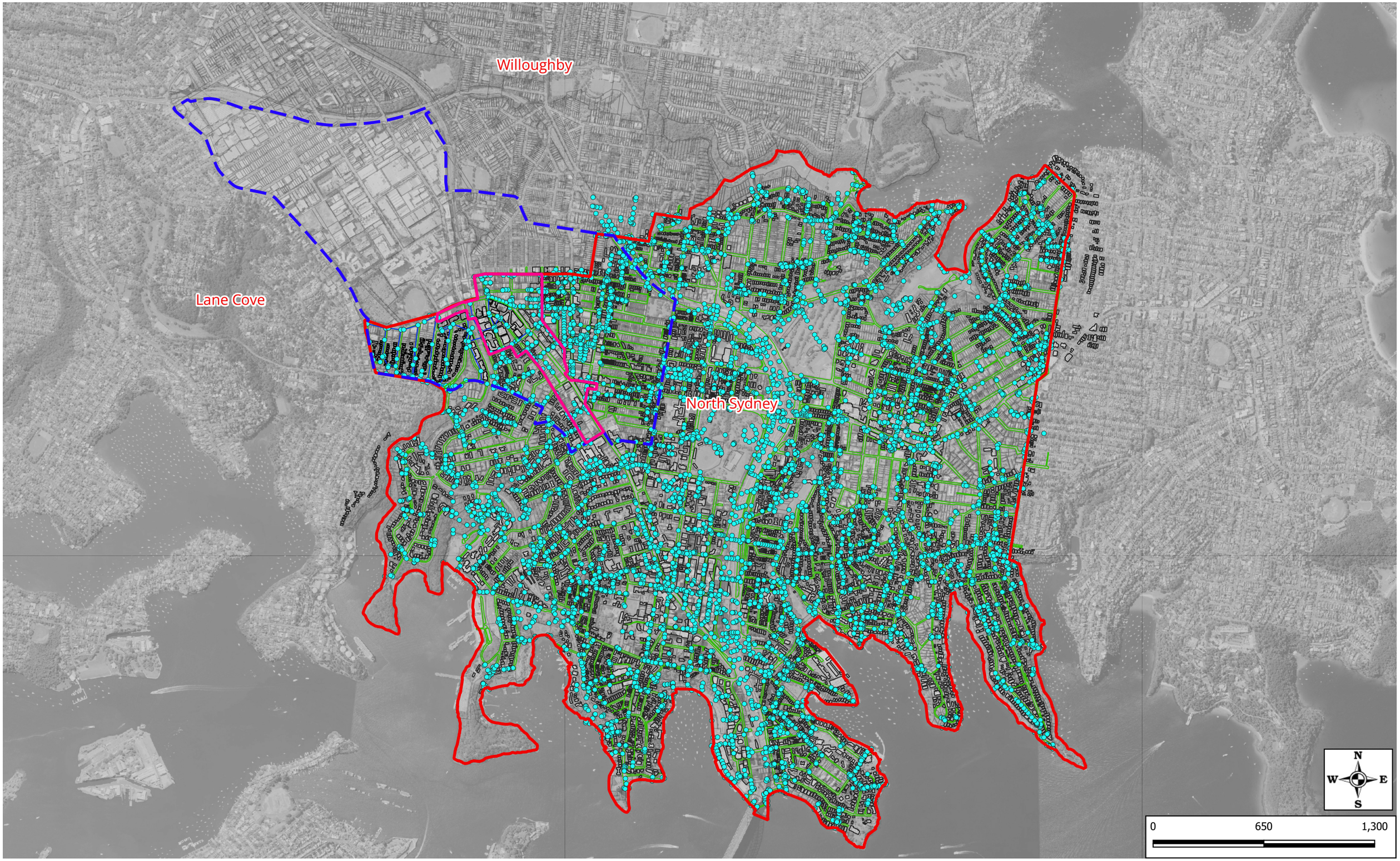
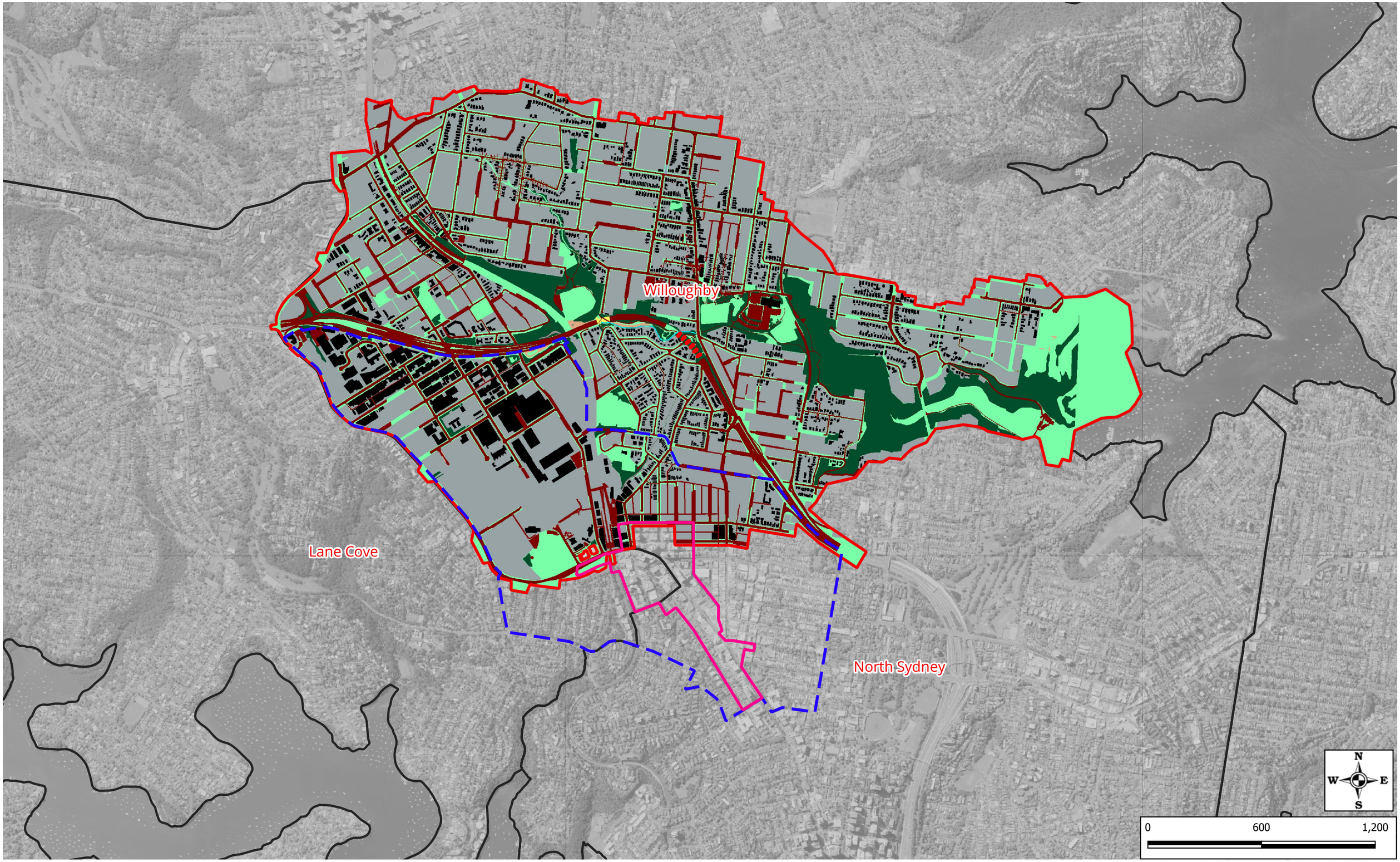


Focus Area
Precinct Boundary
Cadastre

Hydraulic Model Boundary
Buildings
Stormwater Pits
Stormwater Pipes
Kerbs

TITLE: **Hydraulic Model Schematisation - North Sydney**		
PROJECT: **State Led Rezoning Crows Nest - Flooding and Stormwater Study**		
PROJECT No. **240008**		
DATE: **06-2024**	SCALE: 1:20,000	FIGURE No. **04B**

grc HYDRO



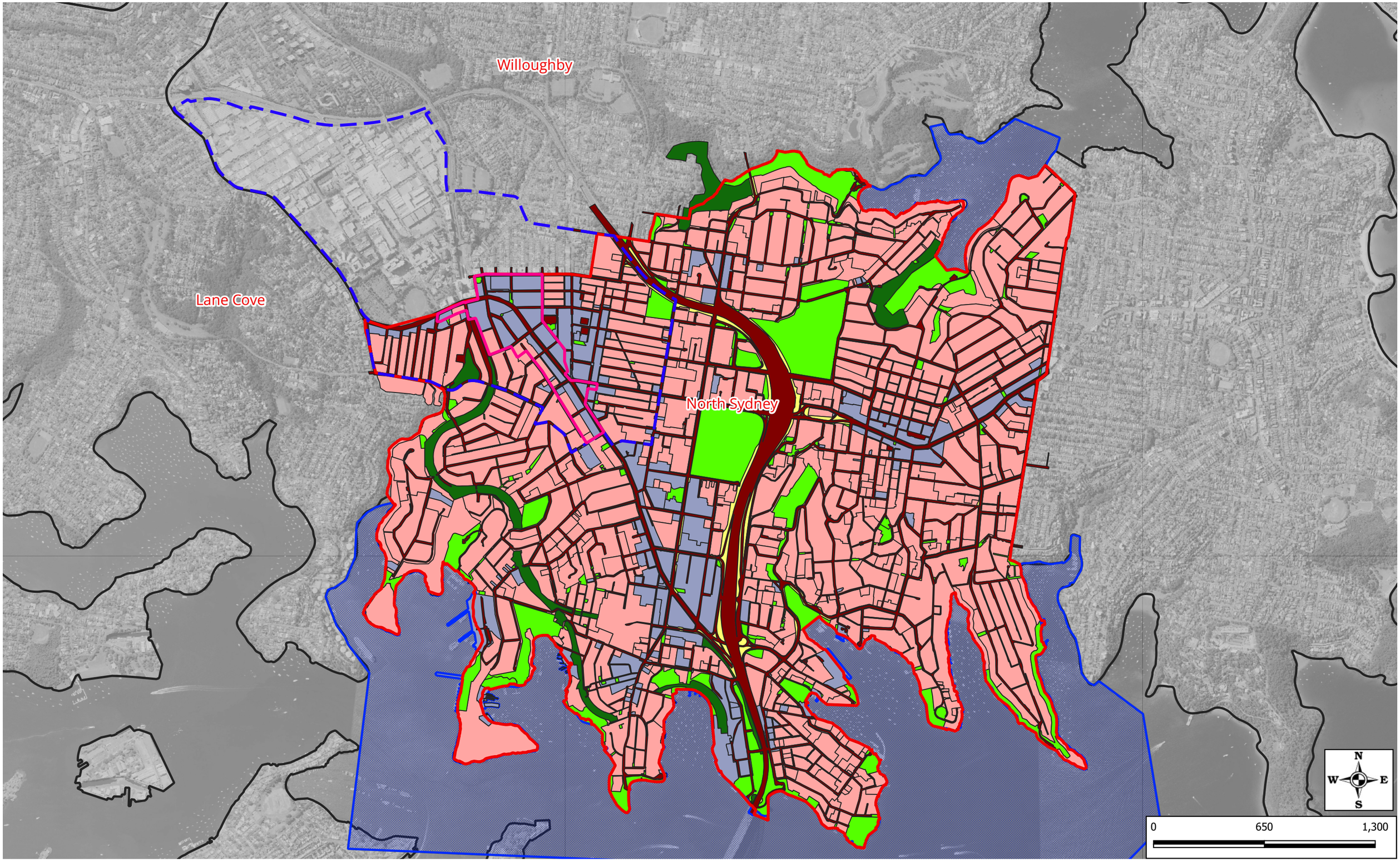
Focus Area
Precinct Boundary
LGA Boundary

Hydraulic Model Boundary
Road and Railway (Manning's Value: 0.02)
Grass/Lawns (Manning's Value: 0.045)
Trees (Manning's Value: 0.08)
Buildings (Manning's Value: 10)

Rough Rock (Manning's Value: 0.05)
Overgrown Shrubs (Manning's Value: 0.06)
Allotments (Manning's Value: 0.1)
Artarmon Reserve Channel (Manning's Value: 0.025)

TITLE: **Hydraulic Model Roughness - Flat Rock Creek**		
PROJECT: **State Led Rezoning Crows Nest - Flooding and Stormwater Study**		
PROJECT No. **240008**		
DATE: **06-2024**	SCALE: 1:18,000	FIGURE No. **05A**

grc HYDRO

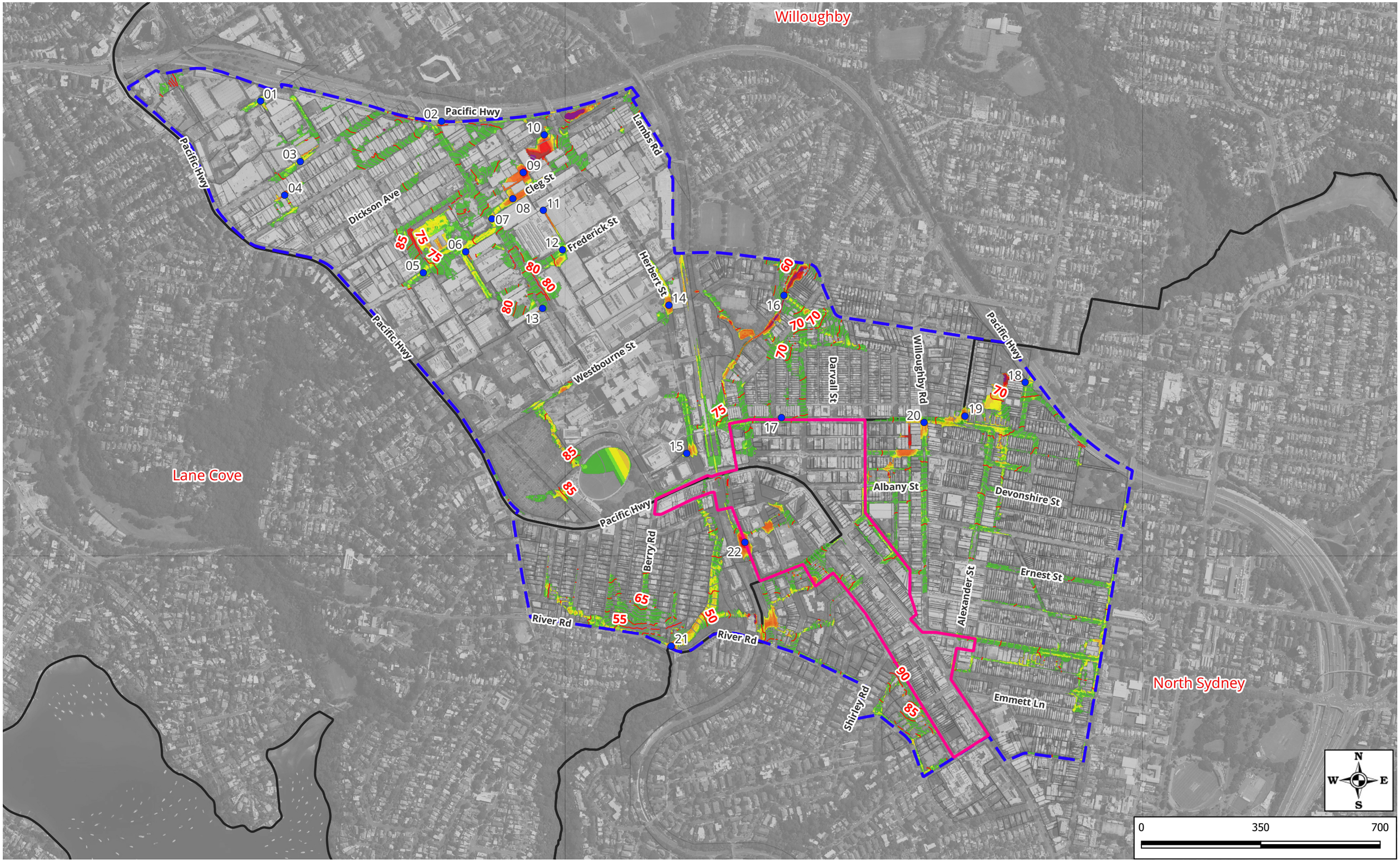


Focus Area
Precinct Boundary
LGA Boundary

Default (Manning's Value: 0.06)
Roads/Pavements (Manning's Value: 0.03)
Light Vegetation/Grass/Field (Manning's Value: 0.048)
Residential Low Density (Manning's Value: 0.06)
Heavy Vegetation/Light Forest (Manning's Value: 0.12)
Industrial/Commercial (Manning's Value: 0.036)
Lake or Estuary/Ocean (Manning's Value: 0.036)

TITLE: **Hydraulic Model Roughness - North Sydney**		
PROJECT: **State Led Rezoning Crows Nest - Flooding and Stormwater Study**		
PROJECT No. **240008**		
DATE: **06-2024**	SCALE: 1:20,000	FIGURE No. **05B**

grc HYDRO



- LGA Boundaries
- Precinct Boundary
- Focus Area
- Cadastre
- Sensitivity Analysis Points

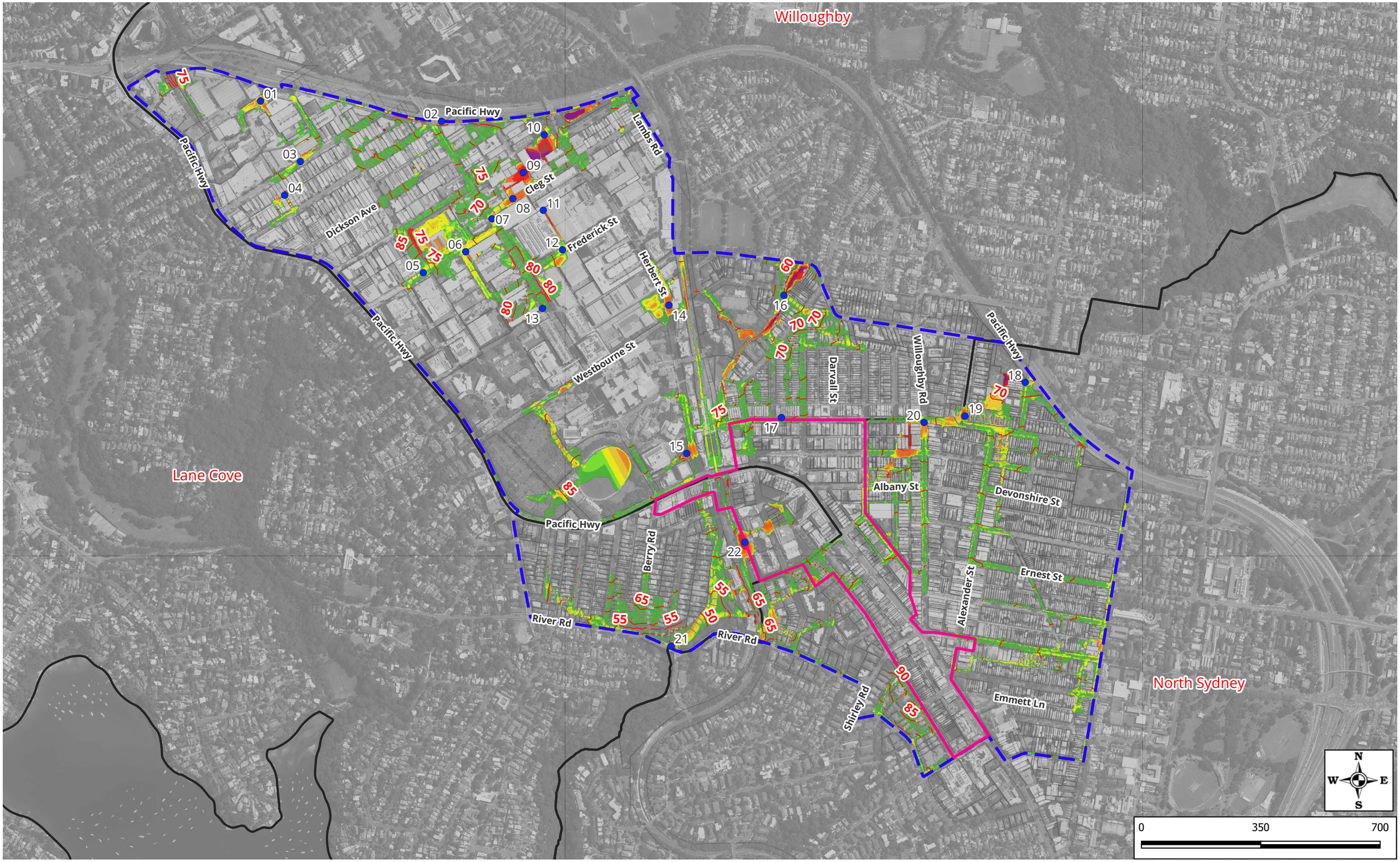
Flood Depth (m)

- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

- Major Flood Level Contours (5m Spacing)
- Minor Flood Level Contours (1m Spacing)

TITLE: **5% AEP Flood Depth and Level**		
PROJECT: **State Led Rezoning Crows Nest - Flooding and Stormwater Study**		
PROJECT No. **240008**		
DATE: **06-2024**	SCALE: 1:10,000	FIGURE No. **06**

grc HYDRO



LGA Boundaries
Precinct Boundary
Focus Area
Cadastre
Sensitivity Analysis Points

Flood Depth (m)
0 - 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
> 2.0

Major Flood Level Contours (5m Spacing)
Minor Flood Level Contours (1m Spacing)

TITLE: **1% AEP Flood Depth and Level**		
PROJECT: **State Led Rezoning Crows Nest - Flooding and Stormwater Study**		
PROJECT No. **240008**		
DATE: **06-2024**	SCALE: 1:10,000	FIGURE No. **07**

grc HYDRO

Willoughby

Lane Cove

North Sydney

0 350 700

N W E S

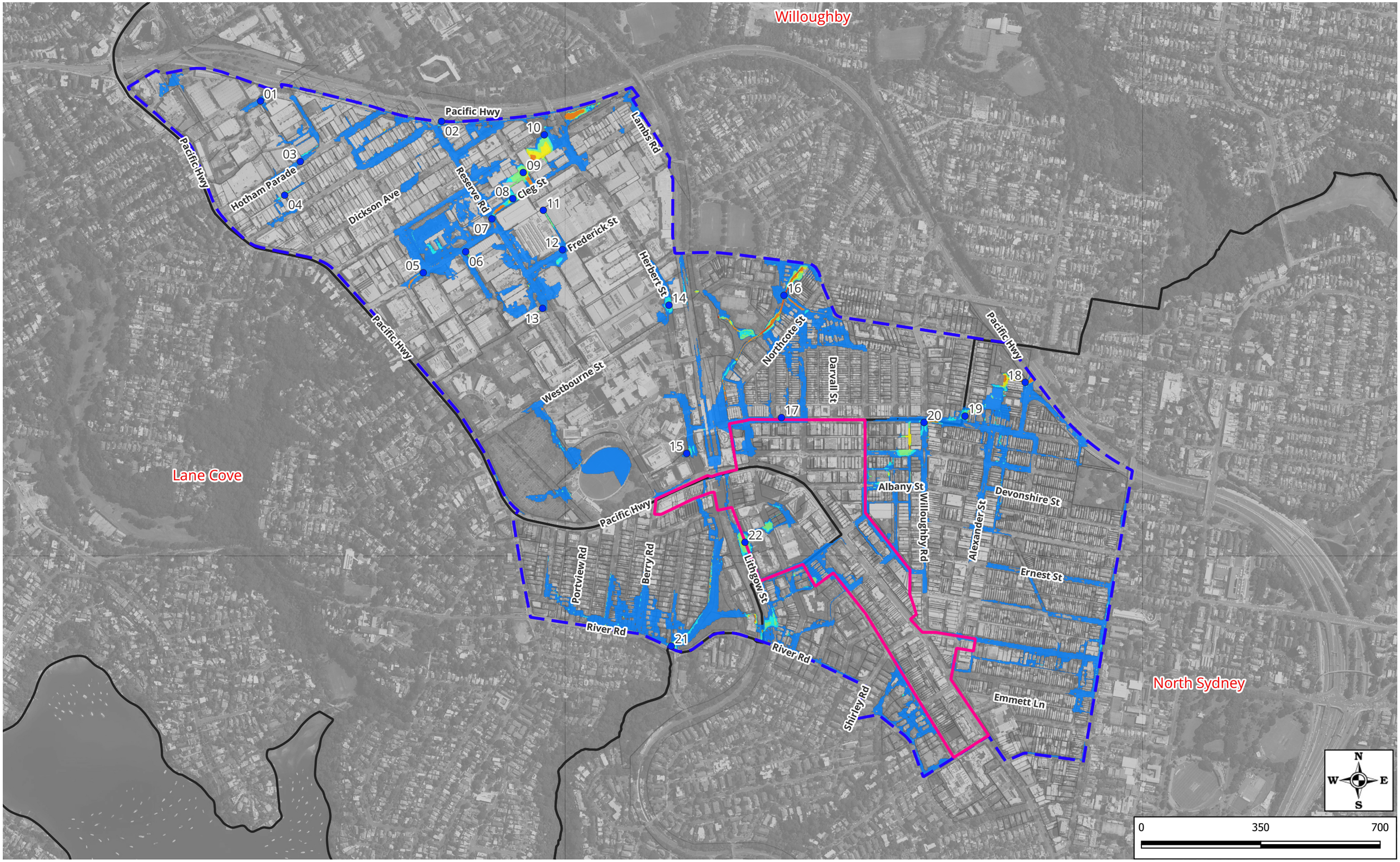
LGA Boundaries
Precinct Boundary
Focus Area
Cadastre
Sensitivity Analysis Points

Flood Depth (m)
0 - 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
> 2.0

Major Flood Level Contours (5m Spacing)
Minor Flood Level Contours (1m Spacing)

TITLE: **PMF Flood Depth and Level**		
PROJECT: **State Led Rezoning Crows Nest - Flooding and Stormwater Study**		
PROJECT No. **240008**		
DATE: **06-2024**	SCALE: 1:10,000	FIGURE No. **08**

grc HYDRO



- LGA Boundaries
- Precinct Boundary
- Focus Area
- Cadastre
- Sensitivity Analysis Points

Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

TITLE: **5% AEP Flood Hazard**		
PROJECT: **State Led Rezoning Crows Nest - Flooding and Stormwater Study**		
PROJECT No. **240008**		
DATE: **06-2024**	SCALE: 1:10,000	FIGURE No. **09**

grc HYDRO

Willoughby

Lane Cove

North Sydney

Pacific Hwy

Lambs Rd

Hotham Parade

Dickson Ave

Reserve Rd

Cleg St

Frederick St

Herbert St

Westbourne St

Northcote St

Darvall St

Albany St

Willoughby Rd

Alexander St

Devonshire St

Ernest St

Emmett Ln

Shirley Rd

Lithgow St

Berry Rd

Portview Rd

River Rd

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22

N W E S

0 350 700

LGA Boundaries
Precinct Boundary
Focus Area
Cadastre
Sensitivity Analysis Points

Flood Hazard
H1
H2
H3
H4
H5
H6

TITLE: **1% AEP FLood Hazard**		
PROJECT: **State Led Rezoning Crows Nest - Flooding and Stormwater Study**		
PROJECT No. **240008**		
DATE: **06-2024**	SCALE: 1:10,000	FIGURE No. **10**

grc HYDRO

Willoughby

Lane Cove

North Sydney

Pacific Hwy

Hotham Parade

Dickson Ave

Reserve Rd

Cleg St

Lambs Rd

Frederick St

Herbert St

Westbourne St

Northcote St

Darvall St

Albany St

Willoughby Rd

Alexander St

Devonshire St

Ernest St

Emmett Ln

Shirley Rd

Lithgow St

Berry Rd

Portview Rd

River Rd

01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22

N W E S

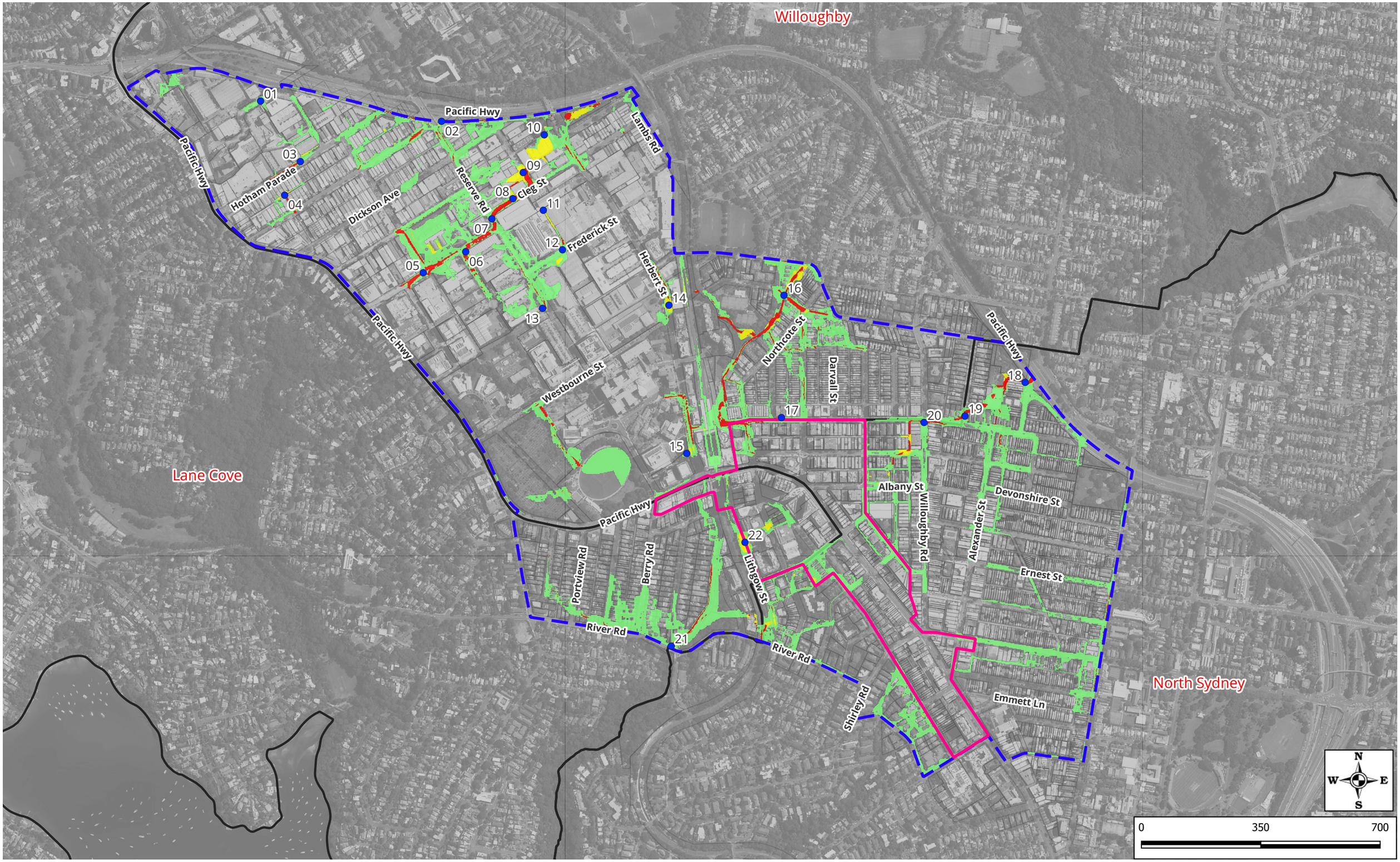
0 350 700

LGA Boundaries
Precinct Boundary
Focus Area
Cadastre
Sensitivity Analysis Points

Flood Hazard
H1
H2
H3
H4
H5
H6

TITLE: **PMF Flood Hazard**		
PROJECT: **State Led Rezoning Crows Nest - Flooding and Stormwater Study**		
PROJECT No. **240008**		
DATE: **06-2024**	SCALE: 1:10,000	FIGURE No. **11**

grc HYDRO



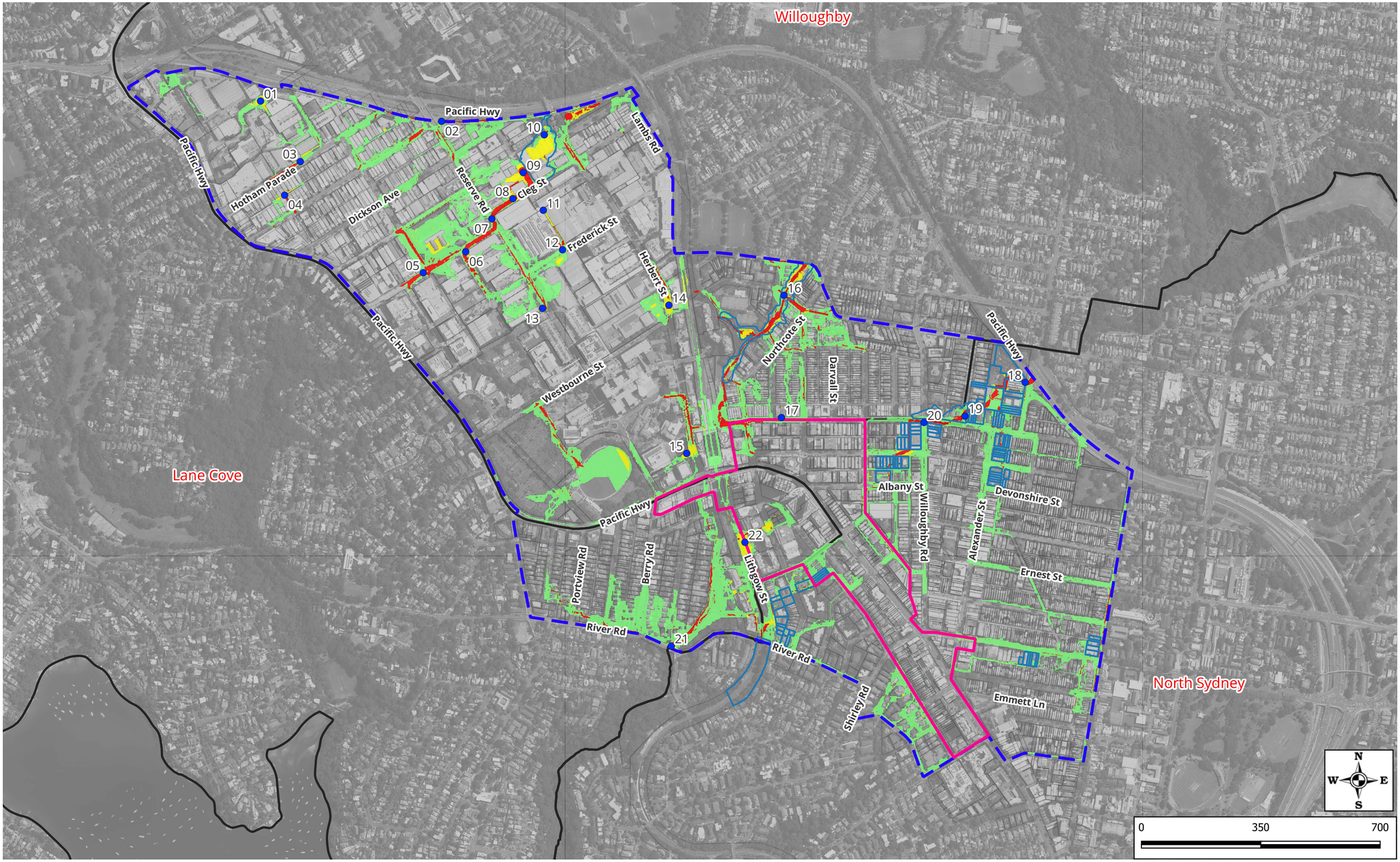
- LGA Boundaries
- Precinct Boundary
- Focus Area
- Cadastre
- Sensitivity Analysis Points

Hydraulic Categorisation

- Flow Conveyance
- Flood Storage
- Flood Fringe

TITLE: **5% AEP Hydraulic Categorisation**		
PROJECT: **State Led Rezoning Crows Nest - Flooding and Stormwater Study**		
PROJECT No. **240008**		
DATE: **06-2024**	SCALE: 1:10,000	FIGURE No. **12**

grc HYDRO



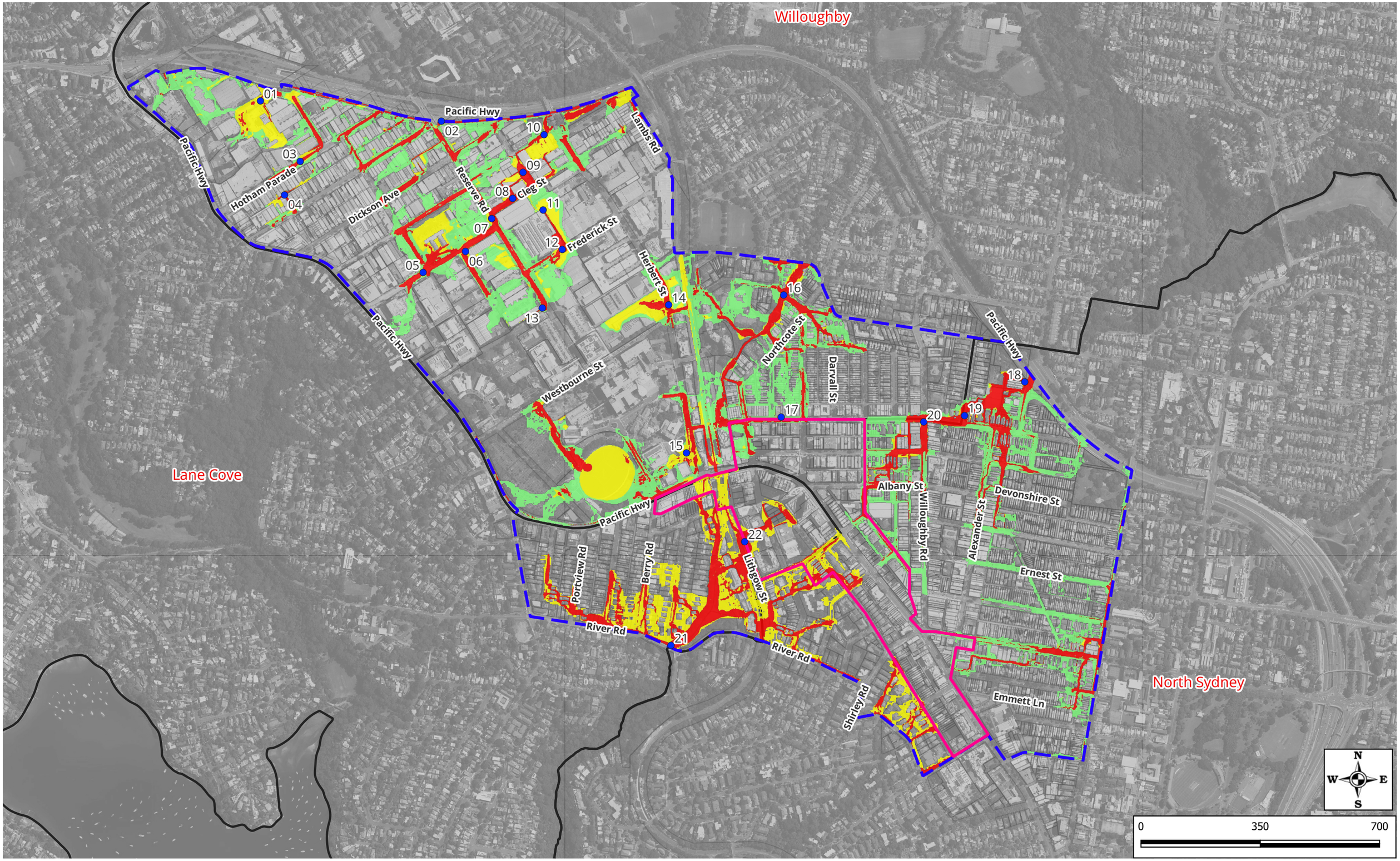
- LGA Boundaries
- Precinct Boundary
- Focus Area
- Cadastre
- Sensitivity Analysis Points

Hydraulic Categorisation
- Flow Conveyance
- Flood Storage
- Flood Fringe

- Flood Planning Area

TITLE: **1% AEP Hydraulic Categorisation and Flood Planning Area**		
PROJECT: **State Led Rezoning Crows Nest - Flooding and Stormwater Study**		
PROJECT No. **240008**		
DATE: **06-2024**	SCALE: 1:10,000	FIGURE No. **13**

grc HYDRO



LGA Boundaries
Precinct Boundary
Focus Area
Cadastre
Sensitivity Analysis Points

Hydraulic Categorisation
Flow Conveyance
Flood Storage
Flood Fringe

TITLE: **PMF Hydraulic Categorisation**		
PROJECT: **State Led Rezoning Crows Nest - Flooding and Stormwater Study**		
PROJECT No. **240008**		
DATE: **06-2024**	SCALE: 1:10,000	FIGURE No. **14**

grc HYDRO