Gwynneville Planning Proposal Flood Impact and Risk Assessment

A flood impact and risk assessment prepared to support the Gwynneville Planning Proposal.

Prepared for:
Homes NSW

24 February 2025

Prepared by:
Jacob Lee

Project/File:
304000956_FIRA_01_00

Stantec Australia Pty Ltd

Revision Schedule

Revision	Description	Author	Date	Reviewer	Date	Approver	Date
1	Draft	GF	24/02/2025	JL	24/02/2025	FG	24/02/2025

Disclaimer

The conclusions in the Report titled Gwynneville Planning Proposal Flood Impact and Risk Assessment are Stantec's professional opinion, as of the time of the Report, and concerning the scope described in the Report. The opinions in the document are based on conditions and information existing at the time the scope of work was conducted and do not take into account any subsequent changes. The Report relates solely to the specific project for which Stantec was retained and the stated purpose for which the Report was prepared. The Report is not to be used or relied on for any variation or extension of the project, or for any other project or purpose, and any unauthorized use or reliance is at the recipient's own risk.

Stantec has assumed all information received from Homes NSW (the "Client") and third parties in the preparation of the Report to be correct. While Stantec has exercised a customary level of judgment or due diligence in the use of such information, Stantec assumes no responsibility for the consequences of any error or omission contained therein.

This Report is intended solely for use by the Client in accordance with Stantec's contract with the Client. While the Report may be provided by the Client to applicable authorities having jurisdiction and to other third parties in connection with the project, Stantec disclaims any legal duty based upon warranty, reliance or any other theory to any third party, and will not be liable to such third party for any damages or losses of any kind that may result.

Prepared by:

Galen Fletcher

Reviewed by:

Jacob Lee

Approved by:

Frank Guo

Table of Contents

List of Tables

List of Figures

List of Appendices

Executive Summary

This report has been prepared by Stantec Australia Pty Ltd (Stantec) as an update to the Gwynneville Estate – Flooding, Water Quality and Stormwater Report (Stantec, 2024) (the FWQSR) prepared by Stantec for Homes NSW (refer Appendix C).

The FWQSR supported a planning proposal to amend the Wollongong Local Environmental Plan 2009 to accommodate urban renewal of land at Gwynneville, NSW.

The planning proposal was submitted to Wollongong City Council (Council) 19 July 2024, and preliminary consultation was undertaken with landowners, community stakeholders and statutory authorities. Regarding flood related matters, Council received preliminary consultation responses from the NSW State Emergency Services (NSW SES) and the Department of Climate Change, Energy and the Environment and Water (DCCEEW) – Biodiversity, Conservation and Science Group (the Department).

Since the preparation of the FWQSR Council have adopted an updated flood risk management study for the site catchment Fairy and Cabbage Tree Creeks Floodplain Risk Management Study & Plan (Wollongong City Council, 2024) (the new Council FRMS). A revised concept masterplan has also been prepared for the planning proposal.

This FIRA is prepared to address flood related comments and requirements from the planning proposal submission, with consideration to the updated Council FRMS and revised concept masterplan.

It is found that the proposal generally lowers flood levels across the site by rezoning existing residential land use in the FPA to open space uses. There is a minor increase to flood levels at the intersection of Irvine Street and Madoline Street. Future development at this location would be designed to mitigate these impacts.

The site is classified as a high flood island located entirely above the PMF, with road access cut off in the 20% AEP. A shelter in place strategy is proposed for the site, and further consideration of refuge requirements / facilities are to be identified during the design of future development.

In general, it is found that the planning proposal reduces flood risk to existing residents, and future development will not result in significant flood impacts to neighbouring properties or significant risk to future residents.

Acronyms / Abbreviations

Acronym / Abbreviation	Full Name
AEP	Annual exceedance probability
AHD	Australian height datum
DCP	Development control plan
IFD	Intensity frequency duration
FPA	Flood planning area
FPL	Flood planning level
FRMS	Flood risk management study
FRP	Flood risk precinct
FS	Flood study
LEP	Local environmental plan
PMF	Probable maximum flood

Glossary

Term	Definition
Floodway	Areas which convey a significant portion of water during floods and are particularly sensitive to changes that impact flow conveyance. They often align with naturally defined channels.
Flood storage	Areas outside of floodways that store a significant proportion of the volume of water and where flood behaviour is sensitive to changes that impact on the storage of water during a flood.
Flood fringe	Areas within the extent of flooding for the event but which are outside floodways and flood storage areas. Flood fringe areas are not sensitive to changes in either flow conveyance or storage.
High flood island	A flood island is an area isolated by floodwaters during a probable maximum flood event. A high flood island includes enough land above the probable maximum flood level for people in the area to retreat to safely.

1 Introduction

1.1 Background

This report has been prepared by Stantec Australia Pty Ltd (Stantec) as an addendum to the *Gwynneville Estate – Flooding, Water Quality and Stormwater Report* (Stantec, 2024) (the FWQSR) prepared by Stantec for Homes NSW (refer Appendix C).

The FWQSR supported a planning proposal to amend the *Wollongong Local Environmental Plan 2009* to accommodate urban renewal of land at Gwynneville, NSW.

The planning proposal was submitted to Wollongong City Council on 19 July 2024, which was then placed on preliminary notification for public and agency comment. Following this notification period, Council and Homes NSW worked together to establish key amendments to the proposal and master plan that formed the basis of the reporting to Council in November 2024. The planning proposal was unanimously approved by Council on 25 November 2024 to proceed to the next step in the approval process, i.e. Gateway Determination. The revised proposal and masterplan included revisions which relate to key sites and implementation, built form outcomes, and public open space delivery. This report has been updated to reflect the outcomes of the amended planning proposal and master plan, current as at February 2025.

Generally, the planning proposal was found to be consistent with local planning directions issued by the Minister for Planning under section 9.1(2) of the *Environmental Planning and Assessment Act 1979* (the Ministerial Direction). The rezoning of land at the intersection of Irvine Street and Madoline Street from R2 Low Density Residential to R4 High Density Residential was considered contrary to Ministerial Direction however it was noted by Council that future development can be designed to mitigate the risk and impact. Further consideration of evacuation risk and a specific flood impact and risk assessment (FIRA) was requested by NSW SES and the Department.

Since the preparation of the FWQSR Council have adopted an updated flood risk management study for the site catchment *Fairy and Cabbage Tree Creeks Floodplain Risk Management Study & Plan* (Wollongong City Council, 2024) (the new Council FRMS). Furthermore, the concept masterplan for the planning proposal has undergone various revisions since the FWQSR – this report represents the most up-to-date masterplan as of February 2025.

1.2 Purpose of the report

This FIRA is prepared to address flood related comments and requirements from the planning proposal submission, with consideration to the updated Council FRMS and revised concept masterplan.

2 Available information

2.1 Gwynneville estate masterplan updates

The concept masterplan for the site was updated following Council feedback. Council noted potential risks associated with creating large key sites and requested that focus should be directed towards existing consolidated areas in the site to fast track the delivery of the project and its objectives.

The key changes in the updated masterplan relevant to flood behaviour are the reconfiguration and resizing of some of the lots within the development area, and the removal of lots on the southeastern boundary of the development area which was completed in accordance with the proposed change of zoning in this area from residential to public recreation. This change reduces flood risk by changing the land use from residential to open space in flood prone lane. Generally open space is considered a more compatible land use for these areas of the site in terms of flood risk.

The original and updated masterplans are provided in **Figure 2-1** and Figure 2-2.

Figure 2-1 Original Masterplan submitted July 2024

Figure 2-2 Updated masterplan (February, 2025)

2.2 Fairy and Cabbage Tree Creeks Floodplain Risk Management Study & Plan (Advisan, August 2024)

The new Council FRMS is adopted for this report, since it supersedes the *Fairy and Cabbage Tree Creeks Flood Study* (Wollongong City Council, 2020) (2020 Council FS), which was previously adopted and was used to inform the FWQSR.

The new Council FRMS adopts the updated 2019 version of *Australian Rainfall and Runoff* (ARR19) (Ball, et al., 2019) guidelines, represents changes in catchment characteristics due to recent development projects, and considered updates to the *Revised Conduit Blockage Policy* (Wollongong City Council, 2016) and the need to evaluate the impacts climate change has on flood behaviour.

Like the 2020 Council FS, Watershed Bounded Network Model (WBNM) was utilised for the hydrologic modelling for the new Council FRMS. Hydraulic modelling was undertaken using an updated version of the TUFLOW model used previously in the 2020 Council FS. The model features the same 3m grid resolution used in the 2020 Council FS.

The hydrology model used in the 2020 Council FS estimated flowrates based on 1987 version of *Australian Rainfall and Runoff* (ARR87) guidelines (Instituition of Engineers, Australia, 1987). The new Council FRMS WBNM was updated to simplify the model's sub-catchment delineation and incorporate revised design flowrates based on ARR19 flood estimation procedures.

The TUFLOW hydraulic model was revised to incorporate design flowrates associated identified in accordance with ARR19 approaches. A Defined Flood Event (DFE) input was identified and adopted to manage flood risk effects of climate change and sea level rise. The updated hydraulic model also incorporates a revised inflow boundary conditions to ensure flooding in upper catchment areas is modelled accurately and contains minor changes to the 1D culvert/stormwater network to enhance model stability.

Furthermore, catchment information was updated in the hydrologic and hydraulic models following the addition of new developments in the catchment area since the release of the 2020 Council FS. The key hydraulic and hydrology parameters adopted in the new Council FRMS are summarised in section 3 of this report.

3 Flood assessment methodology

3.1 Hydrology model

The hydrology model associated with the new FRMS was adopted with no changes.

3.1.1 Hydrology model parameters

The hydrological parameters adopted for the pre-developed assessment are restated in this section of the report. The adopted WBNM runoff lag and stream routing parameters are summarised in **Table 3-1** the effective percentage impervious adopted for each land surface is summarised in

Table *3-2* and the adopted rainfall parameters are summarised in **Table *3-3***

Table 3-1 Adopted WBNM runoff lag and stream routing parameters

WBNM Model Parameter	Parameter value
Runoff lag factor ‘C’	1.4
Impervious runoff lag factor ‘C’	0.1
Stream routing factor ‘F’	1.0

Table 3-2 Effective percentage impervious by land surface type

Surface Type	Effective Percentage Impervious
Watercourses and concrete open channels	100%
Buildings	100%
Residential	40%
Commercial / Industrial	80%
Vegetation	2%
Road Corridor	70%
Rail Corridor	50%

Table 3-3 Adopted rainfall parameters

<table>
<tr><th rowspan="2">Design Flood event</th><th rowspan="2">Storm Duration (minutes)</th><th colspan="2">Pervious Surfaces</th><th colspan="2">Impervious Surfaces</th></tr>
<tr><th>Initial loss (mm)</th><th>Continuing loss (mm)</th><th>Initial Loss (mm)</th><th>Continuing Loss (mm)</th></tr>
<tr><td rowspan="2">20% AEP</td><td>90</td><td>19.7</td><td rowspan="5">1.6</td><td rowspan="7">1.0</td><td rowspan="7">0.0</td></tr>
<tr><td>270</td><td>26.8</td></tr>
<tr><td rowspan="3">1% AEP</td><td>90</td><td>23.5</td></tr>
<tr><td>120</td><td>19.6</td></tr>
<tr><td>120</td><td>19.6</td></tr>
<tr><td rowspan="2">PMF</td><td>60</td><td rowspan="2">10</td><td rowspan="2">2.5</td></tr>
<tr><td>120</td></tr>
</table>

3.1.2 Critical duration

The critical storm durations modelled for the pre-developed case are summarised in **Table 3-4**.

Table 3-4 Critical durations for each storm event

<table>
<tr><th>Design Flood Event</th><th>Critical Storm Duration (minutes)</th></tr>
<tr><td rowspan="2">20% AEP</td><td>90</td></tr>
<tr><td>270</td></tr>
<tr><td rowspan="2">1% AEP</td><td>90</td></tr>
<tr><td>120</td></tr>
<tr><td rowspan="2">PMF</td><td>60</td></tr>
<tr><td>120</td></tr>
</table>

Generally, it was found that there were two critical durations across the catchment for each storm event, with the upper catchment experiencing higher flood levels during the shorter duration (60-90 minute) events. The upper catchment is generally identified as everything upstream of the Princes Highway for the Fairy Creek catchment, which includes the catchment site. Therefore the 60 and 90 minute duration are adopted as the site specific design storm duration for the 1% AEP and PMF respectively.

3.2 Hydraulic model

3.2.1 Pre-development

The TUFLOW model files of the Council adopted *Fairy and Cabbage Tree Creeks Floodplain Risk Management Study & Plan* were adopted to represent the pre-development site conditions.

3.2.1.1 Grid resolution

A 3m resolution grid is adopted, consistent with the new FRMS.

3.2.1.2 Roughness

The Mannings 'n', or roughness coefficients for each land use were adopted in accordance with the new FRMS. The values are adopted for varying depths as summarised in **Table 3-5**.

Table 3-5 Roughness values adopted

Material	ID	Depth 1 (m)	Manning's 'n' for Depth 1	Depth 2 (m)	Manning's 'n' for Depth 2
Watercourses	101	0.3	0.1	1.5	0.04
Residential	201	0.3	0.2	1.5	0.1
Commercial	202	0.1	0.1	0.3	0.06
Buildings	203	0.02	0.03	0.03	3
Open space	301	0.1	0.06	0.3	0.04
Medium vegetation	302	0.15	0.16	0.5	0.08
Road	401	0.05	0.06	0.15	0.03

The materials adopted across the site for the pre-development scenario are shown as **Figure 3-1.**

Figure 3-1 Pre-development roughness materials

3.2.1.3 Digital elevation model

The two dimensional (2D) TUFLOW domain was created using a range of survey and Light Detection and Ranging (LiDAR) data. The following digital elevation models (DEM's) were incorporated into the TUFLOW model to provide a continuous terrain profile for the catchment:

- Updated Airborne Light Detection and Ranging (LiDAR) captured in 2013
- 2005-2007 AAM Hatch Wollongong LiDAR
- Creek survey for a small region of Fairy Creek

The elevation for the site area was obtained from 2013 LiDAR imagining only as stated in the 2020 Council FS. The DEM for the pre-development scenario is shown as **Figure 3-2.**

Figure 3-2 Pre-development DEM

3.2.1.4 One-dimensional model

The one dimensional (1D) network for the new FRMS remains unchanged from the 1D network used in the 2020 Council FS.

3.2.2 Post-development

The TUFLOW model was updated to represent the revised concept masterplan in the post-development scenario. Generally, this includes updating the Mannings 'n', or roughness coefficient based on proposed land uses and updated the digital elevation model (DEM) to represent proposed building footprints as obstructions in the hydraulic model.

3.2.2.1 Roughness

Roughness coefficients were updated to reflect land use in the post developed site. Land use changed from residential to public open space in the sites northwest corner and to the north of the Spearing Reserve watercourse. In these areas, surfaces materials were updated from 'residential' and 'buildings' to 'open space' to reflect the changes in surface roughness of these areas in the post-developed model. The materials adopted across the site for the post-development scenario are shown as **Figure 3-3**.

Figure 3-3 Post-development roughness materials

3.2.2.2 Digital elevation model

The elevations of the buildings in the study area were raised within the model to allow the assessment of the impacts they may cause on flooding in the region. The buildings were modelled using a glass wall approach to identify and assess the potential impacts they may have on flood behaviour.

The post-developed assessment only considers potential impact associated with the proposed built form of the concept plan buildings. Future modelling of proposed design surface may be required to assess the potential impact of associated earthworks. The digital elevation model adopted for the post-developed assessment is shown on **Figure 3-4**.

Figure 3-4 Post-development DEM

3.3 Evacuation

The pre-developed development case was assessed in accordance with the *Support for emergency management planning: Flood risk management guideline EM01* (NSW Government, 2023) (EM01 guideline), with consideration to the current Illawarra Local Flood Plan (SES, 2022) (the LFP).

3.4 Flood results

3.4.1 Defined flood event

The DFE incorporates social, economic, environmental and cultural factors into the determination of the level of exposure to flooding and the associated risks that may be imposed on life and property. The DFE came into effect with the NSW Governments *Revised Flood Prone Land Package* (July 2021), where it was declared that councils have the authority to choose the DFE for floodplain risk management purposes (Department of Planning, Industry and Environment, 2021).

Council has recommended that the DFE be calculated as follows for relevant hydraulic assessments within the catchment:

DFE = 1% AEP + CC rainfall increase + SLR + blockage envelope

Where:

- CC rainfall increase = 16.3% increase in rainfall
- SLR = sea level rise of 0.9m
- Blockage envelope = maximum envelope of blocked and unblocked structures scenarios

Council included the DFE in the updated TUFLOW hydraulic model. The DFE has been adopted in this FIRA for the pre-developed and post-developed hydraulic assessments. The flood planning level (FPL) is adopted as the DFE with an additional 500mm considered.

3.4.2 Flood hazard

Flood hazard curves from ARR19 guidelines (Ball, et al., 2019) were adopted in the new Council FS. The ARR19 hazard curves were adopted to classify the hazard ratings for areas within the scope of the site for the pre and post-development assessment in this report. See **Figure 3-5** for the hazard curves.

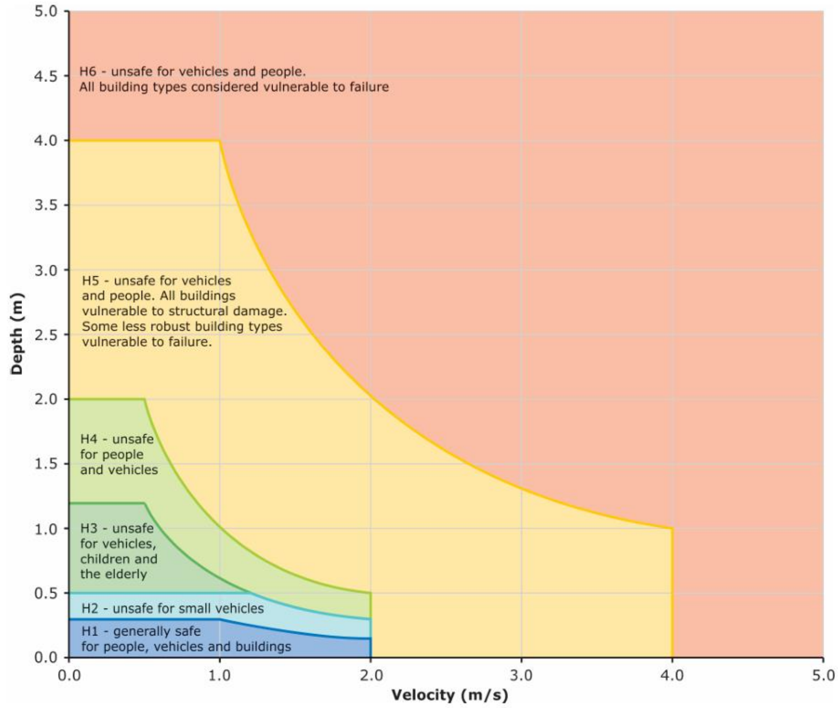


Figure 3-5 Combined hazard curves from ARR19 *(Ball, et al., 2019)*

3.4.3 Flood function

Flood functions represent areas of a floodplain which have been delineated into separate entities to help inform the impacts that may arise due to development within the floodplain. The new Council FS adopted the *NSW Floodplain Development Manual* (NSW Government, 2005) which defined the following flood function categories based on the hydraulic properties of key regions on a floodplain - see **Table 3-6** below.

Table 3-6 Flood function categories from the new Council FS *(Wollongong City Council, 2024)*

Flood Function Category	Definition
Floodways	Areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels, and even their partial blockage would cause a significant redistribution of flood flow or a significant increase in flood level.
Flood storage	Parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. Loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation.
Flood fringe areas	The remaining area of the floodplain after floodway and flood storage areas have been defined. Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

The new Council FS adopts Flood Planning Constraint Category 1 (FPCC1) to identify floodways and flood storage areas associated with the DFE.

4 Flood assessment

4.1 Pre-development scenario results

The existing flood extent is generally concentrated in the southern region of the site, primarily in the Spearing Reserve watercourse which flows through the site from west to east on the northern side of Murphys Avenue.

4.1.1.1 DFE

The proposed buildings associated with the concept masterplan are located outside of FPCC1 and mostly located outside of the flood planning area (FPA) (land below the FPL). A portion of a building proposed at the intersection of Irvine Street and Madoline Street is located within the FPA. As discussed in section 1.1 this has been identified as a minor inconsistency with the Ministerial Direction. The extent of the FPA and the FPCC1 is shown as **Figure 2-1**.

Figure 4-1 FPA and FPCC1 extent

During the DFE the maximum depth and velocity of water within the site is in the Spearing Reserve watercourse at a maximum depth of 2.65m and a velocity of 3.23m/s. In the south western corner of the site depths reach 1.04m in the Spearing Reserve watercourse, and a maximum velocity of 2.62m/s occurs at the intersection of Murphys Avenue and Paulsgrove Street. In the north eastern corner of the site, depths reach a maximum of 0.64m at the intersection of Irvine Street and Northfields Avenue, and a maximum velocity of 0.83 m/s is recorded on Northfields Avenue.

4.1.1.2 PMF

During the PMF the maximum depth and velocity is still in the Spearing Reserve watercourse, which reaches depths of up to 3.26m and a velocity of 4.86m/s. In the south western corner of the site, depths reach a lower (compared to the 1DFE) maximum of 0.56m but a higher (compared to the DFE) velocity of 3.33m/s. In the north eastern corner of the site, depths reach a maximum of 0.54m and a velocity of 1.76m/s.

4.2 Post-development scenario results

The post-development flood extent is very similar to the pre-developed flood extent, except for in the north eastern corner where a building has been represented in the model as per the development masterplan. In this area, the building is raised conservatively above the DFE level using a glasswall approach.

4.2.1.1 DFE

During the DFE, the maximum depth and velocity of water still occurs in the Spearing Reserve watercourse with the same depth of 2.64m and velocity of 3.23m/s as recorded for the pre-development conditions. In the south western corner of the site, the maximum depth has increased slightly to 1.07m the velocity has reduced to 2.61m/s. In the north eastern corner of the site, depths are still 0.64m and the velocity has reduced slightly to 0.82m/s.

4.2.1.2 PMF

During the PMF, the maximum depth and velocity is still within the Spearing Reserve watercourse, which reaches depths of up to 3.25m and a velocity of 4.83m/s. In the south western corner of the site, depths reach a lower (compared to the DFE) maximum of 0.56m and a higher (compared to the DFE) velocity of 3.26m/s. In the north eastern corner of the site, depths reach a maximum of 0.90m and a velocity of 1.85m/s.

4.3 Flood impacts

4.3.1 DFE

Overall, changes in flood levels are mostly contained within the site and flood levels are reduced throughout the site during the DFE. In the post-development case flood levels are lower by up to 158mm in the Spearing Reserve watercourse and by up to 497mm in the south western corner of the site. This is caused by the removal of buildings in these locations which restrict the overland flow path in the pre-development case.

Minor increases to flood levels of between 30 and 50mm are observed at the intersection of Paulsgrove Street and Murphys Avenue. These impacts are considered minor since they are contained within the road reserve, do not increase the hazard classification of either road, or could be mitigated during the detailed design of the adjacent south west open space area.

4.3.2 PMF

Flood level changes associated with the PMF for the post-developed case are generally consistent with flood level changes observed for the DFE post development case. Flood levels within the Spearing Reserve watercourse are reduced by up to 156mm from the pre-development case, and levels in the southern western corner are reduced by up to 529mm.

Localise flood level increases of up to 100mm are observed at the intersection of Madoline Street and Irvine Street. The impact of this increase is considered to be minor given that they are localised to the road reserve of Madoline Street and do not increase the hazard classification of the road.

4.4 Evacuation considerations

4.4.1 Classification

The site is identified as a high flood island in events up to the PMF as per the LFP. The concept of a high flood island is shown as **Figure 4-2.** Access to the area is cut off following inundation by flood water and the flood island will become isolated from other areas of the community, however the site is still located above the PMF.

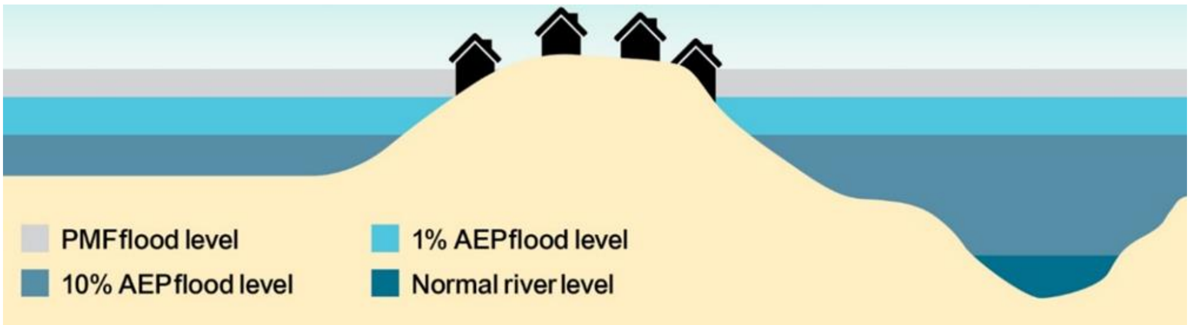


Figure 4-2 High flood island concept *(NSW Government, 2023)*

4.4.2 Road inundation

Access roads become impacted at the 20% AEP event, and the site becomes isolated during the 2% AEP event. See **Table 4-1** for impacted access routes. Access from the south and north of the site are cut off in events up to the 20% AEP, access to University Avenue through Spearing Parade is maintained in events up to and including the 2% AEP. However it is noted that the Princes Highway in both directions is cut off in the 20% AEP, and Foley Street is cut off in the 20% AEP event also which restricts potential evacuation to Wollongong Hospital.

Table 4-1 Flood affected roads within and around the site

Road	Inundated during events up to and including (AEP)
Spearing Parade	PMF
University Avenue	2%
Murphys Avenue	20%
Madoline Street	20%
Irvine Street	20%
Princes Highway	20%

4.4.3 Flood warning times

BoM provides severe thunderstorm warnings for the area. There are no flood level gauges located upstream of the site, and currently there are no flood level gauges in the catchment monitored and used for warnings by NSW SES.

4.4.4 Rate of rise

The watercourse through Spearing Reserve and its crossing at Irvine Street is used as a reference point to inform the rate of rise. The water level in the watercourse peaks at 13.363 mAHD within 50 minutes of the 60 minute duration PMF commencing, which is a rate of rise of approximately 3.5m per hour. During the 120 minute duration PMF the water level still peaks relatively soon within 72 minutes of the storm commencing with a rate of rise of 2.4m per hour.

Irvine Street is inundated very quickly by the PMF, within 15 minutes of the rain event commencing.

4.4.5 Time of isolation

Irvine street remains inundated by the PMF for 2.5 and 3.5 hours during the 60 minute and 120 minute duration event respectively. The duration is found to be less than 6 hours for the critical durations identified in the FRMS.

4.4.6 Flood emergency response strategy

Considering the existing evacuation constraints, the fast rate of rise, the sites classification as a high flood island, and the relatively short time of isolation, a shelter-in-place strategy is recommended. The Department of Planning, Housing and Infrastructure's *Shelter-in-place guideline for flash flooding* were followed.

Residents within the study area will most likely be able to adopt a shelter in place strategy in the short term if evacuation is not possible during flood events. Whilst this strategy mitigates risks associated with flood water entrapment, it is noted that other risks associated with the lack of critical services such as of food/water supply and medical services may arise.

Critical services will likely be unavailable for a period during flood events, except via boat or helicopter, which can increase the risk of residents attempting to navigate flood affected roads to access essential services. Isolation can also create additional risk associated with cumulative hazard (i.e., if a fire, medical emergency or other type of emergency was to occur during periods of isolation). Therefore, during the future development further consideration is to be given to the individual risk profile of future residents (i.e. sensitivity of future development) to ensure adequate provisions are available during periods of isolation.

5 Response to preliminary consultation

A response to the preliminary consultation is provided as **Table *5-1***.

Table 5-1 Response to preliminary consultation

Authority	Recommendation	Response
NSW SES	Recommend consideration of the risks associated with intensifying development at known risk of isolation, and encourage investigating ways to reduce these risks if the development is pursued.	Further consideration of evacuation risks is provided as section 4.4.
	Recommend not pursuing the residential lots to the south of Spearing Reserve, as they appear to be impacted by flood hazard level H3 – H5 in a PMF event.	Residential lots south of Spearing Reserve are not pursued.
	Recommend seeking advice from the Department in relation to the impacts of the proposed development on flood behaviour at the site and on adjacent and downstream areas, particularly considering the potential increase of impervious surfaces.	Preliminary consultation response has been received and is addressed in this table below.
	Recommend ensuring that any future residents and people accessing the site are adequately informed of the flood risk at the site for the life-span of the development.	Future development of the site would require a flood emergency risk plan (FERP) to be prepared prior to construction or operation of the development. The FERP is to consider section 4.4 of this FIRA.
	Recommend ensuring that all openings to the basement (ramp, vents, etc) are situated above the Probable Maximum Flood (PMF), or reconsidering basement carparking if this is not feasible to reduce risk to life and property	Future development of the site would be designed such that basement openings are located above the PMF.
The Department	Identify the full range of flood behaviour and potential impacts on and off site and propose measures to minimise identified impacts	Flood behaviour and potential impacts have been identified for the DFE and PMF. Future development and land grading would consider additional events including the 20% AEP to design and site minor drainage systems.
	Consider the full range of flooding and impacts on public safety, evacuation, flood access and isolation risks, including consultation with the SES to assist in identifying and managing these risks	Preliminary consultation has been received by the NSW SES and is addressed above in this table.

Authority	Recommendation	Response
	Consider the range of possible floods, landform changes, cumulative development, climate change and riverine corridor rehabilitation and public safety in the selection and estimation of flood planning levels and areas	The FPA has been identified in accordance with the adopted FRMS.
	Demonstrate consistency with all elements of the planning circular and Ministerial Direction 4.1 - Flood.	The planning proposal is found to be generally consistent with the Ministerial Directions. As identified during the original submission, the rezoning of land at the intersection of Irvine Street and Madoline Street from R2 Low Density Residential to R4 High Density Residential is considered contrary to Ministerial Direction however it was noted by Council that future development can be designed to mitigate the risk and impact. This complies with the Ministerial Directions, which allow for inconsistencies if the are determined to be of minor significance by the relevant planning authority.

6 Stormwater, water quality and riparian corridor

The recommendations of the previously prepared flooding, water quality and stormwater report (Appendix C) were as follows:

- For stormwater, the proposed development would not result in increased peak flowrates and on-site detention could be provided as rainwater tanks. Alternative on-site detention and detailed design of the stormwater system would be considered in future design stages
- For water quality, the proposed development would achieve pollutant reduction targets using three bioretention areas.
- For riparian corridor zones, a small portion of the development in the southeastern corner of the site would encroach into the Council riparian corridor.

Following the update to the masterplan, the following changes are noted:

- For stormwater, rainwater tanks and stormwater infrastructure in the southeastern corner is no longer required due to the removal of this area from the masterplan extent.
- For water quality, the bioretention area in the southeastern corner is no longer required due to the removal of this area from the masterplan extent.
- For riparian corridor zones, the proposed development no longer encroaches into the Council riparian corridor.

It is concluded that overall, the planning proposal will still result in an overall improvement to existing water quality of stormwater runoff, it will not increase peak flowrate of stormwater runoff, and it will not significantly impact riparian corridor zones. The detailed design of stormwater infrastructure will be finalised during future design of the site (i.e. as part of development application process) to ensure compliance with applicable development controls.

7 Conclusion

In conclusion, this FIRA addresses flood related comments and requirements from the planning proposal submission, with consideration to the updated Council FRMS and revised concept masterplan.

It is found that the proposal generally lowers flood levels across the site by rezoning existing residential land use in the FPA to open space uses. There is a minor increase to flood levels at the intersection of Irvine Street and Madoline Street. Future development at this location would be designed to mitigate these impacts.

The site is classified as a high flood island located entirely above the PMF, with road access cut off in the 20% AEP. A shelter in place strategy is proposed for the site, and further consideration of refuge requirements / facilities are to be identified during the design of future development.

In general, it is found that the planning proposal reduces flood risk to existing residents, and future development will not result in significant flood impacts to neighbouring properties or significant risk to future residents.

8 References

Ball, J., Babister, M., Nathan, R., Weeks, W., Weinman, E., Retallick, M., & Testoni, I. (2019). *Australian Rainfall and Runoff: A Guide to Flood Estimation.*

Department of Planning, Industry and Environment. (2021). *Considering flooding in land use planning.*

Instituition of Engineers, Australia. (1987). *Australian Rainfall and Runoff: A Guide to Flood Estimation, Volume 2.*

NSW Government. (2005). *Floodplain Development Manual.*

NSW Government. (2023). *Support for emergency management planning: Flood risk management guideline EM01.*

SES. (2022). *Illawarra Local Flood Plan.*

Wollongong City Council. (2016). *Revised Conduit Blockage Policy.*

Wollongong City Council. (2020). *Fairy and cabbage Tree Creeks Flood Study.*

Wollongong City Council. (2020). *Fairy and Cabbage Tree Creeks Flood Study.*

Wollongong City Council. (2024). *Fairy and Cabbage Tree Creeks Floodplain Risk Management Study & Plan.*

Appendix A

Flood level difference maps

DFE Flood Impacts

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: Homes NSW
Project Code: 304000956-GS-011
Drawn By: JL, Checked By: FG
Rev: 01
Date: 2025-02-10

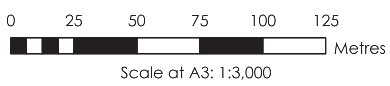
Stantec

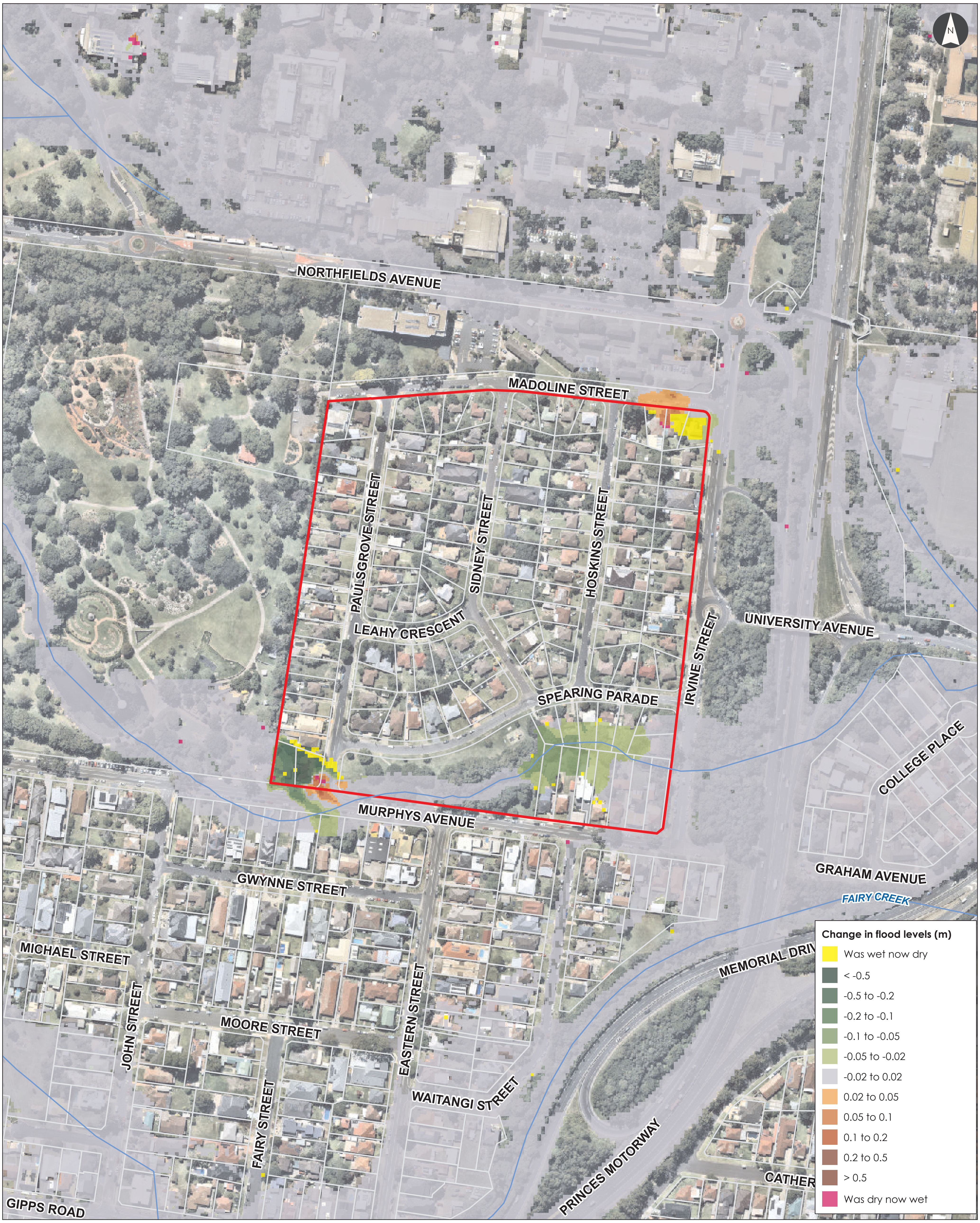
Legend

- Study Area
- Watercourse
- Cadastre

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)





PMF Flood Impacts

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: Homes NSW
Project Code: 304000956-GS-011
Drawn By: JL, Checked By: FG
Rev: 01
Date: 2025-02-10

Stantec

Legend

- Study Area
- Watercourse
- Cadastre

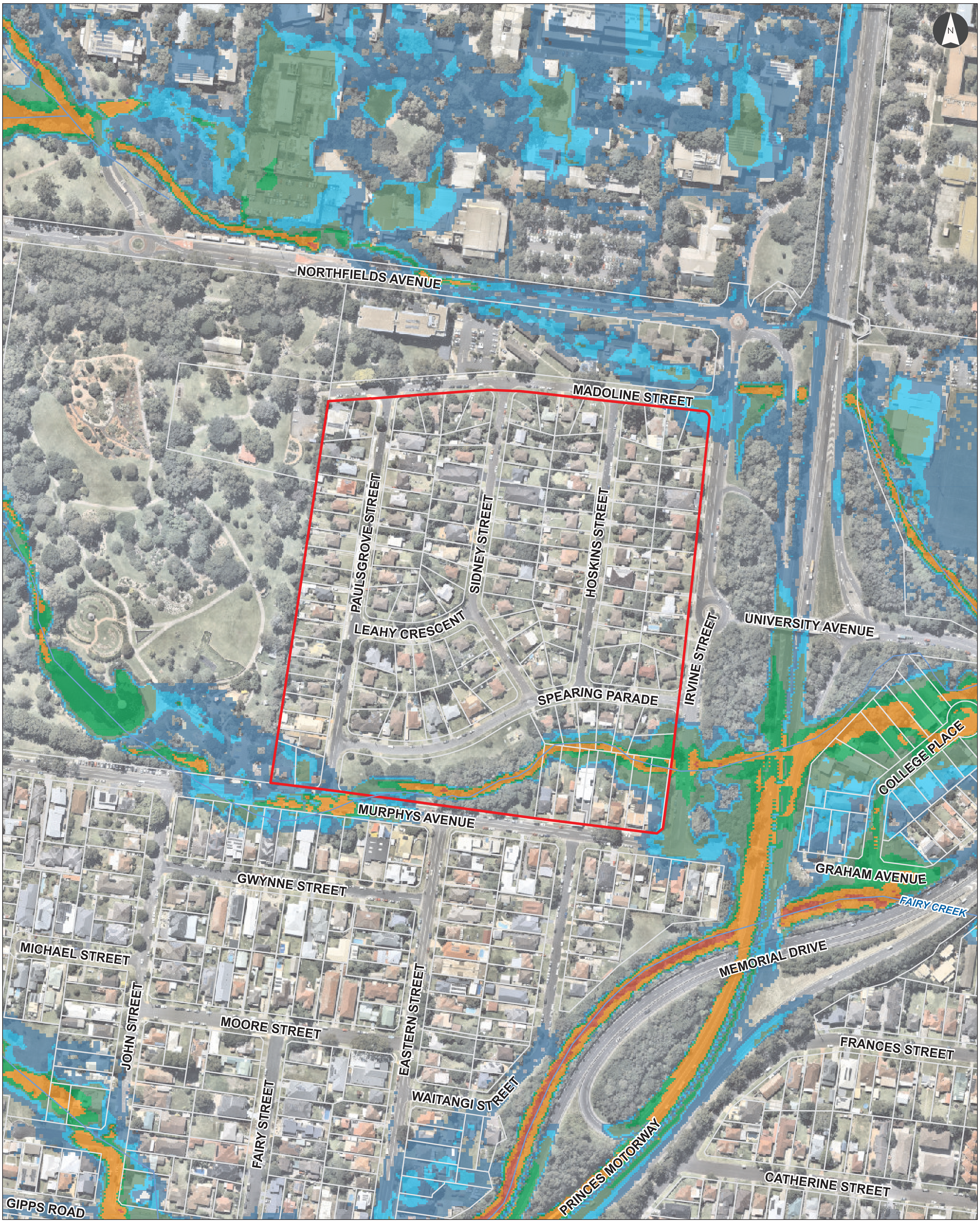
Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)

0 25 50 75 100 125 Metres
Scale at A3: 1:3,000

Appendix B

Flood hazard maps



Existing DFE Flood Hazard

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: Homes NSW
Project Code: 304000956-GS-012
Drawn By: JL, Checked By: FG
Rev: 01
Date: 2025-02-10

Stantec

Legend

- Study Area
- Watercourse
- Cadastre

Flood hazard

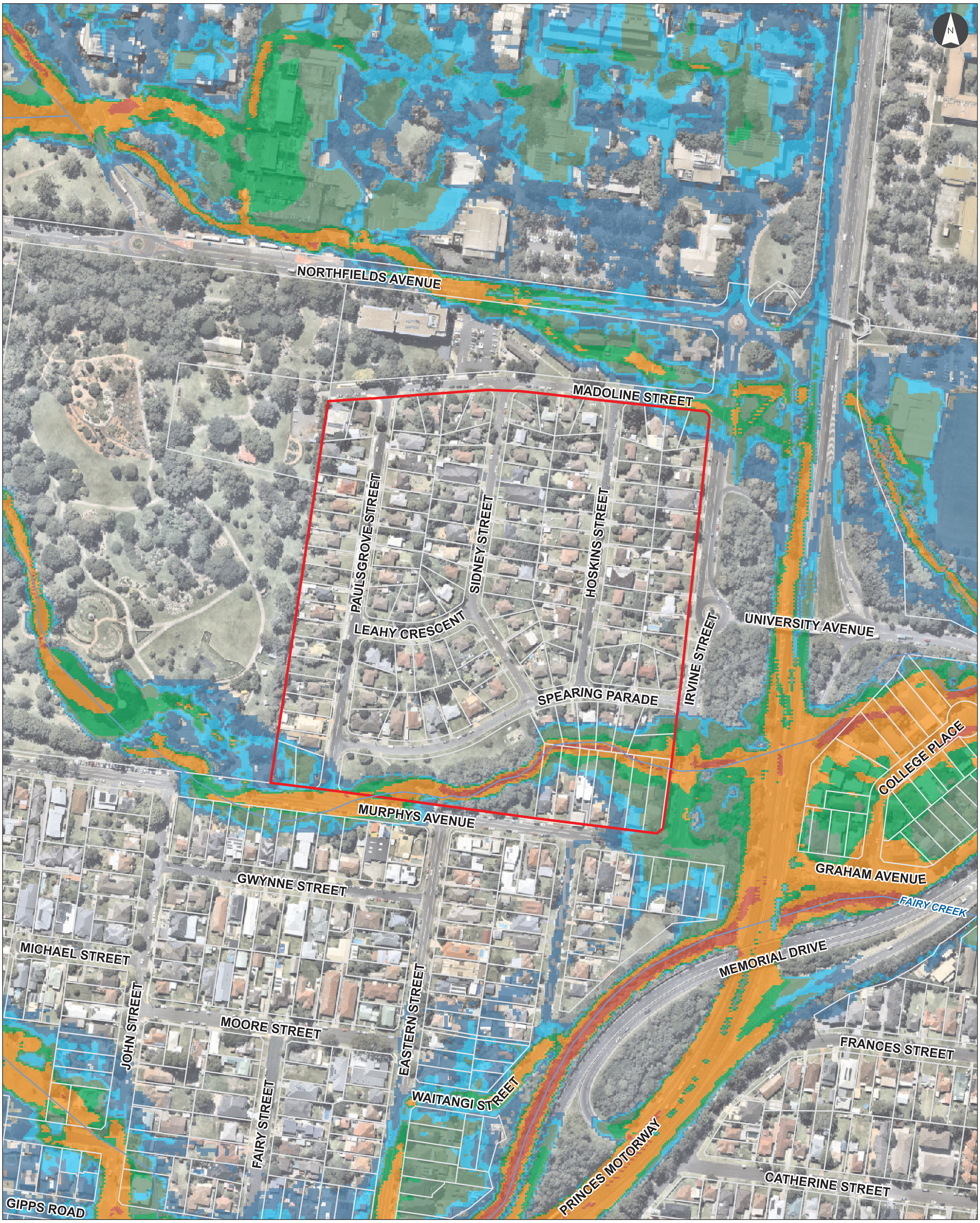
- H1
- H2
- H3
- H4
- H5
- H6

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)

0 25 50 75 100 125 Metres

Scale at A3: 1:3,000



Existing PMF Flood Hazard

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: Homes NSW
Project Code: 304000956-GS-012
Drawn By: JL, Checked By: FG
Rev: 01
Date: 2025-02-10

Stantec

Legend

- Study Area
- Watercourse
- Cadastre

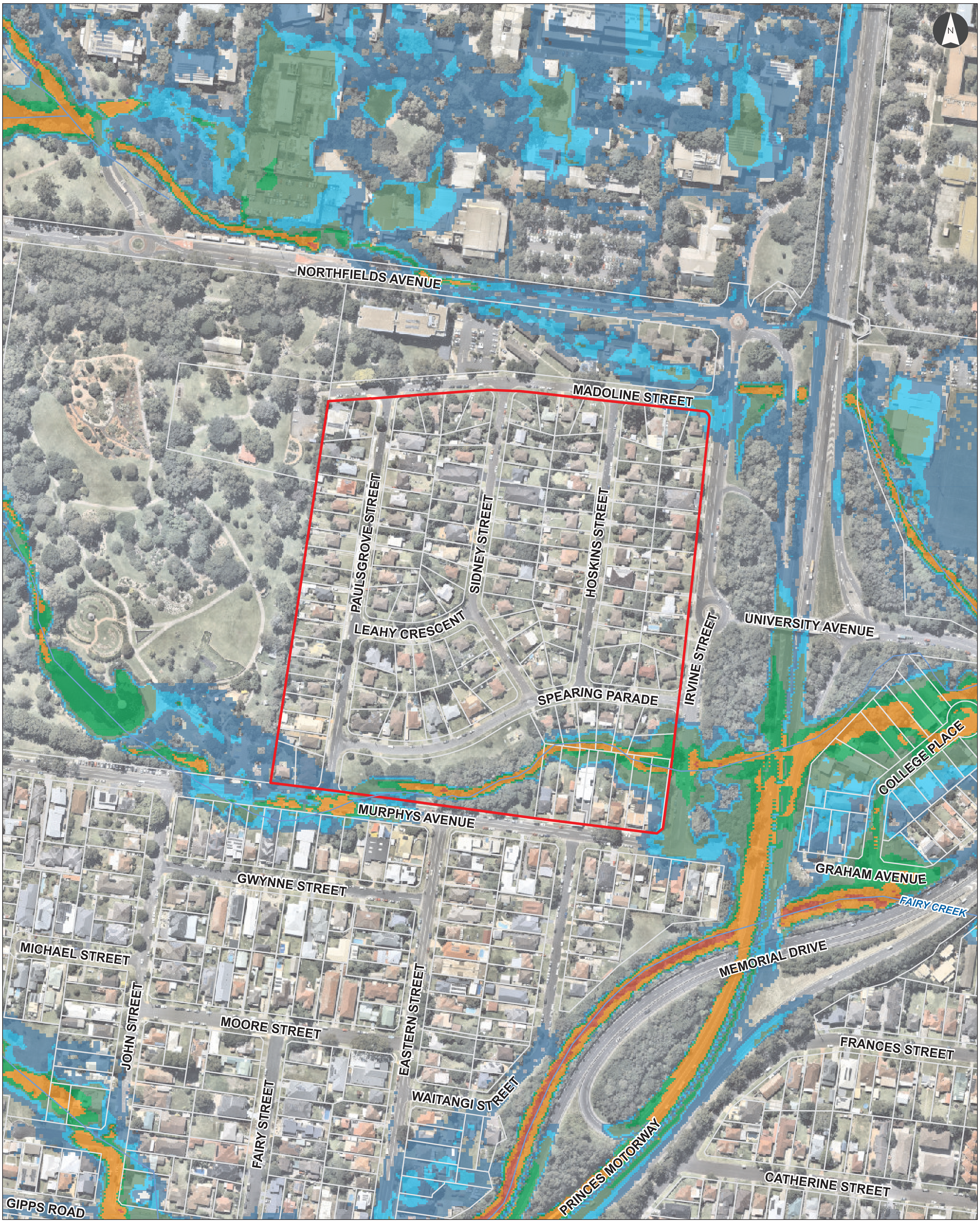
Flood hazard

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

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)

0 25 50 75 100 125 Metres
Scale at A3: 1:3,000



Proposed DFE Flood Hazard

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: Homes NSW
Project Code: 304000956-GS-012
Drawn By: JL, Checked By: FG
Rev: 01
Date: 2025-02-10

Stantec

Legend

- Study Area
- Watercourse
- Cadastre

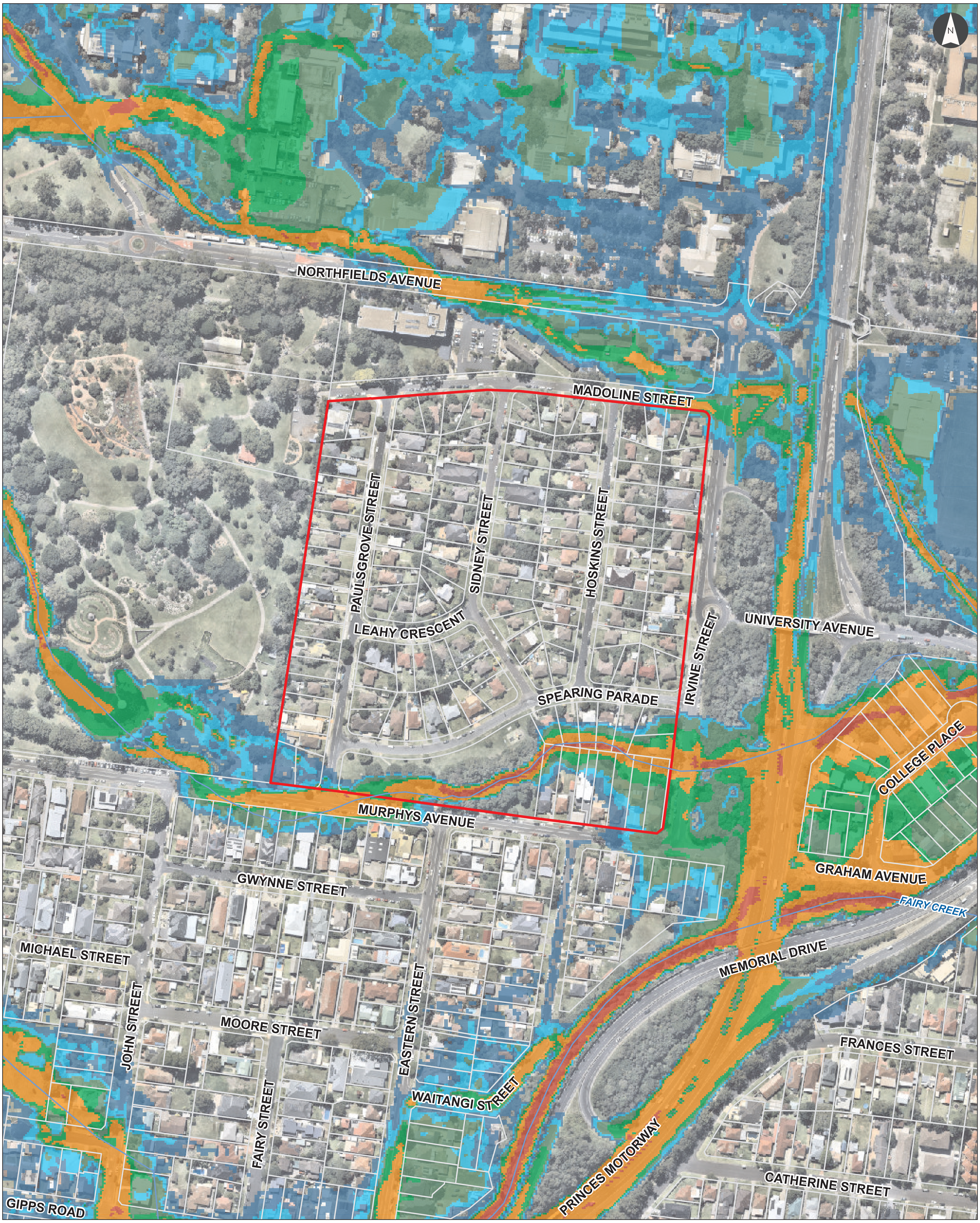
Flood hazard

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

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)

0 25 50 75 100 125 Metres
Scale at A3: 1:3,000



Proposed PMF Flood Hazard

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: Homes NSW
Project Code: 304000956-GS-012
Drawn By: JL, Checked By: FG
Rev: 01
Date: 2025-02-10

Stantec

Legend

- Study Area
- Watercourse
- Cadastre

Flood hazard

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

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)

0 25 50 75 100 125 Metres
Scale at A3: 1:3,000

Appendix C

Flooding, water quality and stormwater report (July 2024)

30400956

Gwynneville Estate – Flooding, water quality and stormwater report

Homes NSW

16 July 2024

Stantec

Gwynneville Estate – Flooding, water quality and stormwater report

This report provides a summary of the flood impact risk assessment, and water cycle management study (including stormwater) undertaken to support the Gwynneville Estate planning proposal.
16 July 2024

Prepared for:

Homes NSW

Prepared by:

Jacob Lee

Revision	Description	Author		Quality Check		Independent Review	
1	Draft for client review	JL	06/09/2023	FG / HE	06/09/2023	ET	27/09/2023
2	Final Draft	JL	16/07/2024	FG / HE	16/07/2024	TM	16/07/2024
2	Issued for Final	JL	16/07/2024	FG / HE	16/07/2024	TM	16/07/2024

Prepared by
Jacob Lee
Environmental Engineer

Reviewed by
Frank Guo
Senior Water Engineer

Reviewed by
Hamed Esfahani
Principal Civil Engineer

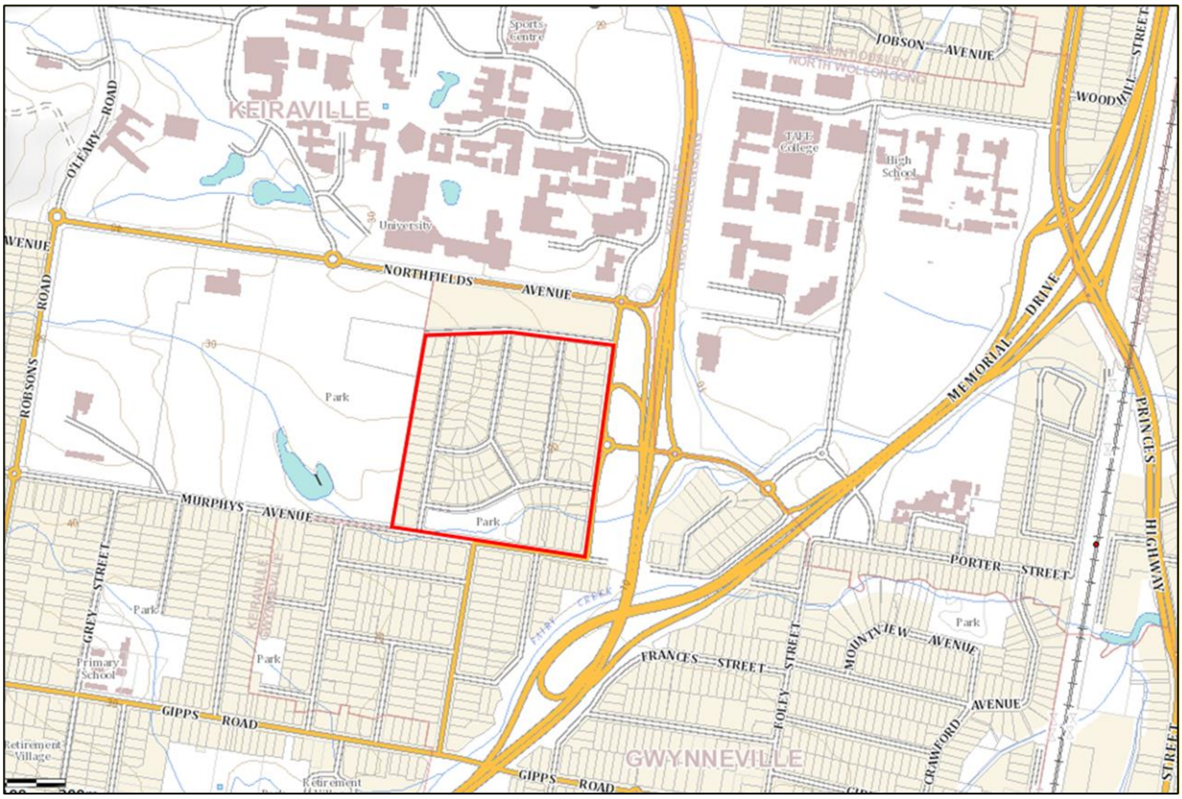
Approved by
Terry Maher
Project Manager – Civil Project Delivery

Gwynneville Precinct – Project Summary

This report has been prepared by Stantec Australia Pty Ltd (Stantec) on behalf Homes NSW (formerly the NSW Land and Housing Corporation - LAHC) to support a planning proposal for urban renewal of land at Gwynneville, NSW.

Covering approximately 9 hectares in area, the Gwynneville precinct is located 2km north-west of the Wollongong CBD. The site sits immediately south of the University of Wollongong, and east of the Botanic Gardens. Irvine Street makes up the site's eastern boundary, with Murphy Avenue to the south. Refer Figure 1 below.

Figure 1



Source: SIX Maps, 2023

The Northfields Avenue Bus Interchange is approximately 150m northwest of the site, and North Wollongong Railway Station is approximately 1km to the east.

Many of the existing dwellings in Gwynneville were constructed by the NSW Government during the 1950s. The precinct is made up of predominantly single storey detached dwellings set in a modified grid-type street layout.

The Gwynneville precinct has been identified as a location capable of supporting more social, affordable and diverse private market housing for the Illawarra community, and to contribute to addressing NSW's housing crisis.

The site currently comprises approximately 131 residential lots, consisting of:

- A total of 79 social dwelling units on 75 individual lots owned by Homes NSW; and
- Approximately 56 privately owned dwelling units on 56 individual lots.

Over 60% of the homes in the precinct are owned by Homes NSW, providing an opportunity to consider additional density while taking into account key constraints such as traffic, views to and from Mount Keira as well potential to increase and embellish existing areas of open space.

Redevelopment of the Gwynneville precinct requires a formal rezoning process to confirm an amended land use zone; increased FSR and building heights, and result in improvements to the current street network, pedestrian connectivity, open space / parkland, and public amenity.

Homes NSW propose amending the Wollongong Local Environmental Plan 2009 (WLEP) to help deliver a diverse range of housing typologies which will include additional social and affordable housing, market housing products and seniors housing, as well as opportunities to develop build-to-rent, key worker housing and student accommodation.

The planning proposal intends to change the current zone of the land from R2 Low Density Residential to R4 High Density Residential, with new and expanded areas of RE1 Public Recreation. This will create the opportunity for more low to mid- rise apartments in the precinct.

The base FSR of 0.5:1 and the height control of 9m that currently applies to the precinct is not proposed change. However, building height and FSR incentives will facilitate site amalgamation to create lots more capable of accommodating increased density and providing amenity. Height and FSR bonuses will be contingent upon achieving design excellence outcomes, providing public benefits such as social and affordable housing, and increased public open space within the precinct.

Homes NSW aims to create a high-amenity, walkable residential neighbourhood with an increased density and choice of affordable and diverse housing options that provide for a broad range of community needs and family types - including students, people on low incomes, people with disability and seniors.

New residential development will enable increased housing choices within in a well-connected location benefiting from frequent free shuttle bus services operating between University of Wollongong, North Wollongong railway station and a multitude of destinations including the city centre and hospital.

Executive Summary

A TUFLOW model was used to assess pre and post development scenarios for the Gwynneville site, mostly adopting the Council model reported in *Fairy and Cabbage Tree Creeks Flood Study (*Wollongong City Council, 2020). The project site is mostly elevated above existing flood levels. A southern drainage line through Spearing Reserve conveys most flood water across the site and functions as a floodway. The remainder of flood extents across the site is mostly flood fringe with some localised areas of flood storage in the south-western and south-eastern corner of the site.

The site is isolated by flood during the PMF event, however the site is a high flood island and is not inundated during the 1%AEP or PMF event. A shelter-in-place strategy is considered suitable in the short-term because the isolation period is less than 6 hours.

The stormwater across the site is in mostly good condition, with a small number of pits and outlets in various states of disrepair (i.e., collapsed lid and damaged headwall). It is recommended that this infrastructure is repaired / maintained in coordination with Council.

DRAINS software is used to model peak flowrates and stormwater volumes The proposed development will not result in increased peak flowrates as on-site detention is provided as rainwater collection tanks. Alternative on-site detention solutions can also be considered in further design stages and/or in consultation with Council.

The project site is an existing urban catchment without existing water sensitive urban design devices. The proposed development results in a minor increase to impervious area and associated pollutant generation since the area is already urbanised. The provision of bio-retention areas and gross pollutant traps will achieve the pollutant removal required, and water quality for the site will improve compared to the existing case.

A small portion of the proposed development would encroach into the Council riparian corridor zone only. Potential impact to the riparian corridor is overall considered to be acceptable but should be further considered in subsequent design stages of the development and consultation with Council.

In summary, this assessment finds that the proposed development:

- Will not significantly increase existing flood extents
- Will not increase the existing flood risk of the area
- Results in an overall improvement to existing water quality of stormwater runoff
- Will not increase peak flowrate of stormwater runoff
- Will not significantly impact riparian corridor zones.

Table of Contents

List of Tables

List of Figures

List of Appendices

Abbreviations

AEP	Annual exceedance probability
AHD	Australian height datum
DCP	Development control plan
IFD	Intensity frequency duration
FPA	Flood planning area
FPL	Flood planning level
FRMS	Flood risk management study
FRP	Flood risk precinct
FS	Flood study
LEP	Local environmental plan
PMF	Probable maximum flood

Glossary

Floodway	Areas which convey a significant portion of water during floods and are particularly sensitive to changes that impact flow conveyance. They often align with naturally defined channels.
Flood storage	Areas outside of floodways that store a significant proportion of the volume of water and where flood behaviour is sensitive to changes that impact on the storage of water during a flood.
Flood fringe	Areas within the extent of flooding for the event but which are outside floodways and flood storage areas. Flood fringe areas are not sensitive to changes in either flow conveyance or storage.
High flood island	A flood island is an area isolated by floodwaters during a probable maximum flood event. A high flood island includes enough land above the probable maximum flood level for people in the area to retreat to safely.

1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

This report has been prepared on behalf of Homes NSW (formerly NSW Land and Housing Corportation) to support a planning proposal to amend the Wollongong Local Environmental Plan 2009 to accommodate urban renewal of land at Gwynneville, NSW.

The amended controls will facilitate the delivery of a diverse range of housing typologies which will include additional social and affordable housing, market housing products and seniors housing, as well as opportunities to develop build-to-rent and student accommodation The proposal will allow for approximately 1,250 dwellings, at least 30% of which will be social and affordable housing.

The report demonstrates that flood impact and risk, water quality and stormwater can be managed with the proposed development.

1.2 PROJECT CONTEXT

Covering approximately 9 hectares, the site is located 2km north-west of the Wollongong CBD. The site is immediately south of the University of Wollongong, and east of the Botanic Gardens. Irvine Street makes up the site's eastern boundary, with Murphy Avenue to the south (refer Figure 1-1). The Northfields Avenue bus interchange is approximately 150m northwest of the site, and North Wollongong railway station is approximately 1km to the east.

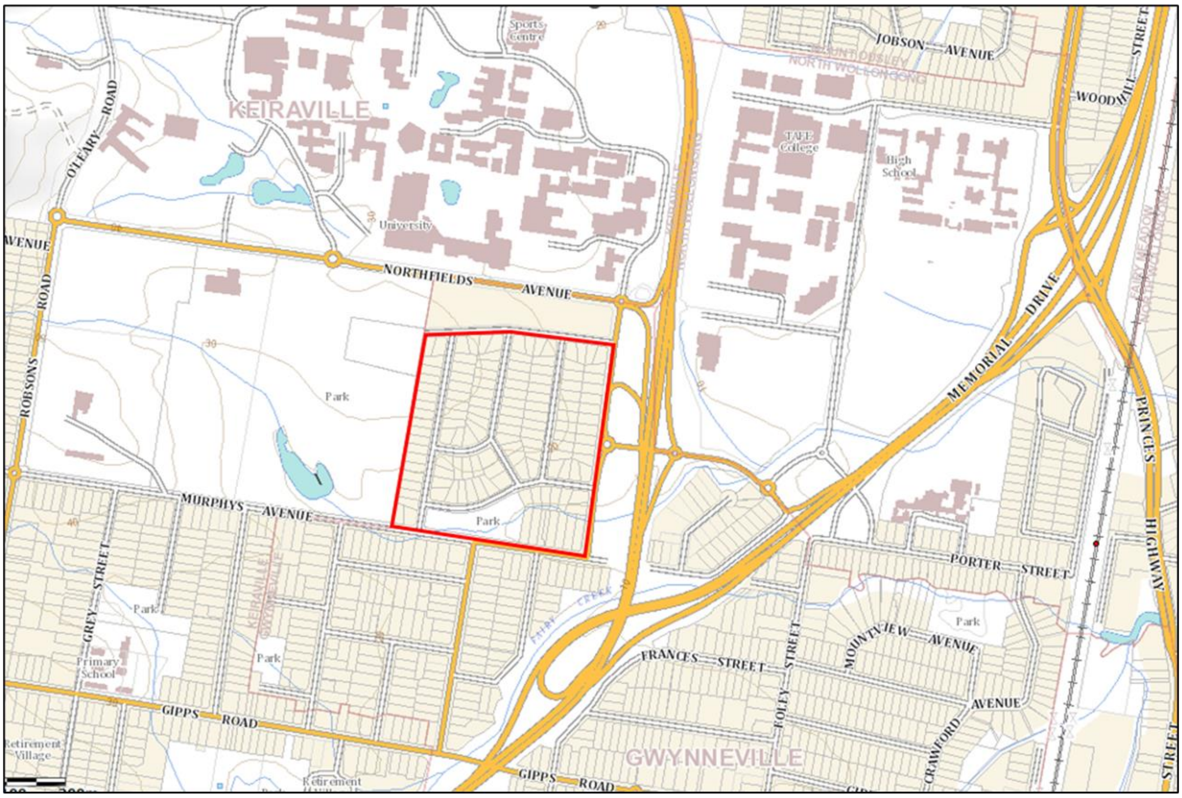


Figure 1-1 Site plan (source: SixMaps 2023)

The site currently accommodates approximately 131 residential lots, consisting of:

- 79 social dwelling units on 75 residential lots owned by Homes NSW; and
- Approximately 56 privately owned dwelling units on 56 residential lots.

Most of the dwellings were constructed during the 1950s. The site is made up of predominantly single storey detached dwellings set in a modified grid-type street layout.

Redevelopment of the Gwynneville precinct will require rezoning to facilitate an amended land use zone; increased FSR and building heights, and result in improvements to the current street network, pedestrian connectivity, open space / parkland, and public amenity. The proposal will improve connections to the University of Wollongong Campus with an opportunity to incorporate student accommodation as part of the overall housing mix.

The site rises from a low point in the south-eastern corner to the west providing important vistas to and from the Botanic Gardens and further west to the escarpment.

The development is well positioned to support the NSW Government’s affordable housing targets and increase housing supply in the Illawarra.

The proposal is supported by an urban design concept plan (refer Figure 1-2).

Figure 1-2 Urban design concept plan (Gyde, 2024)

2.0 FLOOD IMPACT AND RISK

2.1 BACKGROUND

2.1.1 HISTORICAL ENVIRONMENT

The land within the study area was a part of the Paulsgrove estate owned by James Stares Spearing, which was established in 1825. The Paulsgrove estate was a small agricultural community of 43 people. The land was mostly cleared, planted with crops, and used for cattle farming and a piggery.

Colonel John Leahy bought Paulsgrove estate in 1835 and subdivided the land into lots of between 50 to 100 acres. By 1900 the dominant use of the land was dairy farming, and this continued up until the end of World War II.

Following the war, demands for post-war construction and housing the growing population of Wollongong led to many of the farms being purchased for residential use. Homes NSW bought a large portion of the land for housing in 1949, other parts were sold for private housing, and Spearing Reserve was acquired by Council in 1966.

Historical imagery available from the Wollongong City Council Intramaps portal was used to inform an understanding of the history of the site's development and hydrology. The historical development of the site between 1938 to 2006 is summarised in Table 2-1.

In general, the site has developed from cleared agricultural land to a low density residential urban area. As a result, impervious area across the site has increased, and drainage lines have been modified during associated development such as infilling and installation drainage infrastructure. It is uncertain whether the drainage lines observed in 1938 are pre-European alignments or whether they were constructed to channelise water for farming uses. Regardless they have been heavily modified, infilled and conveyed through drainage under roads and development over the years.

The existing riparian corridor in Spearing Reserve appears to be a result of Bushcare group efforts to plant vegetation along the drainage line. The revegetation works have been successful, with more work needed just to maintain the vegetation and clear weeds / overgrowth. However, the corridor is disconnected from the escarpment and downstream environments by existing roads on either side of the site.

Table 2-1 Historical aerials of the study area and surrounds

Year	Aerial	Hydrology
1938		There are two drainage lines visible, one to the north and one to the south. They are both mostly devoid vegetation except for a small upstream portion of the southern drainage line.

Year	Aerial	Hydrology
1961		Sub-division development of low density residential properties within the period of 1938-1961. The southern drainage line appears to be realigned during earthworks associated with the development. Both the northern and southern drainage lines are piped underneath the developed roads.

Year	Aerial	Hydrology
1977		During the period of 1961-1977, the Wollongong Botanic Gardens are further developed and the M1 Princes Motorway is constructed to the east of the site. The southern drainage line is modified upstream of the site with the construction of the Wollongong Botanic Gardens (i.e. Duck Pond and associated drainage). Additional residential development occurs south of Murphys Avenue between Eastern Street and John Street. The southern drainage line is now completely piped where it drains from the Wollongong Botanic Gardens and Spearing Reserve. Riparian corridor works, including vegetation planting in the southern drainage line in Spearing Reserve, are observed in the aerial imagery. The northern draiange line is futher modified and is now mostly piped due to development of University accommodation south-west of the intersection of Madoline Street and Irvine Street.

Year	Aerial	Hydrology
1987		During the period of 1977-1987 there is slight increase indevlopment of the Wollongong Botanic Garden, the University and areas east of the highway. However, drainage and hydrology in proximity to the site largely remains the same. Trunk drainage has been installed to pipe the southern drainage line in the western portion of Spearing Reserve, and vegetation within the riparian corridor has been successfully planted and maintained over the 10 year period. A carpark and associated drainage infrastructure has been developed in the south east corner of the Wollongong Botanic Gardens.

Year	Aerial	Hydrology
2006		In the 20 year period between 1987-2006 there is generally no increse in development, however vegetation growth across the area increases signifcantly particuarly in the Wollongong Botanic Gardens, the riparian corridor of the southern drainage line, and areas east of the highway.

2.1.1.1 HISTORICAL FLOOD EVENTS

The most notable historical flood event in the catchment is the August 1998 event which caused flood damage to public and private property, isolated communities, and resulted in the loss of life of one individual.

At the time of the 1998 event the nearest rain gauge to the site was the Keiraville / Gleniffer Brae (568053) logger which was owned by Wollongong City Council according to the Council FRMS, it was located near the intersection of Robsons Road and Murphys Avenue – approximately 683m west of the site. The rainfall data collected at this location was used to calibrate the modelled events in the Council FS, and the probability of the event was also considered.

The rainfall intensity recorded at the gauge was compared against the modelled intensity frequency duration (IFDs) in the Council FS. An extract of the comparison is provided as Figure 2-1.

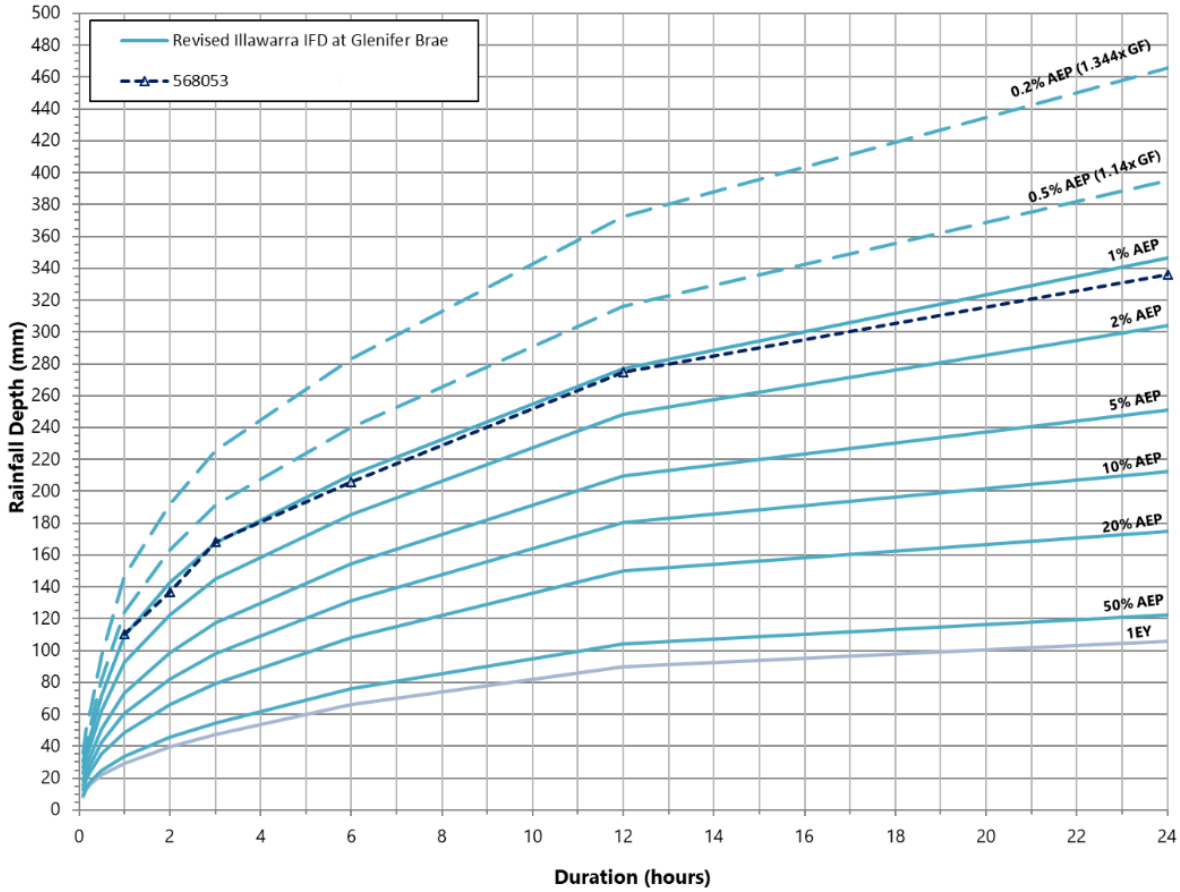


Figure 2-1 1998 event compared to modelled IFD (source: Council FS)

The 1998 event in this location of the catchment was found to be comparable in terms of probability to the 1%AEP event.

2.2 AVAILABLE INFORMATION

2.2.1.1 FAIRY AND CABBAGE TREE CREEKS FLOOD STUDY (2020) - ADVISIAN (WORLEY GROUP).

The current flood study adopted for the catchment is the *Fairy and Cabbage Tree Creeks Flood Study* (Wollongong City Council, 2020) (Council FS). The Council FS aims to define flood behaviour in the catchment to support understanding and management of flood risk.

2.2.1.2 FAIRY AND CABBAGE TREE CREEKS FLOODPLAIN MANAGEMENT STUDY AND PLAN (2010) -BEWSHER CONSULTING PTY. LTD.

The current floodplain risk management study and plan for the catchment is the *Fairy and Cabbage Tree Creeks Floodplain Risk Management Study & Plan* (Wollongong City Council, 2010) (Council FRMS). The Council FRMS assesses existing and future flood risk in the catchment and provides recommendations to limit residual risk for the community in the catchment.

It is noted that the Council FRMS is currently flagged to be ‘under review’ on the Wollongong City Council website at the time of writing.

2.2.1.3 LOCAL EMERGENCY MANAGEMENT FLOOD PLAN

The current emergency local flood plan (LFP) for the catchment is the *Illawarra Flood Emergency Sub Plan* (NSW SES & Wollongong City Council, 2022).

2.3 FLOOD ASSESSMENT METHODOLOGY

2.3.1 FLOOD HAZARD

The combined general hazard curves provided in *Australian Disaster Resilience Guideline 7-3: Technical flood risk management guideline: Flood hazard* (AIDR, 2014) were adopted in the Council FS. These general hazard curves (Figure 2-2) were also adopted for the classification of hazard areas in the pre and post developed assessment of this report.

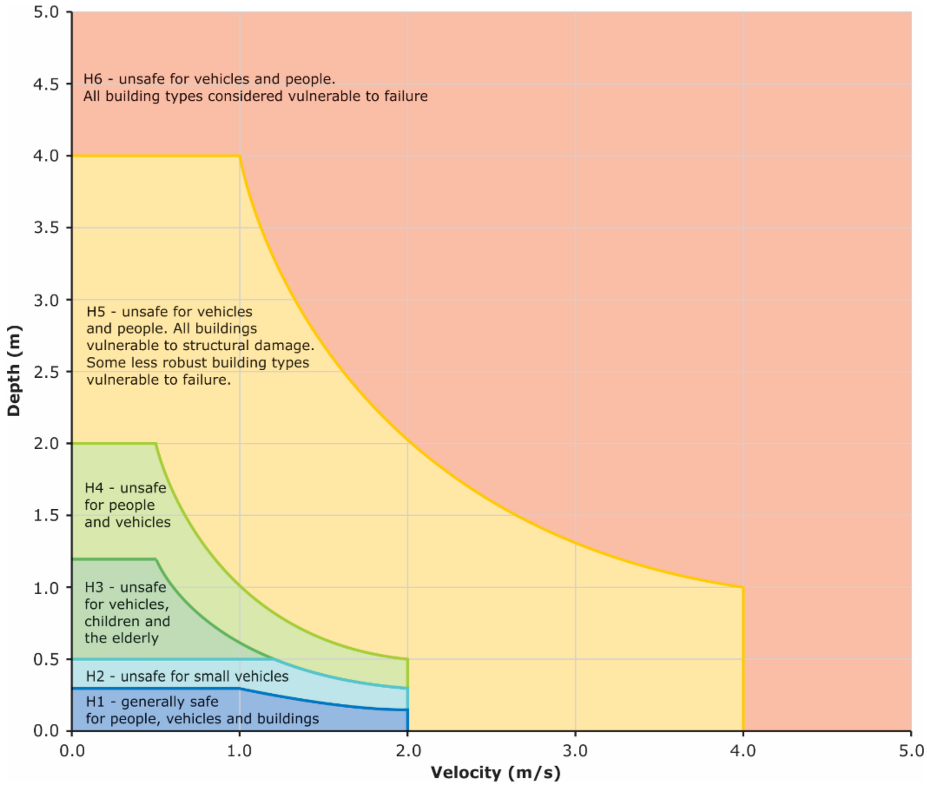


Figure 2-2 General hazard curves (Ball, et al., 2019)

2.3.2 FLOOD RISK PRECINCTS

Flood Risk Precincts are used by Councils to delineate the floodplain into areas with different levels of potential flood risk, and to determine areas where flood related development controls should be applied.

As described in Chapter E13 of Council's DCP (2009), flood prone land is divided into three flood risk precinct categories (refer to Table 2-2).

A flood risk precinct (FRP) plan has been developed for both pre-development and post-development conditions across the site in accordance with the approach taken in the Council FS.

Table 2-2 Flood risk precinct (FRP) categories

Risk Precinct	Definition
High	The High FRP is where high flood damages, potential risk to life and/or evacuation problems would be anticipated or where development would significantly or adversely alter flood behaviour. This area includes floodways. In this precinct, there would be a significant likelihood of flood damages and/or danger to life. The High FRP includes: • Areas greater than H3 hazard conditions during the 1% AEP event • Land within 10m from the top of a watercourse bank • Floodways
Medium	In this precinct there would be a significant likelihood of flood damage and/or danger to life, but these damages or danger to life can be minimised by the application of appropriate development controls. The Medium FRP includes: • Land below flood levels during a 1% AEP event, plus 0.5 metres, that is not within the High FRP area
Low	This precinct is where the likelihood of damages is low for most land uses. The Low FRP includes: • All areas within the floodplain (i.e., within the extent of the PMF) but not identified within either the High FRP or the Medium FRP

2.3.3 FLOOD FUNCTION

The three flood function categories of areas within a floodway include the floodway, flood storage, and flood fringe. The definitions of the three flood function categories are provided in the *Flood Risk Management Manual* (Department of Planning and Environment, 2023), they have been summarised in Table 2-3.

Table 2-3 Flood function categories

Flood function category	Definition
Floodway	Areas which convey a significant portion of water during floods and are particularly sensitive to changes that impact flow conveyance. They often align with naturally defined channels.
Flood storage	Areas outside of floodways that store a significant proportion of the volume of water and where flood behaviour is sensitive to changes that impact on the storage of water during a flood.
Flood fringe	Areas within the extent of flooding for the event but which are outside floodways and flood storage areas. Flood fringe areas are not sensitive to changes in either flow conveyance or storage.

The flood function category has been mapped for the pre and post developed analysis. The flood functions were identified following the approach adopted in Council FS, which is summarised as Table 2-4.

Table 2-4 Flood function identification method

Flood function category	Identification method 1%AEP	Identification method PMF
Floodway	Areas where: • Velocity-depth product ≥ 0.25 m^2/s AND velocity ≥ 0.25 m/s; OR • Velocity ≥ 1.0 m/s AND depth ≥ 0.1 m; OR • Velocity-depth product ≥ 0.5 m^2/s; OR • Provisional Hazard = H6	The 1%AEP floodway extent plus areas during the PMF event where: • Velocity-depth product ≥ 0.5 m^2/s; OR • Provisional Hazard = H6
Flood storage	Areas where: • Depth ≥ 0.5m AND • Not a floodway	Areas where: • Depth ≥ 0.5m AND • Not a floodway
Flood fringe	Remaining areas of the floodplain not classified as floodway or flood storage	

The 1%AEP identification method was adopted to identify the flood functions for the site.

2.4 PRE-DEVELOPED ASSESSMENT

2.4.1 PRE-DEVELOPMENT FLOOD MODEL

The TUFLOW model files of the Council adopted *Fairy and Cabbage Tree Creeks Flood Study* (Advisian, 2020) (Council FS) were used to build the initial pre-development scenario modelled in this report.

A few adjustments were made to the Council model to incorporate an updated site topography which involved updating elevation in the Spearing Reserve watercourse based on latest LiDAR information.

2.4.1.1 HYDROLOGICAL MODEL

Hydrological modelling software

The pre-developed model hydrology adopted the model developed for the Council FS, which used WBNM hydrologic modelling software to simulate catchment rainfall-runoff processes.

Hydrological catchment delineation

The Council FS delineated hydrological catchments using CatchmentSIM hydrologic and terrain analysis software. For the Council FS some manual updates to the catchment layout were made considering local drainage structures and flowpaths – however for the site it appeared catchments were largely automatically delineated by the CatchmentSIM software.

Catchment delineation was found to be roughly correct when compared to further investigation of the site elevation (based on site observations and further desktop assessment of latest LiDAR. However, some minor updates to the catchment boundaries were made to more accurately reflect on-site topography. No changes were made to hydrographs applied to each sub-catchment.

Hydrological parameters adopted

The hydrological parameters adopted for the pre-developed assessment remain unchanged from the Council FS, but are restated in this section of the report. The adopted WBNM runoff lag and stream routing parameters are summarised in Table 2-5, the effective percentage impervious adopted for each land surface is summarised in Table 2-6, and the adopted rainfall parameters are summarised in Table 2-5.

Table 2-5 Adopted WBNM runoff lag and stream routing parameters

WBNM Model Parameter	Parameter Value
Runoff lag factor ‘C’	1.4
Impervious runoff lag factor ‘C’	0.1
Stream routing factor ‘F’	Variable (0.65 to 1.0)

Table 2-6 Effective percentage impervious by land surface type

Surface Type	Effective Percentage Impervious
Watercourses and concrete open channels	100%
Buildings	100%
Residential	40%
Commercial / Industrial	80%
Vegetation	2%
Road Corridors	70%
Rail Corridor	50%

Table 2-7 Adopted rainfall parameters

Parameter	Adopted value
Initial Loss (Pervious)	10 mm

Parameter	Adopted value
Continuing Loss (Pervious)	2.5 mm/hr
Initial Loss (Effective Impervious)	0 mm
Continuing Loss (Effective Impervious)	0 mm/hr

Temporal patterns

The temporal pattern modelled for the catchment was adopted from the Council FS. The standard temporal patterns for 'Zone 1 – East Coast Australia' as per ARR 1987.

Critical storm duration

The critical storm duration modelled for the pre-developed case was based on critical durations identified for the site in the Council FS. The critical durations adopted for each event are summarised in Table 2-8.

Table 2-8 Critical durations for each event

Event	Critical duration (minutes)
20%AEP	120
10%AEP	120
5%AEP	120
1%AEP	120
PMF	60

2.4.1.2 HYDRAULIC MODEL

Grid size

The grid size adopted for the hydraulic model remains unchanged from the Council FS. A model grid size of 3m was therefore adopted.

Roughness

The Manning's 'n', or roughness coefficient, applied to model cells adopted the same values used in the Council FS. A variable depth roughness was applied, with a roughness applied for each material at two different depths as summarised in Table 2-9.

Table 2-9 Roughness values adopted

Material	Depth 1 (m)	Manning's 'n' for Depth 1	Depth 2 (m)	Manning's 'n' for Depth 2
Watercourses	0.3	0.1	1.5	0.04

Material	Depth 1 (m)	Manning's 'n' for Depth 1	Depth 2 (m)	Manning's 'n' for Depth 2
Concrete Open Channels	0.15	0.06	0.3	0.03
Buildings	-	3.0	-	-
Residential Yard	0.3	0.2	1.5	0.1
Industrial/Commercial Yard	0.1	0.1	0.3	0.06
Open Space	0.1	0.06	0.3	0.04
Vegetation – Medium Density	0.15	0.16	0.5	0.08
Vegetation – High Density	0.3	0.2	1.0	0.15
Road Corridor	0.05	0.06	0.15	0.03
Rail Corridor	0.1	0.16	0.3	0.08

The materials adopted in the model for the pre-development assessment are shown on Figure 2-3.

Figure 2-3 Pre-development roughness materials

Buildings

Building envelopes in the pre-developed assessment were modelled by representing building envelopes with a high roughness coefficient of 3 in the model as per Table 2-9.

Geometry / Elevation data

The Council flood study model uses a combination of survey and Light Detection and Ranging (LiDAR) data to represent the geometric properties of the existing topography. The existing topography of the study area within the Council FS model uses a combination of LiDAR and enforced thalwegs (survey not used in the study area).

A thalweg is a topographical line which follows the lowest elevation of a watercourse. Thalwegs are required because LiDAR cannot penetrate water surface and captures a lower resolution of ground points in heavily vegetated areas.

A thalweg is used within the Council FS model to represent the existing topography of the watercourse located to the south of the site.

It was confirmed following a site inspection of the watercourse that it is vegetated (to an extent which would interfere with LiDAR), as shown in viewpoints looking downstream (Figure 2-4) and upstream (Figure 2-5). It is therefore considered justified to enforce a thalweg here to represent the watercourse in the model using the minimum data points from available LiDAR.

Figure 2-4 View looking downstream (west) of the watercourse

Figure 2-5 View looking upstream (east) of the watercourse

The 2013 New South Wales (NSW) Land and Property Information (LPI) (now provided by NSW Spatial Servers (NSW SS)) LiDAR digital elevation model (DEM) (2013 LiDAR) was used as the primary topographic data set for the Council flood study.

A modified DEM comprising of minimum levels from the 2005-2007 AAM Hatch Wollongong LiDAR DEM and the 2013 LiDAR was derived (minimum LiDAR) and adopted to represent the topography along watercourses and heavily vegetated areas.

Since the completion of the Council flood study, 2021 NSW SS LiDAR DEM (2021 LiDAR) is now available. The minimum LiDAR was updated to include the minimum data points from the new 2021 LiDAR.

Following the update of the minimum LiDAR, the thalweg used to represent the existing topography of the watercourse located to the south of the site was also updated. The minimum LiDAR, 2021 LiDAR, council model thalweg, and updated thalweg elevations are shown in Figure 2-6. The updated thalweg smooths elevation spikes in the Council model, and in doing so better represents the expected elevation of the watercourse as it drains from west to east.

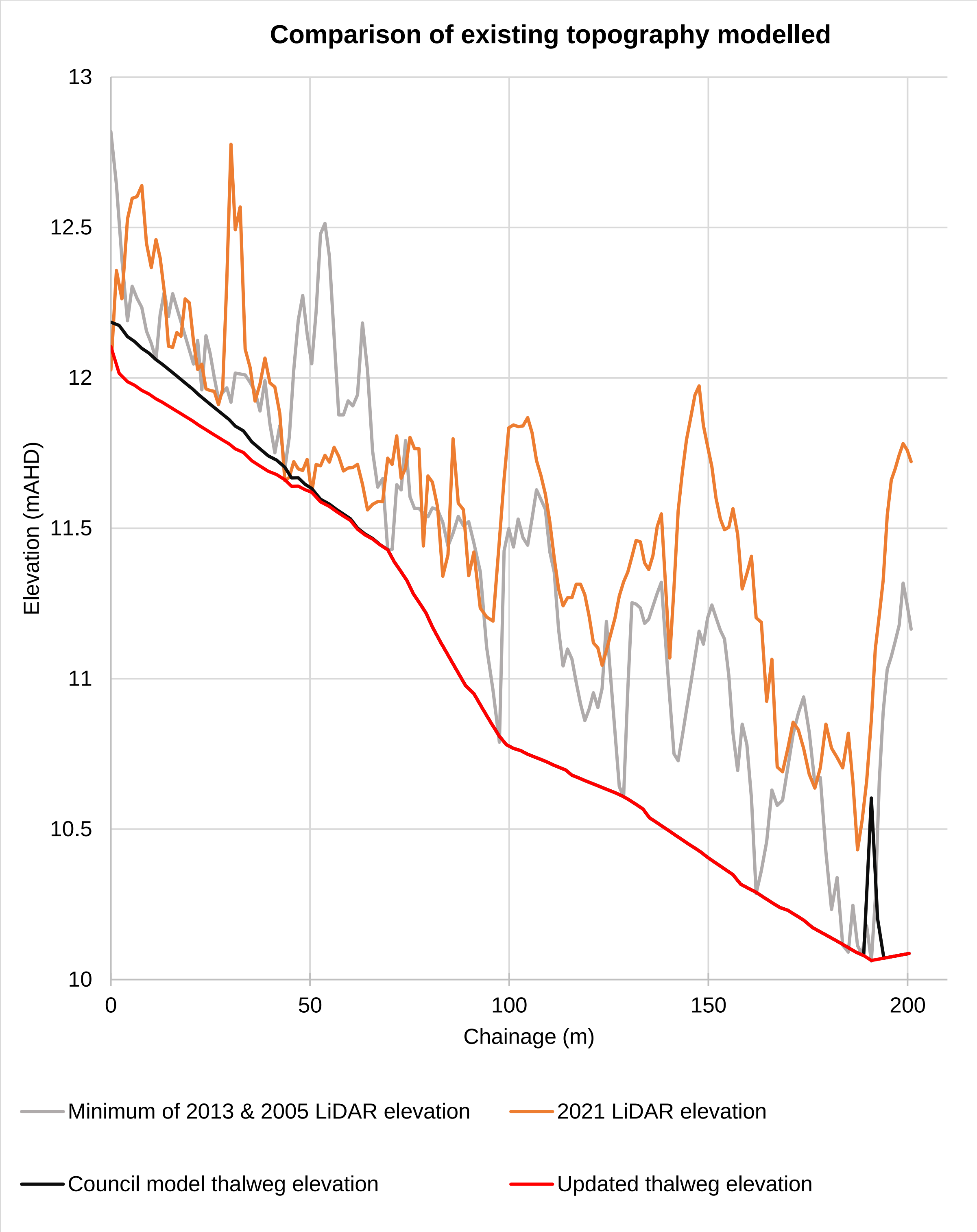


Figure 2-6 Comparison of model topography and available LiDAR

The updated pre-development digital elevation model adopted for the assessment is shown as Figure 2-7.

Figure 2-7 Pre-development digital elevation model

One-dimensional (1D) model

The pre-developed assessment adopted the 1D network and parameters modelled in the Council FS.

The field inlet capacity curves applied in the model are shown as Figure 2-8, they were developed based on application of the *Queensland Urban Drainage Manual* (Department of Natural Resources and Water, 2007).

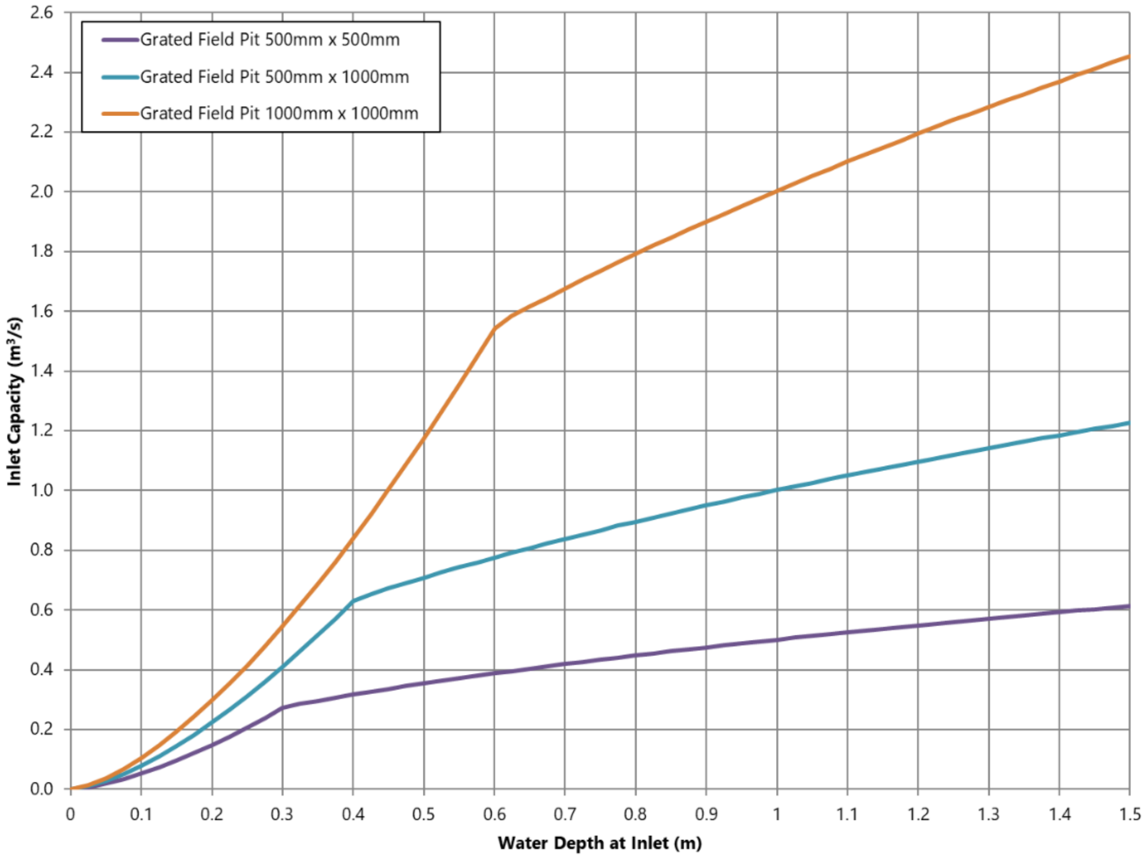


Figure 2-8 Field inlet capacity curves adopted (source: Council FS)

The major drainage infrastructure (with a width or diameter greater than 1m) are shown on Figure 2-9. Drainage infrastructure with a smaller diameter (i.e., less than 1m) are also included within the 1-D model however are further discussed / assessed in section 3 of this report as they are understood to primarily convey overland, and nuisance flows rather than mainstream flood conveyance.

Figure 2-9 1-D Model layout

The details of major culverts for the site are summarised in Table 2-10. The major drainage lines are separated into a northern and a southern drainage line.

The southern drainage line consists of trunk drainage from the Wollongong Botanic Garden and Murphys Avenue which is conveyed to the Spearing Reserve watercourse through culvert 4248, the watercourse is then conveyed under Irvine Street through culvert 2626 and then under the Princes Motorway through culvert 2617.

The northern drainage line consists of trunk drainage from the University of Wollongong which is conveyed under Irvine Street to the northern drainage line through culvert 1495, under the Princes Motorway / Northfields Avenue slip lane through culvert 786 and under the Princes Motorway through culvert 3049.

Table 2-10 Major culverts

Culvert name	Type	Width / Diameter (m)	Height (m)	Number	Blockage factor class
786	Box	2	1.2	4	Class 2
1495	Circle	1.35	N/A	4	Class 2
2617	Box	1.9	0.9	3	Class 2
2626	Circle	1.35	N/A	3	Class 2
3049	Box	2	1.2	4	Class 2
4248	Circle	1.35	N/A	1	Class 2

Blockage policy

The current DCP blockage policy was adopted for the 1D model, and results presented for both the pre-developed and post-developed case are an envelope of ‘no blockage’ and ‘blockage’ scenarios. The blockage applied to the conduits is based on the blockage factor class for each conduit identified in Table 2-10 and the blockage factors summarised in Table 2-11.

Table 2-11 Blockage factor

Event	Class 1 blockage factor	Class 2 blockage factor	Class 3 blockage factor	Class 4 blockage factor
20%AEP and less frequent events	60%	50%	35%	5%
20%AEP event up to and excluding 2%AEP event	75%	65%	50%	10%
2%AEP event up to and including the PMF event	95%	75%	60%	15%

2.4.1.3 EVACUATION

The pre-developed case was assessed considering the flood emergency response classifications in *Support for emergency management planning: Flood risk management guideline EM01* (EM01 guideline) as well as existing information provided in the LFP.

The LFP identifies the Northfields Avenue and Murphys Avenue are roads liable to flooding in the catchment. In larger events the site becomes a high flood island which is an area that is elevated above the PMF extent but isolated due to the flooding of connecting roads. A conceptual cross section of the high flood island is shown as Figure 2-10.

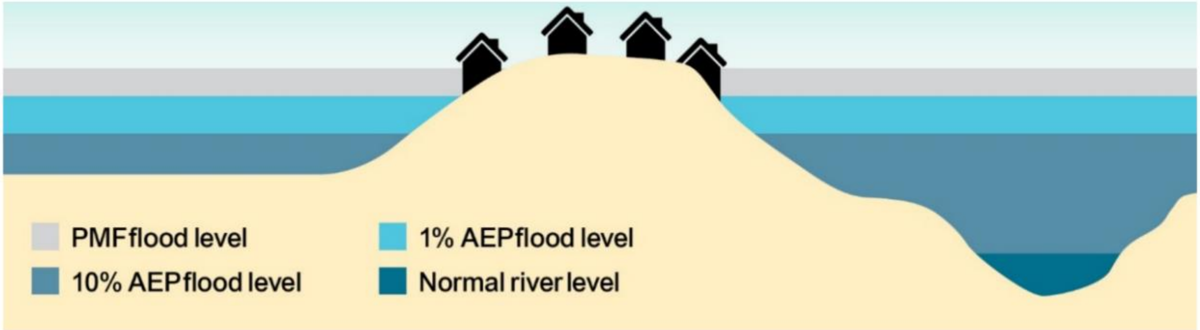


Figure 2-10 High flood island concept (Department of Planning and Environment, 2023)

A high flood island means that residents will likely be able to shelter in place outside of the flood extent in the short-term, however isolation creates indirect risks associated with the potential disruption of critical services such as medical treatment, food, and water supply.

Critical services will likely be unavailable for a period during flood events, except via boat or helicopter, which can increase the risk of residents attempting to navigate flood affected roads to access essential services. Isolation can also create additional risk associated with cumulative hazard (i.e., if a fire, medical emergency or other type of emergency was to occur during periods of isolation).

The existing and proposed hazard across the roads and implication for evacuation strategy is considered further in section 2.6.

2.5 POST-DEVELOPED ASSESSMENT

2.5.1.1 HYDROLOGICAL MODEL

The hydrological model adopted for the post-developed assessment remains unchanged from the model adopted for the pre-developed case assessment.

2.5.1.2 HYDRAULIC MODEL

The hydraulic model including cell size, roughness and 1D model development remains unchanged from the model adopted for the pre-developed case assessment. The only change made was to the elevation of model cells to in order to represent the potential impact of the indicative built form proposed for the site.

Elevation

The concept plan buildings were represented in the model for the post-developed assessment as glass walls.

This is a slightly different modelling approach for buildings compared to the Council FS approach (which modelled buildings as areas of high roughness), however, is both more conservative and more representative of the future built form. The future built form would be larger buildings than those currently on site, raised higher, and are unlikely to be inundated in the post-development scenario.

The post-developed assessment only considers potential impact associated with the proposed built form of the concept plan buildings. Future modelling of proposed design surface may be required to assess the potential impact of associated earthworks. The digital elevation model adopted for the post-developed assessment is shown on Figure 2-11. The elevation model is based off the indicative concept layout (Figure 1-2).

Figure 2-11 Post-development digital elevation model

2.6 FLOOD ASSESSMENT RESULTS

2.6.1 MODEL RESULTS

Flood model results for the pre-developed and post-developed conditions for the 1% AEP and PMF events are included in Appendix A. Included within the flood maps are peak flood depths, water levels and velocities for the 1%AEP and PMF events.

Included within the mapped results is flood level impact figures for post-developed less pre-developed conditions for all design events.

The key outputs of the assessment undertaken have been provided as Appendix A. The list of the outputs is summarised as Table 2-12.

Table 2-12 Key outputs included as Appendix A

Output	Developed case (Pre / Post	Event
Flood Depth and Level Contours	Pre and Post	1%AEP
Flood Depth and Level Contours	Pre and Post	PMF
Flood Velocity	Pre and Post	1%AEP
Flood Velocity	Pre and Post	PMF
Flood Hazard	Pre and Post	1%AEP
Flood Hazard	Pre and Post	PMF
Flood Risk Precinct (FRP)	Pre and Post	1%AEP/PMF
Flood function	Pre and Post	1%AEP
Flood function	Pre and Post	PMF
Flood impact	Pre/Post	1%AEP
Flood impact	Pre/Post	PMF

2.6.2 PRE-DEVELOPED ASSESSMENT RESULTS

2.6.2.1 PRE-DEVELOPED FLOOD EXTENT, DEPTH, AND VELOCITY

The existing flood extent in the site is generally located in four areas across the site. The south-western corner of the site upstream of culvert 4248 (upstream of watercourse in Spearing Reserve), the watercourse in Spearing reserve between culvert 4248 and Irvine Street, a small area at intersection of Madoline Street and Hoskin Street (localised within the road corridor), and the north-eastern corner of the site at the intersection of Madoline Street and Irvine Street.

The existing flood extent adjacent to the site include Murphys Avenue between John Street and Eastern Street, Murphys Avenue between Waitangi Street and Irvine Street, Irvine

Street between Murphys Avenue and Spearing Parade, and Madoline Street between Sidney Street and at the intersection of Madoline Street / Irvine Street.

1%AEP

During the 1%AEP event the maximum depth and velocity of water is within the Spearing Reserve watercourse, which reaches depths of up to 2.64m and a velocity of 3.44m/s. In the south-western corner of the site depths reach a maximum of 3.28m and a velocity of 1.23m/s. In the north-eastern corner of the site depths reach a maximum of 0.43m and a velocity of 0.64m/s.

PMF

During the PMF event the maximum depth and velocity of water is still within the Spearing Reserve watercourse, which reaches depths of up to 3.54m and a velocity of 3.85m/s. In the south-western corner of the site depths reach a lower (compared to 1%AEP) maximum of 1.56m but a higher (compared to 1%AEP) velocity of 3.66m/s. In the north-eastern corner of the site depths reach a maximum of 0.73m and a velocity of 1.40m/s.

2.6.2.2 PRE-DEVELOPED FLOOD FUNCTION

In the pre-developed case, the north-eastern corner of the site is completely flood fringe, however there is a disconnected floodway identified just north of the site at the intersection of Madoline Street and Irvine Street.

The Spearing Reserve watercourse is identified to convey the majority of flows across the site and has an associated floodway. The floodway is mostly contained in the riparian corridor between Spearing Reserve and Irvine Street. However, there is flood storage also identified in the south-western and south-western corner of the site.

2.6.2.3 PRE-DEVELOPED FLOOD RISK PRECINCTS

In the pre-developed case, the site is mostly flood free, and the existing flood extents (with freeboard) in the site are identified to be primarily medium flood risk precinct (FRP). The areas of high FRP within the site are localised and include the extents of the Spearing Reserve watercourse riparian corridor and a localised area in the south-western corner.

2.6.3 POST-DEVELOPED ASSESSMENT RESULTS

2.6.3.1 POST-DEVELOPED FLOOD EXTENT, DEPTH, VELOCITY AND LEVELS

1%AEP

In the post-developed case during the 1%AEP event the maximum depth and velocity of water is still within the Spearing Reserve watercourse, which reaches slightly higher maximum depth of 2.65m and velocity of 3.44m/s. In the south-western corner of the site the maximum depth has reduced maximum depth of 1.23m but an increased velocity of 3.28m/s. In the north-eastern corner of the site depths reach a maximum of 0.39m and a velocity of 0.63m/s.

PMF

During the PMF event the maximum depth and velocity of water is still within the Spearing Reserve watercourse, which reaches depths of up to 3.54m and a velocity of 3.85m/s. In the south-western corner of the site depths reach a lower (compared to 1%AEP) maximum of 1.56m but a higher (compared to 1%AEP) velocity of 3.66m/s. In the north-eastern corner of the site depths reach a maximum of 0.73m and a velocity of 1.40m/s. The maximum values of depth and velocity within the site do not increase compared to the pre-developed case.

2.6.3.2 POST-DEVELOPED FLOOD FUNCTION

The post-developed flood function remains mostly unchanged from the pre-developed case. The only change is a reduction of the extent of flood fringe in the north-eastern and south-eastern corner of the site.

2.6.3.3 POST-DEVELOPED FLOOD RISK PRECINCTS

The post-developed FRPs remain mostly unchanged from the pre-developed case. The only change is a reduction of the extent of medium FRP in the north-eastern and south-eastern corner of the site.

2.6.3.4 FLOOD IMPACT

During the 1%AEP event proposed development results in a maximum increase of flood levels of 45mm in the south-western corner of the site. Maximum change of flood levels of 41mm and 20mm are also observed in the Spearing Reserve watercourse and north-eastern corner of the site respectively. All flood level increases above 20mm are contained within the site boundary.

The largest increase of flood levels during the 1%AEP event offsite as a result of the development is 9mm at the Madoline Street / Irvine Street intersection.

During the PMF event flood level impact is still mostly contained within the site, however the impact to flood levels observed at the Madoline Street / Irvine Street intersection increases to 62mm. On Madoline Street the depth increases from approximately 850mm to 912mm, and the hazard rating of the road remains unchanged when comparing pre and post developed cases.

2.6.3.5 FLOODPLAIN STORAGE

The total volume of water within the floodplain has been calculated for the pre-developed and post-developed case to assess the potential impact on net storage of the floodplain. The floodplain storage volumes during the 1%AEP and the PMF event are compared in Table 2-13.

Table 2-13 Floodplain storage comparison

Event	Pre-developed case storage (m^3)	Post-developed case storage (m^3)	Change in storage (m^3)	Change in storage (%)
1% AEP	17932	18637	705	104%
PMF	25785	27308	1523	106%

The pre-developed case generally reduces flood extent but increases depth in areas including the Spearing Reserve watercourse. This results in a net increase to the volume of water stored in the floodplain of the site.

2.6.3.6 EVACUATION

The maximum hazard rating of possible evacuation routes is not increased in the post-developed case. However, the post-developed case would result in increasing the density of a precinct isolated by floodwaters during the 1%AEP and PMF events. The site is a high flood island and is not inundated during the 1%AEP or PMF event, so a shelter in place strategy is considered suitable in the short-term. In addition, the isolation period is less than 6 hours and therefore a shelter in place strategy is considered appropriate in accordance with the *Draft Shelter-in-place Guideline* (Department of Planning and Environment, 2023).

2.7 FLOOD RELATED REQUIREMENTS

2.7.1 RELEVANT LEGISLATION, POLICIES, AND GUIDES

2.7.1.1 LOCAL PLANNING DIRECTIONS

The current directions of the minister issued under section 9.1 of the Environmental Planning and Assessment Act 1979 (section 9.1 directions) apply to the areas of the development proposed for rezoning.

Focus area 4: Resilience and Hazards of the Section 9.1 directions provide direction related to flooding. The directions and the consistency of the planning proposal with the directions has been identified in Table 2-14.

Table 2-14 Section 9.1 directions

Direction section reference	Direction	Consistency
4.1 (2)	A planning proposal must not rezone land within the flood planning area from Recreation, Rural, Special Purpose or Conservation Zones to a Residential, Employment, Mixed Use, W4 Working Waterfront or Special Purpose Zones.	The development only proposes rezoning existing residential zones within the flood planning area. The proposal would therefore be consistent with this direction.
4.1 (3)	A planning proposal must not contain provisions that apply to the flood planning area which:	See 4.1 (3) (a-g) below
4.1 (3)(a)	permit development in floodway areas	The proposal avoids development within the floodway area and is therefore consistent with this direction.
4.1 (3)(b)	permit development that will result in significant flood impacts to other properties	The development only results in offsite impacts during the PMF event. The property affected is already flood effected in the pre-developed case, and the hazard of the affected land in the post-developed case does not increase. It is therefore not considered to be a significant flood impact, and this proposal would be consistent with this direction.
4.1 (3)(c)	permit development for the purposes of residential accommodation in high hazard areas	The proposal would only permit development within the low-risk flood precinct in the pre-developed case. In the post-developed case, the areas of development are in either the medium or low flood risk precinct, and no development is in the high flood risk precinct. The proposal is therefore consistent with this direction.
4.1 (3)(d)	permit a significant increase in the development and/or dwelling density of that land	The proposal is consistent with direction 4.1 (3)(c) above, and is therefore consistent with this direction.

Direction section reference	Direction	Consistency
4.1 (3)(g)	are likely to result in a significantly increased requirement for government spending on emergency management services, flood mitigation and emergency response measures, which can include but are not limited to the provision of road infrastructure, flood mitigation infrastructure and utilities	The proposal will increase the number of residents within an isolated flood island. The flood island is existing, and there are already residents within this area. The island is a high flood island above the PMF, meaning a short term shelter in place strategy could be used until roads become trafficable. In addition, the isolation period is less than 6 hours and therefore a shelter in place strategy is considered appropriate in accordance with the *Draft Shelter-in-place Guideline* (Department of Planning and Environment, 2023). It is considered unlikely that the proposal would result in significant increased government spending beyond the flood risk management recommendations already in place for the area. The proposal is therefore consistent with this direction.

The direction section 4.1 (4) is not applicable to the development, as Special Flood Considerations are not currently adopted for the land as per part 5 section 5.22 of the LEP.

The proposal is consistent with all section 9.1 directions as they pertain to matters of flooding and resilience.

2.7.1.2 WOLLONGONG DEVELOPMENT CONTROL PLAN 2009

Chapter E13 of the Wollongong Development Control Plan (DCP) (Wollongong City Council, 2009) provides development controls to all land within the flood risk precinct (FRP). Specific controls also apply to the FRPs within the Fairy Cabbage Tree Creek Floodplain.

The high FRP is considered unsuitable for residential land uses as per schedule 5 of Chapter E13. The proposed development does not propose unsuitable land uses within the high FRP.

The medium FRP is considered suitable for residential land use, however additional controls apply to the development. The additional controls required for residential land use within the medium FRP include the following:

- Habitable floor levels to be equal to or greater than the 1% AEP flood level plus freeboard
- Garage and all other non-habitable internal floor levels to be no lower than the 1% AEP flood level minus 300 mm or 300 mm above finished adjacent ground (whichever is the greater)
- All structures to have flood compatible building components below or at the 1% AEP flood level plus freeboard

- Applicant to demonstrate that any structure can withstand the forces of floodwater, debris & buoyancy up to & including a 1% AEP flood plus freeboard, PMF plus freeboard if required to satisfy evacuation criteria
- Either:
  - Engineer's report required to certify that the development will not increase flood affectation elsewhere, includes medium & high-density residential proposals
  - The impact of the development on flooding elsewhere to be considered, includes low density residential.
- Reliable access for pedestrians or vehicles is required from the building, commencing at a minimum level equal to the lowest habitable floor level to an area of refuge above the PMF level, or a minimum of 20 m2 of the dwelling to be above the PMF level
- The development is to be consistent with any relevant flood evacuation strategy or similar plan.

It is considered likely that these controls would be achievable for the future development, however they are to be confirmed at the development application stage of the development.

3.0 STORMWATER

3.1 AVAILABLE INFORMATION

3.1.1 SITE INSPECTION

A site inspection of the road reserve and stormwater infrastructure within the study area was undertaken by an environmental engineer.

The site inspection was undertaken on 12 May 2023. The weather during the site inspection[1] was clear, sunny, with a top temperature of 21.9 °C and a low of 14.2 °C. There was no rain (0mm) recorded on the date of the inspection, and recent rainfall events were 4 days prior (11.8mm total rainfall fell on 8 May 2023), and 12 days prior (32.6mm total rainfall fell on 30 April 2023).

The purpose of the site inspection was to understand topography and drainage of the site, as well a high-level condition assessment of the existing civil and drainage infrastructure. The focus of the inspection was within the existing road reserve and riparian areas.

The inspection of civil infrastructure condition was undertaken from the road reserve only and it is noted that the subsurface condition of the civil infrastructure, including pipe condition and subgrade of pavement is not considered.

3.2 EXISTING STORMWATER SYSTEM

3.2.1 CONDITION OF EXISTING CIVIL INFRASTRUCTURE

The condition of the existing civil infrastructure is based on the findings of the site inspection undertaken for the site.

The civil infrastructure found to be in poor or okay conditions has been identified and assigned a treatment level between level 0 and level 1. The definition and description of each level of infrastructure treatment is provided in Table 3-1.

[1] Weather statistics provided by the Bureau of Meteorology (BOM) (http://www.bom.gov.au/climate/dwo/202305/html/IDCJDW2014.202305.shtml), and sourced from the automatic weather station (AWS) located in Bellambi, NSW.

Table 3-1 Infrastructure treatment level description

Level	Summary	Design item	Description
0	Level 0 treatments include 'make good' and general maintenance repairs	Repair pits, grates, and or outlet	Rectification works to repair existing outlets, pits or grates which were found to have minor damage. For example, may include replacement of grates, backfilling headwalls, or grouting pipe inlets
		Pavement works	Repair and maintain pavements including kerbs and gutters which were found to have minor damage / cracking. For example, may include treating overgrown kerbs or resurfacing pavement.
1	Level 1 treatments include complete replacement of infrastructure or construction of upgraded infrastructure	Replace pits or outlet	Complete replacement of outlet / inlet or stormwater pit which have failed or pose a safety concern. Examples may include constructing a new outlet with a headwall or at a new reduced level or replacing a collapsed pit with an updated pit type.
		Replace kerb and gutter	Complete replacement of kerb and gutter which have failed and are not able to be repaired

The overall condition of the infrastructure across the study area and adjacent road reserve is good, however a total of 6 items were identified to require level 1 treatments, and 16 items were identified to require level 0 treatments.

The level 1 treatments are summarised in Table 3-2, and the level 0 treatments are detailed in Appendix B.

Table 3-2 Level 1 treatment summary

ID (refer Figure 3-1)	Description	Photo
1-1	Inlet underneath Murphys Avenue	
1-2	Outlet into spearing reserve	

ID (refer Figure 3-1)	Description	Photo
1-3	Collapsed pit	
1-4	Pit requiring repairs	

ID (refer Figure 3-1)	Description	Photo
1-5	Cracked kerb with noticeable erosion	
1-6	Collapsed pit	

Figure 3-1 Level 1 infrastructure treatments

The existing stormwater system predominantly consists of surface runoff. Through aerial imagery and street view in combination with LIDAR data, it has been noted that the area is quite steep with nearly all the lots discharging their stormwater via kerb outlets. Approximately, 25% of the site drains towards Madoline Street before discharging into the water course that travels parallel to the Princess Motorway. The rest of the site drains towards the watercourse that travels parallel to Spearing Parade. Figure 2-9 presents the site with existing contours with existing Council stormwater network overlaid. It has been assumed that the existing lots do not have any OSD measures, and that all stormwater runoff discharges directly to the road reserve.

3.3 STORMWATER ASSESSMENT METHODOLOGY

The stormwater assessment approach was conducted in DRAINS using ARR 2019 methodologies to compare the pre and post development flows. The percentage impervious for each scenario was adopted from Wollongong Council DCP as mentioned in Table 3-3. The stormwater quantity analysis only considers the developable area, that is, the road reserve and any areas that will not be developed into medium density lots were not considered as they will have no increase in imperviousness.

In the pre-development scenario, all stormwater runoff has been modelled as overland flow to stimulate existing lots discharging stormwater to the road reserve. In the post-development scenario, the roof portion of the lots are tanked to OSD/rainwater tanks whilst the grassed area has been modelled as overland flow, directly discharging to the road reserve and bypassing the rainwater tanks.

To reduce the post development flows to pre-development levels, rainwater tanks with fitted OSD mechanics are proposed. Each lot/building will have its own OSD tank, the tanks are sized solely for OSD, any BASIX requirements will need to be added addition to the OSD storage. The tanks will then discharge via interallotment drainage which will connect to the nearest council street pit.

3.4 STORMWATER CATCHMENTS

Figure 3-2 provides an outline of the catchment boundary and sizes. Table 3-3 contains additional information regarding the individual catchment characteristics.

Figure 3-2 Stormwater catchment plan

Table 3-3 Stormwater catchment characteristics

Catchment name	Catchment area (ha)	Pre-developed scenario traits (%)	Post-developed scenario traits (%)
Catchment 1	1.35	60% paved: 0.81ha 40% grassed: 0.54ha	80% paved: 1.08ha 20% grassed: 0.27ha
Catchment 2	1	60% paved: 0.6ha 40% grassed: 0.4ha	80% paved: 0.8ha 20% grassed: 0.2ha
Catchment 3	1.55	60% paved: 0.93ha 40% grassed: 0.62ha	80% paved: 1.24ha 20% grassed: 0.31ha
Catchment 4	1.83	60% paved: 1.098ha 40% grassed: 0.732ha	80% paved: 1.464ha 20% grassed: 0.366ha
Catchment 5	1.76	60% paved: 1.056ha 40% grassed: 0.704ha	80% paved: 1.408ha 20% grassed: 0.352ha
Catchment 6	0.56	60% paved: 0.336ha 40% grassed: 0.224ha	80% paved: 0.448ha 20% grassed: 0.112ha

3.5 STORMWATER CONCEPT DESIGN

The concept stormwater design caters to the proposed development by limiting stormwater construction works to be only within the developable areas. As there will be no changes to the road reserve, rainwater tanks are to be provided with each lot/building. The rainwater/OSD system will not be charged. The management of stormwater will follow the following concept:

- No change in topography, the site will fall as its current state
- Lots will become more impervious from 60% to 80%
- Each lot/building will have its own rainwater tank fitted with OSD mechanisms
- All roof stormwater will drain to the rainwater tanks
- Rainwater tanks will discharge via IAD line to the nearest council pit at a controlled rate
- All pervious areas will infiltrate the ground and travel as overland flow once ground storage capacity has been exceeded to follow the natural topography of the site
- Run off will utilise the existing stormwater network and ultimately drain to the watercourses.

3.6 STORMWATER REQUIREMENTS

The proposed redevelopment of the site will trigger OSD requirements as per section 10.1.1 of the Wollongong DCP (2009). Overall, the increase in impervious area is more than 100m^2, thus the site cannot be exempted from OSD. Charged systems are also not permitted as per Section 9.3.4. Table 3-4 summarises the findings of the pre-development and post-development analysis. Table 3-5 further breaks down the results into average per lot to attain an understanding of the average requirements per lot/building.

Table 3-4 Stormwater assessment results

Catchment name	Pre vs post flows (m3/s) 1EY		Pre vs post flows (m3/s) 10% AEP		Pre vs post flows (m3/s) 1% AEP		1% storage (m3)
1	0.2	0.124	0.456	0.239	0.878	0.523	350
2	0.148	0.102	0.337	0.19	0.65	0.307	290
3	0.23	0.133	0.523	0.247	1.01	0.532	460
4	0.272	0.144	0.618	0.264	1.19	0.546	600
5	0.261	0.141	0.594	0.26	1.14	0.538	570
6	0.083	0.049	0.189	0.125	0.364	0.194	160

Table 3-5 Average OSD requirements per lot

Catchment Name	Number of Lots/Buildings1	Post Development Flows (L/s) - 10% AEP	1% Storage (L)
1	16	14.94	21875
2	10	19.00	29000
3	13	19.00	35385
4	11	24.00	54545
5	16	16.25	35625
6	3	41.67	53333

As a result, it has been demonstrated that OSD measures can be met with the implementation of rainwater tanks fitted with OSD mechanisms. It should be noted that this analysis is limited to the assumptions detailed throughout this report. Further studies are required at detailed design stage which involves further detailed analysis on a lot-by-lot basis as some lot areas may not increase in imperviousness and optimisation of rainwater tank size can be further explored. The current study has been conducted as a lumped study at a conceptual level.

4.0 WATER QUALITY

4.1 WATER QUALITY ASSESSMENT METHODOLOGY

Model for Urban Stormwater Improvement Conceptualisation (MUSIC)[1] was used to assess the pre-developed and post-developed water quality of site runoff. MUSIC was applied in accordance with the *NSW MUSIC Modelling Guidelines* (Witt, Mainwright, & Weber, 2015) (MUSIC guideline).

4.1.1 CATCHMENT DELINEATION

The site catchments were delineated from contours derived from 2021 LiDAR. The catchments assessed in the MUSIC model are shown on Figure 4-1.

[1] MUSIC version *MUSIC X 10.0.0.10799 (on Source 4.11.0.a.10799)* was used.

Figure 4-1 Catchment plan

4.1.2 IMPERVIOUS AREA

A land use based effective impervious area (EIA) method is adopted due to the larger size of the proposal, and because impervious area calculations based on direct measurement of impervious surfaces may change during the detailed / built form design phase.

The effective impervious area (EIA) was calculated for each land use type as per the MUSIC guideline (Table 4-1).

Table 4-1 Effective impervious area proportions adopted from MUSIC guidelines

Land use type	EIA Factor
Residential	0.60 x total impervious area (TIA)
Commercial	0.80 x TIA
Industrial	0.90 x TIA
Rural residential	0.05 x TLA
Agriculture	0.00 x total land-use area (TLA)
Forest	0.00 x TLA

The land use type in both the pre and post development case is residential, and therefore this EIA factor of 0.6 was used for catchments in both cases.

The total impervious areas (TIA) calculate for each catchment is based on the land use table in Chapter E14 (Stormwater Management) of the DCP.

Table 4-2 Percentage impervious area for land use types adopted from the DCP

Land use	Percent impervious area
Normal residential lots	60%
Half width road reserve	95%
Medium density residential lots	80%
Commercial areas	100%
Industrial areas	100%
Public recreation areas	25%

The cadastral boundaries of each lot were used to identify land use areas, with all lots except for Spearing Reserve (Spearing Reserve was modelled as a public recreation area) being assigned a normal residential lot land-use in the pre-developed case. The cadastral road reserve was assigned a half width road reserve land use.

In the pre-developed case, the existing normal residential lots were modelled as medium density residential lots with a higher impervious area of 80%.

The impervious area and effective impervious area for the pre-developed and post-develop case is presented in Table 4-3.It is estimated that the development would result in a 15%

increase existing impervious area percentage, which would result in a 9% increase of the effective impervious area of the site.

Table 4-3 Pre and post development catchment impervious areas

Scenario	EIA (m^2)	EIA (m^2)	Area (m2)	Percent TIA (%)	Percent EIA (%)
Pre-developed	71794.65	43076.79	114224	63%	38%
Post-developed	88822.45	53293.47	114224	78%	47%

4.1.3 SOIL CHARACTERISTICS

The site is mostly in the middle slopes of the Gwynneville soil landscape, which is generally overlaid with friable brown sandy loam soil (Hazelton & Tille, 1990). The pervious area rainfall runoff parameters for this soil type were applied to each catchment. The parameters used are summarised in Table 4-4.

Table 4-4 Pervious are property for each catchment

Soil storage capacity (mm)	Initial storage (%)	Field capacity (mm)	Infiltration capacity coefficient - a	Infiltration capacity coefficient - a
98	30	70	250	1.3

4.1.4 HIGH FLOW BYPASS

The peak flowrate for the 4 exceedance per year (EY) event (formerly referred to as the 3 month average recurrence interval (ARI) event) for each of the three catchments was estimated using DRAINS software. The peak flowrate for the 4 EY event was set as the high flow bypass flowrate for proposed treatment devices, meaning that any flows above this rate would bypass the treatment devices in the model.

4.1.5 DEVICE NODE PARAMETERS

The post-developed case was modelled with gross pollutant trap (GPT) and bioretention units to assess likely treatment train requirements to meet the water quality requirements.

4.1.5.1 GROSS POLLUTANT TRAP (GPT) PARAMETERS

The GPT treatment device modelled was based on an Ecosol drop trap (Figure 4-2), and the capture efficiency adopted for the treatment device in the model adopted values provided in the *Ecosol Drop Trap MUSIC Modelling Guideline* (Ecosol Pty Ltd, 2013)

Figure 4-2 Ecosol drop trap (Ecosol Pty Ltd, 2013)

The removal rates / capture efficiency adopted for the treatment device is provided in Table 4-5.

Table 4-5 GPT removal rates adopted

Pollutant	Removal rate (%)	Input value	Output value
Total Suspended Solids (20 – 600µm)	15	1000	850
Total Phosphorus	15	1000	850
Total Nitrogen	4	1000	960
Gross Pollutants (3000 – 6000µm)	97	1000	30

4.1.5.2 BIORETENTION UNIT

Bioretention units were modelled based on parameters provided in the MUSIC guideline. The bioretention area was modelled assuming square dimensions, a depth of 0.3mm and batters with a 1:6 slope.

4.2 PRE-DEVELOPED ASSESSMENT

The MUSIC model for the pre-developed assessment is shown as Figure 4-3.

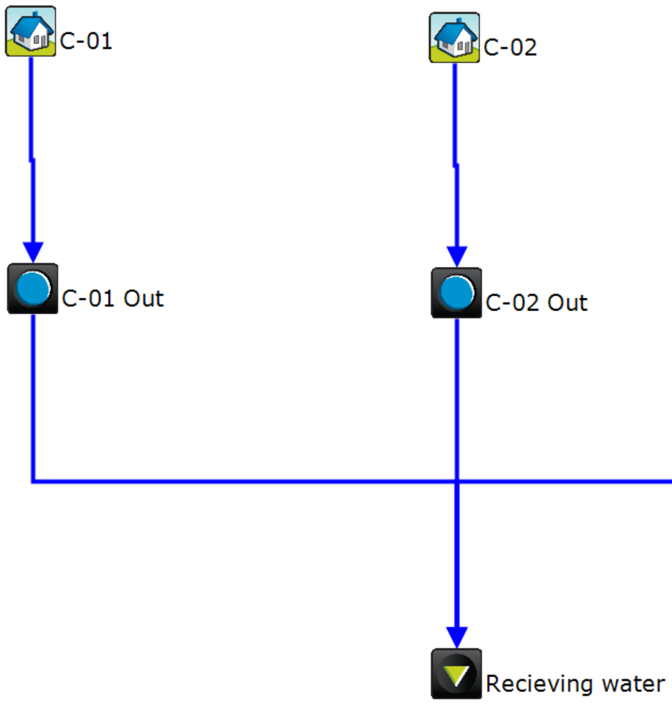


Figure 4-3 Pre-developed assessment MUSIC layout

The pre-developed assessment finds that the runoff from all three catchments results in the pollutant concentrations summarised in Table 4-6.

Table 4-6 Pre-developed assessment results

Pollutant	Pre-developed case concentration (kg/yr)
Total Suspended Solids	8336.387
Total Phosphorus	14.121
Total Nitrogen	107.374
Gross Pollutants	1440.513

4.3 POST-DEVELOPED ASSESSMENT

The MUSIC model post-developed scenario layout is shown as Figure 4-4.

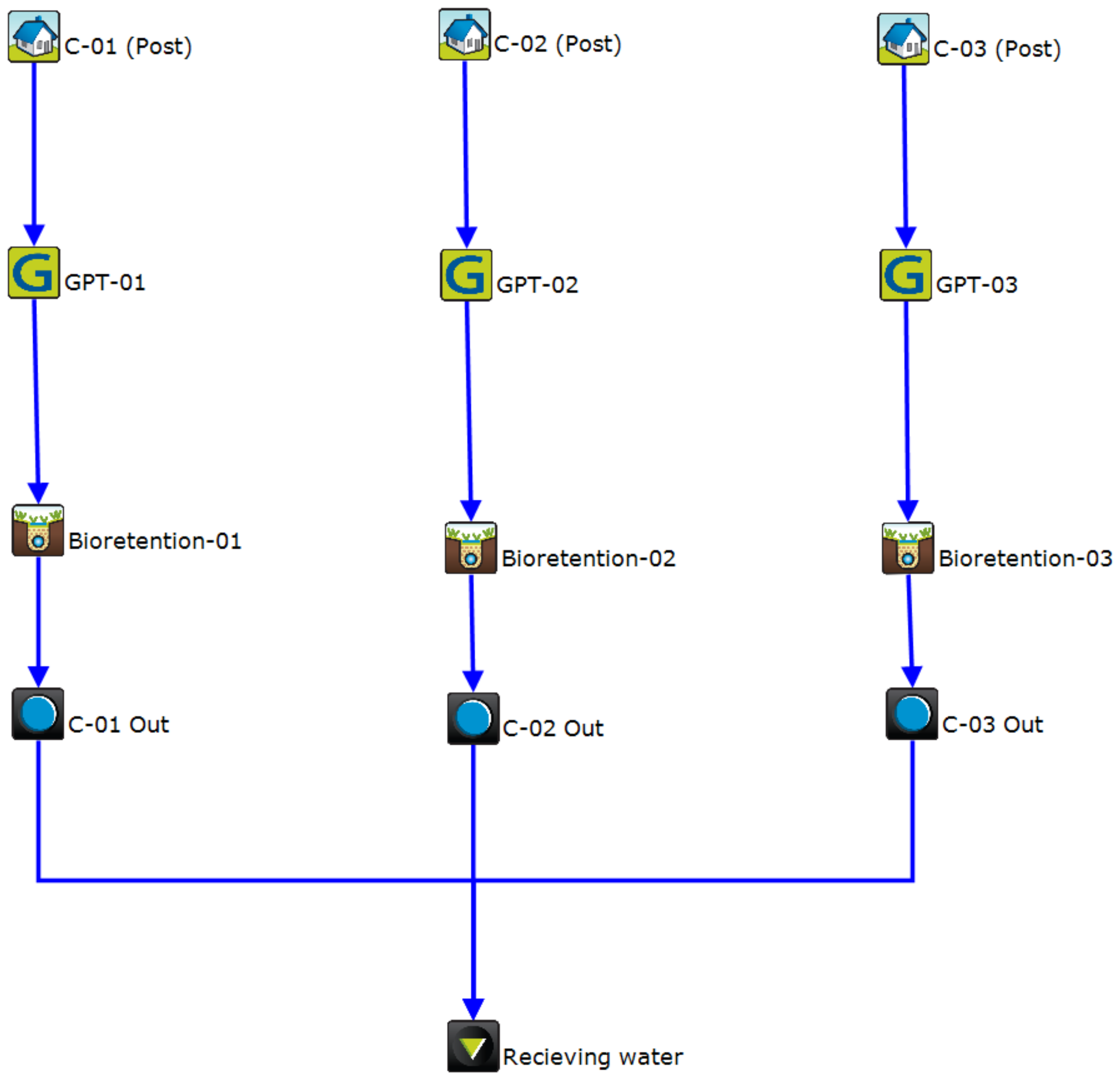


Figure 4-4 Post-developed scenario MUSIC layout

The post-developed case assessment finds that, with no treatment, the development results in an increased concentration of between 13-16% for all pollutants.

Pollutant	Pre-developed case concentration (kg/yr)	Post-developed case (no treatment) concentration (kg/yr)	Concentration compared to pre-developed case (increased %)
Total Suspended Solids	8336.387	9705.712	16%
Total Phosphorus	14.121	16.248	15%
Total Nitrogen	107.374	121.771	13%
Gross Pollutants	1440.513	1652.971	15%

A GPT and bioretention units were modelled for each catchment to treat runoff. The details of bioretention units designed for each catchment is summarised in Table 4-7.

Table 4-7 Bioretention treatment detail for each catchment

Catchment	Bioretention filter area (m^2)	Basin depth (m)	Basin area (m^2)
C-01	120	0.3	212
C-02	300	0.3	438
C-03	40	0.3	98

The bioretention units have been modelled as basins to demonstrate the level of treatment required. It is considered feasible that the relatively small area of each basin will be achievable within the open space areas proposed for the development. However, it is noted that other treatment trains / devices such as bioretention swales would be able to achieve similar removal rates.

A concept plan of the proposed bioretention areas is shown as Figure 4-5. It is considered reasonable that the future development would be able to fit these locations within the site and achieve required pollutant removal targets.

Figure 4-5 WSUD concept plan

The treatment devices pollutant removal rates are summarised in Table 4-8 (results for all catchments), Table 4-9 (results for C-01), Table 4-10 (results for C-02), and Table 4-11 (results for C-03).

Table 4-8 Pollutant reduction for all catchments

Pollutant	Post-developed case (no treatment) concentration (kg/yr)	Post-developed case (with treatment) concentration (kg/yr)	Pollutant reduction (%)
Total Suspended Solids	9705.712	1858.886	80.85
Total Phosphorus	16.248	5.005	69.20
Total Nitrogen	121.771	53.713	55.89
Gross Pollutants	1652.971	3.591	99.78

The pollutant reductions were also assessed on a catchment per catchment basis.

Table 4-9 Pollutant reductions for catchment C-01

Pollutant (C-01)	Post-developed case (no treatment) concentration (kg/yr)	Post-developed case (with treatment) concentration (kg/yr)	Pollutant reduction (%)
Total Suspended Solids	2794.631	523.798	81.257
Total Phosphorus	4.700	1.399	70.228
Total Nitrogen	34.954	15.229	56.433
Gross Pollutants	472.836	1.084	99.771

Table 4-10 Pollutant reductions for catchment C-02

Pollutant (C-02)	Post-developed case (no treatment) concentration (kg/yr)	Post-developed case (with treatment) concentration (kg/yr)	Pollutant reduction (%)
Total Suspended Solids	6195.193	1138.274	81.626
Total Phosphorus	10.427	3.039	70.857
Total Nitrogen	78.346	32.773	58.169
Gross Pollutants	1063.268	2.505	99.764

Table 4-11 Pollutant reductions for catchment C-03

Pollutant (C-03	Post-developed case (no treatment) concentration (kg/yr)	Post-developed case (with treatment) concentration (kg/yr)	Pollutant reduction (%)
Total Suspended Solids	662.384	87.546	86.783

Pollutant (C-03	Post-developed case (no treatment) concentration (kg/yr)	Post-developed case (with treatment) concentration (kg/yr)	Pollutant reduction (%)
Total Phosphorus	1.172	0.272	76.834
Total Nitrogen	8.599	3.011	64.983
Gross Pollutants	116.868	0.001	99.999

4.4 WATER QUALITY REQUIREMENTS

The future development would need to achieve the WSUD stormwater quality performance target reduction for each pollutant as detailed in Table 4-12. The pollutant reduction targets are for multi-dwelling housing development and mixed use development and are required as per Chapter E15: Water Sensitive Urban Design of the DCP.

Table 4-12 Pollutant reduction targets for development (Wollongong City Council, 2009)

Pollutant	Reduction target (%)
Gross pollutants	90
Total suspended solids	80
Total phosphorus	55
Total nitrogen	40

It is shown in Table 4-8 (results for all catchments), Table 4-9 (results for C-01), Table 4-10 (results for C-02), and Table 4-11 (results for C-03) that the proposed development will be able to achieve the reduction targets with the concept WSUD strategy proposed in this report.

5.0 RIPARIAN CORRIDOR

5.1 RIPARIAN CORRIDOR ZONE METHODOLOGY

The riparian corridor zone (RCZ) is an area offset from the top of bank of the watercourse channel associated with the riparian zone. The general purpose RCZ is to avoid impact to the hydraulic function, stability, and ecological values of riparian land. The offsets required for the RCZ are defined in Chapter E23 (Riparian Land Management) of the DCP (Council RCZ) and the guidance *Controlled activities – Guidelines for riparian corridors on waterfront land* (NSW Department of Planning and Environment, 2022) (DPE RCZ).

The DPE RCZ is based on state-wide guidance which recommends an offset based on the Strahler order of the watercourse. Whereas the Council RCZ is based on local guidance which recommends an offset based on the category of the riparian corridor informed by the riparian management study. The Council RCZ offsets are summarised in Table 5-1 and the DPE RCZ offsets are summarised as Table 5-3.

Table 5-1 Council RCZ minimum width requirements

Category	Category definition	RCZ minimum width requirement
1	Environmental corridor	50 metres offset either side of the channel width
2	Terrestrial and aquatic habitat	30 metres offset either side of the channel width
3	Bank stability and water quality	10 metres offset either side of the channel width

The objectives associated the waterway categories are also provided in Table 5-2.

Table 5-2 Watercourse category riparian corridor objectives

Watercourse Category	Riparian Corridor Objectives
Category 1 – Environmental Corridor	• Maximise the protection of terrestrial and aquatic habitat; • Maintain a continuous riparian corridor to provide linkages between stands of remnant vegetation for the movement of terrestrial and aquatic fauna; • Maintain the viability of native riparian vegetation; • Minimise ‘edge effects’ at the riparian corridor / urban interface by the provision of a suitable riparian corridor width; • Maintain adequate riparian corridor width, based on geomorphological and environmental considerations and to maintain or improve bank stability; • Protect water quality of the watercourse through an adequate riparian corridor width; • Restore the vegetation, geomorphic structure, hydrology and water quality of the riparian corridor to its original (preEuropean) state, where practicable; • Locate infrastructure or utility services (i.e. electricity, water, sewerage etc) outside the riparian corridor, wherever practicable; • Maintain the riparian connectivity by the use of piered crossings in preference to pipes or culverts; • Minimise the impact of walkways, cycle ways and general access points by using ecologically informed design principles; • Restrict the encroachment of flood compatible development (e.g. playing fields) to the edge of the riparian corridor; • Treat stormwater run-off outside the riparian corridor before discharge into the watercourse.
Category 2 – Terrestrial and Aquatic Habitat	• Maintain/restore the natural functions of watercourses; • Maintain the viability of native riparian vegetation; • Minimise ‘edge effects’ at the riparian corridor / urban interface by the provision of a suitable riparian corridor width; • Maintain adequate riparian corridor width, based on geomorphological and environmental considerations and to maintain or improve bank stability; • Protect water quality of the watercourse through an adequate riparian corridor width; • Restore the vegetation, geomorphic structure, hydrology and water quality of the riparian corridor to its original (preEuropean) state, where practicable; • Minimise the number of road crossings and such crossings are designed to maintain riparian connectivity; • Restrict the encroachment of flood compatible development (e.g. playing fields) to the edge of the riparian corridor rather than within the core riparian zone; • Locate infrastructure or utility services (i.e. electricity, water, sewerage etc) outside the riparian corridor, wherever practicable; • Treat stormwater run-off outside the riparian corridor before discharge into the watercourse.
Category 3 – Bank Stability and Water Quality	• Minimise sedimentation and nutrient transfer; • Provide bank stability; • Protect water quality; • Protect riparian vegetation, wherever possible; • Emulate a naturally functioning stream with a suitable riparian corridor width; • Provide suitable vegetated habitat refuges for terrestrial and aquatic fauna, wherever possible; • Treat stormwater run-off outside the riparian corridor before discharge into the riparian zone, wherever possible.

Table 5-3 DPE RCZ minimum width requirements

Strahler order	RCZ minimum width requirements
1st	10 metres offset either side of the channel width
2nd	20 metres offset either side of the channel width
3rd	30 metres offset either side of the channel width
4th and greater	40 metres offset either side of the channel width

The DPE RCZ, Council RCZ and riparian category categories for the south watercourse are shown as Figure 5-1. The extent of the channel is based on top of bank which was derived using LiDAR and aerial imagery, it is recommended that this channel extent is confirmed through on-site survey to confirm the riparian corridor zones.

This document has been prepared based on information provided by others as cited in the data sources. Stantec has not verified the accuracy and/or completeness of this information and shall not be responsible for any errors or omissions which may be incorporated herein as a result. Stantec assumes no responsibility for data supplied in electronic format, and the recipient accepts full responsibility for verifying the accuracy and completeness of the data.

Figure 5-1 Riparian corridor zones

5.2 PRE-DEVELOPED ASSESSMENT

The existing riparian corridor is identified to be category 2 (Terrestrial and Aquatic Habitat) corridor where it runs through Spearing Reserve. The eastern section of the corridor, where it runs between the backyards of existing houses, is identified to be category 3 (Bank Stability and Water Quality) riparian corridor. The watercourse associated with the corridor is an unnamed first order tributary of Fairy Creek.

A field survey of the site was undertaken by qualified ecologists on 19 May 2023. The survey identified the riparian corridor vegetation is commensurate with Illawarra Escarpment Bangalay x Blue Gum Wet Forest (Plant community type (PCT) 3153). PCT 3153 is a tall open sclerophyll forest which occurs at low to mid elevation on the Illawarra coastal plain and Illawarra escarpment.

The canopy within this area is dominated by *Eucalyptus saligna x botroides.* The mid storey includes multiple *Melaleuca* species (*M. styphloides, M. quinquenerva and M. linearfolia), Pittosporum undulatum* and *Casuarina glauca*, as shown in Figure 5-2. The ground cover was predominately exotic, including *Lantana camara, Tradescantia fluminensis* and *Bidens Pilosa*.

Figure 5-2 PCT 3153 Illawarra Escarpment Bangalay x Blue Gum Wet Forest.

The extent of PCT 3153 is shown mapped as Figure 5-3.

Figure 5-3 Groundtruthed vegetation

PCT 3153 was identified along most of the riparian corridor, except for the corridor east of the pedestrian path through Spearing Reserve – this vegetation was identified to be planted natives including *Ficus macrophylla*.

Figure 5-4 Planted natives (*Ficus macrophylla*) in Spearing Reserve

The existing riparian corridor is considered to be mildly disturbed, it is piped either side of the site through a single 1.35m diameter culvert just east of Spearing Reserve (Figure 5-5) and a triple 1.35 diameter culvert arrangement underneath Irvine Street (Figure 5-6). The existing houses adjacent to the corridor back onto the corridor zone rather than fronting on to it, which does not provide passive surveillance of the zone. Illegal dumping within the corridor was observed during site surveys (Motorbike found in the corridor is shown as Figure 5-7).

Existing houses have been constructed within the Council RCZ which may indicate that the channel extent adopted in this study and resulting Council RCZ is conservative.

Figure 5-5 Culvert upstream of the unnamed watercourse (east of Spearing reserve, looking west)

Figure 5-6 Culverts downstream of unnamed watercourse (west of Irvine Street, looking east)

Figure 5-7 Motorbike found disposed in the riparian corridor zone

5.3 POST-DEVELOPED ASSESSMENT

The indicative proposed building footprints are located entirely out of the identified DPE RCZ and are mostly located out of the Council RCZ. However, a portion of one building footprint proposed on Murphys Avenue is in the Council RCZ.

The potential impact of this building on the existing RCZ is likely low considering that the building footprint would be located almost entirely within an area already disturbed by the footprint of existing houses (14 and 12 Murphys Avenue).

The proposed development also provides an opportunity to improve the existing condition of the riparian corridor zone and may provide additional riparian zone / more suitable land uses in the area between the watercourse and Spearing Parade. The proposed development would also avoid clearing the riparian vegetation (PCT 3153), and indirect impacts to the riparian corridor and vegetation would be further considered prior to construction works commencing.

5.4 RIPARIAN CORRIDOR ZONE REQUIREMENTS

Clause 10.2.5 of Chapter E23 of the DCP specifies that no development other than environmental management works is to take place within the applicable minimum total riparian corridor width.

Clause 10.2.6 of Chapter E23 of the DCP notes that any variation to the minimum widths of the Council RCZ is to be addressed as a variation to a DCP control. At a minimum the impact to the flood function of the riparian corridor and consideration of reasonable alternative design options are to be considered when preparing the variation. Approved environmental / biodiversity compensation would also be required in the development site.

Given that only a minor portion of the development site is in the Council RCZ, the following is recommended:

- Survey of the watercourse should be undertaken to confirm top of bank, and the RCZ is updated based on surveyed top of bank
- The Council RCZ should be confirmed with Council, noting that existing development such as buildings and fences already encroach further into the Council RCZ than the proposed development.

6.0 CONCLUSION

6.1 FLOOD IMPACT ASSESSMENT

The project site is mostly elevated above existing flood levels. There are existing flood extents associated with historical drainage lines to the north and south of the site. The southern drainage line is associated with the Spearing Reserve watercourse, is the primary conveyer of flood waters across the site and is identified to function as a floodway. The remainder of flood extents across the site are identified to be mostly flood fringe with some localised areas of flood storage in the south-western and south-eastern corner of the site.

The development reduces the extent of flooding across the site and reduces area of medium flood risk precinct. During the 1%AEP event the flood level increases as a result of the development are below 45mm and are entirely contained within the site.

During the PMF event the site results in a 62mm maximum increase of flood levels at the intersection of Madoline Street / Irvine Street. The intersection is already inundated in the pre-developed case, and the flood level increase does not result in changes to the overall hazard category of the road.

6.2 FLOOD RISK ASSESSMENT

The site is mostly flood free, and flood extents across the site are primarily in a medium flood risk precinct (FRP). There are localised areas of high FRP in the south-western corner of the site and within the riparian corridor of the Spearing Reserve watercourse. The proposed development overall reduces the extent of flood risk area by creating additional flood free areas across the site. However, the proposed development would result in additional dwellings and people in this part of the catchment, which has existing flood evacuation constraints.

The site is isolated by flood during the PMF event, however the site is a high flood island and is not inundated during the 1%AEP or PMF event, so a shelter in place strategy is considered suitable in the short-term. In addition, the isolation period is less than 6 hours and therefore a shelter in place strategy is considered appropriate in accordance with the *Draft Shelter-in-place Guideline* (Department of Planning and Environment, 2023).

6.3 STORMWATER ASSESSMENT

The stormwater across the site is in mostly good condition and at a high level appears to be a working solution (i.e., no trapped low points identified across site). There are a small number of pits and outlets in various states of disrepair. It is recommended that this infrastructure is repaired / maintained in coordination with Council.

The proposed development would not result in increased peak flowrates, and on-site detention is provided as rainwater collection tanks. Alternative on-site detention solutions could also be considered in further design stages and/or in consultation with Council.

6.4 WATER QUALITY ASSESSMENT

The project site is an existing urban catchment without water sensitive urban design elements incorporated. The proposed development will only result in a 9% increase to the effective impervious area of the site and an approximate 15% resultant increase to expected concentrations of total suspended solids, nitrogen and phosphorus.

The implementation of three bio-basins with gross pollutant trap arrangements have been modelled in MUSIC software and are found to achieve the required pollutant removal targets stipulated in the Council DCP. The total area required for treatment devices is approximately 600m^2, which is readily achievable for the site as shown in the concept WSUD plan in section 4.0.

6.5 RIPARIAN CORRIDOR ASSESSMENT

The Council and DPE riparian corridor zones associated with the Spearing Reserve watercourse were estimated applying Chapter E23 of the Council DCP and the *Controlled activities – Guidelines for riparian corridors on waterfront land* (NSW Department of Planning and Environment, 2022) respectively.

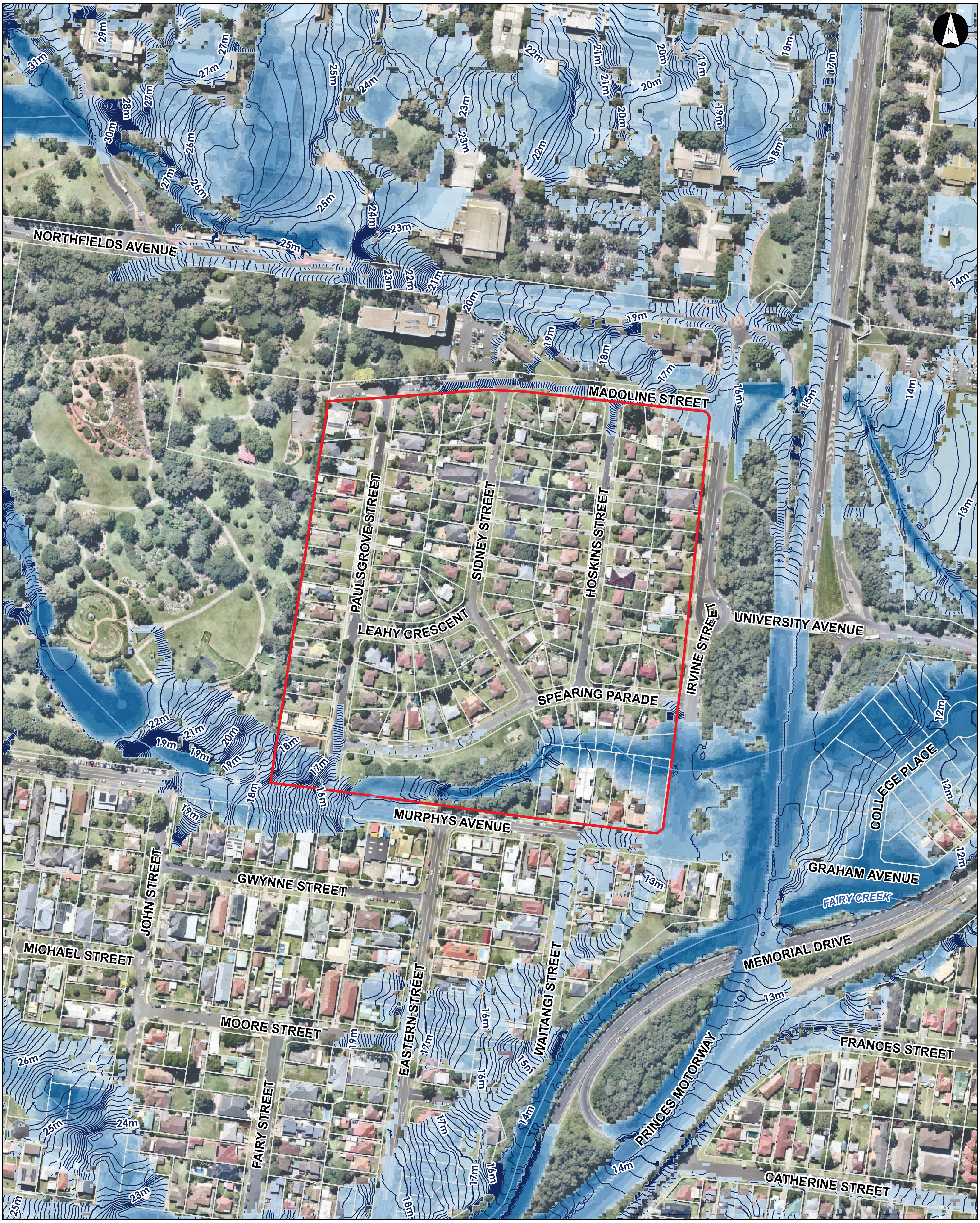
A small portion of the proposed development would encroach into the Council riparian corridor zone only. However, the top of bank used in the assessment was an estimate only, and not based on survey information. In addition, the riparian corridor zone encroached upon by the development has already been subject to existing development associated with existing buildings and fence lines. Potential impact to the riparian corridor is overall considered to be acceptable but should be further considered in subsequent design stages of the development and consultation with Council.

6.6 SUMMARY

In summary, this assessment finds that the proposed development:

- Will not significantly increase existing flood extents
- Will not increase the existing flood risk of the area
- Results in an overall improvement to existing water quality of stormwater runoff
- Will not increase peak flowrate of stormwater runoff
- Will not significantly impact riparian corridor zones.

Appendix A: Flood model results



Existing 1% AEP Flood Extents

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: LAHC
Project Code: 304000956-GS-006
Drawn By: JE, Checked By: JL
Rev: 01
Date: 2023-09-07

Stantec

Legend

Study Area
Watercourse
Cadastre

Flood Height Contour

1m Index Contour
0.1m Contour

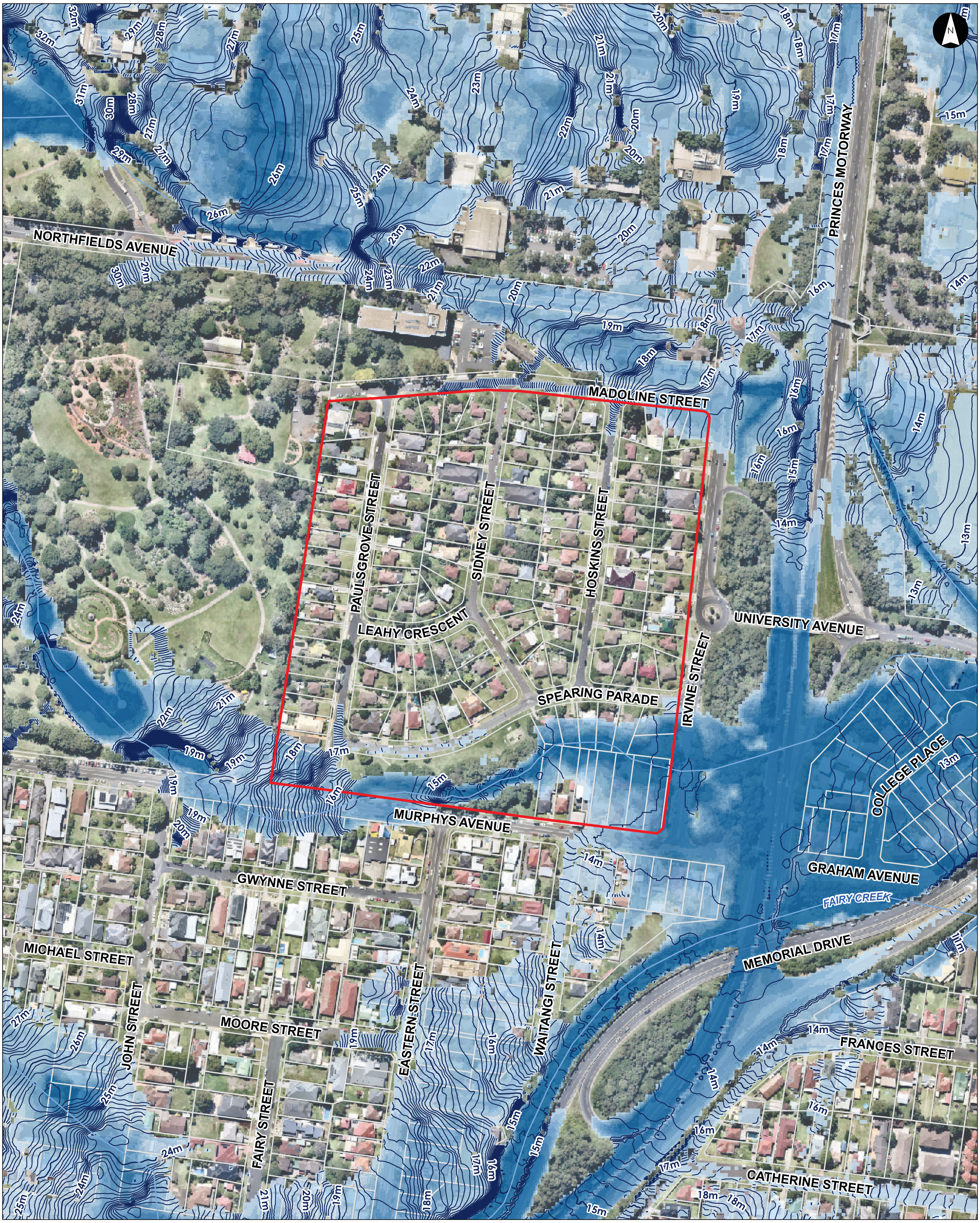
Flood depth (m)

0.00 to 0.25
0.25 to 0.50
0.50 to 0.75
0.75 to 1.00
1.00 to 1.25
1.25 to 1.50
> 1.50

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)

0 25 50 75 100 125 Metres
Scale at A3: 1:3,000



Existing PMF Flood Extents

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: LAHC
Project Code: 304000956-GS-006
Drawn By: JE, Checked By: JL
Rev: 01
Date: 2023-09-07

Stantec

Legend

- Study Area
- Watercourse
- Cadastre

Flood Height Contour

- 1m Index Contour
- 0.1m Contour

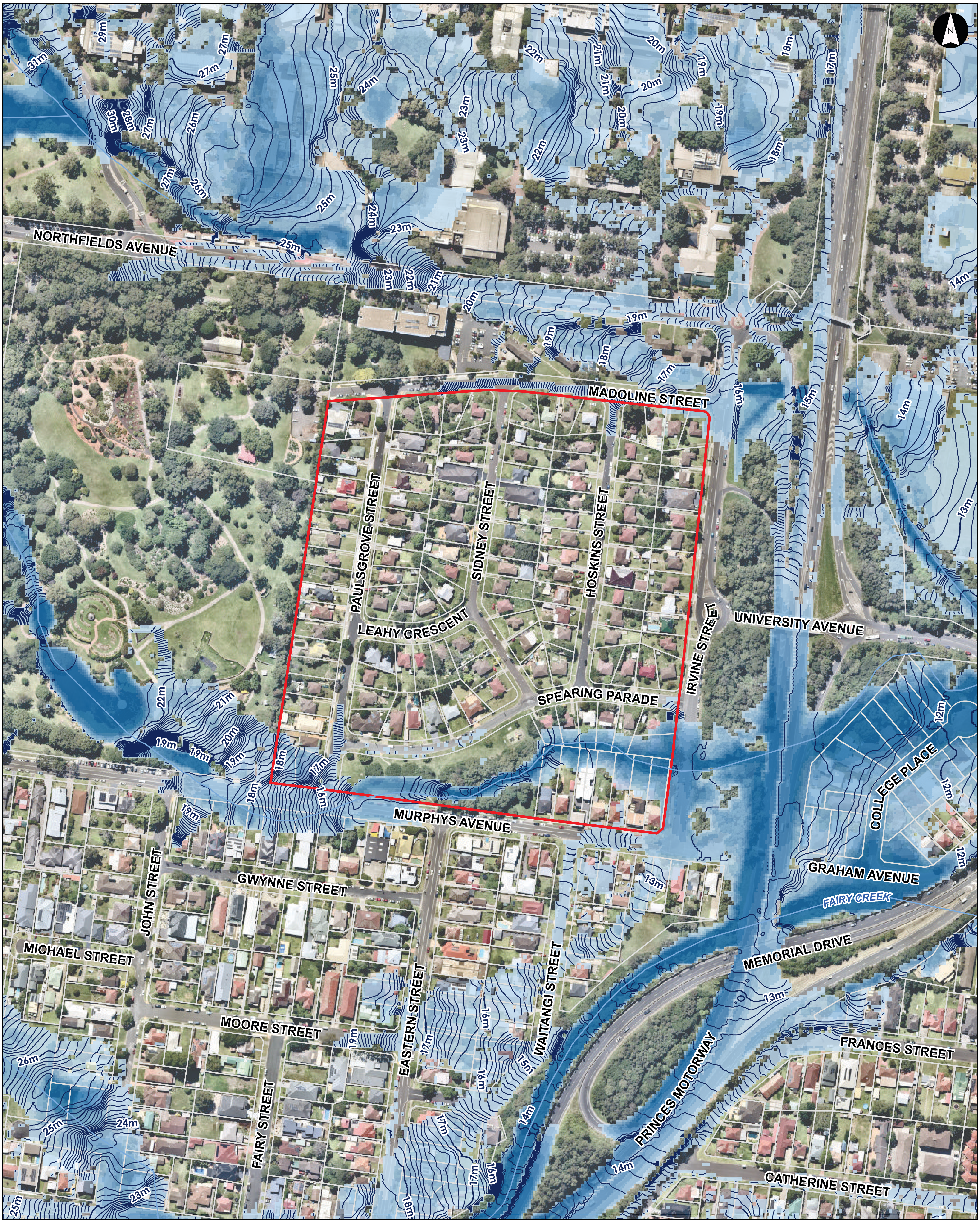
Flood depth (m)

- 0.00 to 0.25
- 0.25 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 1.25
- 1.25 to 1.50
- > 1.50

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)

0 25 50 75 100 125 Metres
Scale at A3: 1:3,000



Proposed 1% AEP Flood Extents

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: LAHC
Project Code: 304000956-GS-006
Drawn By: JE, Checked By: JL
Rev: 01
Date: 2023-09-07

Stantec

Legend

- Study Area
- Watercourse
- Cadastre

Flood Height Contour

- 1m Index Contour
- 0.1m Contour

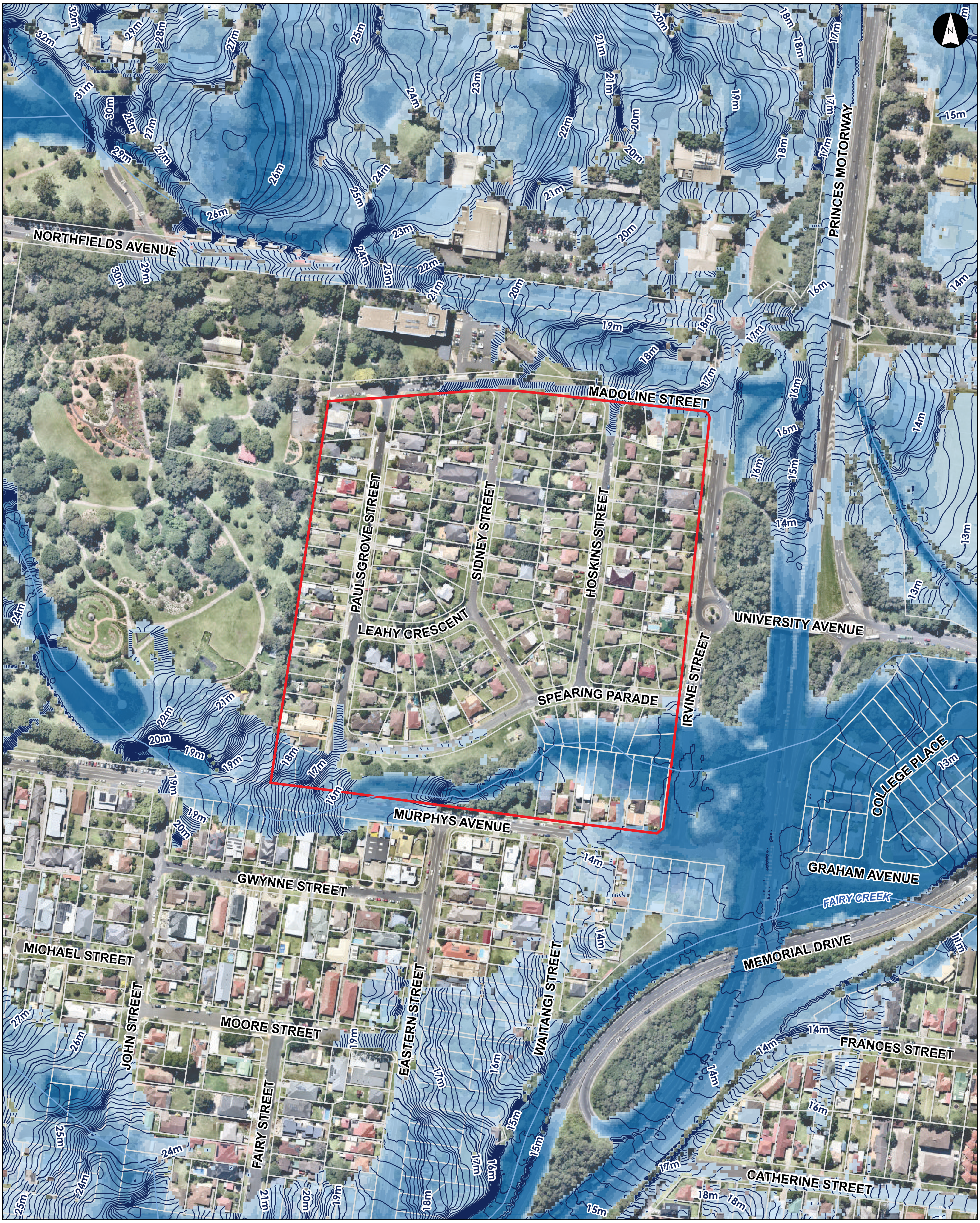
Flood depth (m)

- 0.00 to 0.25
- 0.25 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 1.25
- 1.25 to 1.50
- > 1.50

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)

0 25 50 75 100 125 Metres
Scale at A3: 1:3,000



Proposed PMF Flood Extents

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: LAHC
Project Code: 304000956-GS-006
Drawn By: JE, Checked By: JL
Rev: 01
Date: 2023-09-07

Stantec

Legend

- Study Area
- Watercourse
- Cadastre

Flood Height Contour

- 1m Index Contour
- 0.1m Contour

Flood depth (m)

- 0.00 to 0.25
- 0.25 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 1.25
- 1.25 to 1.50
- > 1.50

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)

0 25 50 75 100 125 Metres
Scale at A3: 1:3,000

Existing 1% AEP Flood Velocity

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: LAHC
Project Code: 304000956-GS-007
Drawn By: JE, Checked By: JL
Rev: 01
Date: 2023-09-06

Legend

- Study Area
- Watercourse
- Cadastre

Flood velocity (m/s)

- 0 - 1
- 1 - 2
- 2 - 3
- >3

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)

0 25 50 75 100 125 Metres
Scale at A3: 1:3,000

Stantec

Existing PMF Flood Velocity

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: LAHC
Project Code: 304000956-GS-007
Drawn By: JE, Checked By: JL
Rev: 01
Date: 2023-09-06

Stantec

Legend

- Study Area
- Cadastre
- Watercourse

Flood velocity (m/s)

- 0 - 1
- 1 - 2
- 2 - 3
- >3

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)

0 25 50 75 100 125 Metres

Scale at A3: 1:3,000

Proposed 1% AEP Flood Velocity

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: LAHC
Project Code: 304000956-GS-007
Drawn By: JE, Checked By: JL
Rev: 01
Date: 2023-09-06

Stantec

Legend

- Study Area
- Watercourse
- Cadastre

Flood velocity (m/s)

- 0 - 1
- 1 - 2
- 2 - 3
- >3

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)

0 25 50 75 100 125 Metres
Scale at A3: 1:3,000

Proposed PMF Flood Velocity

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: LAHC
Project Code: 304000956-GS-007
Drawn By: JE, Checked By: JL
Rev: 01
Date: 2023-09-06

Stantec

Legend

- Study Area
- Watercourse
- Cadastre

Flood velocity (m/s)

- 0 - 1
- 1 - 2
- 2 - 3
- >3

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)

0 25 50 75 100 125 Metres
Scale at A3: 1:3,000

Existing 1% AEP Flood Hazard

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: LAHC
Project Code: 304000956-GS-008
Drawn By: JE, Checked By: JL
Rev: 01
Date: 2023-09-06

Stantec

Legend

- Study Area
- Watercourse
- Cadastre

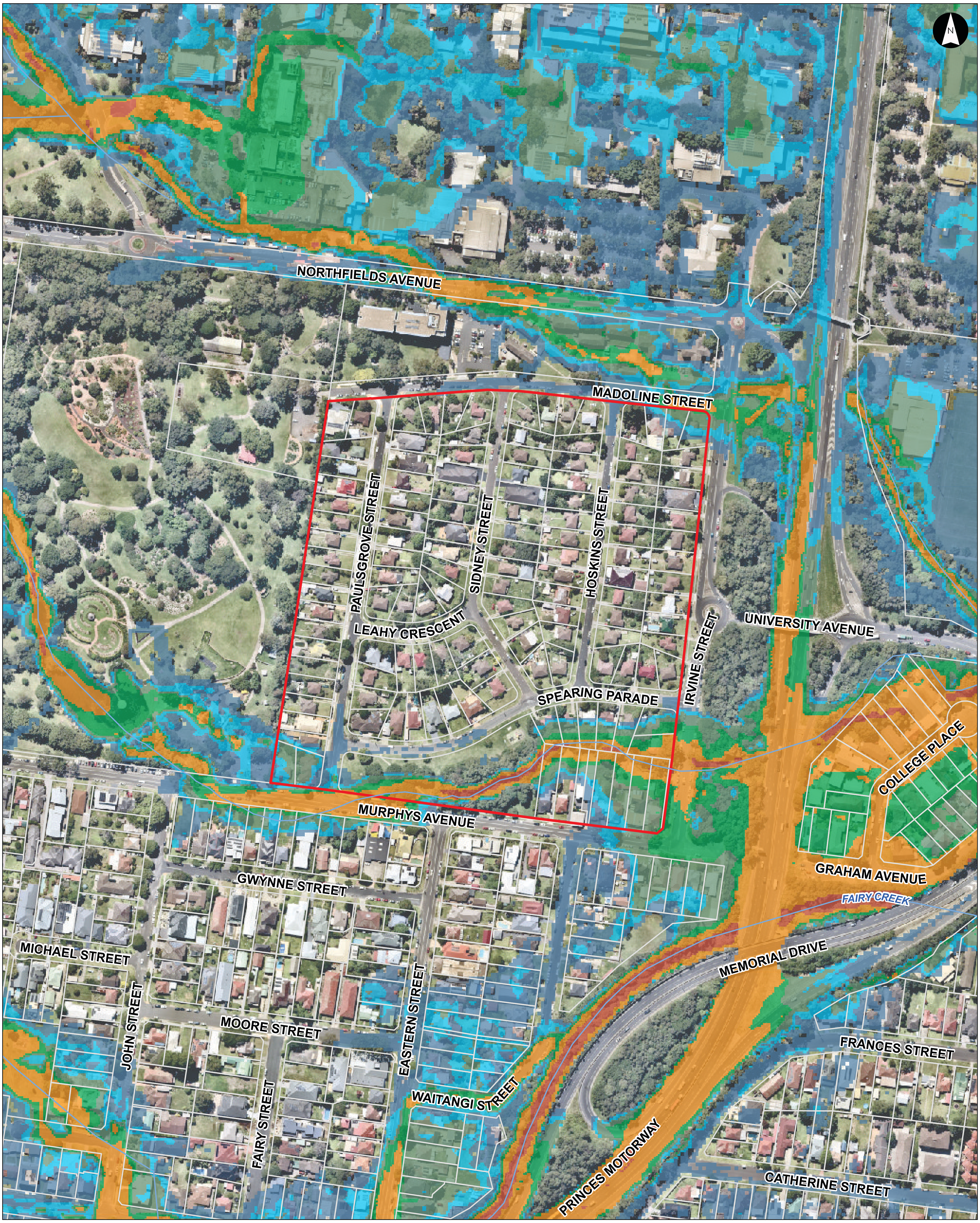
Flood hazard

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

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)

0 25 50 75 100 125 Metres
Scale at A3: 1:3,000



Existing PMF Flood Hazard

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: LAHC
Project Code: 304000956-GS-008
Drawn By: JE, Checked By: JL
Rev: 01
Date: 2023-09-06

Legend

- Study Area
- Watercourse
- Cadastre

Flood hazard

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

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)

0 25 50 75 100 125 Metres
Scale at A3: 1:3,000

Stantec

Proposed 1% AEP Flood Hazard

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: LAHC
Project Code: 304000956-GS-008
Drawn By: JE, Checked By: JL
Rev: 01
Date: 2023-09-06

Stantec

Legend

- Study Area
- Watercourse
- Cadastre

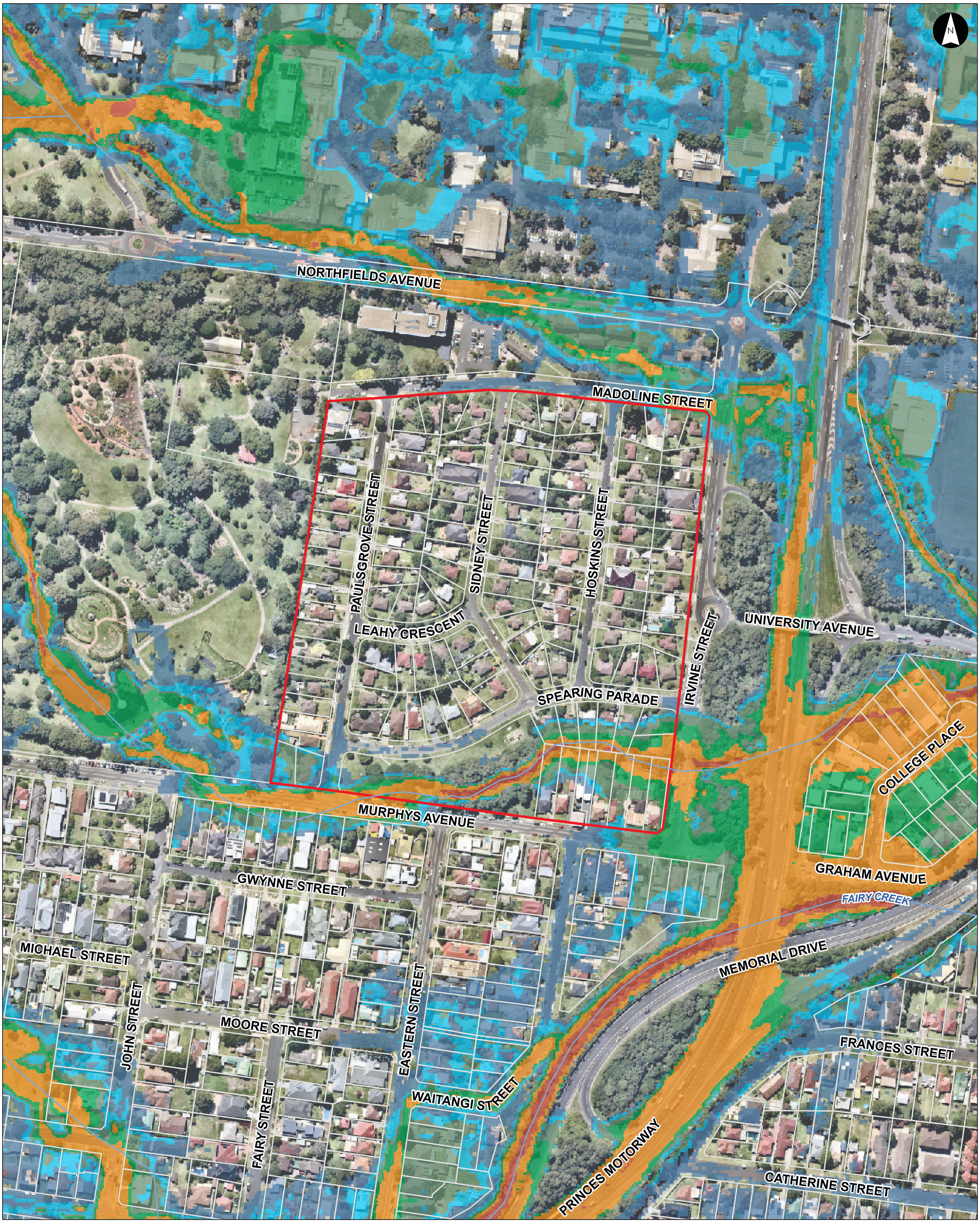
Flood hazard

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

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)

0 25 50 75 100 125 Metres
Scale at A3: 1:3,000



Proposed PMF Flood Hazard

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: LAHC
Project Code: 304000956-GS-008
Drawn By: JE, Checked By: JL
Rev: 01
Date: 2023-09-06

Stantec

Legend

- Study Area
- Watercourse
- Cadastre

Flood hazard

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

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)

0 25 50 75 100 125 Metres

Scale at A3: 1:3,000

1% AEP Flood Impacts

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: LAHC
Project Code: 304000956-GS-009
Drawn By: JE, Checked By: JL
Rev: 01
Date: 2023-09-06

Stantec

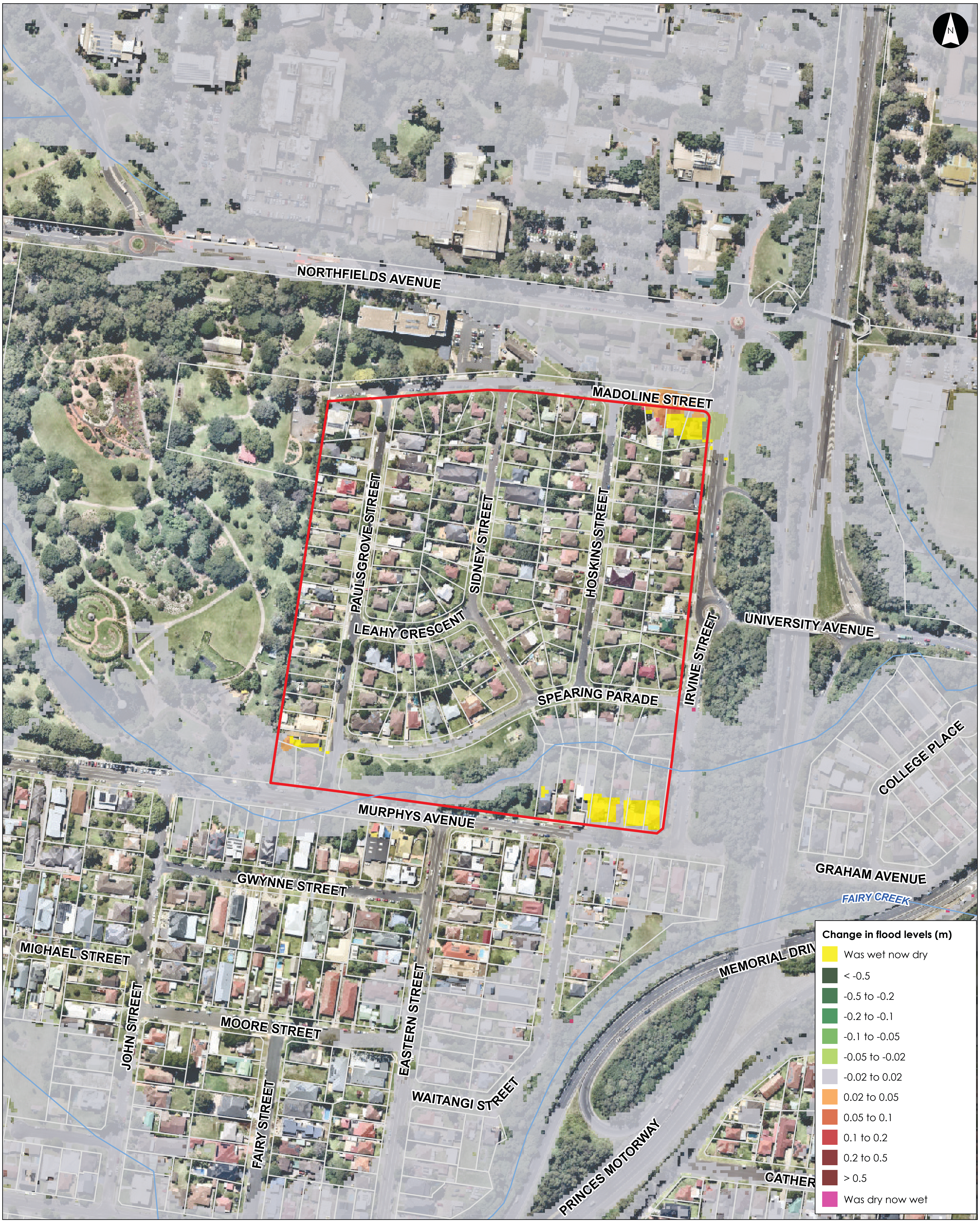
Legend

- Study Area
- Watercourse
- Cadastre

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)

0 25 50 75 100 125 Metres
Scale at A3: 1:3,000



PMF Flood Impacts

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: LAHC
Project Code: 304000956-GS-009
Drawn By: JE, Checked By: JL
Rev: 01
Date: 2023-09-06

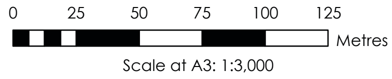
Stantec

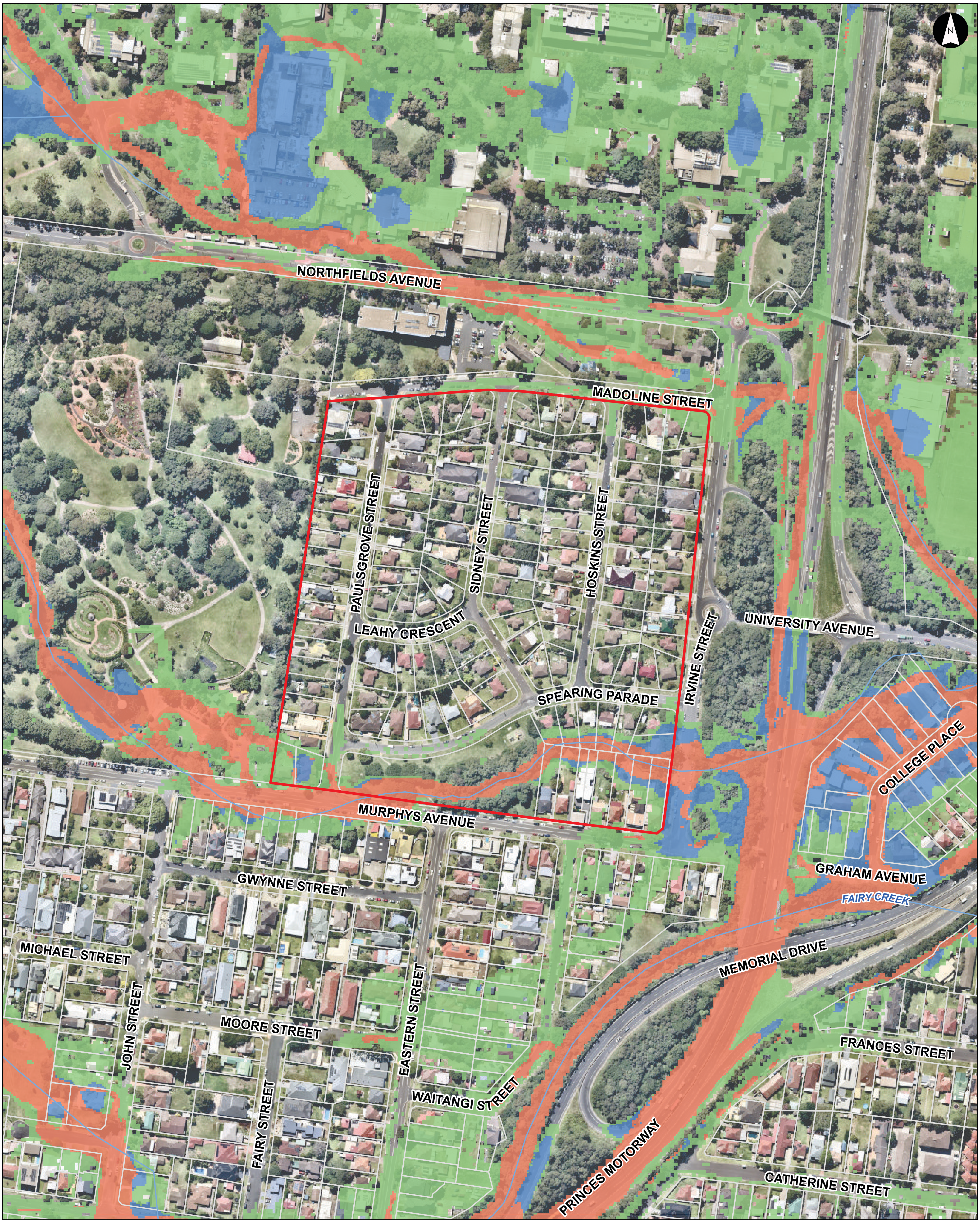
Legend

- Study Area
- Watercourse
- Cadastre

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)





Existing Hydraulic Category for 1% AEP

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: LAHC
Project Code: 304000956-GS-010
Drawn By: JE, Checked By: JL
Rev: 01
Date: 2023-09-07

Stantec

Legend

- Study Area
- Watercourse
- Cadastre

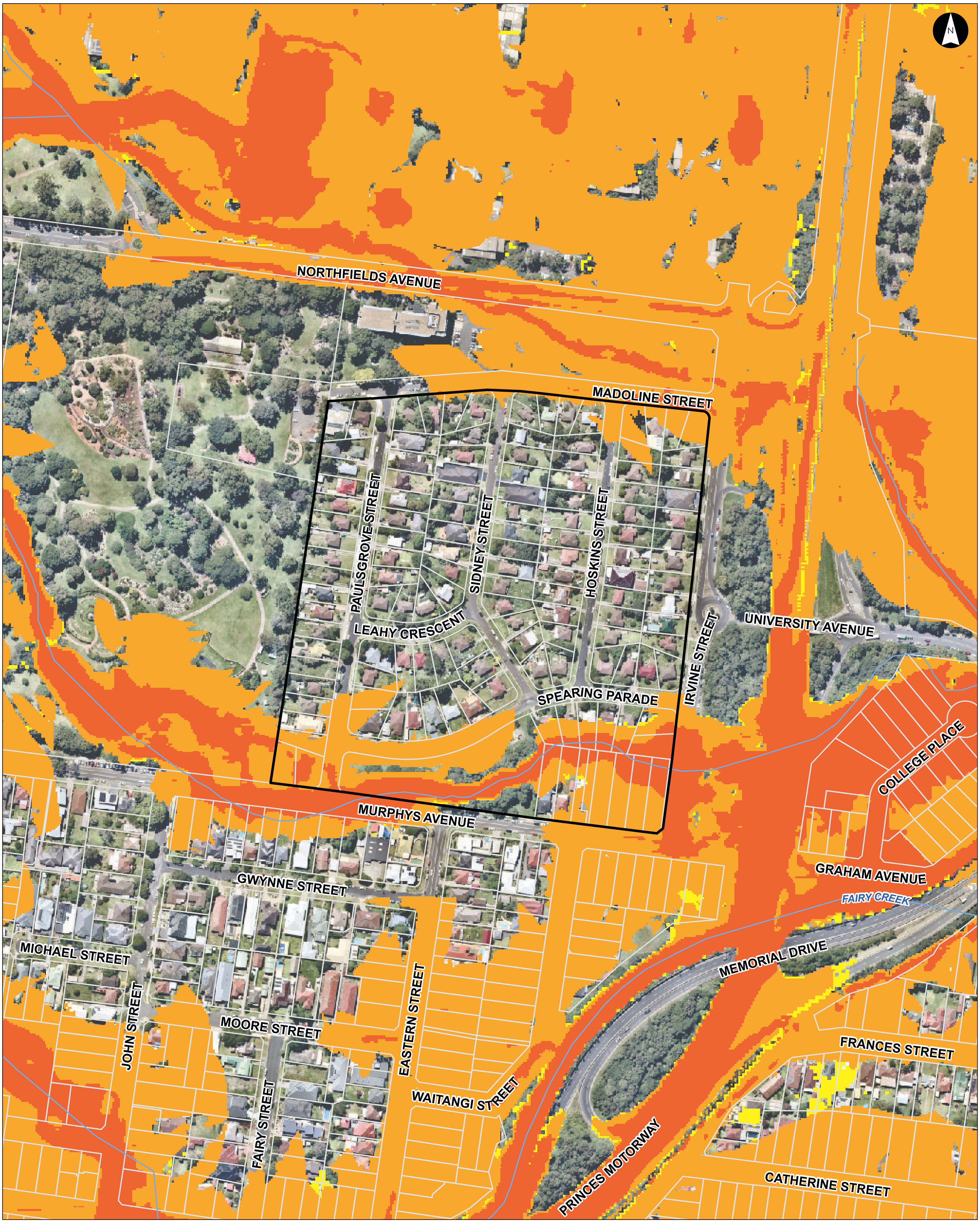
Hydraulic Category

- Flood fringe
- Flood Storage
- Floodway

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)

0 25 50 75 100 125 Metres
Scale at A3: 1:3,000



Existing Flood Risk Precinct

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: LAHC
Project Code: 304000956-GS-010
Drawn By: JE, Checked By: JL
Rev: 01
Date: 2023-09-07

Stantec

Legend

Study Area
Watercourse
Cadastre

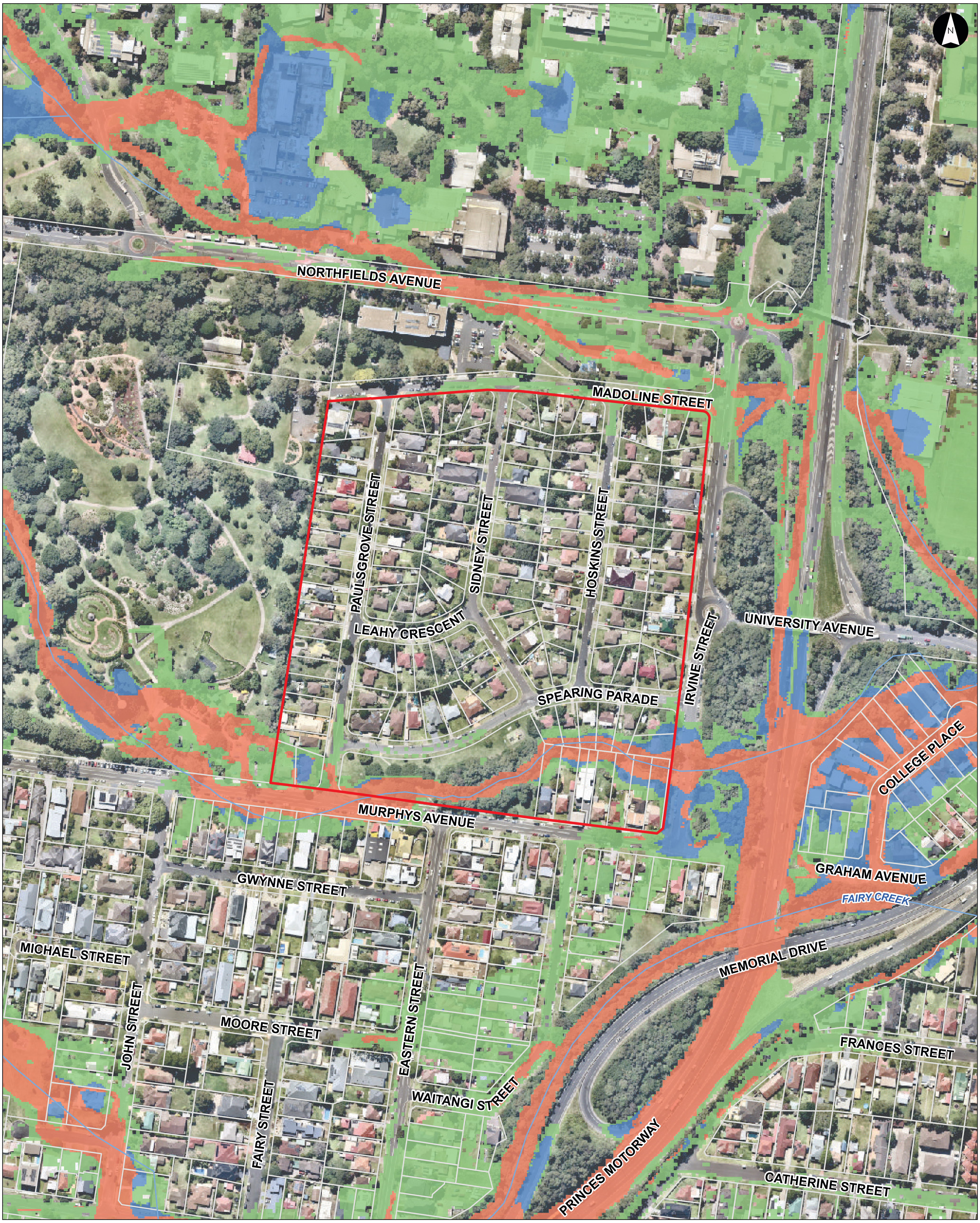
Flood Risk Precinct

Low
Medium
High

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)

0 25 50 75 100 125 Metres
Scale at A3: 1:3,000



Proposed Hydraulic Category for 1% AEP

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: LAHC
Project Code: 304000956-GS-010
Drawn By: JE, Checked By: JL
Rev: 01
Date: 2023-09-07

Stantec

Legend

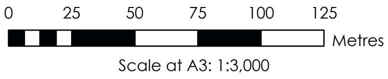
- Study Area
- Watercourse
- Cadastre

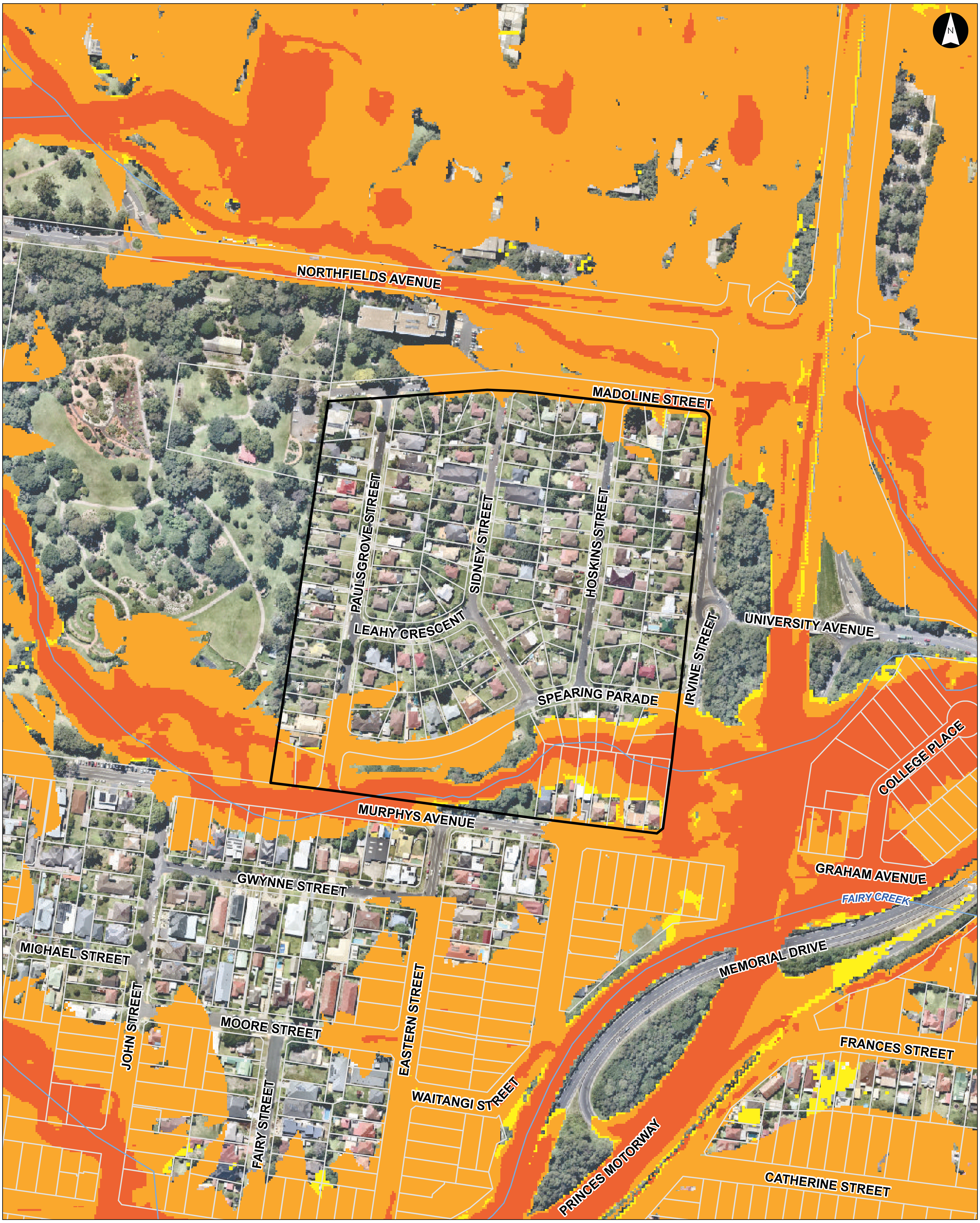
Hydraulic Category

- Flood fringe
- Flood Storage
- Floodway

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)





Proposed Flood Risk Precinct

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: LAHC
Project Code: 304000956-GS-010
Drawn By: JL, Checked By: JL
Rev: 01
Date: 2023-09-07

Stantec

Legend

Study Area
Watercourse
Cadastre

Flood Risk Precinct

Low
Medium
High

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)

0 25 50 75 100 125 Metres
Scale at A3: 1:3,000

Appendix B: Infrastructure condition assessment

Site Inspection Plan

Gwynneville Estate Planning Proposal
Gwynneville, NSW

Client: LAHC
Project Code: 304000956-WA-001
Drawn By: JL. Checked By: JE
Rev: 01
Date: 2023-09-07

Stantec

Legend

Study Area
Watercourse
Cadastre

Infrastructure treatment level

0

Notes:
1. Map displayed in GDA2020 MGA Zone 56

References:
1. Aerial Imagery Nearmap (March, 2023)
2. Cadastre (NSW SS, 2022)
3. Watercourse (NSW SS)

0 20 40 60 80 100 Metres
Scale at A3: 1:2,000

Stantec is a global leader in sustainable engineering, architecture, and environmental consulting. The diverse perspectives of our partners and interested parties drive us to think beyond what's previously been done on critical issues like climate change, digital transformation, and future-proofing our cities and infrastructure. We innovate at the intersection of community, creativity, and client relationships to advance communities everywhere, so that together we can redefine what's possible.

Stantec Australia Pty Ltd
Ground Floor, 16 Burelli Street
Wollongong NSW 2500
AUSTRALIA
ABN 17 007 820 322
stantec.com