



**WATER CYCLE MANAGEMENT STRATEGY
FOR PROPOSED DEVELOPMENT OF**

**CORRIMAL COKEWORKS
STAGE 2-4 Civil Works SSDA
SSD-86131212**

Project No: MKR00452 - 11

VERSION 2



EXECUTIVE SUMMARY

This Water Cycle Management Strategy (WCMS) has been prepared by Maker Consulting Services to accompany a State Significant Development Application (SSDA) which seeks development consent for facilitating civil works and subdivision to support to a concurrent Stage 2a Built Form SSDA (SSD-83789711) and the future redevelopment of Stages 2-4 of the Corrimal Coke Works Precinct. The Civil works proposed by this SSDA include the construction of the Central Park, the Southern Park, and roads, drainage and stormwater infrastructure, and paper subdivision.

This WCMS has been prepared to address the requirements of SEARS matter #11 – Water Management and SEARS matter #19 – Flood Risk.

This civil works SSDA was declared as State Significant Development (SSD) in the State Significant Development Declaration Ministerial Order (No 10) 2025 (dated 30 June 2025) at Clause 5(1)(n) in Schedule 1 (Amendment SSD Declaration Order 2025 (No 5)).



TABLE OF CONTENTS

1	INTRODUCTION.....	5
1.1	Overview.....	5
1.2	Purpose of this report.....	6
1.3	Previous Assessments.....	6
2	SITE AND PROJECT DESCRIPTION	8
3	METHODOLOGY	11
3.1	Flooding.....	11
3.2	On-Site Stormwater Detention	11
3.3	Water Quality and Water Sensitive Urban Design	11
3.3.1	Objectives.....	11
3.3.2	MUSIC Modelling	12
3.3.3	Climate data.....	12
3.3.4	Source nodes.....	13
3.3.5	Treatment nodes	14
4	ASSESSMENT AND FINDINGS.....	15
4.1	Flooding.....	15
4.1.1	Existing Conditions.....	15
4.1.2	Proposed Conditions and Creek Realignment.....	16
4.1.3	Climate Change Assessment.....	17
4.1.4	Site Access and Egress Routes	18
4.1	On-Site Stormwater Detention	19
4.3	Water Sensitive Urban Design Performance	20
5	CUMULATIVE IMPACTS	21
6	RECOMMENDATIONS/MITIGATION MEASURES.....	22
6.1	Detailed Design-Phase Measures.....	22
6.2	Construction-Phase measures	22
6.3	Operational-Phase Measures	22
6.4	Maintenance Measures	23
7	CONCLUSION	24
	APPENDIX A: APPROVED WCMS REV5.....	26
	APPENDIX B: APPROVED STAGE 1 WCMS REV5.....	27



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Version Amendment Record

Version No.	Outline of Amendments	Amended By	Date Amended
1	WCMS for SSDA	CD	13 October 2025
2	Updated for SSDA Submission	DM	06 November 2025



1 INTRODUCTION

1.1 OVERVIEW

Legpro 70 Pty Ltd ATF Legpro 70 Unit Trust (Legacy Property) has engaged Maker Consulting Services Pty Ltd (Maker) to provide a Water Cycle Management Strategy (WCMS) report in support of a State Significant Development Application (SSDA) seeking development consent for facilitating civil works and subdivision to support a concurrent Stage 2a Built Form SSDA (SSD-83789711) and future redevelopment of Stages 2-4 of the Corrimal Coke Works Precinct. The civil works proposed by this SSDA include the construction of the Central Park, the Southern Park, and roads, drainage and stormwater infrastructure, and paper subdivision.

This Water Cycle Management Strategy has been prepared to address the requirements of *Secretary's Environmental Assessment Requirements* (SSD-86131212) issued 3 July 2025 and provides supporting technical evidence for stormwater quality management in accordance with the Wollongong City Council Development Control Plan 2009 (DCP)

This civil works SSDA was declared as State Significant Development (SSD) in the State Significant Development Declaration Ministerial Order (No 10) 2025 (dated 30 June 2025) at Clause 5(1)(n) in Schedule 1 (Amendment SSD Declaration Order 2025 (No 5)). Figure 1 below highlights the Civil Works area for Stage 2-4 development.

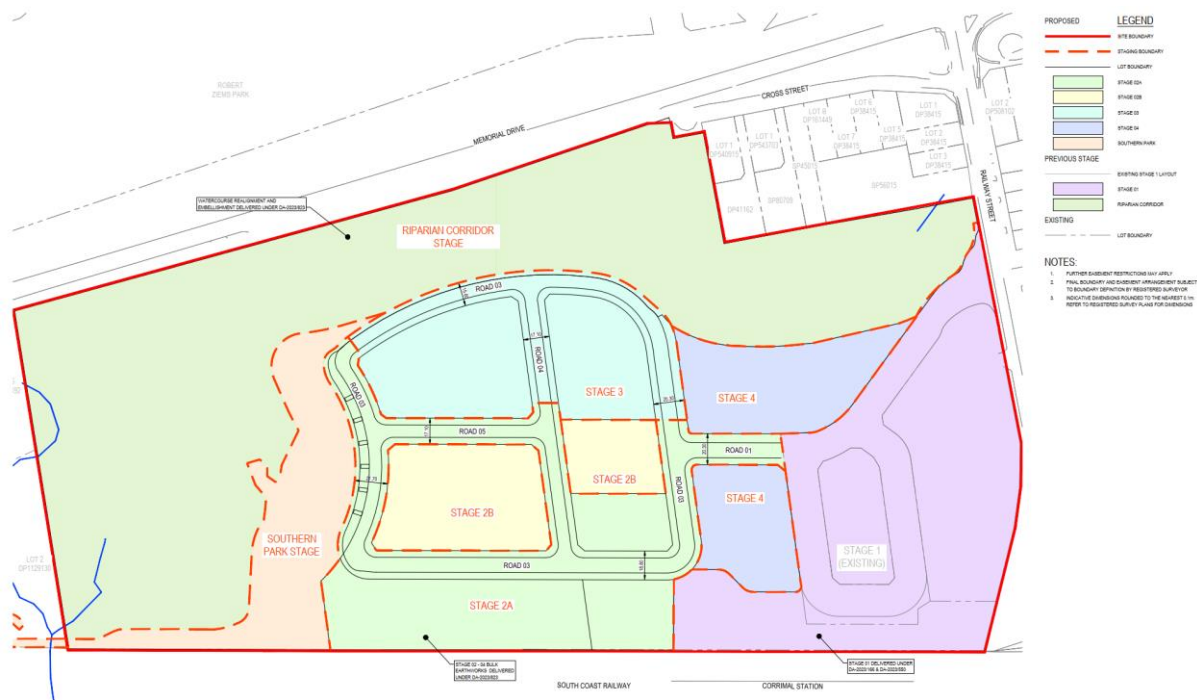


Figure 1 Corrimal Cokeworks Development Stages 2-4 (Civil Works Plans by Maker)



1.2 PURPOSE OF THIS REPORT

The purpose of this WCMS is to address the requirements of SSD-86131212 SEARS matter 11 Water Management which requires an Integrated Water Management Plan to:

- Detail the proposed drainage design and servicing infrastructure to be incorporated as part of the development (stormwater and wastewater)
- Demonstrate how the development complies with council's drainage requirements and identify proposed stormwater treatment and water quality management measures to minimise adverse environmental impacts.

And SEARS matter 19 Flood Risk which requires a report to:

- Identify the flood extent and velocity up to the Probably Maximum Flood and risk on-site having regard to adopted flood studies and floodplain risk management studies and plans
- The site access and egress routes
- The potential effects of climate change
- Any relevant provisions of the NSW Flood Risk Management Manual and any other relevant guidelines
- Where the development is occurring on flood prone land a flood impact and risk assessment must be prepared having regard to the Flood Impact and Risk Assessment – Flood Risk Management Guide LU01
- Detail any flood risk management measures that are to be incorporated as part of the development having regard to relevant guidelines (including any design solutions, flood modification measures, property modification measures, operational procedures or Flood Emergency Response Plan)

To achieve this the report will:

- Quantify the hydrological and hydraulic impacts of the proposed Stage 2-4 Civil works
- Demonstrate compliance with the requirements of DCP Chapters E13 (Floodplain Management), E14 (Stormwater Management), and E15 (Water Sensitive Urban Design), DCP Chapter D19 (Former Corrimal Coke Works Site), and LEP Section 5.21 (Flood Planning)
- Identify that the proposed works are outside of the flood planning area as identified in previous reports, and outline relevant flood risk management measures; and
- Outline the proposed stormwater quality management system to achieve required pollutant reduction targets

Note that this report does not include information about the wastewater infrastructure to be incorporated as part of the development. Sewer servicing of the development will be subject to approval by Sydney Water who will provide requirement following approval of the development application.

1.3 PREVIOUS ASSESSMENTS

Maker has completed the following assessments on the site previously:

- WCMS Corrimal Cokeworks Stage 1 – Rev 2 dated 05/06/2023
- WCMS Corrimal Cokeworks Stages 2-4 – Rev 5 dated 23/09/2024

The Stage 1 WCMS supported the Stage 1 Bulk Earthworks and Stage 1 Built Form DA submissions for site (DA-2023/166 and DA-2023/550 respectively) which are approved. The scope of the report was to assess the hydraulic and hydrological impacts of the proposed development and outline the WSUD features to be implemented as part of the



development. The report determined that the site was not flood constrained and determined that on-site detention would not add benefit to the site or the downstream catchment. Therefore, on-site detention was not proposed.

The Stage 2-4 WCMS supported the Stages 2 - 4 Bulk Earthworks DA (DA-2023/823) which is approved. The scope of Stage 2-4 WCMS was to assess the hydrological impact of the proposed development and to identify proposed mitigation measures, as well as to outline any proposed WSUD treatment train. The report determined that the site is not subject to unacceptable flood risk and did not propose any on-site detention as it was determined to not add benefit to the site or downstream catchment. The report developed the creek realignment concept in line with guidance from the long-term stability assessment and Council feedback; a strategy which has now been approved under the Stage 2-4 Bulk Earthworks DA (DA-2023/823). This report also showed a conceptual strategy for how the future development precinct could suitably meet water quality targets.

This SSSA WCMS develops that site wide conceptual strategy to show how water quality will be managed under this stage of the development, how that integrates with the existing drainage and WSUD network in the approved Stage 1 DA, and how it will accommodate future stages.



2 SITE AND PROJECT DESCRIPTION

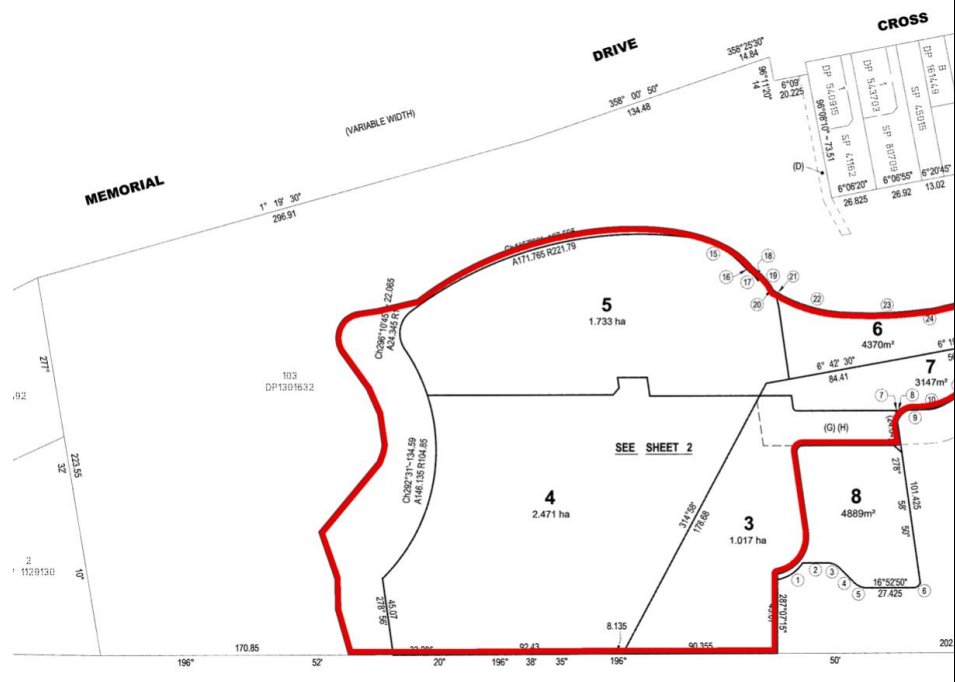
The site and project are described in Table 1 below.

Table 1: Site and Project Description

Descriptor	Site Details
Proponent/Applicant	Legpro 70 Pty Ltd ATF Legpro 70 Unit Trust (Legacy)
Site Ownership	Illawarra Coke Company
SSD Reference	SSD-86131212 [SEARs issued 3 July 2025]
Project Name	Corrimal Coke Works – Stage 2-4 Early Stage (Civil) Works
Street Address	Corrimal Coke Works, 27 Railway Street, Corrimal
Country	Dharawal Country
Project Description	<p>The civil works SSDA seeks development consent for the following works:</p> <ul style="list-style-type: none"> • Torrens subdivision to create nine (9) new title lots (referred to as Lot 200, Lot 201, Lot 202, Lot 203, Lot 204, Lot 300, Lot 301, Lot 302, and Lot 303 in DPI313981). • Detailed civil works associated with the construction of local roads and drainage works relevant to future Stages 2-4. [Note. The detailed civil works will be enabled by the outcomes of the approved Stages 2 - 4 Bulk Earthworks DA (which includes vegetation management and creek alignment / embellishment works) (reference: DA-2023/823)]. • Construction of the Central Park (including embellishment works, lawn areas, landscaping, tree planting, equipment, and services). • Construction of the Southern Park (including embellishment works, lawn areas, landscaping, tree planting, equipment, and services, bicycle path). • Public domain works (landscaping, street tree planting, paving). • Reticulation of site services and infrastructure (electricity, telecommunication, water, and sewer).
Existing Legal Description	<p>The existing legal property description of the former Corrimal Coke Works site is Lot 101 DPI301632, Lot 201 DPI308649, Lot 202 DPI308649, and Lot 103 DPI301632 (registered titles). The former Corrimal Coke Works site boundary extent is identified in blue below.</p> <p>The proposed works associated with the civil works SSDA extend across Lot 201 DPI308649 (part), Lot 202 DPI308649, and Lot 103 DPI301632 (part).</p> <p>The land to which the civil works SSDA relates is identified in red below.</p>



Note. On [... September 2025], Wollongong City Council approved a development application for the paper subdivision of the former Corrimal Coke Works site to create eight (8) new Torrens Title lots (DA-2025/388). The new lots are described as Lot 1 – Lot 8 in DP1313981. The new lots have not yet been registered with the NSW Land Registry Services. However, it is anticipated that formal registration will occur prior to the determination of the subject civil works SSSDA. **For information only**, the below identifies in red the land to which the civil works SSSDA will relate at the point the newly created lots (approved by DA-2025/388) are formally registered.





Site Area	<p>The area of the land to which the Stage 2-4 Civil Works SSDA relates is 66,226sqm. This land is identified in the image above in red.</p> <p>More broadly, the area of the Corrimal Coke Works site is 18.2 hectares.</p>
Existing Development	<p>Existing features across the Corrimal Coke Works site are as follows:</p> <ul style="list-style-type: none">• Structures and infrastructure associated with the former coke work use have been demolished under the Demolition DA (DA-2022/1249).• Towradgi Creek forms the southern boundary of the site and drains in a west to east direction. A tributary of the Creek traverses the site. The western portion of the site is occupied by scattered bush and stockpiling areas. <p>Separate development applications (DAs) have been lodged to Wollongong City Council, and either have been determined or are under assessment. These DAs propose works relating to subdivision, built form (apartment buildings), bulk earthworks, and vegetation management.</p>
Heritage	<p>The site, in part, is subject to the following heritage listings:</p> <ul style="list-style-type: none">• Local heritage listing in the Wollongong LEP 2009 (ID 6607); and• State heritage listing on the State Heritage Register in the NSW Heritage Act 1977 ('Corrimal Coke Works Site', Item No. 02061).
Local Context	<p>The site has an irregular rectangular configuration and is bounded by:</p> <ul style="list-style-type: none">• East boundary: main southern railway line (Corrimal Train Station)• West boundary: dual carriageway (Memorial Drive)• North boundary: Railway Street• South boundary: Towradgi Creek
Regional Context	<p>The site is approximately 1km to the east of the Corrimal Town Centre. Corrimal is approximately 6.5 kilometres north of Wollongong City Centre.</p> <p>The site is located within close proximity to education and recreation facilities, including the Corrimal High School, Corrimal East Public School, Robert Ziems Park, Corrimal Memorial Park, Towradgi Beach Park, and Bowls and Recreation Club.</p>



3 METHODOLOGY

The assessment approach integrates hydrologic, hydraulic, and water quality modelling to quantify the impacts of the proposed Stage 2-4 Civil Works and to demonstrate compliance with Council and State planning controls.

3.1 FLOODING

The proposed development site is located within the Towradgi Creek catchment. Towradgi Creek runs along the southern border of the site and is contained within the adjacent land parcel. The site is covered by the adopted Towradgi Creek Flood Study, Floodplain Risk Management Study and Plan (WMA Water, 2023).

The flooding at the site has been comprehensively assessed as part of the previously approved Bulk Earthworks DA-2023/823, under the Water Cycle Management Strategy for Corrimal Cokeworks Stages 2-4, Rev 5 (s34) dated 23 August 2024.

The assessment incorporated 2D hydraulic modelling using TUFLOW for both the pre-developed and the post-developed conditions, based on the Towradgi Creek Risk Management Study and Plan (WMA Water, 2023). The model included the full realignment of North Corrimal Creek, proposed subdivision grading, and drainage infrastructure.

The outcomes of the assessment were endorsed by council through the s34 concurrence process and are adopted herein. No further flood modelling has been undertaken for this revision of the WCMS. A summary of relevant parts of that assessment is discussed in later sections.

3.2 ON-SITE STORMWATER DETENTION

On-site stormwater detention was also assessed as part of the approved WCMS for Stage 2-4, Rev 5 by Maker, 2024.

The On-site detention requirements were assessed using WBNM in accordance with council DCP Chapter E14 and considering the modelling guidance in the Towradgi Creek Floodplain Risk Management Study and Plan.

The findings of the assessment are discussed in a later section of this report.

3.3 WATER QUALITY AND WATER SENSITIVE URBAN DESIGN

The site is within the Towradgi Creek catchment which drains into Towradgi Lagoon. NSW Department of Environment and Heritage water quality monitoring program has shown Towradgi Creek to have poor water quality, with fair algae abundance, poor water clarity and poor overall estuary health.

The Towradgi Lagoon entrance management policy review of environmental factors (Cardno Lawson Treloar, 2007) notes runoff from the upstream urban area influences water quality within the lagoon and that total nitrogen and total phosphorus are among parameters of particular concern and regularly exceed ANZECC guidelines.

Wollongong DCP Chapter E15 includes pollutant targets to mitigate the impacts of urban development on water quality.

The following sections updates the Water Quality Strategy presented in the approved WCMS for Stage 2-4, Rev 5 (s34) by Maker, 2024 to reflect the current civil design and treatment layout.

The revised strategy maintains the same performance approach and pollutant reduction objectives consistent with WCC DCP Ch E15.

3.3.1 Objectives

The WSUD strategy aims to:



- Improve runoff quality prior to discharge to North Corrimal Creek
- Achieve the DCP E15 pollutant reductions targets
- Integrate stormwater treatment within the public domain and open space network

Table 2 below highlights the stormwater quality performance targets to be achieved for the development as prescribed in Wollongong City Council DCP Chapter E15.

Table 2. WSUD Stormwater Quality Performance Targets (DCP Ch E15)

Development Type	Residential Subdivision	Multi-dwelling Housing
Pollutant	Target % reduction	Target % reduction
Gross Pollutants	90	90
Total Suspended Solids (TSS)	85	80
Total Phosphorus (TP)	60	55
Total Nitrogen (TN)	45	40

3.3.2 MUSIC Modelling

Conceptual modelling has been undertaken using MUSICX 1.40.0 with a 6-minute interval. Figure 2 below shows the schematic of the treatment train model.

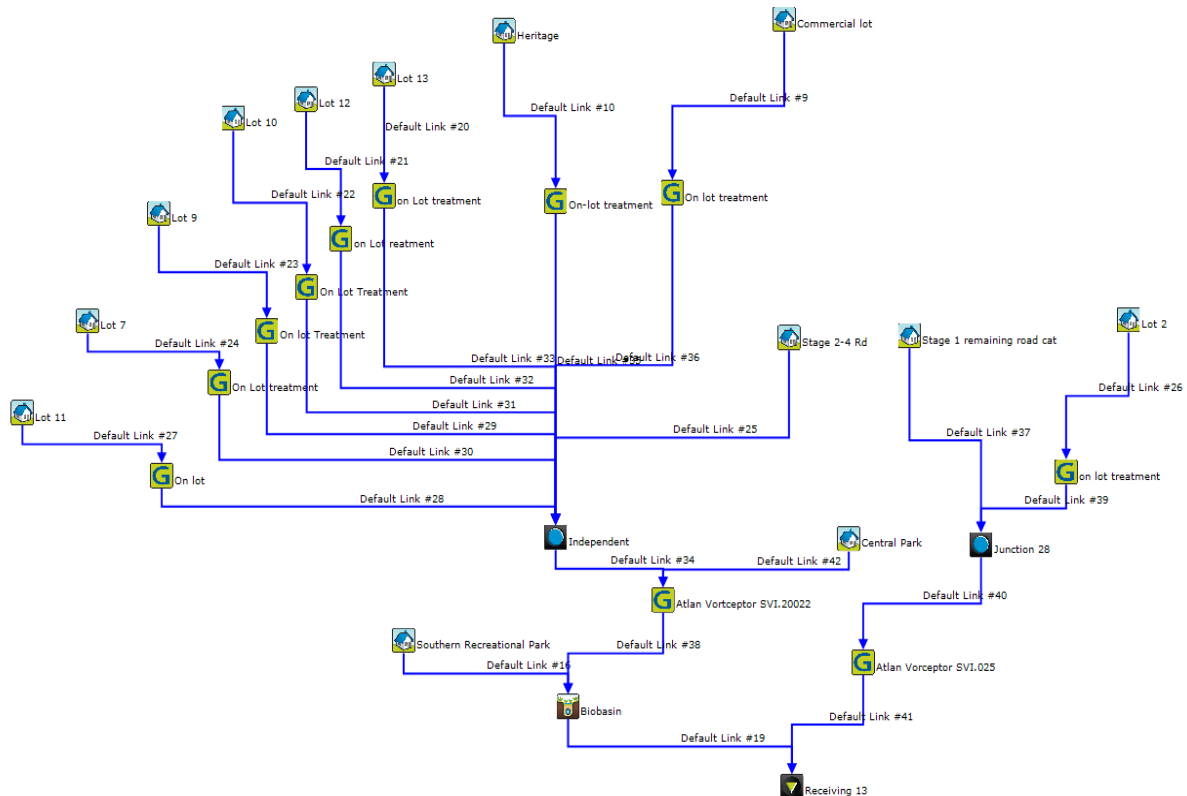


Figure 2. Stage 2-4 MUSIC Model Schematic

3.3.3 Climate data

6-minute pluviography data from Port Kembla over a 15-year period between January 1966 – January 1981 was used. It is reasonably complete with a mean annual rainfall of 900mm.



Monthly average areal potential evapotranspiration data was interpolated for the site from BOM gridded data.

3.3.4 Source nodes

The site was modelled using 13 source nodes. The design naming was based on the architectural plans from DKO shown in Figure 3 below.

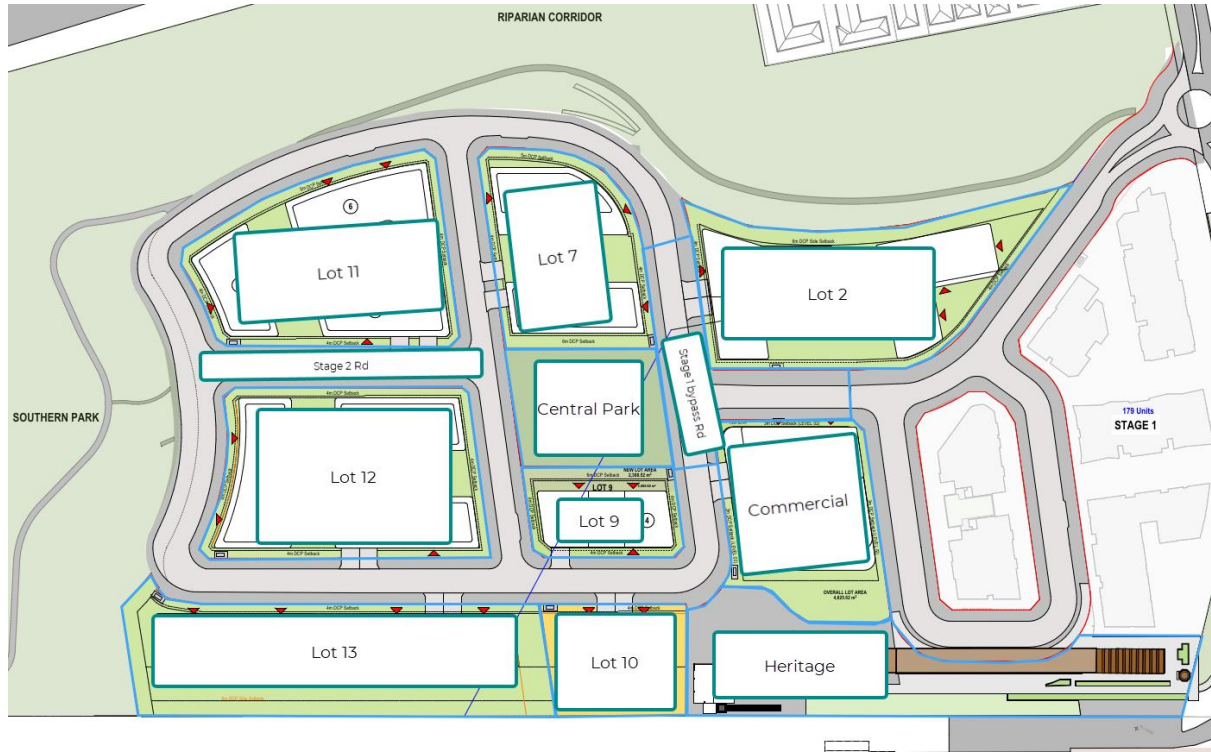


Figure 3. MUSIC Model Source Node Delineation

The source nodes and the impervious areas were modelled as in Table 3 below.

Table 3. Water Quality Catchment Areas and Impervious Percentages

Source Node	Area (ha)	Impervious %
Stage 2-4 Road	1.48	95
Stage 1 Road Catchment	0.29	95
Central Park	0.3	10
Heritage Site	0.5	95
Commercial	0.117	60
Southern Park	0.782	5
Lot 2	0.738	75
Lot 7	0.48	75
Lot 9	0.195	75
Lot 10	0.257	75
Lot 11	0.69	75
Lot 12	0.735	75



Lot 13	0.793	75
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The following catchment assumptions were made for the modelling:

The residential lots are modelled as urban mixed nodes and are subject to more detailed modelling as part of the Stage 2a Built Form application (SSD-83789711) and other future applications, as detailed in the Stormwater Management Report for that application prepared by Siteplus (Project Number 25152, Rev 1 dated 12 September 2025). As such, Lots 2, 7, and Lots 9-13 are assumed to have an 75% impervious area, with the total area based on the Built Form plans collectively 3.88 ha.

The heritage site and the commercial sites were both modelled as commercial nodes, with 95% and 60% imperviousness respectively.

The Southern Park was modelled as an urban mixed area with 5% imperviousness and is 0.782ha.

As part of sequential development at the Cokeworks site, parts of Stages 2-4 are directed to a drainage line and GPT constructed as part of the Stage 1 civil works. This treated area is then discharged into the Creek by a different outlet from the rest of Stages 2-4. 0.29ha of the Stage 2-4 road area is modelled as a separate source node to reflect this.

3.3.5 Treatment nodes

The proposed treatment train for the civil works includes proprietary Gross Pollutant Traps (GPT) followed by an end-of-line bioretention basin. The nominated Atlan Vortceptor effectively captures gross pollutants, sediments, silt, some nutrients, and oil and grease.

The bioretention basin will be located within the Southern Park extents.

It is assumed that the treatment of the built form entities will be achieved to relevant targets (Multi dwelling housing in Table 1 above) on-lot prior to discharge in the street network. The heritage and commercial areas will be assessed as part of separate applications and will be treated to their relevant target reductions requirements. As such these have been included in this assessment to represent the hydraulic loading at the bioretention node located at the downstream end of line.

These lots are modelled to be treated to their target reduction requirements using a generic treatment node. The Stormwater Management Report for the Stage 2a Built Form Application shows how Stage 2a meets these targets on lot, and it is assumed other future built form stages will have similar strategies. The lots discharge into the street network before being treated by a GPT, followed by the downstream bioretention basin. Note that in **Table 2** the pollutant reduction targets for subdivision are higher than those for multi-dwelling unit development, so the street network is to be sized to remove further pollutants from the built form stages as well as to treat the subdivision works.

The street drainage network is modelled to be treated using an Atlan Vortceptor. The Vortceptor GPT is a SQIDEP verified, non-blocking hydrodynamic separator that has a unique screen and treatment action producing low vortex conditions.

The Vortceptor nominated for the Stage 2-4 works is an Inline series model SVI.200/22 with a High Flow Bypass of 200L/s with Max Flow Rate of 990L/s.

The Vortceptor on the Stage 1 outlet is designed to capture flows from Lot 2 built form and part of the road as noted above. Lot 2 while assumed to have independent on-lot treatment, will discharge via the Stage 1 Vortceptor before discharging to the Creek west of Lot 2.



4 ASSESSMENT AND FINDINGS

All hydraulic and geomorphic analyses for Stages 2-4 are contained within the approved WCMS Rev 5, attached as part of Appendix A of this report.

The adopted model and results remain current and continue to represent the approved design configuration for flooding assessment. Figure 4 below shows the site context plan with the creek realignment with the staging plan.

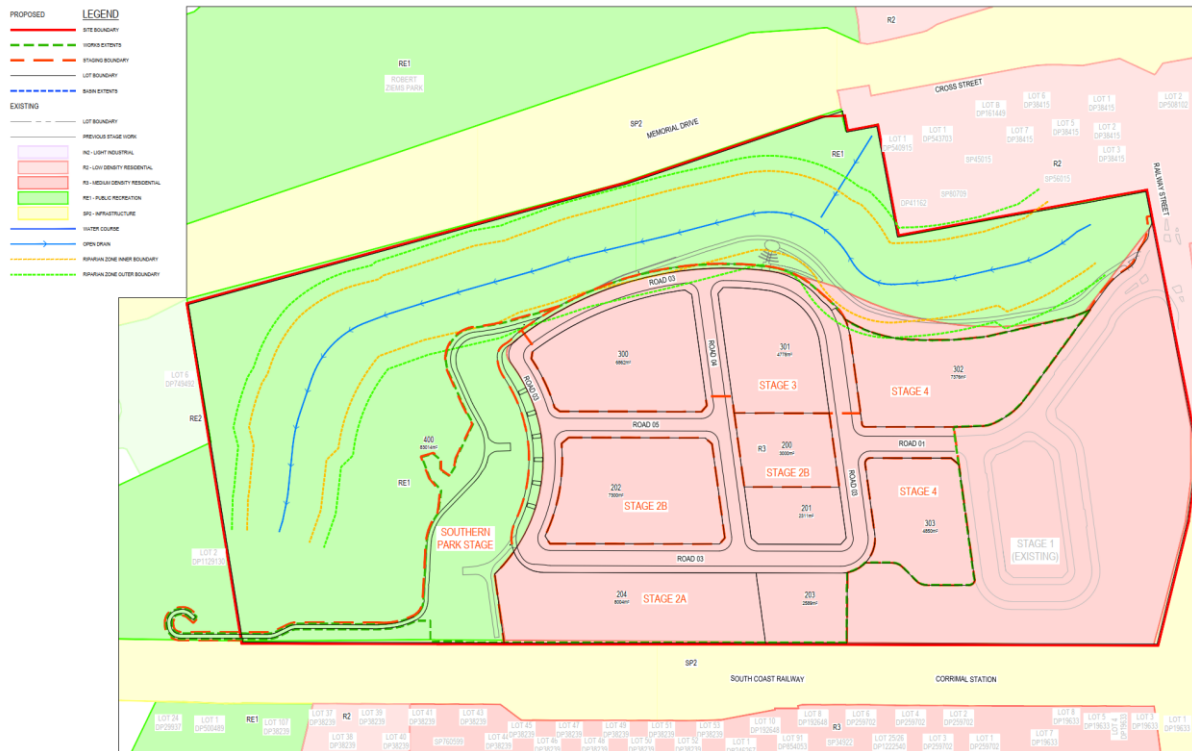


Figure 4: Site Context Plan

4.1 FLOODING

4.1.1 Existing Conditions

Under the existing conditions:

- North Corrimal Creek transverses the site north to south before joining Towradgi Creek at the southern boundary
- Flooding in storms 10% AEP and below is confined to the creek corridor, expanding into the central low area during rarer events
- Depths in the 1% AEP event range between 1.5-2m in the channel, with velocities up to 2m/s
- Flooding is locally affected by upstream culvert control at Memorial Drive and downstream tailwater from the railway bridge.

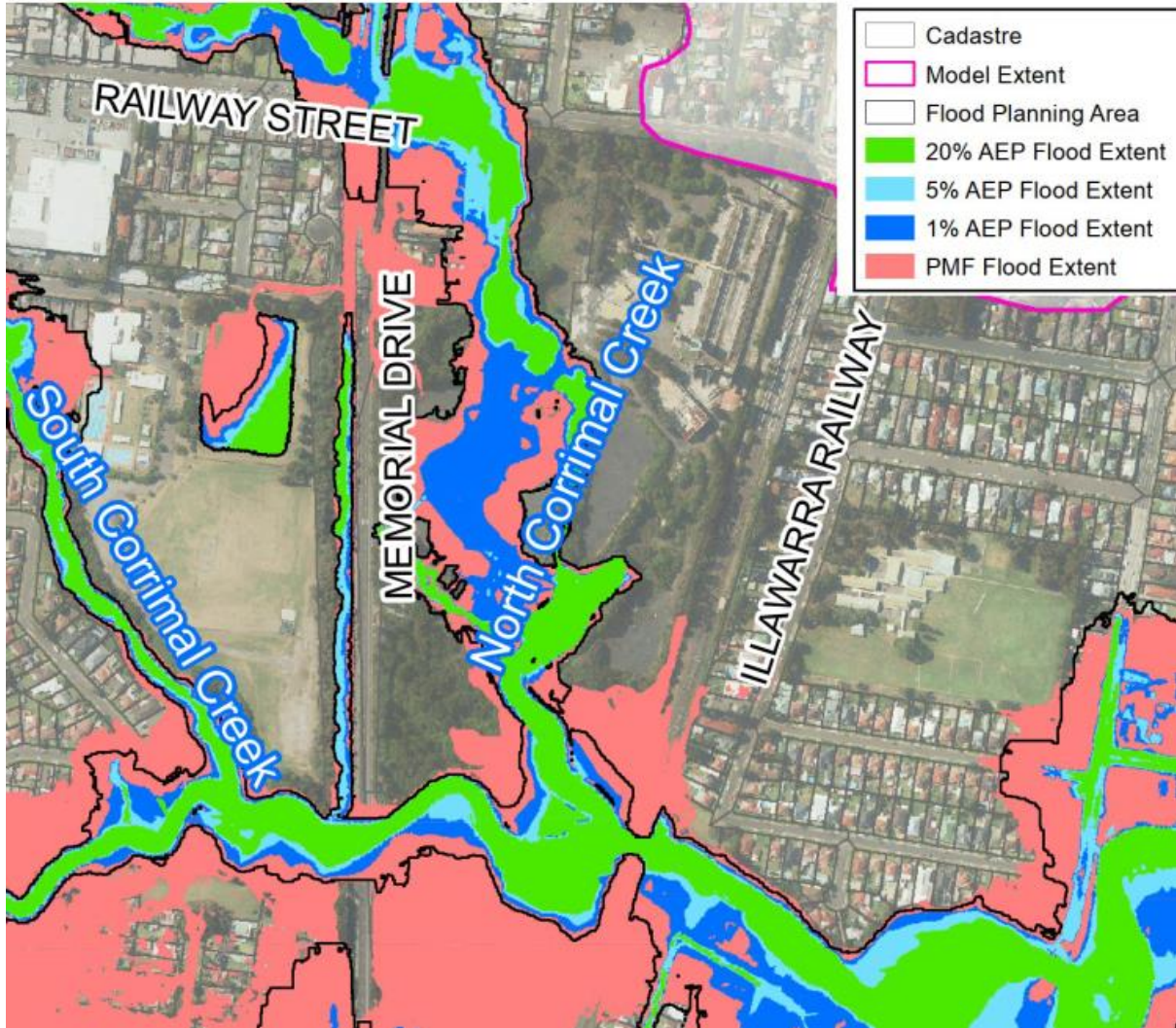


Figure 5: Results from Towradgi Creek Flood Study (WMA Water, 2023)

4.1.2 Proposed Conditions and Creek Realignment

The post-development model assessed the flooding including realignment of the North Corrimal Creek to the western site boundary.

The realignment replaces the former central channel and connects back to Towradgi Creek at the southeast corner. Towradgi Creek is slightly realigned at the connection point. Key outcomes from the approved WCMS highlights:

- The flood planning level (DFE +500mm) at the southern end of the site (including the entire southern park extent) is less than 9.2m AHD
- The realigned channel contains flows up to and including the PMF between the northern end of the site and the southern edge of the land to which the civil works SSDA relates - see **Figure 7** – the entire Stage 2-4 civil works extent is no longer flood prone land
- Flood levels reduced by 30-50mm along Railway Street and Cross Street
- No increase in the flooding external to the site is greater than 20mm
- Floodplain storage increases from existing conditions
- The channel corridor has areas of high velocity (more than 2m/s, see Figure 8) and high hazard (H5, H6) during flood events



- The creek realignment has been assessed for geomorphic and geotechnical stability and found to be stable in the long-term
- The new shared-path bridge provides 10% AEP immunity with 0.5m freeboard

4.1.3 Climate Change Assessment

The Towradgi Creek FRMS, 2023 and the approved WCMS Rev 5. Applied climate change allowances of +0.9m sea-level rise and +16.9% rainfall-intensity increase

Under these future conditions:

- Maximum flood-rise of ~0.37m occurs behind the railway bridge
- Increase along Railway Street ~ 0.15m
- No change in flood extent within the developable area – flooding still contained to the realigned creek
- Increased tailwater levels slightly lower velocities at the downstream end and have negligible effect on the realigned creek’s stability

The channel remains hydraulically effective and geomorphologically stable under these scenarios.

The Towradgi Creek FRMSP suggests the adoption of flood planning levels as an adjusted 1% AEP including these climate change factors (the defined flood event, DFE) plus a 500mm freeboard. The relevant flood planning levels for the site and associated flood planning area are shown in **Figure 6**.

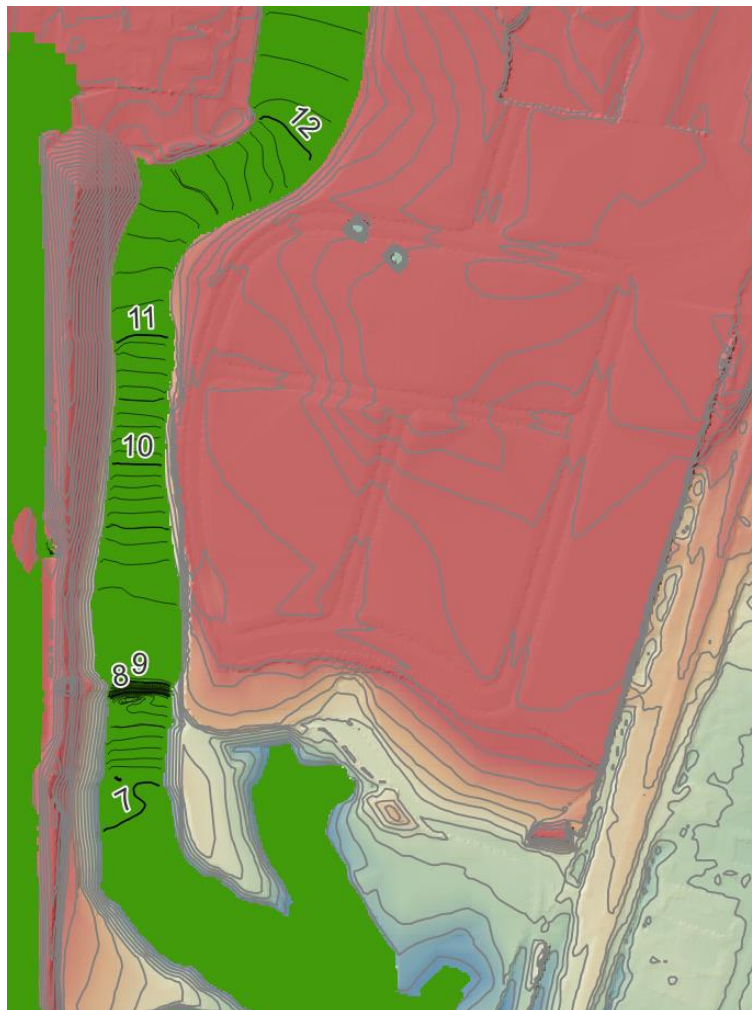


Figure 6: Flood Planning Area (green) and Flood Planning Levels (0.1m contours) around the Stage 2-4 Civil Works area



4.1.4 Site Access and Egress Routes

Evacuation and access were assessed in the approved WCMS using the validated flood model. The assessment confirmed that all five internal roads proposed within Stage 2-4 civil works area are flood free in all modelled events including the PMF.

These roads provide multiple flood-safe egress routes connecting to Railway Street, which has flood free access to evacuation routes to the east, but the connection to Memorial Drive is flooded in major flood events.

The shared-path bridge across Towradgi Creek is designed as a low-level structure, remaining above the 10% AEP flood but inundated in larger events. Users have direct rising-path access to high ground on both sides of the creek during floods.

Accordingly, the proposed road layout and bridge design comply with WCC DCP Chapter E13 evacuation and refuge criteria, providing safe, flood-resilient access and egress for future residents and maintenance personnel. Figure 7 below shows the Proposed PMF extents with the Stage 2-4 civil works extent.

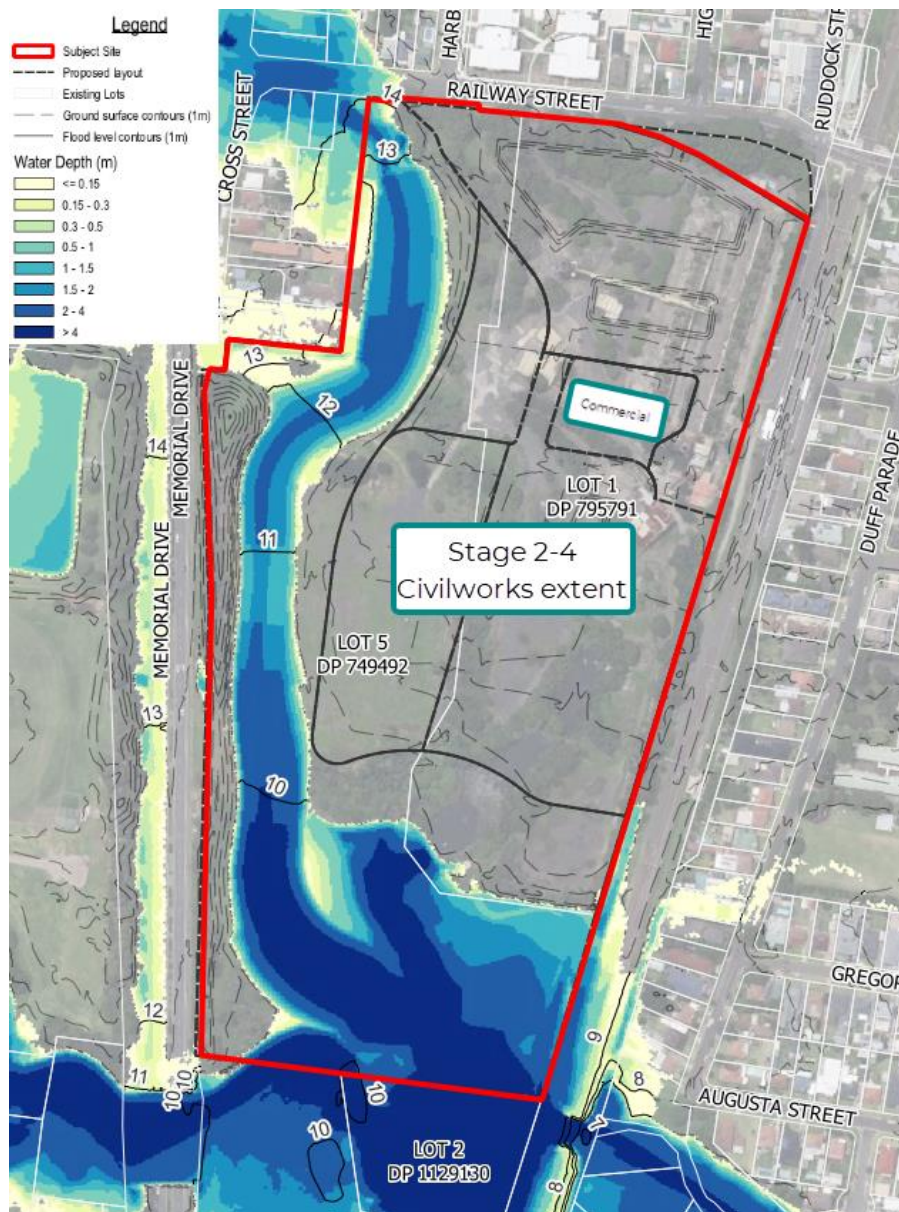


Figure 7. Proposed Case PMF Extents and levels



Figure 8: Proposed Case PMF velocity

4.1 ON-SITE STORMWATER DETENTION

The approved WCMS by Maker concluded that detention within this reach of the catchment would not provide downstream benefit due to the location in the lower reaches of the North Corrimal Creek and Towradgi Creek catchments.

Although development and associated increases in impervious area lead to an increase in local runoff, post-development peak discharges in North Corrimal Creek remain less than existing conditions, satisfying the requirements of WCC DCP Ch E14.

Accordingly, no on-site detention is proposed for the Stage 2-4 Civil works SSDA. Stormwater will discharge through the approved drainage network to the realigned North Corrimal Creek, consistent with the adopted flood and hydraulic design in WCMS Rev 5 by Maker, 2024.



This approach remains compliant with Council policy and has been accepted through the Section 34 conciliation process for the approved Bulk Earthworks approval (DA-2023/523), and the Stage 1 built form development application (DA-2023/550).

The assessment and the findings for the flooding and the OSD assessment has been covered in further detail in approved WCMS by Maker, 2024 attached as part of Appendix A.

4.3 WATER SENSITIVE URBAN DESIGN PERFORMANCE

The WSUD strategies were designed to comply with the guidance provided in WCC DCP Chapter E15. The bioretention basin was designed to maintain the hydraulic integrity and to minimise storm flow damage.

The bioretention basin with the parameters in **Error! Reference source not found.** was included in the MUSIC model

Table 4. Proposed Bioretention Basin Parameters

Parameters	Bioretention basin
Filter media area (m ²)	220
Filer media depth (m)	0.6
Extended detention depth	0.3
Extended detention area (m ²)	250
Saturated hydraulic conductivity (mm/hour)	100
Filter media TN	400
Filter media Orthophosphate	40

The nominated GPT are suitably sized for their catchments, with less than 10% of annual flow volumes bypassing. This includes the southern GPT and the Stage 1 outlet GPT with the additional Stage 2-4 catchment.

Pollutant load reduction results of the MUSIC model are shown in Table 5. The proposed treatment train achieves the target reduction percentages for all pollutants.

Table 5. MUSIC Model Treatment Train Effectiveness Stage 2-4

Pollutant	Source Load (kg/year)	Residual Load (kg/year)	Reduction (%)	Target Achieved?
Gross Pollutants	1360	10	99	Yes
Total Suspended Solids	14090	1460	89	Yes
Total Phosphorus	26.49	5.82	78	Yes
Total Nitrogen	159.5	60.6	61	Yes



5 CUMULATIVE IMPACTS

In line with the NSW Government *Cumulative Impacts Guidelines* the proposal will have neutral to beneficial cumulative impacts on flooding, drainage, and water quality when viewed at the precinct and catchment scale.

The Stage 2-4 Civil Works form part of the wider Corrimal Cokeworks redevelopment together with Stage 1., the approved bulk earthworks and Creek Realignment DA2023/823, and the future Stage 2a built form SSDA (SSD-83789711), the heritage plaza DA as well as future built form stages.

When considered in the broader context of the Corrimal Cokeworks:

- **Flooding:** Combined modelling across all stages confirms no cumulative increase in flood levels or hazard within the Towradgi Creek system.
- **Stormwater Quantity:** The shared trunk drainage network and realigned creek collectively manage flows from all stages without adverse impacts.
- **Water Quality:** WSUD measures across stages including tree pits, GPTs, and bioretention basins operate as an integrated treatment network, achieving overall pollutant reduction as per WCC DCP Chapter E15 requirements. The design in line with the Cumulative Impacts Guidelines and the DCP guidance, helps integrate WSUD measures into landscape to enhance ecological, visual, economic, and cultural values.
- **Geomorphic and Environmental Effects:** The creek realignment and revegetation work deliver long-term improvement to stream stability and riparian habitat relative to pre-development conditions
- **Construction Phase Impacts:** Any short-term cumulative sediment or erosion risks will be mitigated by implementation of site-wide Blue Book erosion and sediment control measures. The Stage 2-4 civil works are dependent on the completion of the Stage 2-4 bulk earthworks including the stabilisation of the realigned stream and decommissioning of the onsite dams.

When considered in the broader context of Corrimal and the Wollongong LGA:

- **Flooding:** The Towradgi Creek Floodplain Risk Management Study and Plan considered future development in the catchment, including that outlined in the Corrimal Town Centre Plan, proposed but not constructed development in Corrimal and Tarrawanna and possible future development commensurate with current zoning as well as specifically considering the Corrimal Coke Works development. It assessed the impact from this development on flooding behaviour and assessed a range of measures to mitigate these impacts. The development has integrated all the recommended measures, including considering future changes to lagoon entrance management policy and changes to defined flood event to consider climate change.
- **Stormwater Quantity:** The Stage 1 built form DA included an assessment of the cumulative impact of development with and without OSD for all areas downstream of the Princes Highway and used this to inform the OSD strategy for the site
- **Water quality:** The DCP targets have been developed to manage the cumulative impact of developments on water quality throughout the LGA. Council have proactively adapted this policy and adjusted targets so that the future development does not jeopardise water quality objectives in receiving waterways.



6 RECOMMENDATIONS/MITIGATION MEASURES

The following recommendations and mitigation measures are established to ensure that the Stage 2-4 civil works perform in accordance with the adopted WCMS by Maker, 2024 and the updated WSUD design undertaken as part of this assessment.

6.1 DETAILED DESIGN-PHASE MEASURES

1. Creek Realignment
 - Maintain the approved North Corrimal Creek alignment, invert levels, bank profiles, and floodplain storage volumes.
 - Confirm final bed and bank stabilisation design (rock protection, coir logs, and vegetation) consistent with Soil Conservation Service (2018,2020) recommendations.
2. Flood Immunity
 - Ensure all internal roads and critical access routes remain above the PMF and comply with DCP Chapter E13 evacuation and refuge provisions.
 - Confirm the Towradgi Creek shared-path bridge deck level provides greater than 10% AEP immunity and 0.5m freeboard.
3. Drainage Network
 - Verify hydraulic connectivity and capacity through the 10% AEP and 1% AEP events to prevent surcharge onto road pavements
 - Maintain continuity of overland flow paths to North Corrimal Creek
4. WSUD Infrastructure
 - Ensure the detailed design of Atlan Vortceptor is in line with manufacturer recommendations and as calibrated as part of this study.
 - Ensure bioretention basin detailed design is in line with Wollongong City Council standard drawings, liners are in accordance with manufacturer specification and ensuring media specification is in line with MUSIC modelling calibrations.
 - Ensure that the WSUD and drainage assets are protected from service conflicts during construction layout.

6.2 CONSTRUCTION-PHASE MEASURES

1. Prepare and implement a Construction Environmental Management Plan (CEMP) covering:
 - Erosion and Sediment Control Plan compliant with the Blue Book (Vol 1 & 2)
 - Stockpile management, material containment, and stabilised entry/exit points
 - Staging of works to minimise exposed surfaces within the Towradgi Creek floodplain
 - Spill and sediment containment around the GPT and basin excavations
 - Protection of the creek corridor and existing riparian vegetation
2. Conduct pre and post-storm inspections during construction to ensure Erosion and Sediment Control measures remain effective
3. Ensure temporary drainage channels maintain flow conveyance equivalent to existing conditions

6.3 OPERATIONAL-PHASE MEASURES

1. Stormwater Management



- Confirm as-constructed details of surface levels and drainage infrastructure against design to ensure intended flood performance
 - Prevent storage or fill placement within flood storage areas
2. Access and Egress
 - Maintain unobstructed evacuation routes along internal roads and Railway Street
 - Include flood-safety signage near low-lying pedestrian crossings or path entries
 3. Water Quality
 - Implement landscaping consistent with WSUD devices' specifications

6.4 MAINTENANCE MEASURES

All elements of the proposed treatment train require regular maintenance to operate effectively. Responsibility for ongoing management rests with the asset owner, which is Council for the in-street GPT and the end of line bioretention basin.

1. GPT

Maintenance requirements vary by model but generally include inspection bi-annually and cleaning out with a sucker truck when accumulated litter reaches a design level. Indicatively, the Vortceptor GPT with the appropriate treatable flow rate for the catchment has a sump of sufficient capacity to carry just over a year of the MUSIC estimated captured pollutants.

Maintenance should not require any equipment or training that would be unavailable to those who maintain other GPTs already under council management. It would indicatively include twice yearly maintenance checks and clean-up of accumulated sediment and gross pollutants every 12 months.

2. Bioretention Basin

The bioretention basin within the southern park would be dedicated to council. It would need to be maintained with weeding, unblocking the inlets and outlets, removing litter debris. It would also need to be replanted as required and repairing any scour

3. Creek Monitoring

- Conduct post-construction geomorphic stability inspections after significant rain fall events to confirm bank protection performance
- Undertake routine audit of channel stability, vegetation establishment, and sediment deposition patterns as per Soils and Construction guidance (2008)



7 CONCLUSION

This Water Cycle Management Strategy has been prepared to support the Stage 2-4 Civil Works SSDA for Corrimal Cokeworks redevelopment. The strategy draws directly from the approved WCMS Stage 2-4, Rev 5 s34, maker 2024, which remains the approved reference document for flooding, on-site detentions, and overall hydrological performance.

This report outlines the updated WSUD strategy to align with the latest civil design.

The flooding behaviour of the site has been considered, and it has been established that the site is not subject to unacceptable flood risk and does not increase the flood risk elsewhere.

The stream realignment concept has been further developed in line with the guidance from the stability assessment and council feedback and the long-term stability of the realignment considered.

No onsite detention has been proposed as part of this strategy as it was determined to not add benefit to the site or the surrounding area.

A treatment train has been proposed to manage water quality and assessed against the requirements in DCP Chapter E15. MUSIC modelling has been undertaken and shows that the proposed treatment train consisting of the Vortceptor GPT and an end of line bioretention basin within the Southern Park achieves WCC DCP Ch E15 requirements, including considering the cumulative impacts of treating a portion of the Stage 2-4 road area and the Lot 2 area through an independent Vortceptor GPT within the northern extents of Stage 2-4.

The SEARS requirements considered have been addressed as shown in **Table 6**.

Table 6. SEARS requirements

Requirement	Compliance
11. Water Management	
Detail the proposed drainage design and servicing infrastructure to be incorporated as part of the development (stormwater and wastewater)	This report and the civil plans show the drainage design including an arrangement of pits and pipes and stormwater quality improvement devices
Demonstrate how the development complies with council's drainage requirements and identify proposed stormwater treatment and water quality management measures to minimise adverse environmental impacts.	A treatment train has been proposed and shown to meet the requirements in Wollongong DCP Chapter E15
19 Flood Risk	
Identify the flood planning area and level as set out in the relevant EPI and other supporting documents to determine	The flood planning area and flood planning levels have been identified
The flood extent and velocity up to the Probable Maximum Flood and risk on-site having regard to adopted flood studies and, floodplain risk management studies and plans	The flood extent and velocity in the PMF have been calculated in previous work, and the proposed works are outside the PMF extents
The site access and egress routes	Site evacuation routes have been identified
The potential effects of climate change	Climate change impacts have been quantified and the development has been shown to be not sensitive to climate change



	induced changes to flood behaviour
Where the development is occurring on flood prone land a flood impact and risk assessment (FIRA) must be prepared having regard to the Flood Impact and Risk Assessment – Flood Risk Management Guide LU01. When determining the scope and category of the FIRA the requirements outlined in the FIRA guide must be considered.	The development is not on flood prone land considering the results of the approved Stage 2-4 Bulk Earthworks DA
Detail any flood risk management measures that are to be incorporated as part of the development having regard to relevant guidelines (including any design solutions, flood modification measures, property modification measures, operational procedures or Flood Emergency Response Plan)	Flood Risk Management measures for detailed design, construction and operational phases have been identified

Overall, the Stage 2-4 civil works design provides a flood-safe, hydraulically efficient, and environmentally sustainable stormwater management solution that supports the ongoing redevelopment of Corrimal Cokeworks Precinct. Furthermore, the recommendation and mitigation measures prepared as part of this assessment are aimed at ensuring long-term hydraulic, geomorphic, and environmental performance of the drainage and WSUD infrastructure. Their implementation through the detailed design, construction, and operational stages will provide ongoing compliance with Council and DPHI requirements and secure the sustainable operation of the recommended strategies.



APPENDIX A: APPROVED WCMS REV5



**WATER CYCLE MANAGEMENT STRATEGY
FOR PROPOSED DEVELOPMENT OF**

CORRIMAL COKEWORKS STAGES 2-4

Project No: MKR00452

VERSION 5



TABLE OF CONTENTS

1	INTRODUCTION.....	6
1.1	Project and Site Background.....	6
1.2	Purpose of this report.....	6
2	FLOODING.....	8
2.1	Proposed development.....	8
2.2	Assessment framework, Relevant STUDIES, and Guides.....	8
2.2.1	Previous Towradgi Creek Flood Studies.....	9
2.2.2	Corrimal Coke Works Flood Study.....	9
2.2.2.1	Existing Scenario.....	10
2.2.2.2	Developed Scenario.....	12
2.2.2.3	Watercourse Realignment.....	14
2.2.2.4	Geomorphological Considerations.....	16
2.2.3	Council Adopted Towradgi Creek Flood Study.....	17
2.3	Model development and validation.....	19
2.3.1	Elevations.....	19
2.3.1.1	Pre-development.....	19
2.3.1.2	Post-development.....	19
2.3.2	Materials.....	20
2.3.3	Blockage/Debris.....	20
2.3.4	Validation.....	21
2.3.5	Results.....	26
2.3.5.1	Depth.....	26
2.3.5.2	Hazard.....	26
2.3.5.3	Hydraulic Classification – Flood Function.....	27
2.3.5.4	Flood Risk Precincts.....	27
2.3.5.5	Predicted Impacts.....	28
2.3.5.6	Floodplain Storage.....	29
2.3.5.7	Conveyance capacity.....	29
2.3.5.8	Economic impact of flooding.....	30
2.3.5.9	Geomorphological Considerations.....	31
2.3.5.10	Evacuation.....	40
2.3.5.11	Climate Change Impacts.....	40
2.3.6	Conclusion.....	41
3	ONSITE STORMWATER DETENTION	42
3.1	Site discharge point.....	42



3.2	WCC OSD policy.....	42
3.3	Permissible site discharge.....	43
3.4	Post-developed site discharges.....	45
3.5	Site Storage Requirement.....	46
4	WATER QUALITY STRATEGY.....	47
4.1	Stages 2-4.....	47
4.1.1	MUSIC modelling.....	47
4.1.2	Climate data.....	48
4.1.3	Source nodes.....	48
4.1.4	Treatment nodes.....	48
4.1.5	Results.....	49
4.1.5.1	Operation and maintenance plan.....	50
4.1.5.2	Tree Pits.....	50
4.1.5.3	GPT.....	50
4.1.5.4	OceanProtect StormFilter cartridges.....	50
4.1.5.5	Bio basin.....	51
5	CONCLUSION	52
APPENDIX A:	SURVEY	
APPENDIX B:	BLOCKAGE ASSESSMENT	
APPENDIX C:	HYDRAULIC MODEL SETUP	
APPENDIX D:	HYDRAULIC MODEL RESULTS	
APPENDIX E:	GEOMORPHOLOGY REPORT	



Prepared By: Chetak Dalvi Date: 23/08/2024

Approved: Angus Dyson Date: 23/08/2024

Version Amendment Record

Version No.	Outline Amendments	of	Amended By	Date Amended
1	Draft Issue for DA		Chetak Dalvi	28 April 2023
2	Revised issue for DA.		Angus Dyson	25 August 2023
3	Revised issue with updated Heritage Plaza info		Chetak Dalvi	26 September 2023
4	Revised to address SOFAC		Angus Dyson and Sophie Johnson	23 August 2024
5	Revised as part of s34		Angus Dyson	23 September 2024



Design revisions in V5

Design request	Response
Typical Sections showing surface treatments for the realigned creek	Typical sections and a plan of surface treatments have been prepared showing protection measures for areas of high stress. These have been adjusted following consultation with the geomorphologist
Smooth the upstream transition	The upstream transition was smoothed to make a less abrupt change between the existing channel cross section and the proposed revised channel section – especially on the western bank
Consider changes due to the sewer works	The civil set has been updated to consider the sewer works. The existing case flood modelling has not been altered.
Adjust the shared path bridge to reduce the afflux on the neighbouring lot, and to achieve 10% AEP flood immunity for the bridge	The bridge has been raised to provide 500mm freeboard between the 10% AEP flood level and the bridge soffit. The bridge has also been widened and the southern approach abutment adjusted to decrease the afflux due to the bridge.
Adjust the batter adjacent to Towradgi Creek to reduce the risk of stream capture	The cross section in the realigned creek and the steepness of the batters have been increased to increase the offset between the top of batter of the realigned creek and the top of the highest bank of Towradgi Creek. This has resulted in a decreased conveyance capacity of this section of the stream, but the flood storage targets are still achieved and the channel still has sufficient capacity to convey the DFE.

Changes in the text in version 5 are noted in teal throughout



1 INTRODUCTION

1.1 PROJECT AND SITE BACKGROUND

Legacy Property (Legacy) has engaged Maker ENG Pty Ltd (Maker) to provide a Water Cycle Management report in support of Stages 2-4 of the Corrimal Cokeworks proposed development, otherwise known as the 'site'. The site consists of Lot 5 DP 749492, Lot 1 DP 795791 & Lot 126DP 598190.

The site is located in the northern suburbs of Wollongong, 5.5km north of the Wollongong CBD and 63km south of Sydney CBD. It is within walking distance to Corrimal town centre (350 m), local primary and secondary schools (500 m) and community recreational facilities including sporting fields, Corrimal Pool, Corrimal District library and community centre (500 m) and Corrimal Beach (1.2 km). The project site, shown below in **Figure 1**, is bordered by Railway Street (north), Corrimal Train Station (east) and Stage 1 of the Corrimal Cokeworks development (north).

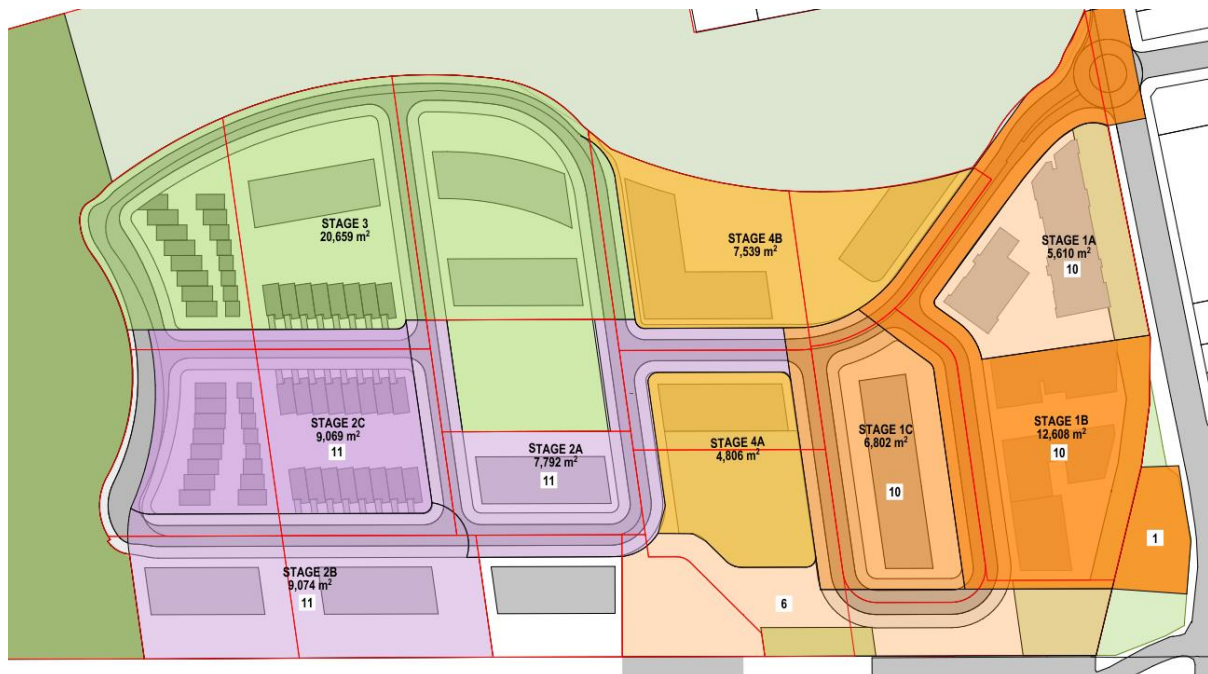


Figure 1: Corrimal Cokeworks Development Stage 1-4 (Architectural plans by DKO)

The concept development masterplan consists of approximately 550 dwellings comprising of a mix of low-midrise apartments and medium density dwellings. Stages 2-4 comprises approximately 6.55ha of the site and includes 5 roadways. The scope also includes the realignment of the riparian corridor through the site.

1.2 PURPOSE OF THIS REPORT

The scope of the Water Cycle Management Strategy identifies the hydrological impact of the proposed development and the proposed mitigation measures, as supported by flood modelling of pre and post development scenarios. Modelling has been undertaken to assess and quantify any impacts and provide adequate mitigation. This report has been prepared for Stages 2-4 which is to operate independently from Stage 1.



This report has been prepared to address the requirements identified within Wollongong City Council Development Control Plan (DCP) 2009 and relevant guidelines, particularly:

- DCP Chapter E13: Floodplain Management
- DCP Chapter E14 Stormwater Management
- DCP Chapter E15 Water Sensitive Urban Design
- DCP Chapter D19 Former Corrimal Coke Works Site
- LEP Section 5.21



2 FLOODING

The proposed development site is located within the Towradgi Creek catchment. Towradgi Creek runs along the southern border of the site and is contained within the adjacent land parcel. The site is covered by the adopted Towradgi Creek Flood Study, Floodplain Risk Management Study and Plan (WMA Water, 2023).

2.1 PROPOSED DEVELOPMENT

Stages 2-4 of the Corrimal Cokeworks development will contain 10 medium density residential lots, 56 townhouses in conjunction with open space recreational areas. A conceptual layout of the proposed development is depicted in **Figure 2**. It is proposed for the existing creek to be realigned in accordance with the previous planning proposal documentation and site specific DCP Chapter D19.

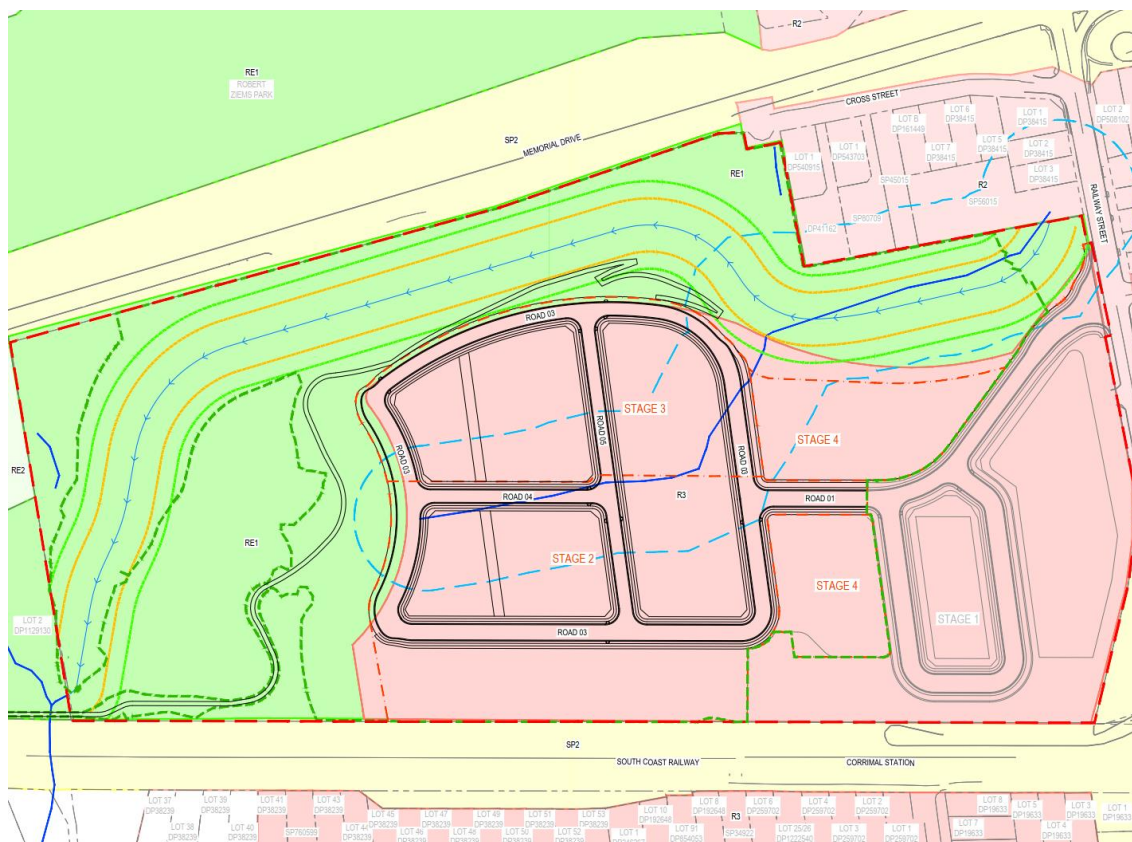


Figure 2: Site context plan

2.2 ASSESSMENT FRAMEWORK, RELEVANT STUDIES, AND GUIDES

This flood strategy has been developed to be consistent with the Wollongong Local Environment Plan 2009, Wollongong City Council Development Control Plan 2009 (DCP), and other guidelines and studies relevant to the area, particularly:

- NSW Flood Risk Management Manual
- DCP Chapter E13: Floodplain Management
- DCP Chapter D19: Former Corrimal Coke Works Site
- Corrimal Coke Works Flood Study (Cardno, 2019)
- Corrimal Coke Works Creek Realignment Stability Assessment (BG&E, 2020)



- Proposed Creek Re-alignment former Corrimal Cokeworks (Douglas Partners, 2020)
- Geomorphology Assessment Proposed Creek Realignment (Soil Conservation Service, 2018)
- Addendum Geomorphology Report – North Corrimal Creek diversion (Soil Conservation Service, 2020)
- NSW Flood Prone Land Policy

DCP Chapter E13 outlines information to be provided in a flood report in support of a development application. This report and the supporting maps have been prepared to address the requirements within Chapter E13. The report will provide information on the impacts of the proposed development on flood behaviour.

2.2.1 Previous Towradgi Creek Flood Studies

Previous studies have been completed for Towradgi Creek south of the proposed development site.

An XP-RAFTS hydrologic model was established as part of the 2003 Floodplain Risk Management Study for the Towradgi Creek Catchment. This XP-RAFTS model formed the basis for development of the WBNM hydrologic model as part of the 2015 Flood Study Review and subsequently the 2019 Flood Study. TUFLOW was used to simulate the hydraulics within a 2D domain that extended from the base of the escarpment to the beach adjacent to Towradgi Lagoon.

The catchment and sub-area delineations were based on a high-resolution DEM (1m grid) developed from the LiDAR data in 2005. 206 sub-areas were considered within the hydrological model. The model split the effects of urbanisation within WBNM into directly connected impervious and pervious parts. The gross fraction impervious for the entire model area was 27%.

The 2015 Flood Study Review built on the existing studies completed and was undertaken in accordance with the methodologies outlined in Australian Rainfall and Runoff 1987 (ARR 1987), which were appropriate at the time. The hydrologic and hydraulic model parameters were used to simulate flood behaviour for a range of design events and produced the corresponding flood mapping.

The 2019 Towradgi Creek Flood Study prepared by WMA Water was an addendum to the 2015 review of the Towradgi Creek Flood Study. It takes into account the revised Conduit Blockage Policy (2016) which was not considered within the Towradgi Creek Flood Study Review conducted in 2015. The 2015 Flood Study Review was based on Council's previous Conduit Blockage Policy (2002). It also included consideration of the interaction between different storm tides and catchment flooding and an examination of the potential impact of climate change for the 1% AEP design event considering sea level rise and increased rainfall intensity.

2.2.2 Corrimal Coke Works Flood Study

Cardno prepared the Corrimal Coke Works Flood Study (2017) to support the planning proposal submission. The flood study was developed to be in accordance with Wollongong City Council's DCP (2009) and NSW Government Flood Prone Land Policy. The reporting addressed the flooding component for the design of development.

The study adopted the WBNM hydrological model from the Towradgi Creek Study (2015) for the estimation of inflow hydrographs for the 100-year ARI and PMF events. The critical



storms were adopted from the 2015 Review to be 120 minutes for 100 Year ARI, and 90 minutes for PMF storm.

Detailed 2D flood study was undertaken for both the existing scenario and a developed case for the ICC site.

This model used a 2 m grid extracted from ALS data and the detailed survey of the site. The study also factored in the location of structures in the catchment as sourced from the Towradgi Creek Flood Review (2015) as well as site inspections. These structures were modelled to include the revised blockage in accordance with the Council's blockage policy revision of 2016.

2.2.2.1 Existing Scenario

The hydraulic model established in the Cardno study was validated by comparing the existing 100-year ARI results against the 100-year ARI results in the 2015 Review. The results for the existing peak flow depths can be found in **Figure 3** and **Figure 4**.

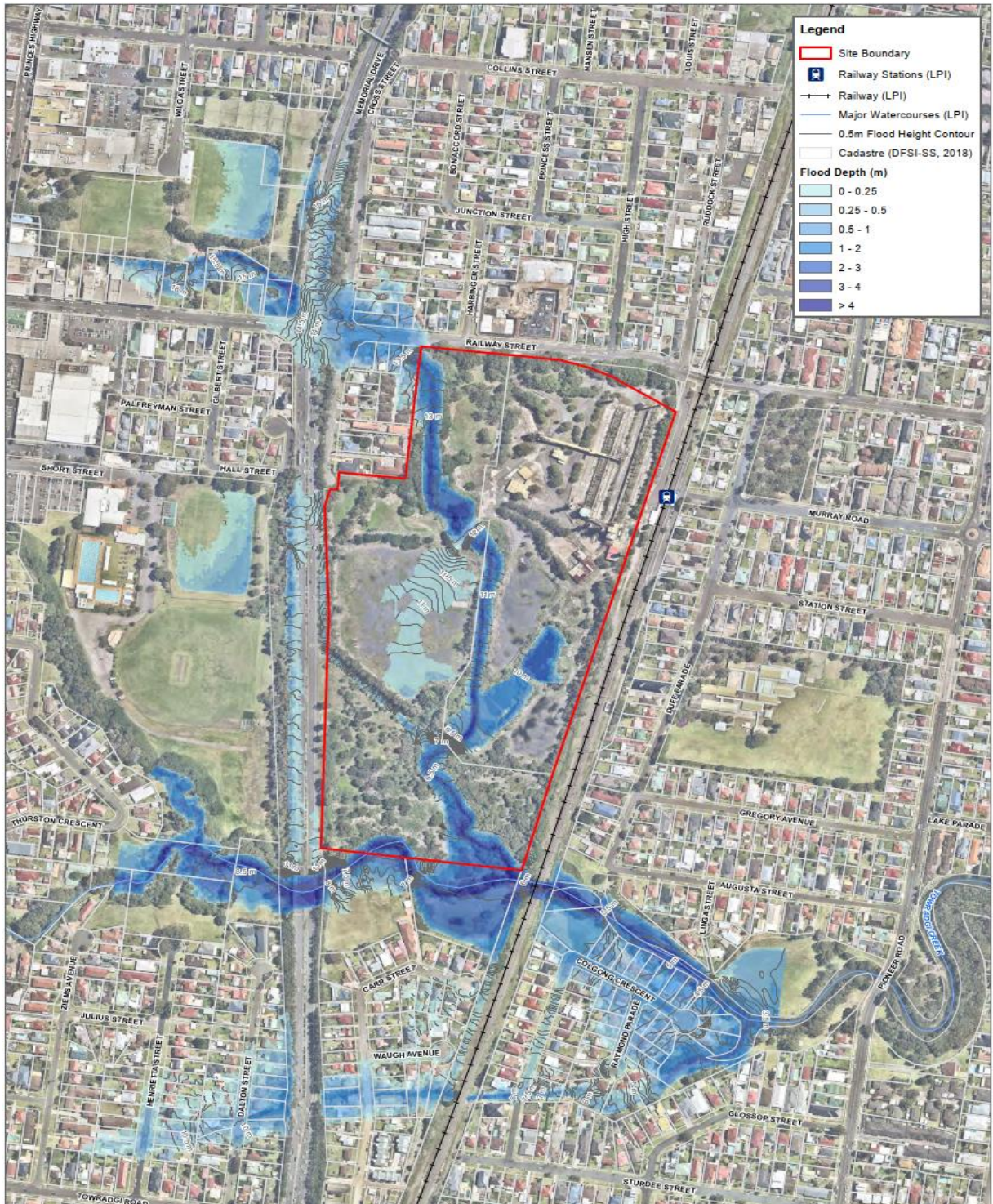


Figure 3: Existing 100-year ARI Flood Depth (Cardno, 2017)

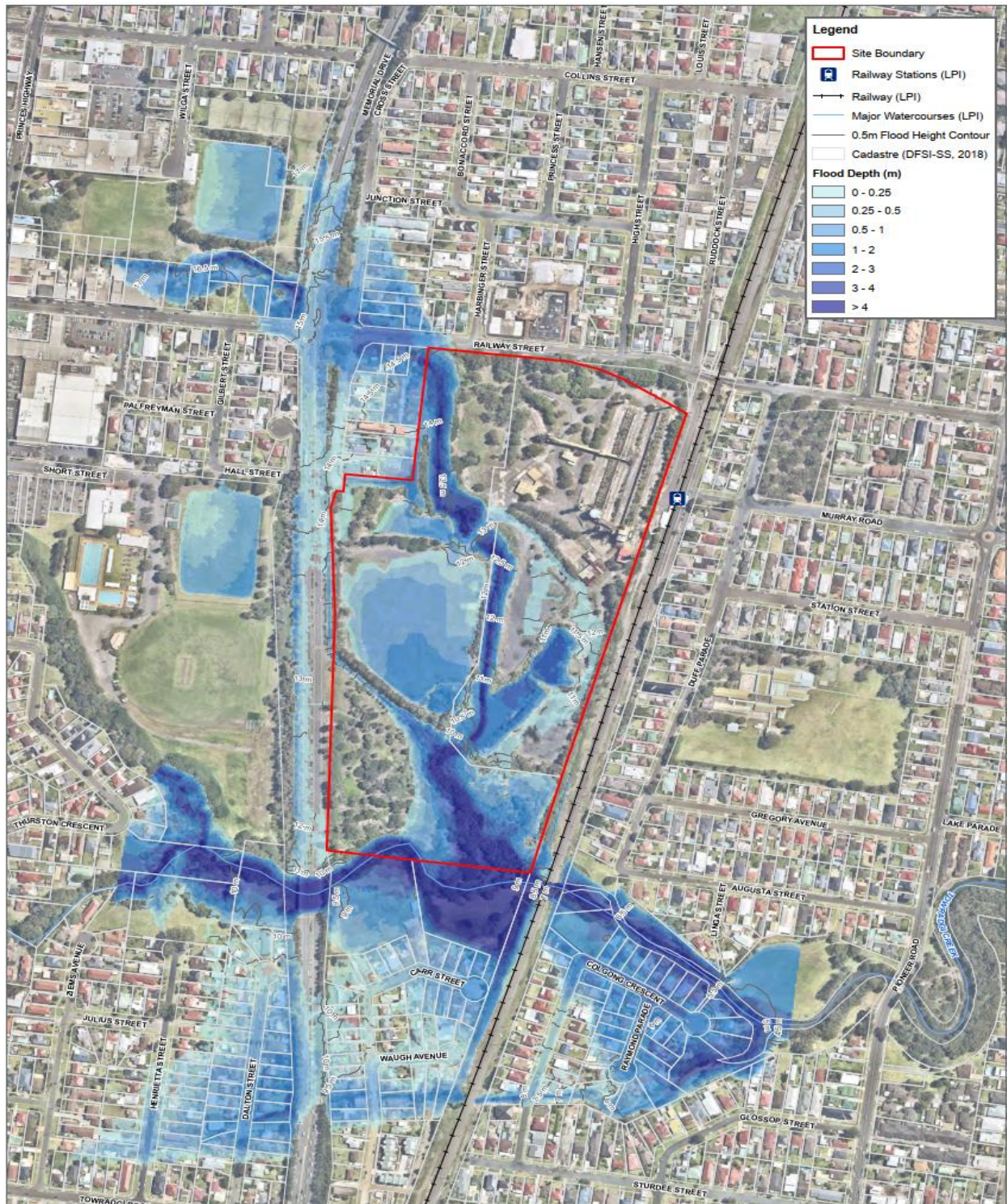


Figure 4: Existing PMF Flood Depth (Cardno, 2017)

2.2.2.2 Developed Scenario

The developed scenario used in the Cardno study was based off the Proposed Masterplan prepared by DKO Architecture (Drawing reference: SK102 Rev P7, Nov 2018). The development scenario also included the realignment of the North Corrimal Creek to the western portion of the site to create a flood free developable area. The 100 year ARI and PMF water depth results for the developed scenario can be noted in **Figure 5** and **Figure 6**.

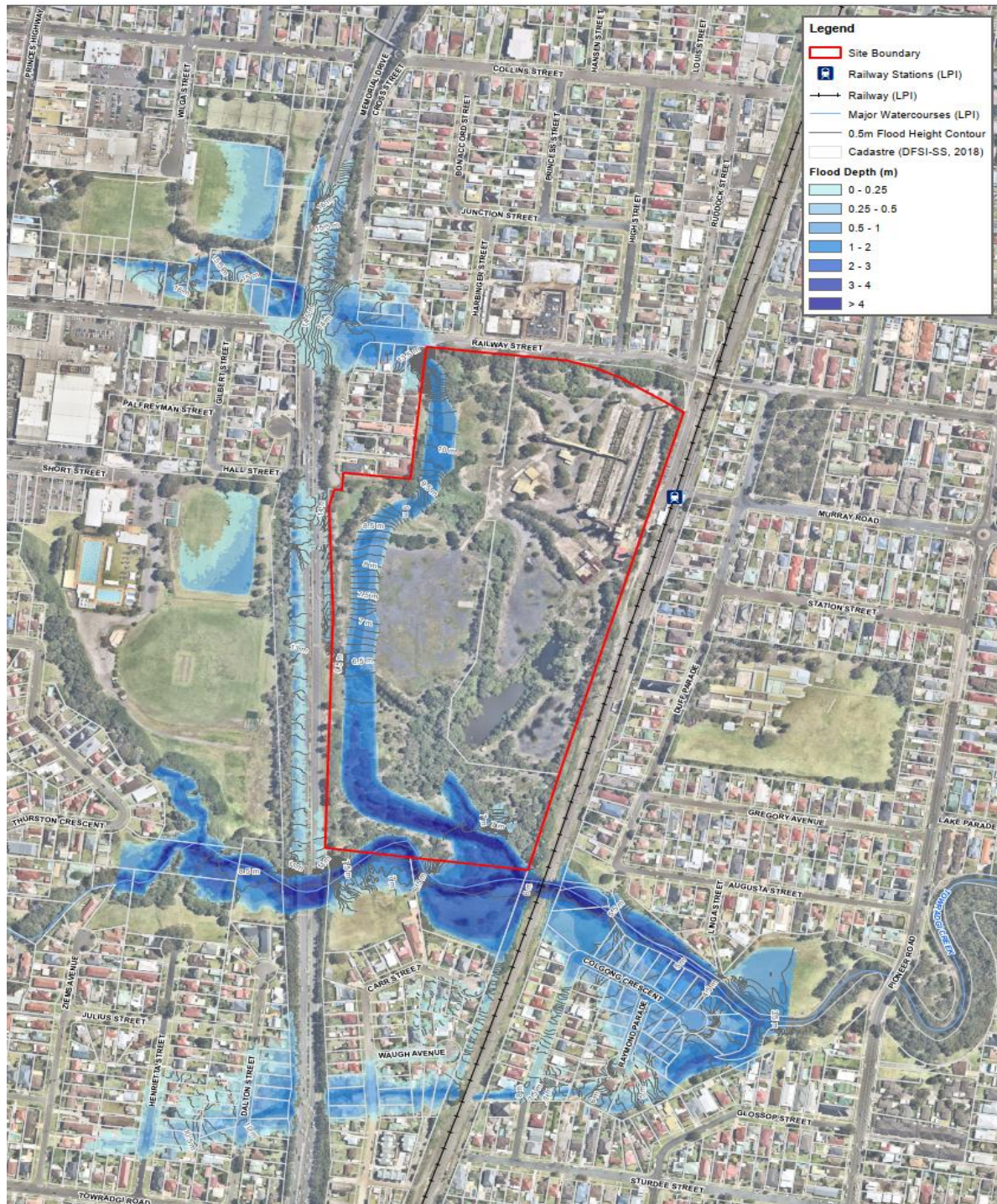


Figure 5: Developed Scenario Flood Depth 100-year ARI Flood Depth (Cardno, 2017)

The proposed scenario showed reduced flood levels on Railway Street and within the existing residential buildings located to the north-west of the site. The flood levels immediately downstream of the site remained unchanged in the developed scenario.

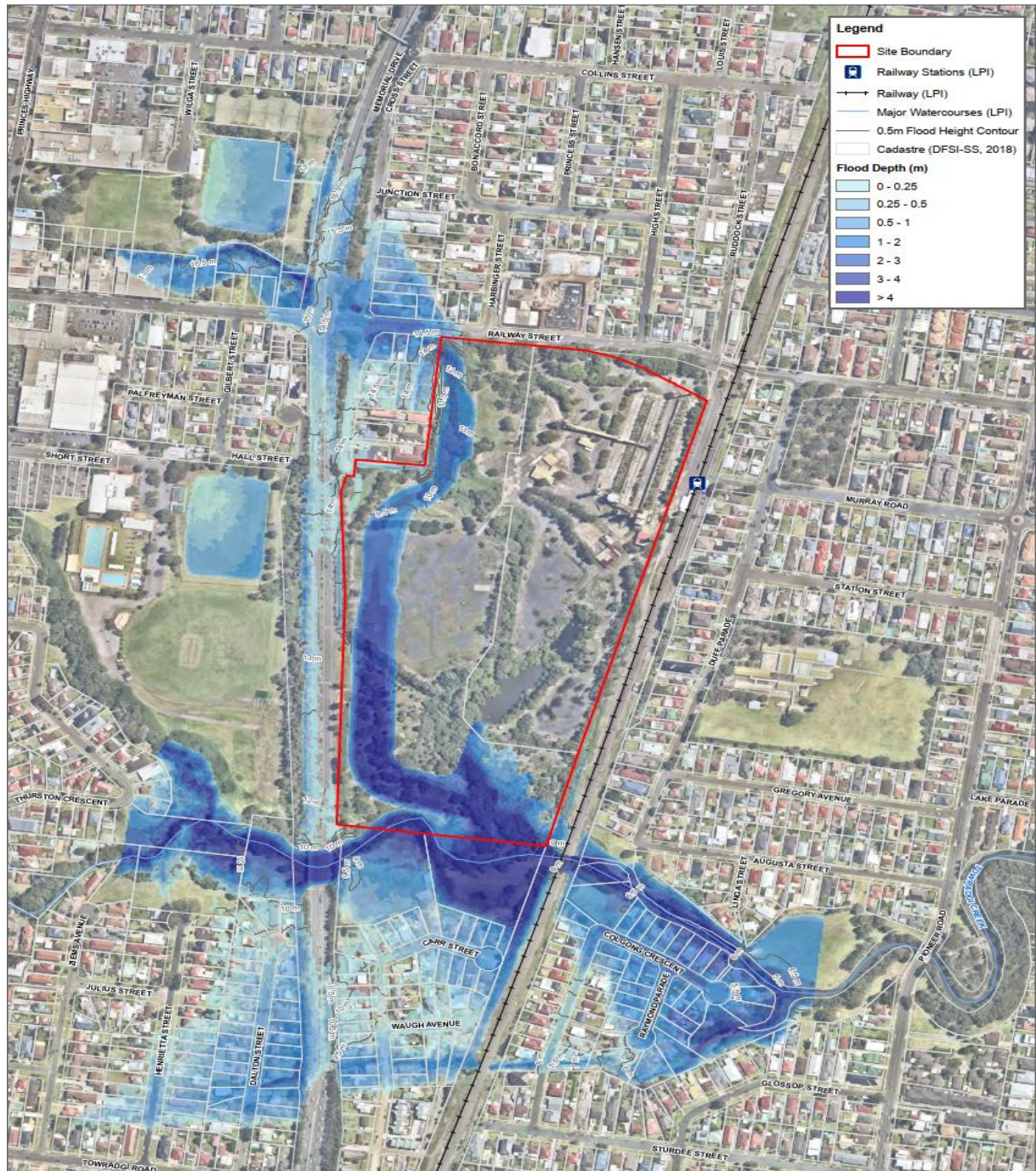


Figure 6: Developed Scenario PMF Flood Depth (Cardno, 2017)

2.2.2.3 Watercourse Realignment

The development scenario within the study completed by Cardno proposed the realignment of the existing creek through the site to along the western boundary, connecting back into Towradgi Creek at the southeastern corner of the site. This included formalising the existing minor channel that runs along the western boundary. The proposed creek realignment also considered works required for decommissioning of the existing creek alignment. A summary of the key design features in the Cardno Model are featured in **Figure 7** and are mentioned below.

1. Rehabilitate the existing North Corrimal Creek alignment bounding the Cross Street residential development.
2. Divert existing North Corrimal Creek alignment towards the western ICC site boundary.



3. Provide an opportunity to improve drainage of the existing residential area. Remove existing levee located on ICC site.
4. Formalise new creek alignment along the western ICC site boundary.
5. Divert the new creek alignment back towards to existing North Corrimal Creek.
6. Area to be revegetated and used for VRZ offsets.
7. Rehabilitate and formalise the existing North Corrimal Creek alignment.
8. Maintain ground levels and sensitive vegetation within this area.

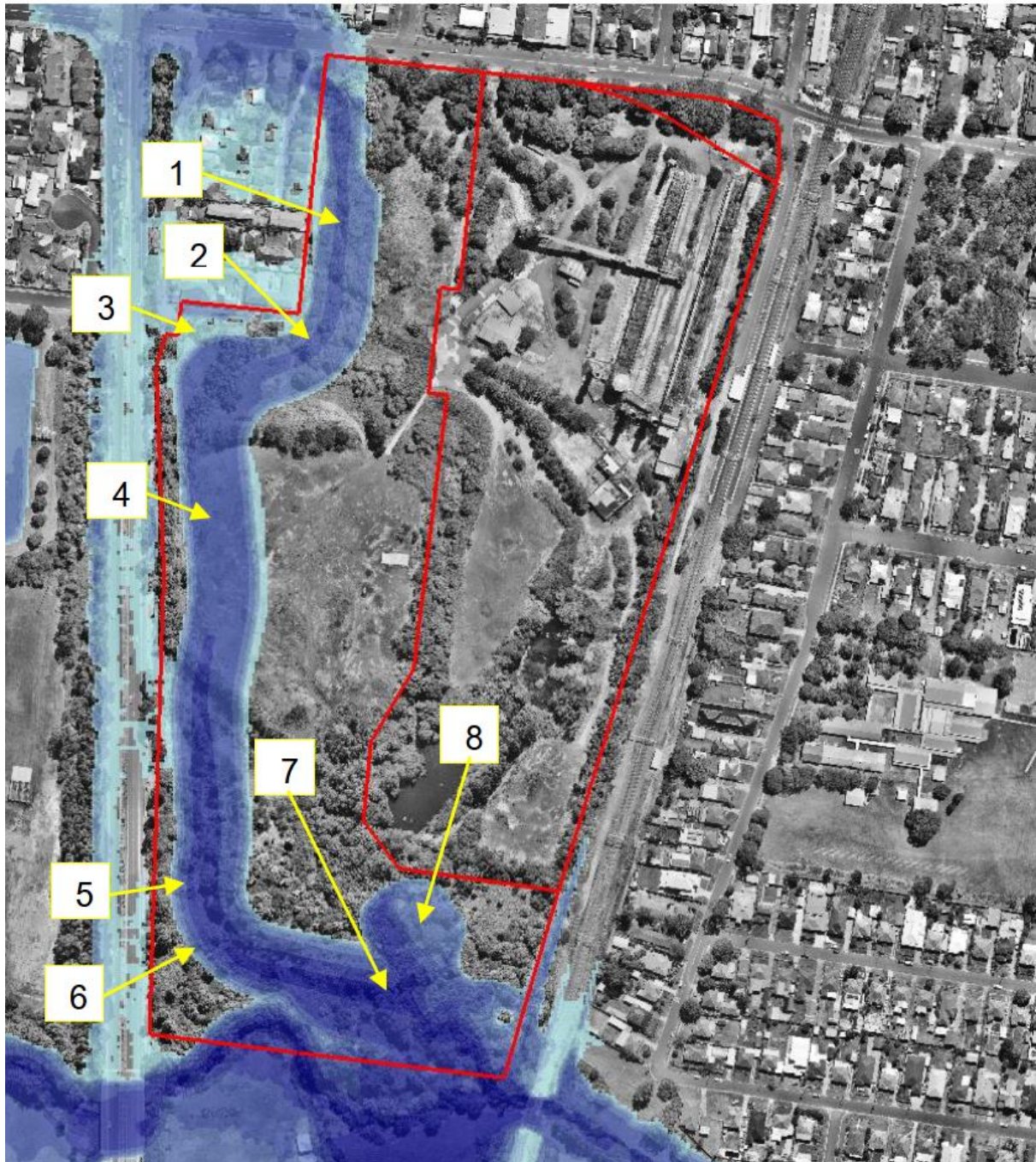


Figure 7: Initial Watercourse Realignment Option and PMF Extents

The realigned channel was designed with sufficient capacity to convey major flood events up to and including the PMF, resulting in flood immune developable area in the eastern part of the site.



2.2.2.4 Geomorphological Considerations

A geomorphological report prepared by NSW Soil Conservation Service (2018) (included within Appendix E) was used to appraise the proposed watercourse realignment. It also verified that the proposed design channel pattern will be sustainable for long term channel stability. From a geomorphological perspective, the 1% AEP event was found to be suitable to assess the considerable adjustment to the channel form, but reference is made to considering smaller events, including the 2-year ARI event.

The realignment design contained a concept level design of the macro-channel, on which this assessment was based, as seen in **Figure 8**.



Figure 8: Realignment Design Geomorphology Assessment ICC Redevelopment



Review of the velocity outputs for the 1% AEP flow event indicated that for the bulk of the realignment length, flow velocities were below 3 m/s. These velocities were also like those along the existing creek alignment. The key exception was an approximate 100m section at the upstream extent of the site where velocities were predicted to increase from 1.5 – 2 m/s under existing conditions, to 3 – 4 m/s under proposed. This can be seen in **Figure 9**.



Figure 9: Proposed Design Velocities 1% AEP (Geomorphology Assessment, ICC Redevelopment)

The report provided recommendations for the future phase of the design to ensure flood mitigation and achieve the overall creek realignment intentions specified in the Cardno study (2019).

2.2.3 Council Adopted Towradgi Creek Flood Study

The 2023 Towradgi Creek Floodplain Risk Management Study and Plan was prepared by WMA Water. It included updated hydrological and hydraulic modelling taking into account revised ARR guidelines adapted to the Illawarra and changed catchment conditions since the previous report.



The study found that the 120-minute duration was critical for 1% AEP flooding at the coke works site (and elsewhere between Memorial Drive and Linga Street) and identified representative temporal patterns. It noted that the results of this new study are similar to the old study, with generally lower flows.

Tailwater levels at the lagoon considered the Towradgi Lagoon Entrance Management Policy (2007) and included envelopes of normal tides and high tides (5% AEP and 1% AEP)

The study included updated climate change cases with ocean levels below the lagoon and increased rainfall intensities considering the latest ARR advice on sea level rise and rainfall increases. It notes that the impact of sea level rise considered is limited to downstream of the railway.

The study also considered changes to the NSW Flood Prone Land Policy, including defining a flood planning area (FPA) and flood planning level (FPL) based on a defined flood event (DFE). The study suggested adopting a DFE, FPL and FPA calculated by:

$$DFE = 1\% \text{ AEP} + \text{blockage envelope} + 0.9\text{m sea level rise} + 16.9\% \text{ increase in rainfall}$$

$$FPL = DFE \text{ level} + 0.5\text{m freeboard}$$

$$FPA = \text{Area defined by the extent of DFE} + 0.5\text{m freeboard}$$

Extracts from the published results for the site are shown in **Figure 10**.

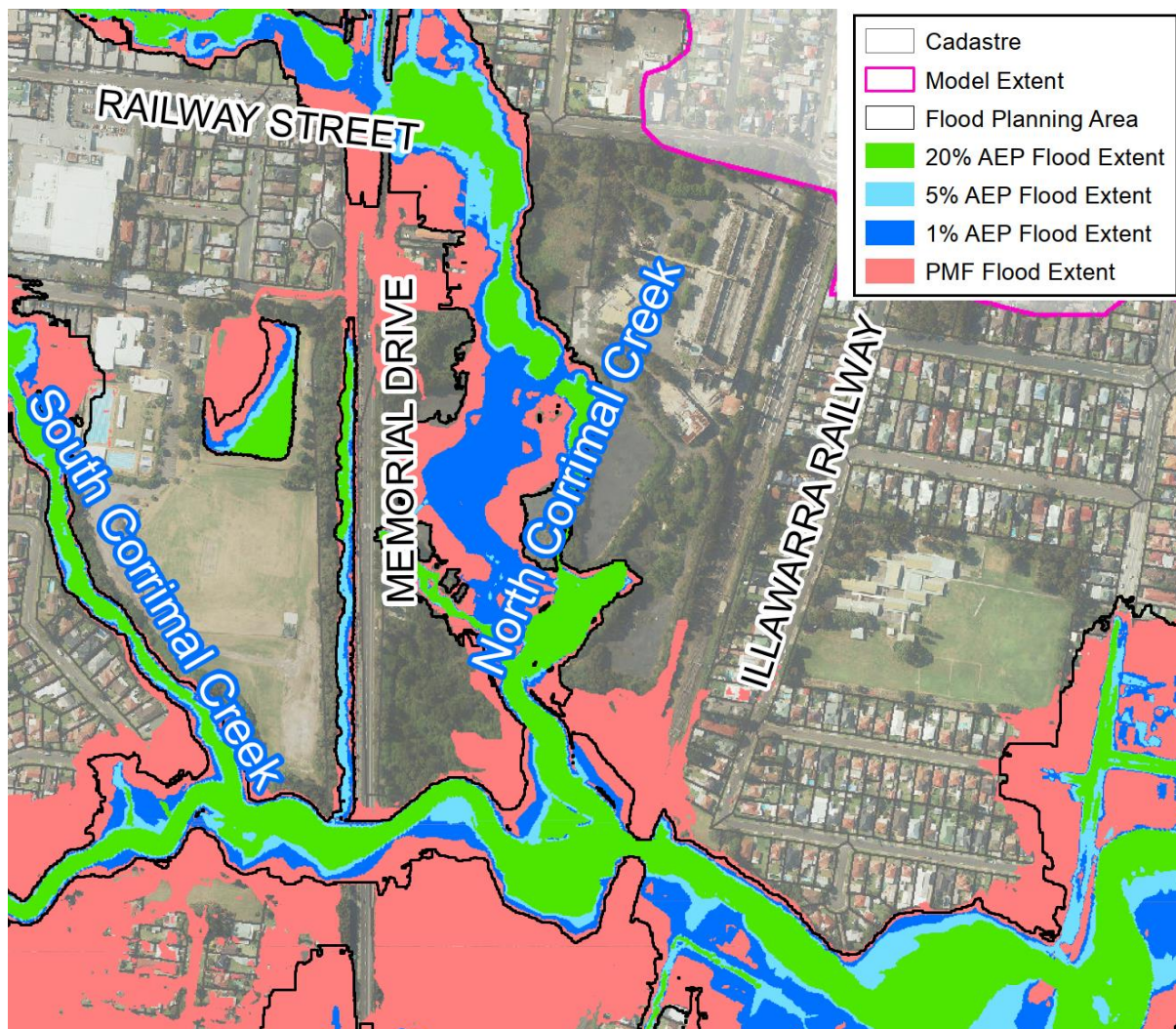


Figure 10: Results from Towradgi Creek Flood Study (WMA Water, 2023)



The study noted that properties along Railway Street near Memorial Drive (adjacent to the northern end of the site) were 'more frequently inundated' (one in the 20% AEP, two in 10% AEP and one in 2% AEP).

The study considered the development of the coke works site as 'future development'. It noted that:

“the site is subject to significant flood risk due to its proximity to the confluence of North and South Corrimal Creeks. North Corrimal Creek flows through the centre of the site, flows are fairly contained to the creek corridor, until the 2% AEP when flow breaks from the creek inundating more of the site. The higher areas of hydraulic hazard are generally contained to the creek corridor. Modelling of the DFE event which includes future climatic conditions shows that this area has the potential to experience higher hazard than in the current conditions 1% AEP event. During the DFE the extent of hydraulic hazard H5 is larger. The planning proposal includes realignment of the creek to the west of the site As part of the on going design this development should give consideration to any potential increases in flood levels as well as suitable access during flood events”

The Floodplain Risk Management Plan includes assessment of a range of options to modify flood behaviour. None of the recommended options have a significant impact on flooding behaviour on the site (CM01 results in slightly higher flood levels along North Corrimal Creek). It notes that council's existing vegetation management program includes management of Towradgi Creek at the southern end of the site and suggests that this reduces flood levels and should be continued.

2.3 MODEL DEVELOPMENT AND VALIDATION

Maker have undertaken flood modelling using a 2-dimensional TUFLOW model. The model was developed from council's adopted Towradgi Creek flood model (WMA Water, 2023), as made available through the SES flood data portal. The method and assumptions made in developing the site model and results of the validation are outlined below.

2.3.1 Elevations

2.3.1.1 Pre-development

The base elevations from the Towradgi Creek model were updated using detail survey of the site undertaken by Maker in 2022 and 2023, provided as a appendix A. The pre-development elevations are shown on Map D010 in Appendix C.

2.3.1.2 Post-development

The post-development surface was made by superimposing the concept grading of the proposed development on the pre-development elevations. This included roadways and residential parcels based on the indicative layout and the realigned creek. It also includes a new shared path bridge across Towradgi Creek. The abutments are included based on the design surface and the bridge opening itself is included as a 2D layered flow constriction. Post-developed elevations are shown in Appendix C Map D110.

The bridge has been modelled as a 22m opening, allowing a form loss coefficient of 0.12 for piers (this could allow for piers making up 8% of the opening area). A clear span of 10m would allow for there to be no piers within the Towradgi Creek channel. To achieve a 10% AEP flood immunity for the bridge it has been located with a deck level of 5.9m AHD. This is roughly 5.7m above the channel invert and 3.2m above the top of bank level. To tie in with



existing surface levels, the abutment on the southern side needs to grade down. The abutment is proposed to grade down at 7% grade (suitable for a shared path) over 35m to tie in to the surrounding ground levels at 3.5m AHD. The abutment ramp has been angled relative to the flow to reduce the restriction on the flow of flood waters. Tying in with the existing surface here means the end of the path does not have 10% AEP immunity, but does allow the path to connect with the existing path under the railway bridge.

2.3.2 Materials

The materials for the site were defined based on the council approved flood model, detailed survey, design plans for the site and aerial imagery. The materials in the existing case were varied from the council model to reflect the location of the creek from the detail survey. The post-development case included materials for the proposed roads, lots, and vegetation of the realigned North Corrimal Creek. The proposed model also includes the southern village park. The materials used in the existing and proposed cases are shown in Maps D011 and D111 in Appendix C.

2.3.3 Blockage/Debris

During April 2024 the Corrimal cokeworks site experienced heavy rainfall causing a 'bank full' flow along Towradgi creek. An assessment of the site after the event, found a large number of floating debris (FD), see example in **Figure 11**. In particular vegetation ranging from small sticks to trees 10m in length were found in the riparian corridor. Additionally urban debris (UD) was located, consisting predominately of trolleys and tyres on the larger end for a maximum length of 1.5m. A blockage assessment following the procedure outlined in ARR Book 6 Chapter 6 was undertaken, provided as appendix B. This assessment concluded the debris potential at the hydraulic structures around the site was high. The conclusion based on that assessment is that floating debris would result in a 100% blockage of the railway bridge, but the blockage cause by floating debris would only occur on the falling limb and the inlet would only be partially blocked at the peak. Blocked and unblocked cases have been included in the TUFLOW model based on Wollongong Council's blockage policy (outlined in E13), consistent with the council supplied model.



Figure 11: Floating Debris at 22 Colgong Crescent

2.3.4 Validation

The results of the site predevelopment case were compared against the council approved Towradgi Creek flood model. The DFE water level contours for the two models are shown in **Figure 12**, and the difference between the two is shown in **Figure 13**. There are several areas where there are differences between the results of the two models, as highlighted on **Figure 13**:

1. The North Corrimal Creek channel as surveyed is significantly less narrow than is shown in the council flood model. In the council model, North Corrimal Creek is defined through a series of draped channel strings with a fixed width on top of underlying LIDAR. There are two notable areas where the surveyed cross section is wider and has more capacity than the council model, shown on **Figure 13** as 1a and 1b and also noted in **Figure 14**. This leads to significantly decreased flood levels at the upstream end of the site, transitioning back to equal levels upstream of the Memorial Drive North Corrimal Creek crossing.
2. There are variations in the flood levels through the site, which we attribute to changes in elevation in the detailed site survey. In the area marked as 2a in **Figure 13** the detail survey shows mounds which are visible on the aerial images from 1993, which are not shown on the council flood model surface (see **Figure 15**) In the area marked as 2b the channel and the riparian corridor have been picked up on the survey.
3. The stormwater outlet channel between Memorial Drive and North Corrimal Creek (labelled 3a in **Figure 13**) is significantly deeper and more defined in the existing case than in the council model. This leads to decreased tailwater levels on the eastern side



of Memorial Drive, increased pipe flows under the road and decreased flows along the western side of Memorial Drive (resulting in lower water levels in area labelled 3b)

Apart from flood levels we also considered differences in flows between the two models. The increased capacity of the channel discussed in point 1 above means that slightly more flow enters the site from Railway Street in the existing case compared to the council model (less than 2% difference in peak flows), hydrographs for the unblocked normal tide 10 year and DFE cases are shown in **Figure 16**.

The site flood model is considered validated for the purposes of this assessment. Changes have been incorporated into council's adopted flood model to account for areas within the site where new elevation information is available.



Figure 12: Published DFE depth and water level (black contours) and existing case extent (green) and water level (orange contours)

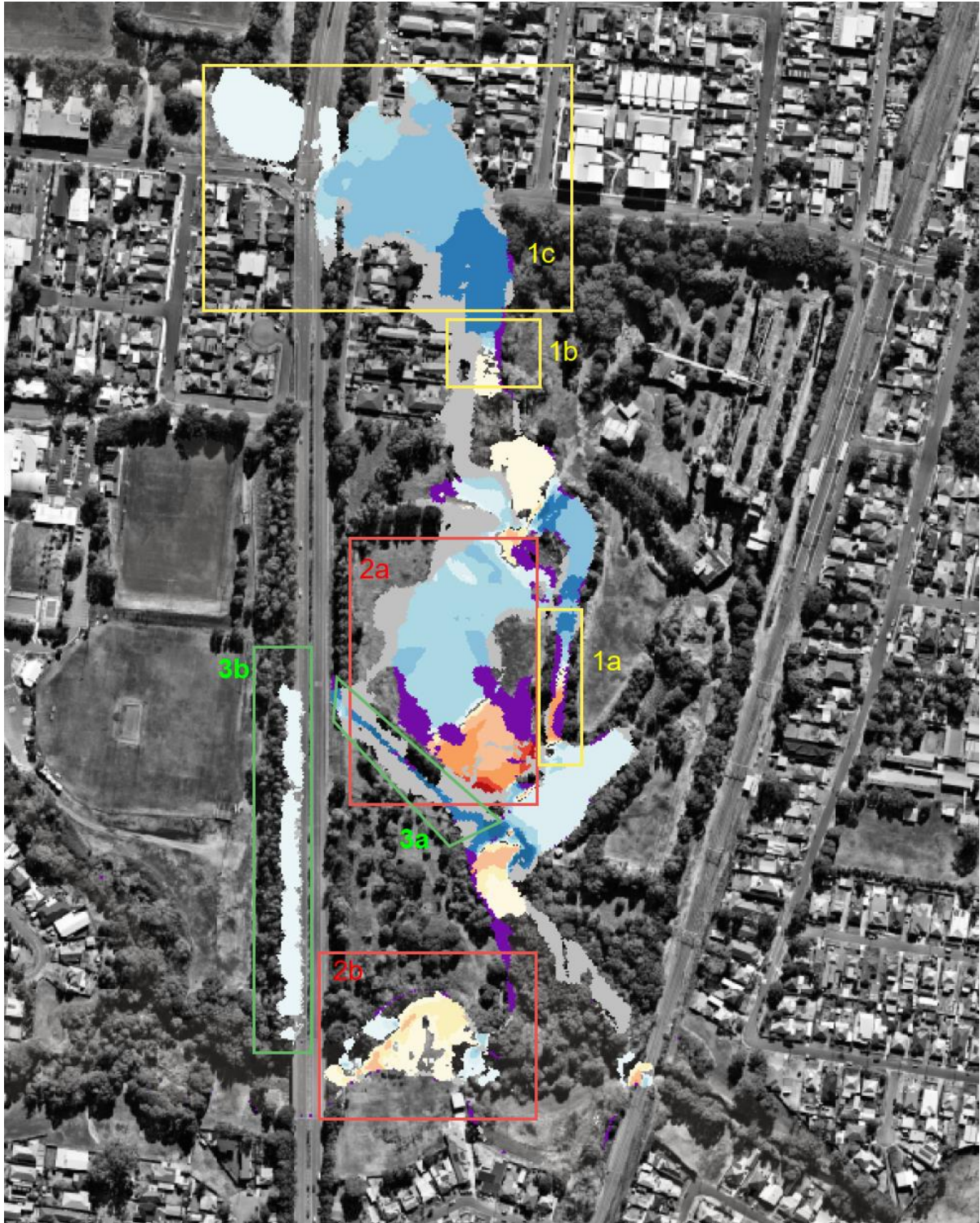


Figure 13: Difference between Council model DFE water level and existing case

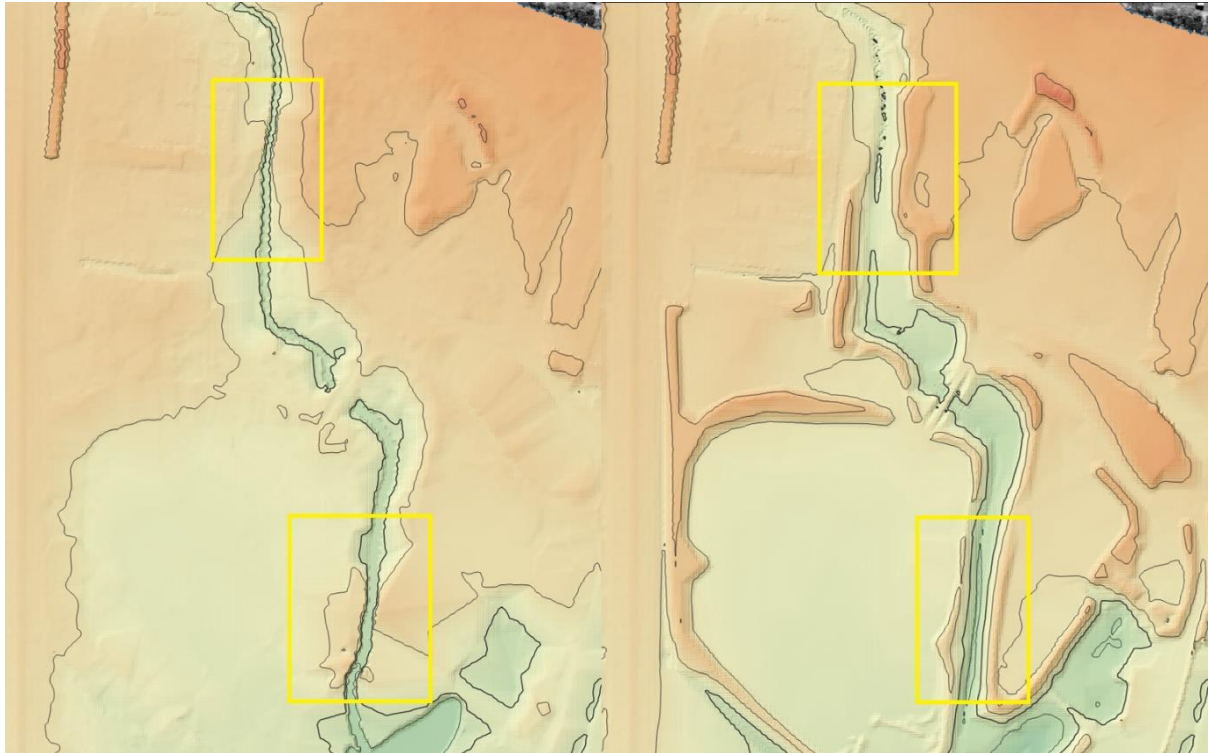


Figure 14: Council topography along North Corrimal Creek (left) and existing case incorporating detail survey (right)

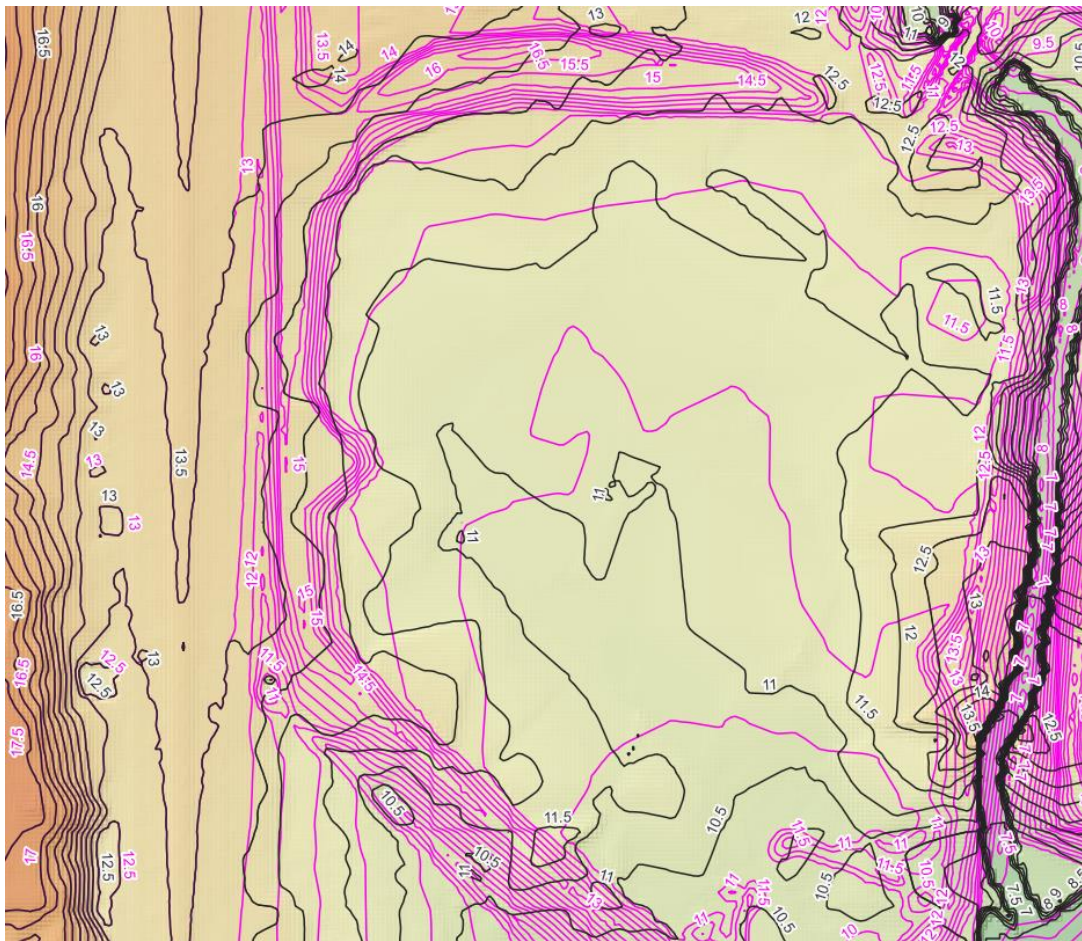


Figure 15: Area within the site between North Corrimal Creek and Memorial Drive, council flood model ground level 0.5m contours in black, existing case contours from this study shown in magenta

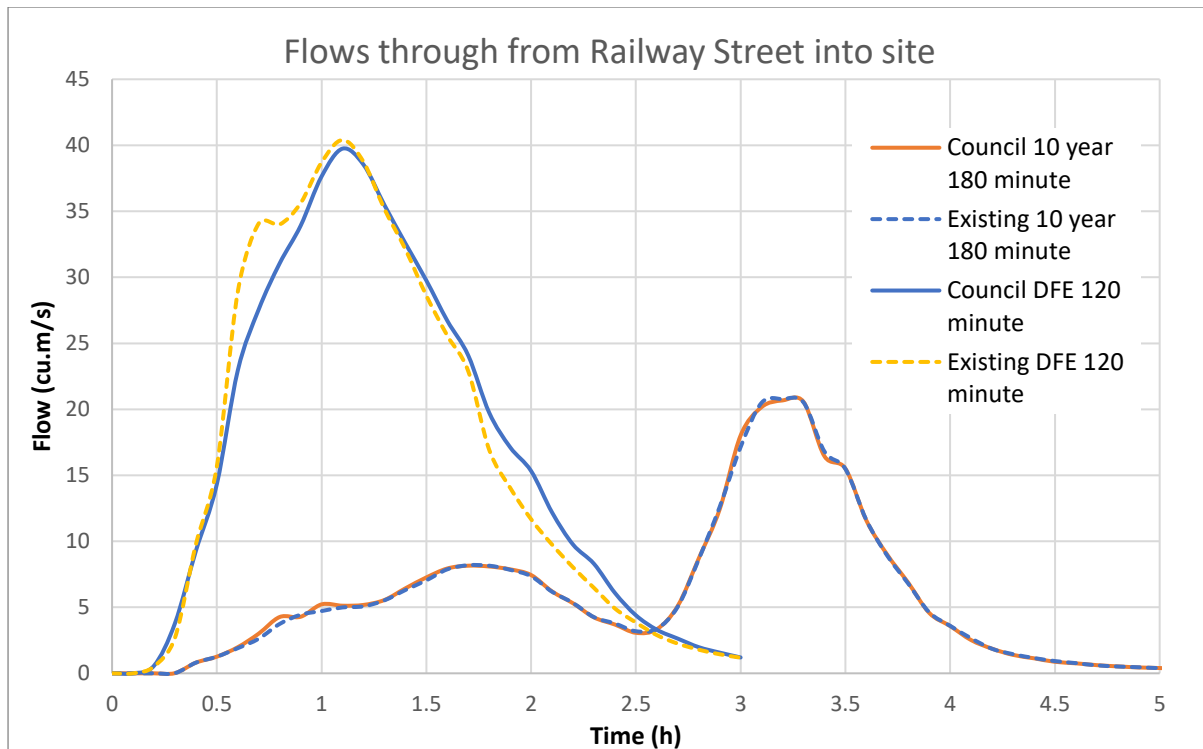


Figure 16: Hydrograph comparing flows between existing case and council model in North Corrimal Creek into the site

2.3.5 Results

Flood maps including a range of outputs requested in DCP Chapter E13 Section 9 for the existing and proposed scenario are provided in Appendix D

2.3.5.1 Depth

The depth results within the site have been well distributed through the creek. In the existing case the channel through the site contains the 2% AEP flows but the 1% AEP flows spill into the open area to the west of the channel. The proposed pedestrian bridge across Towradgi Creek is flood free in the 10% AEP but is inundated in larger floods, with the DFE level 500mm above deck level. Houses in Carr Street south of the site are only impacted in the PMF, remaining flood free in the 0.2% AEP event. Frontages of lots along Railway Street at the north of the site are inundated across the range of flood events considered (as small as the 50% AEP), with above flood flooding in the existing case in the DFE. In the proposed case the realigned creek has been designed to contain flows up to and including the PMF creating a large flood free area for development. The upstream and downstream ends of the site show no worsening across the range of events.

2.3.5.2 Hazard

Wollongong City Council suggest the definition of flood hazard in accordance with the hazard curves defined in Technical Report 2014/07 'Flood Hazard' (UNSW Water Research laboratory, 2014)

The existing North Corrimal Creek channel has H5 hazard in the 50% AEP, and H6 in the 10% AEP and larger storms.

The realigned creek has H4 hazard in the 50% AEP, H5 in the 20% AEP and H6 in the PMF. The high-risk areas (areas with hazard more than H3) within the site are contained to the



channels. The hazard outside of the site both in the upstream and downstream ends are the same as in the existing conditions.

2.3.5.3 Hydraulic Classification – Flood Function

The 2023 Towradgi Creek Flood Study, Floodplain Risk Management Study and Plan identifies the flood function of different parts of the floodplain by categorising it into Floodway, Flood Storage and Flood Fringe areas, using the criteria shown in **Table 1**. These criteria were arrived at after consideration of the definitions in the 2005 Floodplain Development Manual and use of an encroachment technique. The site flood study results have been mapped using this categorisation.

The maps presented for flood function are a pure application of this hydraulic definition and have not been adjusted to satisfy any other floodway criteria. There are some isolated patches marked as floodway in the existing case which appear to be better classified as storage areas.

Table 1: Hydraulic Category Definition

Hydraulic Category	Definition
Floodway	Velocity depth product greater than 0.25m ² /s AND Velocity greater than 0.25m/s OR Velocity greater than 1m/s
Flood storage	Areas outside the floodway where depth is greater than 0.25m
Flood fringe	Areas outside the floodway where depth is less than 0.25m

2.3.5.4 Flood Risk Precincts

Wollongong City Council has adopted a three-tier flood risk precinct classification. The precincts have been mapped for the existing and post-developed cases following the definitions given in the Floodplain Risk Management Study (shown in **Table 2**), an adapted form of those in DCP Chapter E13. It is worth noting that the Floodplain Risk Management Study suggests altering the definition of high flood risk precinct in the Towradgi Creek catchment to that shown in **Table 2** to refer to the DFE in the hydraulic controls (which incorporates climate change) and to remove the high flood risk criteria for land within 10m of the top of watercourse banks. For the sake of completeness, we have included the linework showing 10m from the top of watercourse bank on provided maps M066 and M166.

The high-risk precinct in the existing case covers the creek, Memorial Drive and some of the property frontages on Railway Street.

In the proposed case the high flood risk precinct on Railway Street is reduced and within the site is contained within the realigned creek corridor.

Table 2: Flood risk precinct definition

Flood risk precinct	Definition
High Flood Risk Precinct	<ul style="list-style-type: none"> ▪ Areas greater than H3 hazard conditions in the DFE ▪ Floodways in the DFE
Medium Flood Risk Precinct	Areas within the flood planning area and not identified as High Flood Risk



Low Flood Risk Precinct	All areas within the floodplain (defined by the PMF extent) not within the high or medium flood risk precincts
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The NSW Flood Risk Management Manual notes that flood risk is made up of a number of factors, including flood behaviour (as described by the flood risk precincts). It notes that a flood only poses a risk to a community if it has consequences to the community. It is the human interaction with flooding due to occupation and use of the floodplain that creates risks to communities. In line with the objectives to improve the recreation values of the waterway corridor the proposal will result in increased public accessibility into the floodplain, which increases the risk of consequences. The design of the waterway corridor provides focus on the stream, which gives users an awareness that they are in a waterway corridor and makes areas outside the corridor flood free. There will also be increased usage of Railway Street due to the development, which is inundated and hazardous to motorists and pedestrians as frequently as 50% AEP. Although the creek realignment reduces the hazard in the road, the increased population using Railway Street increases the risk that someone will choose to drive through floodwaters, the most common way people in Australia die during floods. Community education will be key to ensuring that the new development does not increase flood risk.

2.3.5.5 Predicted Impacts

The difference in flood levels between the existing and proposed case were calculated and are shown for the [10% AEP \(M173\)](#) and the [DFE \(Map M176\)](#).

The proposed realignment of the creek results in the old creek channel within Lot 1 being no longer flooded across the range of flood events. The realignment creates new flooding to the west of the site within the realigned creek. [The construction of the shared path bridge does not lead to significant increases in flood level upstream of the bridge in the 10% AEP and DFE events.](#)

Predicted impacts on the development in the DFE include:

- [Flooding is increased to the south of the site by less than 20mm.](#)
- Change in flood level downstream of the railway bridge or upstream of Memorial Drive less than 10mm.
- The amplified creek at the north-west of the site shows a decrease in the flooding of up to 1m.
- decreases in flood level at the junction of Railway Street and Cross street by 30-50mm.

Predicted impacts in the PMF event:

- The junction of Railway Street and Cross Street shows an approximate 40mm decrease in flooding.
- The lots located on Cross Street show a decrease in flooding by up to 300mm.
- The flooding on Memorial Drive along the site extents decreases by roughly 30mm, with places decreasing near the Railway Street slip lane by more than 150mm.

DCP Chapter E13 gives a list of criteria for assessing PMF impacts:

- Impacts to evacuation routes and onsite refuge service levels.

The proposed works do not decrease the service levels of evacuation routes and creates significant new refuge areas in events up to and including PMF.

- Additional Flood affected allotments.



North Corrimal Creek being retained has capacity for ~80cu.m/s (both more than the 0.2% AEP). The proposed bridge over Towradgi Creek has capacity for the 10% AEP flow to be conveyed under and is located in the wider floodplain in a location so that it is not limiting the conveyance capacity in the large events.

2.3.5.8 *Economic impact of flooding*

The Towradgi Creek Floodplain Risk Management Study includes a recent assessment of the economic costs resulting from damage to communities as a result of flood events.

In their contention council asserted that the proposed works do not reduce private and public losses from flooding. As such, the economic assessment in the FRMS has been reviewed and any changes caused by the development considered.

That assessment has a focus on direct tangible damages, and notes that it is intended to be a regional assessment using a standard methodology to allow for easy comparison with other flood prone communities. It excludes costs associated with restoring or maintaining public services and infrastructure during and after a flood. The assessment of damage is based on flooding above floor level of residential and commercial properties. Council provided the surveyed floor levels of surrounding flood affected properties. The results were reviewed, and there is no difference between the existing and proposed cases in the first event flooded at any property. As noted in Section 2.3.5.5, the proposed works lead to a decrease in flood levels on surrounding properties, so, although it may not lead to a decrease in above floor flooding (because the change in level does not lead to a change from above floor to below floor), it will not lead to an increase in flood damages. There are four properties where the smallest event that leads to above floor flooding is different between the published study and both the existing and design cases (due to the change in flood levels between the published and existing cases around Railway Street discussed in Section 2.3.4), tabulated in **Table 4**. This represents roughly a 4% reduction in total catchment residential above floor flooding compared to the council model.

Table 4: Changes to above floor flooding

Property	Surveyed floor level	First event flooded		
		Council Study (2023)	Existing	Proposed
29 Railway Street	13.226	10% AEP	1% AEP	1% AEP
31 Railway Street	13.718	2% AEP	0.5% AEP	0.5% AEP
69 Cross Street	13.44	10% AEP	1% AEP	1% AEP
65A Cross Street	13.947	1% AEP	0.2% AEP	0.2% AEP

The FRMSP also notes there are other contributors to flood damages apart from above floor flooding, including damage to infrastructure, cleanup, disruption of services and intangible damages like inconvenience and stress. Some of the impacts of the development would lead to a decrease in some of these losses. For example, the slightly reduced flood level in Railway Street may slightly reduce losses. The difference is not very significant but is a reduction rather than an increase.



2.3.5.9 Geomorphological Considerations

DCP Chapter D19 Clause 5.14.2 requires that the “realigned North Corrimal Creek must be geomorphologically stable when considering shear forces, velocities, stream power and flow, as well as the impact and dynamic changes of debris for all storm events up to and including “bank full’ flows, and more frequent flood events up to and including the Probable Maximum Flood. A study on climate change impacts must be undertaken to ensure geomorphological stability is achieved for predicted changes in rainfall intensity”.

The recommendations from the Geomorphology Assessment (Soil Conservation Service, 2018) are reviewed in **Table 5** along with commentary on each recommendation. The Geomorphology Assessment report has been included within Appendix E. That report notes that the bounding sediments of the low flow channel consists of mud and silt, there are no significant accumulations of mobile bed load deposits, and that the existing watercourse does not exhibit any significant channel stability issues.

Table 5: Recommendations from Geomorphologists

Recommendations	Commentary
Macro Channel	
An approximate 100 m section at the upstream extent of the site where hydraulic modelling indicates higher velocities are expected along the realignment. Further design of the realignment form and long profile was recommended to lessen the impact to avoid the necessity of providing substantial rock protection measures along the macro-channel at this location.	The longitudinal profile of the stream and channel section through this area have been adjusted. The increased velocities are reduced to within <15 m of the headwall in the 100-year ARI, significantly reducing the area requiring rock protection measures
A section of alignment where the design is proximal to the outside bank of a bend in Towradgi Creek, presenting a potential for capture of the downstream extent of the realignment in the future through migration of the bend in Towradgi Creek. Confirmation of the subsurface conditions at this location is recommended to determine the need to address bend migration and realignment capture risks through provision of bank protection measures on the bend.	Geotechnical investigation undertaken by Douglas Partners gave a conceptual model of the subsurface conditions in this location. This was considered in the Creek Realignment Stability Assessment (BG&E, 2020) who found the proposed batter slopes, offsets and morphology are robust and provide high confidence for long-term stability
Low Flow Channel	
Establishing a pool - rock step morphology with rock steps constructed of large sandstone boulders. Some of the rock steps can be designed to provide opportunities for community access to the creek during low flows.	Low flow channel concepts have been developed in consultation with landscape architects and ecologists, to be further developed during detailed design. Minor changes to the low flow channel will not compromise the flood mitigation intent of the total channel design through the site.



Recommendations	Commentary
Providing alternating low benches along the low flow channel. Lower benches to be approximately 500 mm below the current design level of the macro-channel base and grade up gently in a downstream direction. These are to be vegetated with dense plantings of native ground cover grasses/edges and shrubs.	Alternating benches have been provided along the low flow channel. Vegetation has been considered in the proposed case roughness mapping.
On outside bends initial stabilisation of the low flow channel bank can be afforded through the installation of vegetated coir logs. Where outside bends of the low flow channel are proximal to the bank of the macro-channel, rock protection of the bend is recommended to prevent scour at the toe of the macro-channel bank.	Bed shear stress maps have been prepared for 2 year and 100-year flood events. Scour protection location will conceptually align with areas of high bed shear stress identified in these maps. Where rock protection is required, it will be sized as part of the detailed design. A bench is included in all areas between the low flow channel and the toe of the macro-channel bank.
Provision of random in-channel and bank attached rocks as flow constructions and deflector type structures to increase hydraulic diversity and habitat complexity.	Size and location of larger rocks will be designed to ensure they can withstand the predicted velocities while not increasing the manning's values greater than what has been assumed in the flood model, or the flood model will be adapted for the changes in roughness.
Riparian Vegetation Establishment	This has been considered in the proposed case roughness mapping.

The March 2020 addendum to the geomorphology report reviewed the hydraulic outputs and suggested that below a threshold value of 100N/m² the potential for erosion of vegetated bed and banks is low, and that it is probable for shear stress values exceeding 200 N/m².

The maximum bed shear stress calculated by the TUFLOW model for storm events between 50% AEP (~bank full) and the PMF are presented in Maps M181, M187, M189.

All storms considered (existing and proposed, 50% AEP to PMF) have some areas where the bed shear stress exceeds the threshold value for damage to bed and banks.

The 'excess' bed shear stress (bed shear stress greater than 100Pa) was summed across the site. The existing and proposed cases are compared across the full range of storm events in **Figure 18**. The proposed case has less 'excess' bed shear stress than the existing case in all storms up to and including the DFE, and less than 1% more in the PMF. Given that the existing watercourse does not exhibit significant channel stability issues this suggests that although there will be local scour and erosion in significant storm events this is within the amount for normal healthy function of the stream and does not present long term stability issues.

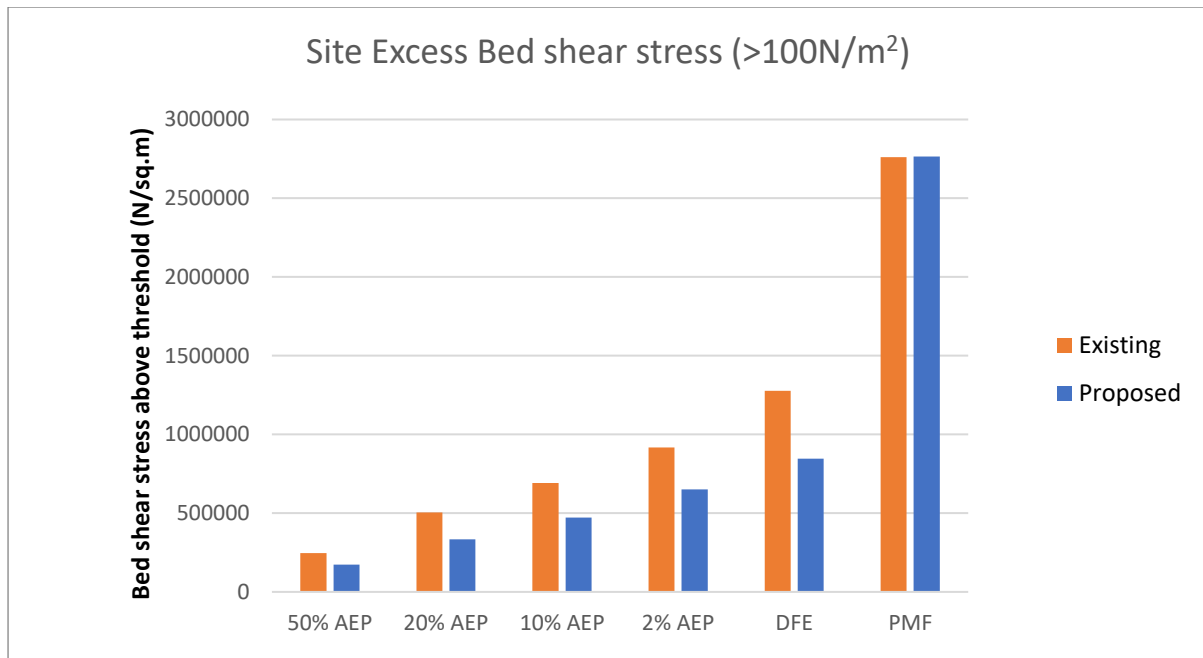


Figure 18: Site excess bed shear stress in existing and proposed case across range of storm events

The geomorphological report reviewed velocities, considering how velocities changed between the existing and proposed case and how much flows exceeded 3m/s.

In the 50% AEP storm in both the existing and proposed cases there are very few places the velocity exceeds 2m/s. In the proposed case the realigned stream has peak velocities around 1.3m/s and the retained parts of the stream show similar velocities to the existing case (slightly (<5%) lower), apart from the retained portion between the existing dam location and the join with the realigned creek, which does experience a notable decrease in velocity.

This pattern is also true in the 20% AEP and 10% AEP storms. In the 2% AEP and DFE small patches with velocity above 2m/s are evident in places in both proposed and existing events, and in the PMF there are areas with velocity above 3m/s. The realigned portion of the stream has velocities below 3m/s in all events up to and including the PMF.

The proposed case velocity is generally lower than in the existing case because the proposed low flow channel is generally wider and less deep than the existing channel, and has a low, relatively flat overbank bench. The exception is the existing dams, which provide an area of low velocity, especially in smaller events. The average velocity through the site in the 50% AEP increases from 0.72m/s in the existing case to 0.92m/s in the proposed case, but if you only consider the areas outside the dam (more relevant for consideration of scour in the bed and banks) the average velocity in the existing case is 0.99m/s, higher than the proposed case. In the DFE the average velocity through the site decreases from 1.43m/s in the existing case to 1.35m/s in the proposed case, even including the dam.

As noted above, the only significant area of velocity increase is around the headwall out beneath Railway Street, as identified in the Geomorphology report.

Stream Power has been mapped across a range of storm events in Maps M031 – M039 (existing) and M131- M139 (proposed). The geomorphology report does not provide any guideline values for stream power. 300 W/m² is a generic cutoff for geomorphic change (after Magilligan, 1992¹). Others have suggested that streams will attain a state of stability

¹ Magilligan, F. J. (1992). Thresholds and the spatial variability of flood power during extreme floods. *Geomorphology*, 5(3-5), 373-390.



when the stream power is lower than 35 W/m² (Bledsoe et al.²) and some studies show rivers with much larger stream power values (>700 W/m²) that remain stable³. The QLD guideline for watercourse diversions for mining operations (QLD Department of Natural Resources, Mines and Energy guideline: “Works that interfere with water in a watercourse for a resource activity – watercourse diversions authorised under the Water Act 2000”, 2018) says that the hydraulic criteria of the existing watercourse should be used as first preference to develop design parameters for the watercourse diversion. It also gives guideline values for average stream powers from a case study in the Bowen Basin.

The existing case has a large range of stream power, with areas reaching values over 1000 W/m² in several places even in the 50% AEP storm. The stream power is generally higher below the dam (50% AEP average stream power 183 W/m²) than it is above the dam (50% AEP average stream power 63 W/m²). The average across the entire site and various reaches is shown in **Table 6**. In general, the larger, wider channel means that stream power is reduced across the parts of the creek being adjusted. In the lower part of North Corrimal Creek below where the realigned stream joins in there are moderate (5-25%) reductions in average stream power in storms between 50% AEP and the DFE, with a 22% increase in the PMF. The addition of the shared path bridge leads to an area of reduced stream power upstream of the bridge in Towradgi Creek, which is most significant in small events.

The average stream power in the realigned reach of North Corrimal Creek achieves the guideline values for average stream power from the QLD diversions guideline (average <35 W/m² in 50% AEP and <150 W/m² in 2% AEP), and retained portions do not show an increase in stream power, so the stream powers do not suggest the realigned North Corrimal Creek will be geomorphologically unstable.

Flows were measured across two observation lines, shown on **Figure 19**:

- at the top of the site near Railway Street (named FL_17 unchanged from the council model) and
- near where North Corrimal Creek joins Towradgi Creek (named WBNM50 unchanged from the council model)

As discussed in Section 2.3.5.7 the realigned low flow channel retains the same capacity as the existing low flow channel to retain the frequency of overbank flows.

Nanson (1981) identified increased peak flows and increased frequency of flows as causes of the observed significant erosion of urban streams in the Illawarra⁴. Peak flows in the existing and proposed case are compared in **Table 7**.

The stream erosion index is a stormwater flow target adopted by several authorities in NSW. It is calculated by considering the impact the development has on the volume of flows above a critical flow threshold. The critical flow is defined as the flow threshold below which minimal erosion is expected to occur within a waterway. Based on the geomorphology advice on bed shear stress above, it was considered that minimal erosion was expected if the bed shear stress stayed below 100N/sq.m. Reviewing the TUFLOW results it was established that a flow of 5.2cu.m/s was required to induce bed shear stress above 100N/sq.m in the realigned portion of the channel. Volumes above this flow threshold across a range of storm events were calculated and are shown in **Table 7**.

² Bledsoe, B. P., & Watson, C. C. (2001). Logistic analysis of channel pattern thresholds: meandering, braiding, and incising. *Geomorphology*, 38(3-4), 281-300.

³ Yochum, S. E., Sholtes, J. S., Scott, J. A., & Bledsoe, B. P. (2017). Stream power framework for predicting geomorphic change: The 2013 Colorado Front Range flood. *Geomorphology*, 292, 178-192.

⁴ Nanson, GC, Stream channels of the Illawarra, Wollongong Studies in Geography No.7, Department of Geography, University of Wollongong, 1980



The results show that the proposed works lead to an increase in peak flow rates and volumes above the critical threshold at the top of the site. This is discussed in Section 2.3.5.5, the proposed case increases the channel capacity at the top of the site compared to the existing, slightly increasing the amount of flow entering the site and decreasing flood levels on Railway Street and adjoining properties. In spite of the increase in flows at the top of the site, in most storms there is a decrease in peak flows and volumes above the threshold at the bottom of the site. The realigned stream increases the flow length of the watercourse through the site (from 751m to 770m), decreasing average channel slope and (as discussed above) the wider, shallower section decreases average velocities. Together these mean that travel time from the top to the bottom of the site increases in large storms, (e.g. from 8.7 minutes in the existing case DFE to 9.6 minutes in the proposed case) attenuating flows. The hydrograph for the critical 10% AEP event shown in **Figure 20** shows this clearly.

As discussed in Section 2.3.3 the catchment is a significant source of floating debris up to 10m in length and urban debris. The debris control structure and restricted pipe size at Memorial Drive limit the flow of large debris from the catchment upstream of Memorial Drive into the site. The existing online dam is a sink for sediment and debris and its removal will likely lead to an increase in debris loading downstream. The vegetation of the low flow channel and retaining the frequency of overbank flows will provide increased opportunities for recruitment of woody material and vegetation to create diverse environments and increase long scale geomorphic stability.



Figure 19: Flow observation line locations

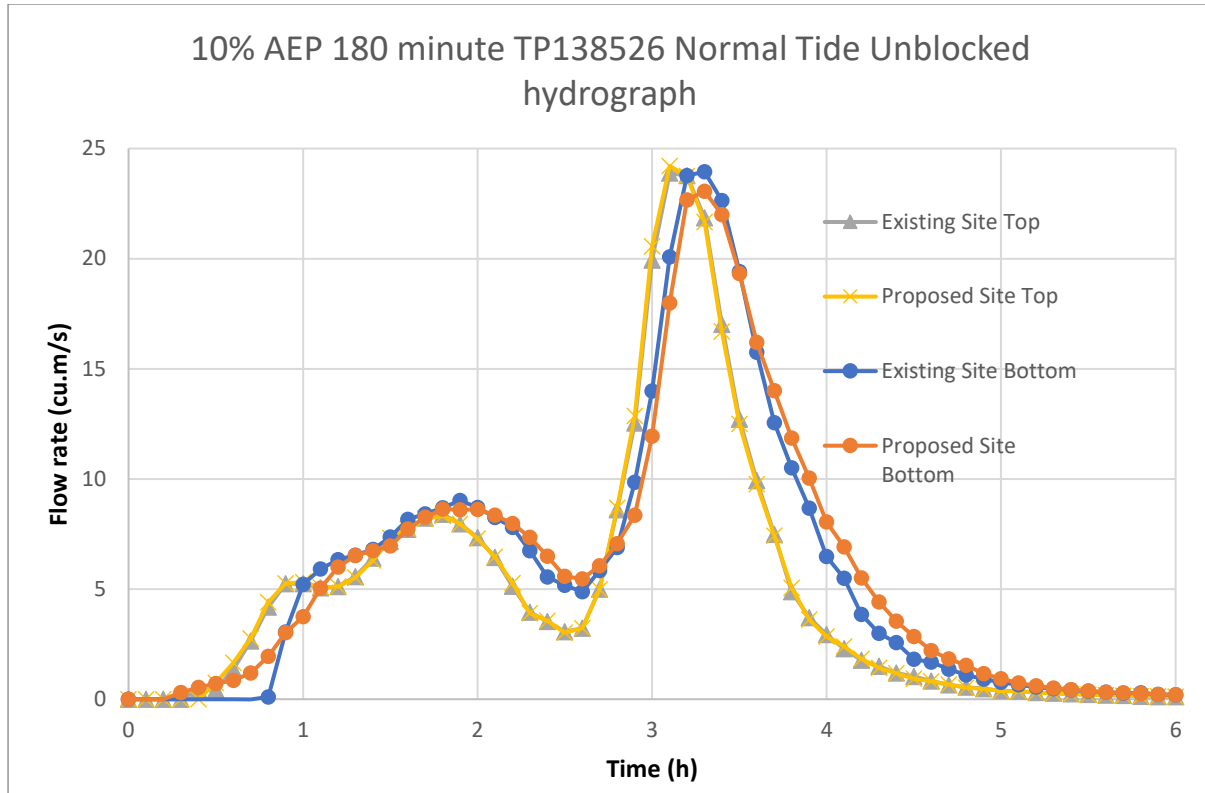


Figure 20: 10% AEP existing and proposed case hydrographs at top and bottom of site



Table 6: Stream Power average

Across entire site:

Scenario	50% AEP mean (W/m ²)	20% AEP mean (W/m ²)	10% AEP mean (W/m ²)	2% AEP mean (W/m ²)	DFE mean (W/m ²)	PMF mean (W/m ²)
Existing	80	107	130	155	125	154
Proposed	48	75	90	103	120	178

North Corrimal Creek upper portion:

Scenario	50% AEP mean (W/m ²)	20% AEP mean (W/m ²)	10% AEP mean (W/m ²)	2% AEP mean (W/m ²)	DFE mean (W/m ²)	PMF mean (W/m ²)
Existing	62	100	126	147	189	392
Proposed	28	49	63	74	130	243

Realigned portion:

Scenario	50% AEP mean (W/m ²)	20% AEP mean (W/m ²)	10% AEP mean (W/m ²)	2% AEP mean (W/m ²)	DFE mean (W/m ²)	PMF mean (W/m ²)
Existing	NA	NA	NA	NA	NA	NA
Proposed	32	95	118	137	165	348

North Corrimal Creek retained lower reach:

Scenario	50% AEP mean (W/m ²)	20% AEP mean (W/m ²)	10% AEP mean (W/m ²)	2% AEP mean (W/m ²)	DFE mean (W/m ²)	PMF mean (W/m ²)
Existing	96	82	75	85	99	128
Proposed	86	62	60	65	94	156



Towradgi Creek (Memorial Drive to railway):

Scenario	50% AEP mean (W/m ²)	20% AEP mean (W/m ²)	10% AEP mean (W/m ²)	2% AEP mean (W/m ²)	DFE mean (W/m ²)	PMF mean (W/m ²)
Existing	127	165	195	264	413	594
Proposed	114	163	191	261	405	607

Table 7: Flows

Scenario	50% AEP		20% AEP		10% AEP		2% AEP		DFE		PMF	
	Volume above threshold (cu.m)	Peak flow (cu.m/s)	Volume above threshold (cu.m)	Peak flow (cu.m/s)	Volume above threshold (cu.m)	Peak flow (cu.m/s)	Volume above threshold (cu.m)	Peak flow (cu.m/s)	Volume above threshold (cu.m)	Peak flow (cu.m/s)	Volume above threshold (cu.m)	Peak flow (cu.m/s)
Existing FL_17	6.17E+03	8.2	3.73E+04	18.5	4.47E+04	23.9	8.96E+04	28.5	1.39E+05	40.3	4.01E+05	98.3
Proposed FL_17	6.28E+03	8.2	3.73E+04	18.6	4.49E+04	24.2	8.97E+04	28.5	1.39E+05	40.6	4.08E+05	102.5
Existing WBNM50	1.09E+04	9.0	4.27E+04	19.2	5.74E+04	23.9	1.08E+05	31.9	1.66E+05	41.8	5.37E+05	131.5
Proposed WBNM50	1.07E+04	9.1	4.02E+04	18.8	5.73E+04	23.1	1.08E+05	30.3	1.68E+05	41.7	6.22E+05	150.8



2.3.5.10 Evacuation

All the 5 proposed local roads within the site are flood free and have considerable flood free island above the PMF level, as required by the prescriptive controls for the Towradgi Creek Floodplain. These roads also provide sufficient evacuation access in the event of a flood.

The shared path across Towradgi Creek is designed to be low level and will be inundated in floods larger than 10% AEP. The connecting area on the southern side of Towradgi Creek will be inundated in floods larger than the 50% AEP. Shared path users have a rising path access out of the floodplain.

External to the site there are flood free evacuation routes east along Railway Street, but Memorial Drive is flooded in major flood events.

2.3.5.11 Climate Change Impacts

The proposed development is designed to remain viable for the long term by considering projected changes because of climate change.

The Towradgi Creek Floodplain Risk Management Study outlines a range of impacts climate change may have in the future. This included changes to sea level of 0.4m and 0.9m and increases to rainfall intensity of 7.6% to 16.9%. The DFE includes a 0.9m sea level rise and 16.9% increase in rainfall intensity. That study found that these changes led to increases in flood levels of up to 500mm in Towradgi Creek near the railway bridge and increases of more than 100mm but less than 300mm on Railway Street. Sea level rise of 900mm without rainfall intensity increase led to change of less than 100mm throughout the site. The proposed case results from this study show that the sea level rise and increased rainfall intensity lead to a roughly 370mm increase in water levels behind Towradgi Creek railway bridge and 150mm increase in water levels on Railway Street in the 1% AEP (as shown on Map M190).

In relation to geomorphic stability, the increased water levels from climate change induced sea level rise would have little impact on the realigned stream, but they will have an impact on the stability of the banks in Towradgi Creek and the low end of the site which will be increasingly impacted by tides. The council study defined a 'normal tide' level of RL 0.63m AHD, and a 5% AEP ocean tide of 2.35m AHD. Surveyed surface levels in Towradgi Creek near the railway bridge are as low as 0.3m AHD and the top of bank as low as RL2.17 m AHD. North Corrimal Creek has bank levels as low as RL1.34m AHD. As such, the lower parts of Towradgi Creek and North Corrimal Creek will see increased frequency of tidal inundation with an increase of 'normal tide' level up to RL 1.53 and 5% AEP tide up to RL 3.25. This may lead to changes in vegetation, pore water pressure and other factors which may alter stream form. This part of the creek is not being altered by the development.

The increase in tailwater levels generally lead to a decrease in velocity, bed shear stress and stream power at the bottom end of the site and the increased rainfall intensity generally leads to an increase in velocity, bed shear stress and stream power at the top end of the site. In the realigned parts of the stream the low flow channel will typically see an increase of less than 0.2m/s for velocity, 30N/sq.m for bed shear stress and 50W/sq.m for stream power. The analysis in Section 2.3.5.9 includes consideration of these changes in the DFE. The stability of the realigned watercourse will not be significantly altered by the impacts of climate change.



2.3.6 Conclusion

The flood impact assessment has been prepared in accordance with the requirements of DCP Chapter E13 to allow council to assess the effects of the proposed development of Stage 2-4 Corrimal Coke Works on flooding and the effects of flooding on the proposed development. The 20% AEP flood event, DFE and PMF have been modelled. Impacts have been mapped and flood risk precincts have been identified.

The modelling undertaken shows that development would not increase residential density in flood hazard areas.

The proposed development has been aligned with consideration of the floodplain context and creating a restored creek corridor in a way that does not create significant new flood hazard. Proposed residential development has been restricted to outside the PMF extents. The proposed North Corrimal Creek realignment ensures no loss of floodplain storage across range of flood events considered.

The development has been shown to be consistent with the Wollongong LEP provisions on flood planning, as summarised by the objectives given in **Table 8**.

Table 8: LEP Compliance table

LEP Section 5.21 Objectives	Compliance
2a) Compatible with the flood function and behaviour on the land.	See Section 2.3.5.9. The change in flood function and the overall affectation with the proposed works is limited to the realigned creek channel. There are no adverse impacts within the areas proposed for residential use.
2b) Adverse effect on flood behaviour in a way that results in detrimental increases in the potential flood affectation of other development or properties, and	The proposed realignment of the creek within the lot leads to a positive impact on the flood behaviour. The flooding is restricted to the newly formed creek, reducing flooding through the middle of the development site., and has a neutral or beneficial impact on flooding on surrounding properties, see Section 2.3.5.5
2c) Adverse effect on the safe occupation and efficient evacuation of people or exceed the capacity of existing evacuation routes for the surrounding area in the event of a flood	The proposed roads within the development provide sufficient evacuation access and refuge areas in the event of a flood. See Section 0
2e) No adverse effect on the environment or cause avoidable erosion, siltation, destruction of	The creek realignment proposed as part of the development is in accordance with a qualified geomorphologist recommendation, considering factors including erosion, the replanting of riparian vegetation, and the effect of the realignment on the overall stability of the watercourse. See Section, 2.3.5.9



3 ONSITE STORMWATER DETENTION

WCC's DCP requires there be no increase in the peak flows discharging from a site due to a new development. As such, Onsite Stormwater Detention (OSD) is required to be considered for all new development.

As part of the planning proposal for the site Cardno prepared the 'Corrimal Coke Works Flood Study' (Rev 5, 2019). That report includes an assessment of the benefits of OSD for the site and recommends that OSD not be provided for this development. It calculated changes to the flow rates at the Rail bridge downstream of the site with and without the provision of OSD as part of the development. It was concluded that detaining the site would increase peak flows downstream.

At the pre-lodgement meeting (3rd May 2023, Wollongong City Council reference PL-2023/39) for the Stage 2-4 Bulk Earthworks DA (which includes the major earthworks for the site including the realignment of North Corrimal Creek) Maker outlined our intention to continue in line with this strategy and not installing any on-site detention structures as part of the proposed works.

At the meeting and in subsequent conversations, council officers identified that generally it was expected that on-site stormwater detention would be required for future development. It was noted that council's OSD policy relies on a general blanket application of OSD on new development outside the exclusion zone, and that an analysis of the impact of downstream flows considering development of this site in isolation was not sufficient to justify not providing OSD.

3.1 SITE DISCHARGE POINT

DCP Chapter E14 Section 9.3 outlines requirements for the disposal of stormwater from development sites.

Apart from in special circumstances, development sites are required to show that they have a legal point of discharge for stormwater runoff from the development. The legal point of discharge may be to a watercourse (Section 9.3.3). The watercourse must be well defined, having defined bed and banks. The legal point of discharge from the development is North Corrimal Creek near the south-eastern corner of the site, just upstream of the confluence with Towradgi Creek.

Properties are also required to allow for flow from adjacent properties to flow through the site (Section 9.3.17). In this case, the proposed development is required to allow for flows from the culvert out of the adjoining property in Cross Street and to allow for discharge from council drains onto the site.

3.2 WCC OSD POLICY

Section 9.3.1 outlines the requirement to control peak discharge. It notes that a consequence of increasing urbanisation is an increase in stormwater runoff. It notes that this increase can overload existing drainage systems, with resulting nuisance and potential damage to existing properties. It identifies that one of the methods adopted by council to alleviate this problem is to require developers to include detention storage in developments.

Section 10 outlines the on-site stormwater detention controls for developments. OSD is generally required for all types of development, except for specific exclusions given in Section 10.1.2. None of these exclusions apply to the proposed works with the possible exception of (ix).



- ix) In addition, OSD may not be required where development is located in the lower reaches of a catchment where OSD does not provide downstream benefits and where it can be demonstrated that runoff from the site can be conveyed through intervening property to 'receiving waters' without adversely impacting flooding of these properties. Areas where OSD would not benefit downstream flooding are shown on the plans of Appendices A1.

The site is clearly shown as not being in the OSD concession zone, which lies on the other side of the railway line.

The Wollongong policy can generally be thought of as a catchment-based approach, where a Site Storage Requirement (SSR) and Permissible Site Discharge (PSD) are applied based on analysis of entire catchments rather than a site-based approach.

Section 10.2.3 outlines the design basis of OSD.

10.2.3 Design Basis

- a) The design objective of this section is the control of post development discharges, at all points in a catchment, to pre-development levels. This control is to be implemented by introducing small basins (OSD basins) on each developing site that serve to delay and reduce peak runoff from the site such that post-development discharges do not exceed pre-development levels anywhere in the catchment. Key to the design of these basins are two parameters, the permissible site discharge (PSD l/sec) and the site storage requirement (SSR m³). The PSD is the discharge limit for runoff from a development site, and SSR is the storage associated with this PSD, required to ensure that there is no increase in flood peak discharges anywhere in the catchment, for all storm frequencies and durations.

3.3 PERMISSIBLE SITE DISCHARGE

The permissible site discharge is the limit required to ensure that there is no increase in flood peak discharges anywhere in the catchment.

The peak site discharges from the site based on the Towradgi Creek Flood Study WBNM model are shown in **Table 9**.

Note that because of elevated tailwater conditions (and some cross catchment flows) these do not reflect well the flows in the council approved Towradgi Creek Flood Study TUFLOW model. As the existing condition these numbers represent the permissible site discharge.

Table 9: Permissible Site discharge (existing condition from Towradgi Creek Flood Study at site outlet)

Storm	WBNM peak flow	TUFLOW peak flow
5-year ARI - 120 minute	28.66	25.46
10-year ARI - 120 minute	34.40	25.58
100-year ARI - 120 minute	58.60	44.19

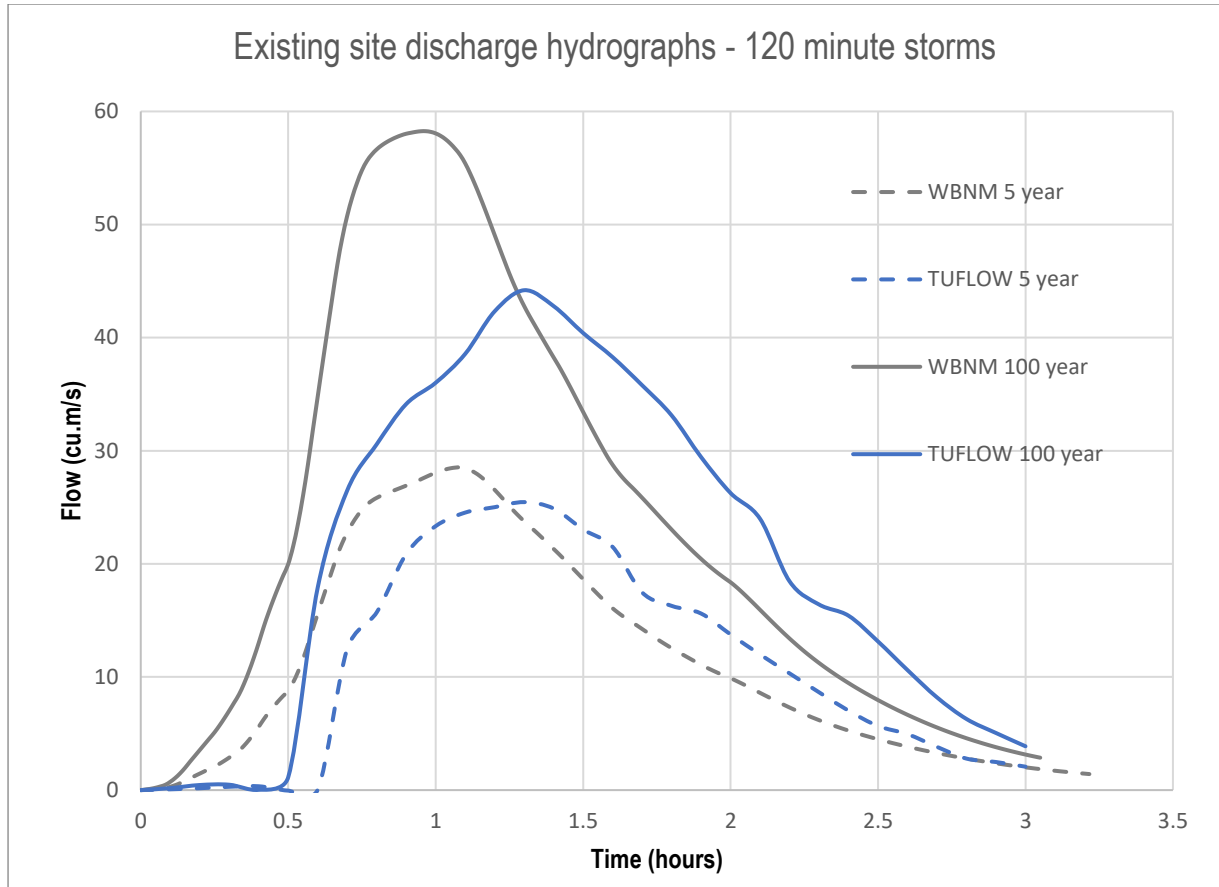


Figure 221: Existing Site discharge hydrographs from Towradgi Creek Flood Study (2019)

3.4 POST-DEVELOPED SITE DISCHARGES

The Towradgi Creek Flood Study WBNM model was adjusted to increase the imperviousness of the area to be developed.

The area to be developed already contains substantial impervious areas, and the containing sub-catchment (which includes areas that will be pervious post-development and adjoining properties on Cross St) is modelled as 55% impervious in the TCFS WBNM model.

Post development this sub-catchment imperviousness will increase to 78%.

This is based on the area to be developed having a post-developed gross impervious fraction of 90% representing roads and medium density areas.

This site discharge from the WBNM model considering this change is shown in **Table 10**. The flows from the developed WBNM model were fed into the post-developed TUFLOW model (which also includes changes to elevations and materials due to the development). The results are shown in **Table 10**. In both the hydrological and hydraulic models, the post-developed site discharges do not exceed the pre-developed site discharges.

Table 10: Post-developed site discharge

Storm	WBNM peak flow	TUFLOW peak flow
5-year ARI - 120 minute	28.54	23.55
10-year ARI - 120 minute	34.24	23.97
100-year ARI - 120 minute	58.25	37.8



3.5 SITE STORAGE REQUIREMENT

The SSR is defined as the storage associated with the PSD, required to ensure that there is no increase in flood peak discharges anywhere in the catchment. It has been shown that the post-developed discharges are less than the permissible site discharges. It had earlier been shown that downstream the post-developed discharges without any additional detention storage resulted in no increase in flood peak discharge. Considering the lack of increase in local discharge from the site and at a significant structure downstream we have some confidence that a similar analysis would show no increase anywhere in the catchment, showing that the site storage requirement for the site is 0 cu.m.

As part of the Stage 1 built form development application (DA-2023/550) modelling was undertaken to test the cumulative impact of not providing OSD across the wider catchment (Corrimal Cokeworks Stage 1 Water cycle Management Strategy Version 4, Maker prepared by. It was found that increasing the impervious fraction on all site below the Princes Highway and not providing OSD would lead to a decrease in peak flows within Towradgi Creek in both minor and major events.



4.1.2 Climate data

6-minute pluviography data from Port Kembla over a 15-year period between January 1966 – January 1981 was used. It is reasonably complete with a mean annual rainfall of 900mm. Monthly average areal potential evapotranspiration data was interpolated for the site from BOM gridded data.

4.1.3 Source nodes

The site was modelled using 10 source nodes. These being road area, village park, residential roof, residential communal, heritage site (otherwise known as the heritage plaza), commercial roof area, commercial building lot, townhouse roof and townhouse external, and southern recreational area. The following catchment assumptions were utilised for the modelling:

- The road area is modelled as sealed road with 1.94ha area and 95% imperviousness.
- The village park was modelled is modelled with an area of 0.3ha, with 5% imperviousness.
- Residential roof, which includes 10 x residential buildings according to the preliminary architectural plans, is modelled with 100% imperviousness and has an area of 2.749ha.
- The residential communal area was assumed to be 70% imperviousness and has an area of 1.178ha.
- The heritage site located to the east of the site, is assumed as a commercial area.
- The commercial area was split based on treatment train, as commercial 70% roof area (0.143ha), commercial roof bypass (0.061ha), and commercial lot area (0.117ha).
- The 56 townhouses (according to preliminary architectural plans) have been modelled collectively as townhouse roof area, which was assumed to be 130 sq.m for each house (0.728ha).
- The lot area for the townhouses was modelled at 75sq. m for each townhouse (0.42ha).
- The Southern Recreational area was modelled as an urban mixed area with 95% perviousness and is 0.782ha.

4.1.4 Treatment nodes

The treatment train for the road reserves includes stormwater quality treatment tree pits and a GPT, located at the outlet. The tree pits have been modelled as Ecosol Tree Pit with the following properties applied to a bioretention node as per the Urban Asset Solutions Ecosol Tree Pit Technical Specification.

Table 12: Ecosol Tree Pit MUSIC Technical Specification

Item	Value
Low flow bypass (m ³ /s)	0.00
High flow bypass (m ³ /s)	100.00
Extended detention depth (m)	0.10
Surface area (m ²)	1.44*
Filter area (m ²)	1.44*
Hydraulic conductivity (mm/hr)	224



Item	Value
Filter media depth (m)	0.75
TN content (mg/kg)	500
Orthophosphate content (mg/kg)	40
Base lined	Yes
Vegetated with effective nutrient removing plants	Yes
Overflow weir width (m)	1.2*
Under drain present	Yes
Submerged zone	Optional

* Numbers noted change based on the number of pits proposed -to model multiple tree pits, simply multiply the surface area, filter area and overflow widths above by the proposed number of tree pits.

The 145 tree pits are required to meet the required pollutant reduction targets for Stages 2-4 road reserve area. These tree pits would also be used to treat the village park area, and the area from the commercial lot which includes the roof area and the rest of the lot. These pits will be located on both sides of the road, roughly every 12-20m of road chainage.

70% of the commercial roof area is modelled to drain in a 20KL rainwater tank, while 30% of the area bypasses the rainwater tank and is treated with the tree pits. The tree pits would also treat the remaining commercial lot area not covered by roof. The reuse for the commercial building is calculated as specified in the Sydney Water MUSIC guidelines. 100% of the water from the residential roof area is modelled to drain in 5 x 18KL custom built rainwater tanks. The reuse for the tanks is modelled for irrigation.

The communal area for residential area would be treated with a 10 x (600 x 600mm) Atlan Stormsacks, followed by 10 x 690mm OS-Psorb Stormfilters. These filters would be housed in a 2.1 sq. m vault with pit access.

The high flow bypass from the treatment trains for the Residential roof, residential communal, heritage, the collective commercial area, and the road reserve is further treated by an OceanSave GPT (OS-1618), followed by 6 x 690mm OS-Psorb Stormfilters, housed in a 2.8 sq.m vault with pit access. The low flow bypass is sent to the receiving node.

Townhouse roof area and the communal areas along with the southern recreational park area would be treated by 3 x (600 x 600mm) Atlan Stormsacks, followed by a 300 sq.m Bio basin.

The heritage area is assumed to be pretreated with an independent treatment train as described in the site specific WCMS, separate to this document. The treated water will be conveyed through the site and connect into the stormwater network for Stages 2-4.

It should be noted that the final configuration may differ based on the DA for each stage but will none the less meet the performance criteria outlined within Wollongong City Council Chapter E15.

4.1.5 Results

Pollutant load reduction results of the MUSIC model are shown in **Table 13**. The proposed treatment train achieves the target reduction percentages for all pollutants.



Table 13: MUSIC model treatment train effectiveness Stage 2-4.

Pollutant	Source Load (kg/year)	Residual Load (kg/year)	Reduction (%)	Target Achieved?
Gross Pollutants	1933	0	100	Yes
Total Suspended Solids	13550	1533	88.69	Yes
Total Phosphorus	28.49	9.022	68.33	Yes
Total Nitrogen	206.3	105.3	48.74	Yes

4.1.5.1 Operation and maintenance plan

All elements of the proposed treatment train require regular maintenance to operate effectively. Responsibility for ongoing management rests with the asset owners, which is Council and the Lot owners.

4.1.5.2 Tree Pits

The tree pits will be dedicated to council who will be responsible for the ongoing maintenance of the units. Regular inspection of filter media to monitor sediment, gross pollutants and leaf litter accumulation should be performed alongside weed removal, monitoring of plant health and detention zones and periodic flushing of the underdrain system. The design of the Ecosol tree pit allows easy access for both cleaning and maintenance using standard equipment. It is recommended that the cleaning frequency will be quarterly, however this is dependent on specific catchment size and pollutant loading so should be adapted based on observations as the trees establish.

4.1.5.3 GPT

The GPT will be dedicated to council who will be responsible for the ongoing management. Maintenance requirements vary by model, but generally include inspection bi-annually and cleaning out with a sucker truck when accumulated litter reaches a design level. Indicatively, the Ecosol GPT with the appropriate treatable flow rate for the catchment has a sump of sufficient capacity to carry just over a year of the MUSIC estimated captured pollutants.

Maintenance should not require any equipment or training that would be unavailable to those who maintain other GPTs already under council management. It would indicatively include twice yearly maintenance checks and clean-up of accumulated sediment and gross pollutants every 12 months.

Atlan Stormsacks proposed to treat the residential areas, would be dedicated to each lot who will be responsible for the overall maintenance of the units. The Atlan Stormsacks proposed downstream to treat the recreational area would be managed by council. This would include bi-annual inspections and cleaning when the accumulated litter reaches design levels.

4.1.5.4 OceanProtect StormFilter cartridges

Stormfilter cartridges (or other proprietary treatment devices) would be owned by lot owners who will be responsible for ongoing management.

Standard inspections for the StormFilter cartridges would need to be carried out at regular six-month intervals. Build-up of debris/pollutants within the vault greater than 100mm, or accumulation on the outlet chamber would warrant general cleaning of the filter system. It



is also recommended to be inspected after large storm events. The filter cartridges need to be replaced every 1-3 years (as required).

4.1.5.5 *Bio basin*

The bioretention basin within the southern park would be dedicated to council. It would need to be maintained with weeding, unblocking the inlets and outlets, removing litter debris. It would also need to be replanted as required and repairing any scour.



5 CONCLUSION

A Water Cycle Management Strategy has been prepared for the proposed development of Stages 2-4 of the former Corrimal Cokeworks Site, consisting of Lot 5 DP 749492, Lot 11 DP 749492, Lot 1 DP 795791 & Lot 126DP 598190. The proposed strategy has been developed to meet the stormwater controls contained with the Wollongong City Council DCP.

The flooding behaviour of the site has been considered and it has been established that the site is not subject to unacceptable flood risk and does not increase the flood risk elsewhere.

The stream realignment concept has been further developed in line with the guidance from the stability assessment and council feedback and the long-term stability of the realignment considered.

No onsite detention has been proposed as part of this strategy as it was determined to not add benefit to the site.

A treatment train has been proposed to manage water quality and assessed against the requirements in DCP Chapter E15. MUSIC modelling has been undertaken and shows that the proposed treatment train meets the required pollutant reduction targets.



APPENDIX A: SURVEY

APPENDIX B:
BLOCKAGE
ASSESSMENT

APPENDIX C:
HYDRAULIC MODEL
SETUP

APPENDIX D:
HYDRAULIC MODEL
RESULTS

APPENDIX E:
GEOMORPHOLOGY



REPORT



APPENDIX B: APPROVED STAGE 1 WCMS REV5



WATER CYCLE MANAGEMENT STRATEGY
FOR PROPOSED DEVELOPMENT OF
CORRIMAL COKEWORKS
STAGE 1

Project No: MKR00452

VERSION 1



TABLE OF CONTENTS

1	INTRODUCTION.....	4
1.1	Project and Site Background.....	4
1.2	Purpose of This Report.....	5
2	FLOODING.....	5
3	ONSITE STORMWATER DETENTION.....	5
4	WATER QUALITY STRATEGY.....	6
4.1	Stage 1.....	6
4.1.1	MUSIC Modelling.....	6
4.1.2	Climate Data.....	7
4.1.3	Source Nodes.....	7
4.1.4	Treatment Nodes.....	8
4.1.5	Results.....	9
4.1.6	Operation and Maintenance Plan.....	9
4.1.6.1	Tree Pits.....	9
4.1.6.2	GPT.....	9
4.1.6.3	Spel StormFilter cartridges.....	9
5	CONCLUSION.....	10



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Date: 26/05/2023

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Date: 26/05/2023

Version Amendment Record

Version No.	Outline of Amendments	Amended By	Date Amended
1	Initial issue to Legacy	-	-
2	Updated Lot & DP Description	SS	05/06/2023



1 INTRODUCTION

1.1 PROJECT AND SITE BACKGROUND

Legacy Property (Legacy) has engaged Maker ENG Pty Ltd (Maker) to provide a Water Cycle Management report in support of Stage 1 of the proposed development located at the Corrimal Cokeworks, otherwise known as the 'site'. The site consists of Lot 1 DP 795791, Lot 5 DP 749492 & Lot 126 DP 598190.

The Site is located in the northern suburbs of Wollongong, 5.5km north of the Wollongong CBD and 63.5km south of Sydney CBD. The Site is also within walking distance to Corrimal town centre (350 m), local primary and secondary schools (500 m) and community recreational facilities including sporting fields, Corrimal Pool, Corrimal District library and community centre (500 m) and Corrimal Beach (1.2 km). The project site, shown below in **Figure 1**, is bordered by Railway Street (north), Corrimal Train Station (east) and Stages 2-4 of the Corrimal Cokeworks Development (south & west).



Figure 1-Corrimal Cokeworks Development Stage 1

The vision for Corrimal Coke Works is to create a strong community with diverse people and places that is built on shared stories and experience. This will be achieved by basing the development around the values of friendship, diversity, revitalising, and heritage. The concept development masterplan consists of approximately 550 dwellings comprising of a mix of low-midrise apartments and medium density dwellings has been proposed for



the development. Stage 1 will include 5 apartment complexes with 181 total dwellings and is approximately 3.16ha including 2 public roads.

1.2 PURPOSE OF THIS REPORT

The Water Cycle Management Strategy (WCMS) outlines the Water Sensitive Urban Design (WSUD) features to be implemented with the proposed development, to manage any impact on receiving waterways. Modelling has been undertaken to assess those impacts and provide adequate measures to manage any pollutants generated by the site to an acceptable level. This report has been prepared for Stage 1 of the proposed development which is to operate independently from the future Stages 2-4.

This report has been prepared to address the requirements of the Wollongong City Council Development Control Plan 2009 and other guidelines, particularly:

- DCP Chapter E13: Floodplain Management
- DCP Chapter E14 Stormwater Management
- DCP Chapter E15 Water Sensitive Urban Design
- DCP Chapter D19 Former Corrimal Coke Works Site

2 FLOODING

The proposed Stage 1 development is located outside of the flood plain (PMF extents), as demonstrated in the Wollongong City Council; Towradgi Creek Flood Study dated December 2019. This supports the flooding results presented in the previous report titled **Corrimal Coke Works Flood Study* (82019112 Report 002 Ver 5, Cardno) dated 2nd May 2019. As such there are no flooding related controls to be considered with Stage 1 of the proposed development.

*Please note, the report may be provided upon request.

3 ONSITE STORMWATER DETENTION

WCC's DCP requires there be no increase in the peak flows discharging from a site due to a new development. As such, Onsite Stormwater Detention (OSD) is required to be considered for all new development.

The proposed development lies just outside of the OSD concession zone mapped in DCP Chapter E14. OSD was determined to be unnecessary in the report **Corrimal Coke Works Flood Study* (82019112 Report 002 Ver 5, Cardno) dated 2nd May 2019, which was submitted in support of the Planning Proposal approval for the Corrimal Cokeworks rezoning.

The findings from the report indicated that any retention of stormwater would delay the peak discharge from the site, to coincide with the peak discharge of Towradgi Creek and consequentially has the ability to worsen downstream flooding. The omission of OSD is consistent with developments located within the lower reaches of a catchment which discharges to the ocean. OSD is found to have little benefits in such situations.



4 WATER QUALITY STRATEGY

4.1 STAGE 1

The sitewide stormwater strategy is split up between the on-lot and public owned water quality assets. The following strategy talks about the individual on-lot strategies and the proposed public assets to meet water quality requirements.

Chapter E15 requires that the stormwater quality performance targets given in **Table 1** are achieved for the development.

Table 1: Stormwater quality performance targets (DCP Chapter E15)

Pollutant	Target % reduction
Gross Pollutants	90
Total Suspended Solids (TSS)	80
Total Phosphorus (TP)	55
Total Nitrogen (TN)	40

Stormwater treatment will be managed independently on each lot, with a stormwater treatment train proposed site wide for the road reserve area.

4.1.1 MUSIC Modelling

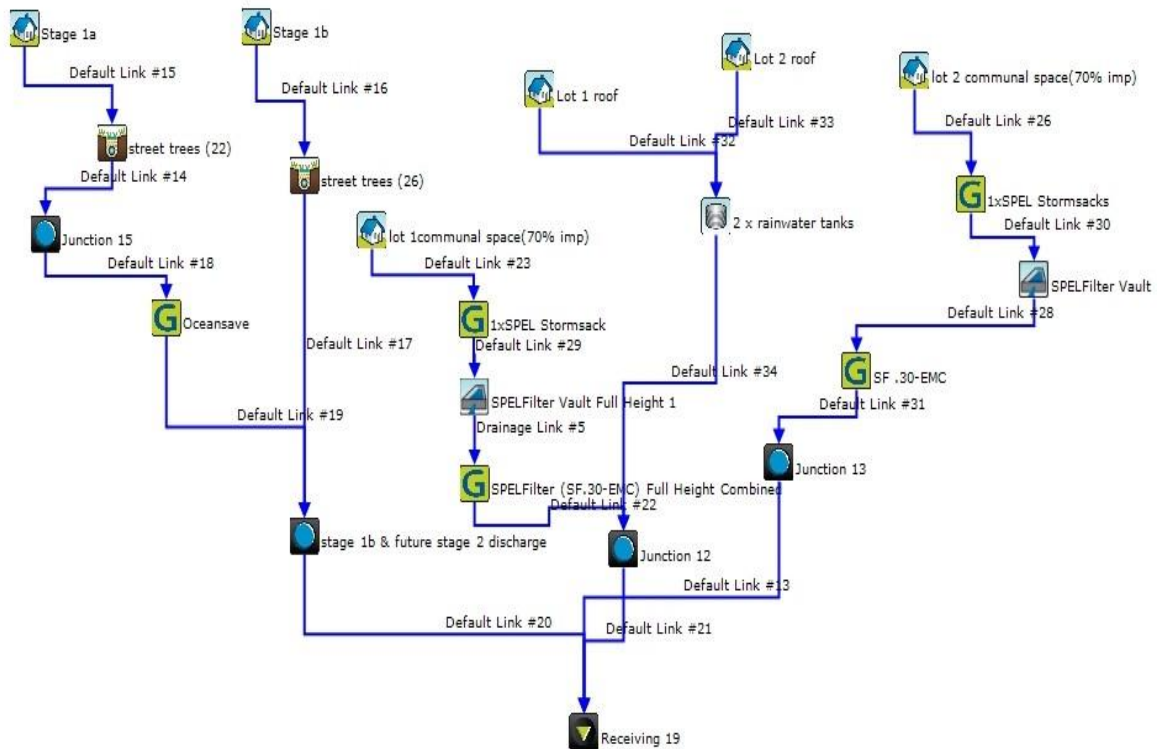
For the purpose of the MUSIC model, Stage 1 has been divided into subcatchments. The residential allotments (Lot 1 and Lot 2) are considered as individual built form catchments with appreciable roof areas. Lot 1 is located on the northern portion of the site and includes four buildings. Lot 2 is located directly south of Lot 1 and is contained within the southern portion of the site. Only one building is anticipated for Lot 2.

Stage 1a and Stage 1b is representative of the road catchments within the site.

Conceptual modelling was undertaken using MUSICX 1.10.0 with a 6-minute time interval. A diagram of the MUSIC model is shown in **Figure 2**.



Figure 2: Stage 1 MUSIC model schematic



4.1.2 Climate Data

6-minute pluviograph data from Port Kembla over a 15-year period between January 1966 – January 1981 was used for the modelling. It is reasonably complete with a mean annual rainfall of 1120mm, close to the long-term average at Popes Rd Woonona (the nearest BOM weather station with good length of record, 3.2km south of the site, mean annual rainfall 1229.7mm). It includes at least one wet and one dry year. Monthly average areal potential evapotranspiration data was interpolated for the site from BOM gridded data.

4.1.3 Source Nodes

The site was modelled using 6 source nodes. These being Stage 1a, Stage 1b, Lot 1 roof, Lot 2 roof as well as Lot 1 and Lot 2 communal areas. The areas along with their imperviousness considerations are mentioned in **Table 2**.

Table 2: Source nodes in model

Source Node	Area (ha)	Impervious fraction
Stage 1A (Urban sealed road)	0.452	95%
Stage 1B (Urban sealed road)	0.551	95%
Lot 1 Roof Area	0.55	100%
Lot 2 Roof Area	0.20	100%
Lot 1 Communal Area	0.236	70
Lot 2 Communal Area	0.086	70



4.1.4 Treatment Nodes

The treatment train for the road reserves includes stormwater quality treatment tree pits and a GPT, to be located at the outlet. The tree pits have been modelled as Ecosol Tree Pit with the following properties applied to a bioretention node as per the Urban Asset Solutions Ecosol Tree Pit Technical Specification.

Table 3: Ecosol Tree Pit MUSIC Technical Specification

Item	Value
Low flow bypass (m ³ /s)	0.00
High flow bypass (m ³ /s)	100.00
Extended detention depth (m)	0.10
Surface area (m ²)	1.44*
Filter area (m ²)	1.44*
Hydraulic conductivity (mm/hr)	224
Filter media depth (m)	0.75
TN content (mg/kg)	500
Orthophosphate content (mg/kg)	40
Base lined	Yes
Vegetated with effective nutrient removing plants	Yes
Overflow weir width (m)	1.2*
Under drain present	Yes
Submerged zone	Optional

* Numbers noted may change based on the number of pits proposed -to model multiple tree pits, simply multiply the surface area, filter area and overflow widths above by the proposed number of tree pits.

The 28 tree pits are required to meet the required pollutant reduction targets for stage 1. These will be located on both sides of the road, roughly every 16-20m of road chainage in accordance with the final landscape plans.

100% of the water from the roof of Lot 1 and Lot 2 is modelled to drain into 2 x 18KL custom built rainwater tanks under the ramp to the basement car parking for the built form. The tanks are sized to allow reuse for toilets and irrigation as specified in DCP Chapter E15 Water Sensitive Urban Design. The communal area for Lot 1 is to be treated with 1 x Spel stormsack, followed by 4 x Spelfilter cartridges housed in a 7 m² vault with pit access. While lot 2 communal area is treated with a similar train of 1 x Stormsack, followed by 2 x SpelFilter cartridges.

It should be noted that the configuration may differ based on the final detailed design but will non the less meet the performance criteria outlined within Wollongong City Council Chapter E15.



4.1.5 Results

Pollutant load reduction results of the MUSIC model are shown in **Table 4**. The proposed treatment train achieves the target reduction percentages for all pollutants.

Table 4: MUSIC model treatment train effectiveness Stage 1

Pollutant	Source Load (kg/year)	Residual Load (kg/year)	Reduction (%)	Target Achieved?
Gross Pollutants	525.3	0	100	Yes
Total Suspended Solids	4431	811.8	81.68	Yes
Total Phosphorus	8.548	2.741	67.93	Yes
Total Nitrogen	50.84	27.49	45.92	Yes

4.1.6 Operation and Maintenance Plan

All elements of the proposed treatment train require regular maintenance to operate effectively. Responsibility for ongoing management rests with the asset owners, that is Council and the Lot owners.

4.1.6.1 Tree Pits

The tree pits will be dedicated to council who will be responsible for the ongoing maintenance of the units. Regular inspection of filter media to monitor sediment, gross pollutants and leaf litter accumulation should be performed alongside weed removal, monitoring of plant health and detention zones and periodic flushing of the underdrain system. The design of the Ecosol tree pit allows easy access for both cleaning and maintenance using standard equipment. It is recommended that the cleaning frequency will be quarterly, however this is dependent on specific catchment size and pollutant loading so should be adapted based on observations as the trees establish.

4.1.6.2 GPT

The GPT will be dedicated to council who will be responsible for the ongoing management. Maintenance requirements vary by model, but generally include inspection bi-annually and cleaning out with a sucker truck when accumulated litter reaches a design level. Indicatively, the Ecosol GPT with the appropriate treatable flow rate for the catchment has a sump of sufficient capacity to carry just over a year of the MUSIC estimated captured pollutants.

Maintenance should not require any equipment or training that would be unavailable to those who maintain other GPTs already under council management.

4.1.6.3 Spel StormFilter cartridges

Standard inspections for the SpelFilter cartridges would need to be carried out at regular four-month intervals. Build-up of debris/pollutants within the vault greater than 150mm, or accumulation on the outlet chamber would warrant general cleaning of the filter system. It is also recommended to be inspected after large storm events. The filter cartridges need to be replaced every 6-8 years (as required).



5 CONCLUSION

A Water Cycle Management strategy has been prepared for the proposed development of Stage 1 of the former Corrimal Cokeworks Site, consisting of Lot 1 DP 795791, Lot 5 DP 749492 & Lot 126 DP 598190. The proposed strategy has been developed to meet the stormwater controls contained with the Wollongong City Council DCP.

There are no flooding controls constraining the developments within the Stage 1 area of the site. No onsite detention has been proposed as part of this strategy as it was determined to not add benefit to the site or downstream catchment.

A treatment train has been proposed to manage water quality and assessed against the requirements in DCP Chapter E15. MUSIC modelling has been undertaken and shows that the proposed treatment train meets the required pollutant reduction targets. A maintenance plan has been included.