Flood Impact and Risk Assessment Report

40 Memorial Avenue,
Bella Vista

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theoriongroup.au

Document Control

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Rev 00	Elise Luu	Rory McLoughlin	Stephen Brain	12/04/2024	DRAFT
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Rev 05	Rory McLoughlin	Rory McLoughlin	Stephen Brain	13/09/2024	Hazard maps added, sections updated
Rev 06	Rory McLoughlin	Chris Scholes	Chris Scholes	21/08/2025	Updated for SEARs
Rev 07	Hadi Lashlarbolouk	Chris Scholes	Chris Scholes	12/03/2026	Updated for CPHR and SES comments

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Executive Summary

Orion Group has prepared this flood impact and risk assessment report to support a proposal for a residential development at 40 Memorial Avenue, Bella Vista. This flood impact and risk assessment report has been requested to assess the flooding impact of the proposed residential development on the flood levels and the compliance of the proposed developments with council's flood control requirements in the development control plan. To facilitate this assessment, 3 modelling scenarios have been considered for a range of events including the 1% Annual Exceedance Probability (AEP), also known as the 1% AEP event, 1% AEP with climate change factor, 0.5% AEP, 0.2% AEP and Probable Maximum Flood (PMF):

1) A 'Pre Development' or 'Base Case' Scenario– This considers the site and surrounding area in its current state but critically, with the DA approved Hodges Road Bridge and Roundabout upgrade (DA563/2024/ZB) that crosses Elizabeth Macarthur Creek.

2) An 'Interim Development' Scenario – This considers the surrounding area, the approved bridge and the proposed development (Buildings A, B, C and D and the road fronting). In this scenario Elizabeth Macarthur Creek remains in its current state.

3) An 'Ultimate Development' Scenario - This considers the approved bridge, and proposed development within the context of the Sydney Water led Elizabeth Macarthur Creek Trunk Drainage Upgrade works. Terrain modelling and materials mapping for the creek are consistent with the latest Creek designs received from Sydney Water.

This flood study confirms the maintenance of existing flood levels and hazard conditions within Elizabeth MacArthur Creek Flood levels with the addition of the and the proposed 40 Memorial Avenue development. The Study also confirms the compliance of the proposed development with respect to flood building protection as per Hills Shire Council's Development control plan with respect to flooding. The proposals have also undergone a comprehensive sensitivity analysis. The development was tested for the 10%, 25% and 50% blockage scenarios for the critical 1% AEP and PMF events at the approved Hodges Road Bridge as well as the Memorial Avenue Bridge downstream and the Balmoral Bridge upstream.

<u>Update in Revision 06 – Response to SEARs Application</u>

This report was originally prepared to comply with the flood-related requirements of The Hills Shire Council and the NSW Department of Planning and Environment (2023), Flood Risk Management Manual and associated toolkit guidelines.

This revised version (***Revision 06***) has been updated to address the Planning Secretary's Environmental Assessment Requirements (SEARs) for the proposed development. Notable updates include an assessment of the potential impacts of climate change on flood behaviour affecting the development, as well as a review of changes to architectural and

landscape layouts that have occurred since Development Application (DA 308/2024/JP PAN-363100) approval. These updates have been incorporated into the relevant sections of the report, and a dedicated section has been added to demonstrate how the report responds to each applicable SEAR.

As part of the SEARS assessment an additional sensitivity analysis on blockage of local culverts/bridges at a level of 10% was undertaken to determine the impacts on the updated ARR2019 hydrology from the previously modelled ARR87 hydrology. This is conservative given that the catchment was evaluated as being at 'Low-Medium' risk of blockage based on the "Australian Rainfall & Runoff Revision Project 11: Blockage of Hydraulic Structures - Blockage Guidelines" (February 2015).

Update in Revision 07 – Response to CPHR (Ref DOC25/900849) & SES (Ref ID 3429) regarding SSD-80102979

Orion, with the development team met with CPHR and DPHI on 12th Feburary 2026 to workshop appropriate responses and additional information required to address the matters raised in the request for information letter provided. As such, this revised version (***Revision 07***) has been updated to address CPHR (Ref DOC25/900849) & SES (Ref ID 3429) regarding SSD-80102979 for the proposed development. In response to the comments, the results and maps for 0.5% AEP and 0.2%AEP have been added to this report.

This flood modelling shows that the potential impacts of the changes to architectural and landscape layouts that have occurred since Development Application (DA 308/2024/JP PAN-363100) approval is minimal in 0.5% AEP and 0.2% AEP flood events. Flood elevation afflux study reveals that the impacts of the Interim Development scenario and Ultimate Development scenario are limited to the Elizabeth MacArthur Creek and the development scenarios do not adversely affect the properties outside of the creek boundary. To study the impacts of the development on the creek flood condition, a quadtree layer has been added to the flood model where the size of cells around the proposed buildings reduced from 1.5m to 0.375m for higher modelling resolution around the buildings

Summary of Changes to FIRA planning report to comply with SEARs

Revision	Date	Section(s) Updated	Description of Change	Reason for Update
Rev 06	2025.08.21	Executive Summary, Introduction	Added summary of SEAR-related updates and clarified scope of revised report	Response to Planning Secretary's SEAR
Rev 06	2025.08.21	Section 2 - 2 Planning Secretary's Environmental Assessment Requirements (SEARs)	Included section to outline the requirements as per SEARs	Response to Planning Secretary's SEAR
Rev 06	2025.08.21	Section 3 - Proposed Development	Updated proposed layouts with most recent architectural layouts	Changes to proposed development design to be modelled in Post-Dev
Rev 06	2025.08.21	Section 5 - Hydrology	Updated section to reference upgrade of hydrology from ARR 1987 to ARR 2019 in line with latest guidelines	Response to Planning Secretary's SEAR – Climate Change consideration required – Hydrology required to be updated
Rev 06	2025.08.21	Section 5.1.7 - climate change factors	Climate change factors section updated with reference to SEARS and ARR 2019 Book 1 Chapter 6	Response to Planning Secretary's SEAR - Climate Change consideration required
Rev 06	2025.08.21	Section 7 - Results	Updated results section with post-dev updates and climate change event	Response to Planning Secretary's SEAR, revised architectural layouts
Rev 06	2025.08.21	Section 8 – Flood Emergency / Evacuation Management	Added section summarising Flood Emergency / Evacuation Management	Response to Planning Secretary's SEAR
Rev 06	2025.08.21	Section 9 - Conclusions and Recommendations	Updated conclusion with reference to SEAR and findings	Response to Planning Secretary's SEAR, revised architectural layouts

Summary of Changes to FIRA planning report to comply with CPHR (Ref DOC25/900849) & SES (Ref ID 3429) Comments

Revision	Date	Section(s) Updated	Description of Change	Reason for Update
Rev 07	2026.03.04	Executive Summary	Added summery of assessment undertaken to response CPHR and SES Comment and the results	Response to CPHR and SES Comment for extra storm events
Rev 07	2026.03.04	Section 5.1.4 Loss Model Parameters	The impact of climate change on initial and continuing losses	Adjust the model's initial and continuing losses for climate change assessment
Rev 07	2026.03.04	6.1.3 Model Cell Size	The change of cells size from 2mx2m to 1.5mx1.5m	Increase the resolution of the computational grid to increase the level of model accuracy
Rev 07	2026.03.04	6.1.5 Hydraulic Roughness	Add **Figure *13*** to show the material layer around the desired site	Clarifying the material layer and roughness values around the desired site
Rev 07	2026.03.04	Section 5.1.7 - climate change factors	Climate change factors section updated with reference to SEARS and ARR 2019 Book 1 Chapter 6	Response to Planning Secretary's SEAR - Climate Change consideration required
Rev 07	2026.03.04	6.2.3 Model Cell Size	The cells size in the site area and over the proposed buildings reduced to 0.375mx0.375m	Proposed buildings have elements with the size of less than 1m. As a result, the cells size over the proposed buildings reduced to increase the grid resolution and capture more proposed buildings details
Rev 07	2026.03.04	6.2.5 Hydraulic Roughness	Change material layer for Interim Development scenario as shown in **Figure *18***	To match the material layer information with Interim Development surface
Rev 07	2026.03.04	6.3.3 Model Cell Size	The cells size in the site area and over the proposed buildings reduced to 0.375mx0.375m	Proposed buildings have elements with the size of less than 1m. As a result, the cells size over the proposed buildings reduced to increase the grid resolution and capture more proposed buildings details
Rev 07	2026.03.04	6.3.5 Hydraulic Roughness	Change material layer for Ultimate Development scenario as shown in **Figure 19**	To match the material layer information with Ultimate Development surface

Rev 07	2026.03.04	7.1 1% AEP	Flood elevations for 1% AEP flood event and in the interested areas have been updated	Flood elevation in the interested area has changed and the report has been updated based on the new flood elevation data
Rev 07	2026.03.04	7.2 1% AEP + CC	Flood elevations for 1% AEP flood event with climate change factor and in the interested areas have been updated	Flood elevation in the interested area has changed and the report has been updated based on the new flood elevation data
Rev 07	2026.03.04	7.3 0.5% AEP	The results for 0.5% AEP have been added to the report	According to CPHR and SES comment, the flood study for 0.5% AEP (200 years) flood event has been undertaken and added to the report
Rev 07	2026.03.04	7.4 0.5% AEP	The results for 0.2% AEP have been added to the report	According to CPHR and SES comment, the flood study for 0.2% AEP (500 years) flood event has been undertaken and added to the report
Rev 07	2026.03.11	8.0	Removal of evacuation/emergency management commentary inclusion of risk response matrix	A dedicated FEEMP is provided. A full risk assessment matrix was requested under the CPHR RFI.

Table 1 - CPHR RFI Comments Register (Ref DOC25/900849)

RFI No.	Issue	CPHR Comment / Requirement	Proposed Response	WFC comment on Proposed Response	REV 07 Final Response
1	The FIRA has not been prepared in accordance with the requirements of FB01	The FIRA does not provide details of the full range of storm events and provides no mapping of flood function. The FIRA notes that the development impacts flood storage however no mapping is provided to show where flood storage and floodway exist on the site and the adjacent creek line.	The FIRA was prepared in accordance with the previously submitted flood report for DA approval with selected events updated for ARR19 procedures including climate change. This modelling and extent of reporting has been based off the original models and mapping provided by Sydney Water and The Hills Shire Council for Elizabeth Macarthur Creek Rehabilitation Project. However, an updated range of events (20%, 5% and either 0.5 or 0.2% AEP) will be provided and mapped, including flood function. It is highly anticipated that this will not change any planning or project outcomes as critical duration 1%, 1% + climate change and PMF events have already been provided and assessed.	It is agreed that the smaller events, less than 1% are not required in this instance however there is significant difference between the 1% and PMF therefore rarer events are considered necessary are afflux maps and flood function. The FIRA must contain a risk assessment in addition to the impact assessment due to the very large increase in residential occupation of the site.	Full suite of maps for 1%, 1% + CC, 0.5% and 0.2% AEPs as well as PMF Mapping Added, including flood function (Howells Et Al, 2003) and afflux. Risk Matrix added to report.
2	Buildings C and D do not meet flood planning requirements for floor level	The FIRA shows that in the ultimate development scenario only 300mm of freeboard is achieved for Buildings C and D. This is not consistent with the required flood planning levels of 500mm above the 1% Annual Exceedance Probability (AEP) flood level.	We disagree. The proposed Lower Ground Floor level is RL 58.30 m AHD (lowest habitable floor RL for Buildings C and D). The highest adjacent 100 Year (1% AEP) water surface level within Elizabeth Macarthur Creek is just below 57.70 mAHD giving at least 0.6m at the worst case location in the south eastern most corner of building C and D (outside and adjacent to Unit 22). Moving downstream, the water surface levels within the creek drop, with a water surface level of 56.90m outside the frontage of Unit 15 (increasing the freeboard available to FFL RL 58.30 mAHD).	The mapping is missing contours in some areas and it is not possible to read floor levels within the FIRA figures. Section 7.1 contradicts the statement made in this spreadsheet. It is recommended that flood levels and floor levels be clearly set out at each entry point once the model has been updated to show building footprints separately from landscaped areas where flow may occur.	Building Footprint has been fully digitised against Architectural Layouts for the Lower Ground Floor. Architectural Plans included in Appendix for ease of reference. All habitable dwellings are above the Flood Planning Level. Refer to architectural plan extracts and floor versus flood level summaries in Section 3.

3	The proposed road bridge has unacceptable impacts	A new bridge over Elizabeth Macarthur Creek (Hodges Road Bridge) is proposed, as currently approved under DA/563/2024/ZB, to provide access to the proposed development. CPHR has not assessed the bridge. The FIRA states that the bridge as approved causes significant increases in flood levels of 300mm upstream. Limited mapping extent is provided and no afflux mapping for the bridge is given. The impact of the bridge alone is also not mapped therefore it is not possible to separate impacts from the development of the site and the impacts from road and bridge works required to develop the site. The bridge also holds water in the upstream portion of the creek line which masks the impact of the loss of flood storage because of the proposed building footprint encroachment into the flood storage area. There is no assessment of whether the proposed bridge is consistent with the bridge included in the Sydney Water Trunk Drainage Works design or if Sydney Water has been consulted regarding the impacts of the bridge on the drainage corridor.	The bridge has been DA approved and is a condition of consent whereby the Bridge and this Development are required concurrently (the bridge is required to facilitate the apartment development). The bridge and other associated works within Elizabeth Macarthur Creek are not part of this SEARs application and have already been approved; the bridge has been included in the post development assessment for information only due to the concurrent nature of development. The DA for the bridge was assessed between The Hills Shire Council and Sydney Water (Sydney Water were part of the DA referral process for design concurrence with original strategic designs by RHDHV on behalf of Confluence Water for the Elizabeth Macarthur Creek Rehabilitation Project). The assessment of the proposed bridge was covered under the approved DA (DA563/2024/ZB) and includes approval for the offsite impacts nominated here as this is consistent with original strategic designs for the creek corridor. The bridge is the primary cause of any offsite impacts in the PMF, primary due to the impedance of the bridge itself and the proposed roundabout and local road levels in Free Settlers Drive being lower than the bridge deck level. This results in an overland flow path around the bridge along Free Settlers Drive which results in the associated minor impacts in the PMF on the lots fronting. A long section of the proposed bridge is shown, with the sag RL near the Roundabout sitting lower than the bridge deck level. To decouple the flood impact assessment for the buildings, the 'base case' can be updated whereby the bridge is considered as 'existing' (as it is currently approved) under the pre development modelling scenario. This will enable an independent flood impact assessment for the apartments. The flood impacts for the apartments is minor/negligible as the flooding characteristics are primarily driven by the overtopping of Memorial Avenue (acting as a weir) in the PMF event. Question - does this modelling approach (considering the bridge as 'pre developed') meet the requirements of CPHR? Noting the bridge is DA approved in accordance with prior stakeholder reviews already completed being Sydney Water and The Hills Shire Council.	The change in flood behaviour which is caused by the bridge is acknowledged in the FIRA and clearly shown in the mapping. DCCEEW remains concerned that the bridge impacts evacuation ability for residents on the opposite side of the creek and causes flooding in areas which did not previously flood together with greatly increased hazard on evacuation routes. The bridge forms the evacuation route for the proposed development.	A floor level survey was undertaken to review any over floor flooding risks, primarily on the BaptistCare Site. This data is included in the Risk Matrix.

4	Offsite impacts are not shown	The FIRA shows significant increase in flood level on site because of the development. However, no afflux mapping is provided to allow assessment of the offsite impacts. The flood mapping provided currently indicates that adjacent development sites, sites on the opposite side of the creek upstream of the bridge and the public road have unacceptable changes in flood behaviour particularly for the PMF event.	Afflux maps can be provided. Refer to the above response with for detail around bridge impacts. The proposed bridge (approved under separate DA) is the main cause of offsite impacts in the PMF due to the impedance of the bridge deck level and lower existing road levels along Free Settlers Dr. If required - the bridge impacts can be isolated from the assessment by considering it as a separate modelling scenario. This would allow any impacts from the proposed buildings to be assessed in isolation.	Afflux maps are required for a FIRA where flood behaviour changes as is clearly the case from the provided mapping. These maps should be prepared for the 1%, climate change, 0.2%, 0.5% and PMF	Afflux Maps Provided
5	Buildings are not correctly represented in the model	The entire building footprint including landscaping connections is represented as a blocked footprint. This incorrectly suggests that flood water does not enter buildings in floods greater than the 1% AEP plus freeboard. The PMF mapping shows water flowing around buildings at depths of up to 1.7m. The buildings are separate tower buildings with walkways and landscaping connecting them. The buildings should only be represented as blocked out where no water can enter.	While the buildings have been shown as 'blocked out' the results clearly show water levels and depths with water surface contour levels immediately adjacent to the building footprint - from this impacts the building can be clearly determined. The current modelling of buildings are within standard industry guidelines as this method selected is one of several available. However, the finished floor levels and additional modelling resolution will be incorporated to more clearly show flooding impacts on the Lower Ground Floor in the PMF event to address this comment.	Blocking out of buildings is common practice however the FIRA has blocked out areas which are landscaping and will not imped entry of water. Blocking of buildings also suggests that buildings will not be inundated by water which is not correct for the rarer floods.	Buildings fully digitised to accurately represent the building footprint, surrounding landscape levels and internal courtyards within the DEM.

6	The site is in a flash flood area without flood warning and will require evacuation	The provided flood mapping indicates flood depths in the order of 1.7m above floor level in the PMF event. There is no safe vehicle egress from the basement, and pedestrian egress from Buildings A and B is unlikely to be feasible once the buildings and landscaping areas are accurately modelled The provided flood emergency procedures do not describe the flood risk on site or how evacuation would be triggered or the evacuation routes which may be used. There is no flood warning system in place or proposed which would trigger an evacuation. It is likely that evacuation from the lower ground floor of Buildings A and B would present significant challenges. This is likely to pose significant risk to life and increase reliance on emergency services. The building at present does not demonstrate compliance with Shelter in Place Guidelines.	A Flood Emergency/Evacuation Management Plan can be provided. We note that the PMF event is of a short duration (60 minute critical storm) and any evacuation management is deemed impractical. Question for CPHR - how do you intend for evacuation to be a realistic strategy for an short PMF event (<6 hours)? These GSDM derived storms are typical for *all* urban catchments and sites like this, both existing and future proposed. This is not a site specific issue in the application of this RFI request and is impractical. We note this application is not a development type covered under the Special Flood Considerations and design requirements around shelter in place for short duration PMF impacts needs to be coordinated. Time to inundation and time of inundation mapping could be provided for PMF to help clarify and communicate the magnitude of the short term impacts for these residents on the lower ground floor.	DCCEEW agree that evacuation is unlikely to be possible for this development due to the flash flood nature however if evacuation is not feasible the risk assessment must indicate how the risk will be managed. Buildings located within the flood plain and below the PMF are generally required to evacuate. If evacuation is not feasible due to time frames and warning systems then buildings need to be designed to manage the risk and allow safe shelter in place together with the ability to return to functionality after the flood. The building as designed does not demonstrate that evacuation is feasible or that shelter in place and protection of the basement and entrances can be achieved. Refer DPE shelter in place guidelines.	Floor Levels have been adjusted to lower the latent risk on the lowest Habitable floor levels (Lower Ground) to achieve H1-H3 (maximum) in a PMF event. A dedicated FEEMP has been provided discussing evacuation, cutoff times, inundation times and secondary evacuation opportunities.
7	Timing of works which impact flood behaviour is unknown	Mapping is provided for the predevelopment scenario, Buildings A and B concurrent with the new bridge and Buildings C and D concurrent with the Sydney Water Channel works. Although it may be possible to determine the impacts of the various scenarios and the ultimate development scenario, each proposed stage of the development has different consequences, and it is not possible at this stage to ensure that the staging occurs as modelled. The proposed bridge is included in post development modelling, and the bridge effectively decreases flows through the development site by retaining these flows upstream of the	The bridge and proposed development will occur concurrently. Mapping has been provided for both the Development proceeding as a standalone (with the bridge) and for the ultimate scenario when the channel works are completed; to show flood information for both an interim design and ultimate design as the interim design will go first.	DCCEEW remains concerned that multiple works are required to facilitate this development including works in the Sydney water channel which is outside of the care and control of the development. Although multiple iterations have been provided it remains difficult to ensure that the risk to residents of the development and upstream properties can be adequately managed throughout the staged development process.	3 Scenarios are provided for assessment: 1) The Pre Dev or Base Case - current natural site AND the DA Approved Hodges Street Bridge and Roundabout. 2) Interim Development Scenario - Where *just* the proposed Apartment Buildings are delivered. 3) Ultimate Development Scenario - Where the Sydney Water Creek Works are delivered. Impact assessment is provided against the base case (1) for both development scenarios to demonstrate compliance. i.e. (1) versus (2) and (1) versus (3).

		bridge. The floor levels modelled are unlikely to be high enough if the bridge does not proceed. The timing of Sydney Water channel works is outside of the control of the development and cannot be relied upon to mitigate flood risk on site.			
8	Overland flooding has not been considered	The model includes flooding from Elizabeth Macarthur Creek only. No local overland flooding has been included. The site requires evacuation; however, without information on the serviceability of the roadway, it is not possible to determine whether evacuation can be achieved.	Refer to response under point 6) above. It is unrealistic to evacuate this site for a 60 minute critical duration PMF event and offsite evacuation will not form part of the proposed FEEMP strategy for this event. Local overland flow (or local stormwater management) is achieved via standard major-minor stormwater drainage design principles via the supporting road and drainage civil engineering plans by others.	The development must demonstrate either safe evacuation without SES assistance or safe shelter in place given the large number of residents proposed to be accommodated on a site which previously had no residential usage. At present neither have been demonstrated therefore the risk has not been managed	An FEEMP has been provided which demonstrates localised shelter in place can be easily achieved and is only required in the PMF event for a sort duration of inundation given the established short duration of flooding in the PMF event. Localised overland flow from any future roads is managed by major/minor design principles under Council Engineering Design Specifications.

9	Buildings A and B are surrounded by high hazard floodwaters in the PMF event	The FIRA indicates that the proposed Buildings A and B will be surrounded by H4 and H5 floodwaters in the PMF event. H3 floodwaters impact the creek side of buildings in the 1% event. This poses significant risk to life and the potential for damage to structures. Escape via vehicle is not feasible due to the basement entry location and escape on foot is likely to be found unviable once the buildings are correctly presented in the model. The current design also appears to connect the basement for Buildings C and D from Building A. The flood levels shown indicate that Buildings A and B will be inundated well above habitable floor levels in a PMF event and significant quantities of water will be able to enter the proposed basement.	Refer to response under point 6) above. Changes to the design requirements around shelter in place for short duration PMF impacts need to be coordinated with CPHR prior to any design amendments and actioning by the project team.	Refer to the comments above	
10	Too large grid size for afflux determination	The model uses a 4sqm grid size. This may not be fine enough to model flow around and through buildings or adequately represent afflux.	We disagree. A 2m grid is standard practice for a model of this nature and adequately achieves the minimum accepted industry standard for approximately 3 cells to capture any significant flow paths within the 2D domain. A significantly reduced grid size (resolution increase) is computationally impractical and not standard practice because of this reason. However, a 1.5m grid will be adopted to respond to this request (any smaller and we hit computational memory restrictions on the HPC analysis).	No afflux mapping has been provided therefore it is not possible to determine at this stage if the grid size is adequate.	Afflux Maps Provided, Quadtree Domain incorporated to increase localised modelling resolution

11	No details have been provided regarding flood compatible building or structural adequacy	The building and landscaping are exposed to flows likely to cause erosion in smaller events and damage to structures and buildings in rare events. No indication of structural adequacy or the need for flood compatible building materials is included in the provided documents	Please refer to the Structural Compliance Certificate provided by Capital Engineering Consultants certifying structural compatibility for flooding. Note that any on-site impacts are predominantly low velocity only and are less than 1 m/s in the PMF event. This results in a comparatively low to negligible risk for any scour or erosion for the major events. Standard practice involves reviewing scour protection traditionally for flow regimes with a velocity of at or greater than 2m/s at detailed design phases.	The degree of structural integrity required will depend on whether risk management on site requires shelter in place. If SIP is used the design event for structural adequacy is the PMF event.	Note only

1 Introduction

Orion Group has been engaged by Landen Dev No. 8 Pty Ltd to prepare a Flood Impact Assessment Report in accordance with the Hills Shire Council requirements to support a proposed residential development at 40 Memorial Avenue, Bella Vista.

The report provides an assessment on flood conditions of the site and summarises the flood modelling results for 3 modelling scenarios for the 1% Annual Exceedance Probability (AEP), 1% AEP with climate change factor, 0.5% AEP, 0.2% AEP and Probable Maximum Flood (PMF) events. The 3 modelling scenarios are as follows:

1) A 'Pre Development' or 'Base Case' Scenario – This considers the site and surrounding area in its current state but critically, with the DA approved Hodges Road Bridge and Roundabout upgrade (DA563/2024/ZB) that crosses Elizabeth Macarthur Creek. As the bridge crossing is DA approved – this was included in this scenario to provide an independent impact assessment of the proposed apartment development.

2) An 'Interim Development' Scenario – This considers the surrounding area, the approved bridge and the proposed development (Buildings A, B, C and D and the road fronting). In this scenario Elizabeth Macarthur Creek remains in its current state.

3) An 'Ultimate Development' Scenario - This considers the approved bridge, and proposed development within the context of the Sydney Water led Elizabeth Macarthur Creek Trunk Drainage Upgrade works. Terrain modelling and materials mapping for the creek are consistent with the latest Creek designs received from Sydney Water.

The revised version (***Revision 06 & 07***) of the report has been prepared to address the Planning Secretary's Environmental Assessment Requirements (SEARs) and includes additional assessment of the potential impacts of climate change on flood behaviour, as well as a review of architectural and landscape design updates that have occurred since Development Application (DA) approval.

The revised version (***Revision 07***) of the report has been prepared to address concerns raised by CPHR (Ref DOC25/900849) & SES (Ref ID 3429) regarding SSD-80102979 and includes additional assessment of the potential impacts of Interim Development and Ultimate Development scenarios in the case of 0.5% AEP and 0.2% AEP flood events.

1.1 Project Objectives and Methodology

Project scope and objectives are as follows:

i. Inherit previous hydraulic model (TUFLOW) for Elizabeth MacArthur Creek from Sydney Water and calibrate our model to their published results for the 1% AEP flood event for both baseline and detailed design models.
ii. Update calibrated baseline model with recent topographical changes observed on site using site survey information to create a Pre-Development model.

iii. Update Pre-Development model with proposed finished levels for the proposed buildings, landscaping, roadway and bridge as well as adjusting the material layer to create Interim Development model.
iv. Update calibrated detailed design model with proposed design details due to the construction of the proposed development and also update material layer based on the proposed development to create a Final Development (80% EMC Design) model.
v. Recreate hydrological model using Australian Rainfall and Runoff 1987 (ARR 1987) methodologies and calibrate to Sydney Water model hydrological flow inputs for the 1% AEP event.
vi. Estimate PMF runoff flows using the Generalised Short-Duration Method (GSDM) using calibrated hydrological model.
vii. Run simulations for Pre-Development, Interim Development and Final Development scenarios using the updated hydrology for the 1% AEP, 1% AEP + CC, 0.5% AEP, 0.2% AEP and PMF flood events.
viii. Prepare relevant flood maps including flood extents, depths, levels, velocities, hazards and impacts.
ix. Comment on the site's flood characteristics and model outcomes in the existing and proposed conditions.
x. ***Revision 06***: Analyse the potential impacts of climate change on flood behaviour and its effects on the development as per ARR 2019 guidelines Book 1, Chapter 6 (updated in 2024) to comply with the Planning SEARs. Update all hydrology to ARR 2019 rainfall and temporal patterns to be consistent in design philosophy.
xi. ***Revision 06***: Examine any changes to proposed architectural, civil or landscape proposals since DA Approval that may have an impact on the flooding regime at the site or elsewhere in the catchment.
xii. ***Revision 07***: Analyse the potential impacts of 0.5% AEP and 0.2% AEP flood events on flood behaviour and its effects on the development as per ARR 2019 guidelines Book 1, Chapter 6 (updated in 2024) to comply with the Planning SEARs. Update all hydrology to ARR 2019 rainfall and temporal patterns to be consistent in design philosophy.

1.2 Reference Documents

This report has been prepared in accordance with the following guidelines and policies:

i. Elizabeth Macarthur Creek Trunk Drainage Works - Flood Impact Assessment (Royal HaskoningDHV, 2024)
ii. Australian Rainfall and Runoff (ARR) Data 2019 with ARR 2016 rainfall datasets sourced from Bureau of Methodology (BoM)
iii. ARR 2019 – A Guide to Flood Estimation
iv. The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method (Bureau of Meteorology, Melbourne, Australia, June 2003)
v. NSW Department of Planning and Environment (2023), Flood Risk Management Manual and associated 'toolkit' guidelines
vi. The Hills Shire Council Development Control Plan (DCP, 2012)
vii. The Hills Shire Council Local Environment Plan (LEP, 2019)
viii. The Hills Shire Council Design Guidelines for Subdivision/Developments (December 2023)

ix. ***Revision 06***: NSW Planning Secretary's Environmental Assessment Requirements (SEARs) for Housing, Version 1 (NSW Department of Planning, Housing and Infrastructure, 2024).

1.3 Site

The site is located at 40 Memorial Avenue and is within Hills Shire Council Local Government Area (LGA), as shown in **Figure 1**.

The site is bordered by Memorial Avenue to the North, Balmoral Road to the south, Old Windsor Rd to the west and Elizabeth MacArthur Creek to the east. The site in existing condition is predominantly greenfield with a single existing dwelling within the site boundary.

The site generally slopes from 62mAHD at the southwest boundary to 56mAHD at the northeast boundary adjacent to the Elizabeth MacArthur Creek. See **Figure 2** for existing site topography and drainage layout.

Elizabeth Macarthur Creek flows in a northward direction, rising at Bella Vista Farm Park about 2.5km south of the development site. The catchment upstream of the development site is 167 hectares (see **Figure 3**). The upstream catchment is significantly developed with R2, R3 and R4 Residential and SP4 Enterprise zonings (see **Figure 4**).

Figure 1 Site location map

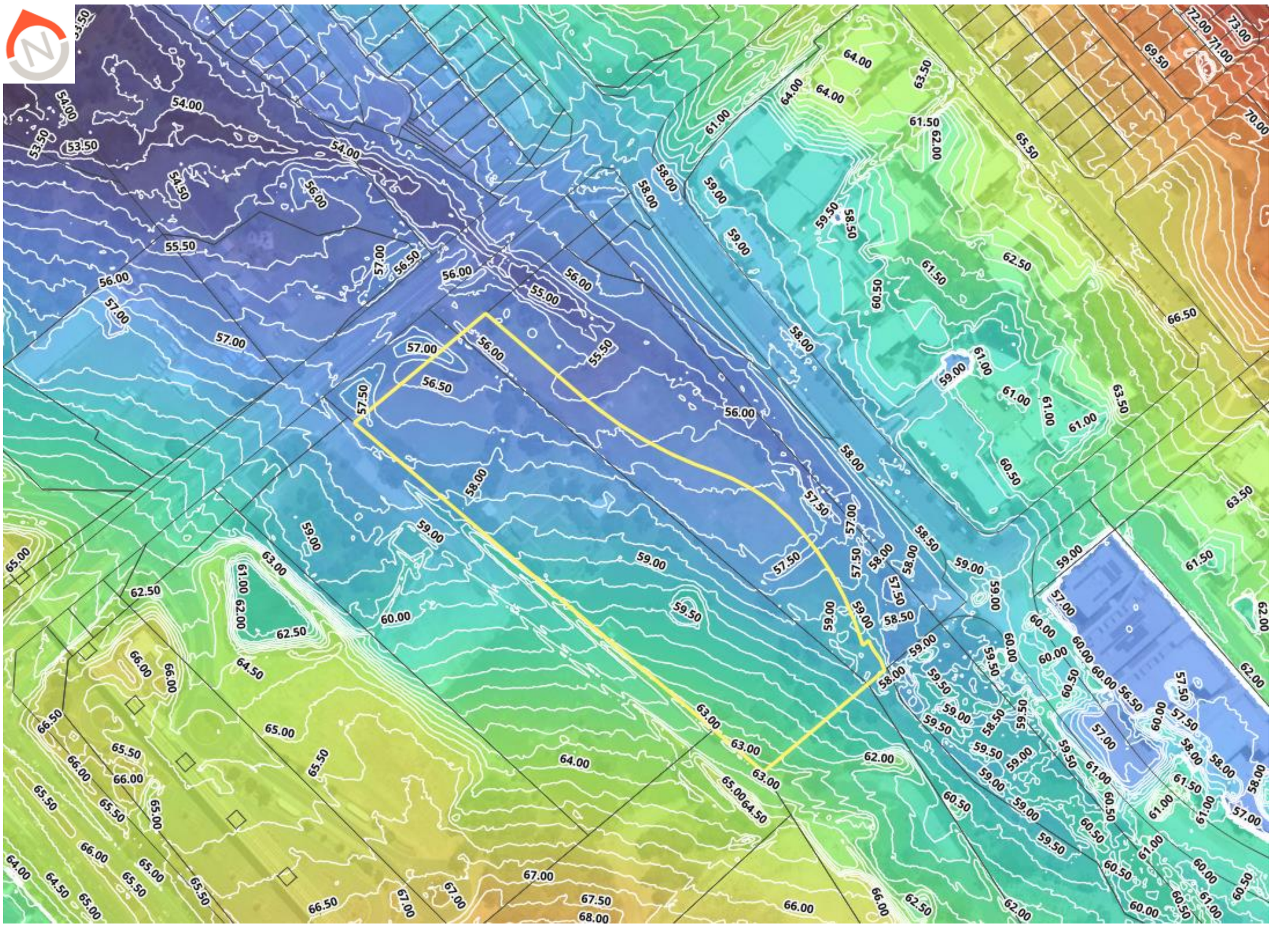

Figure 2 Existing site topography

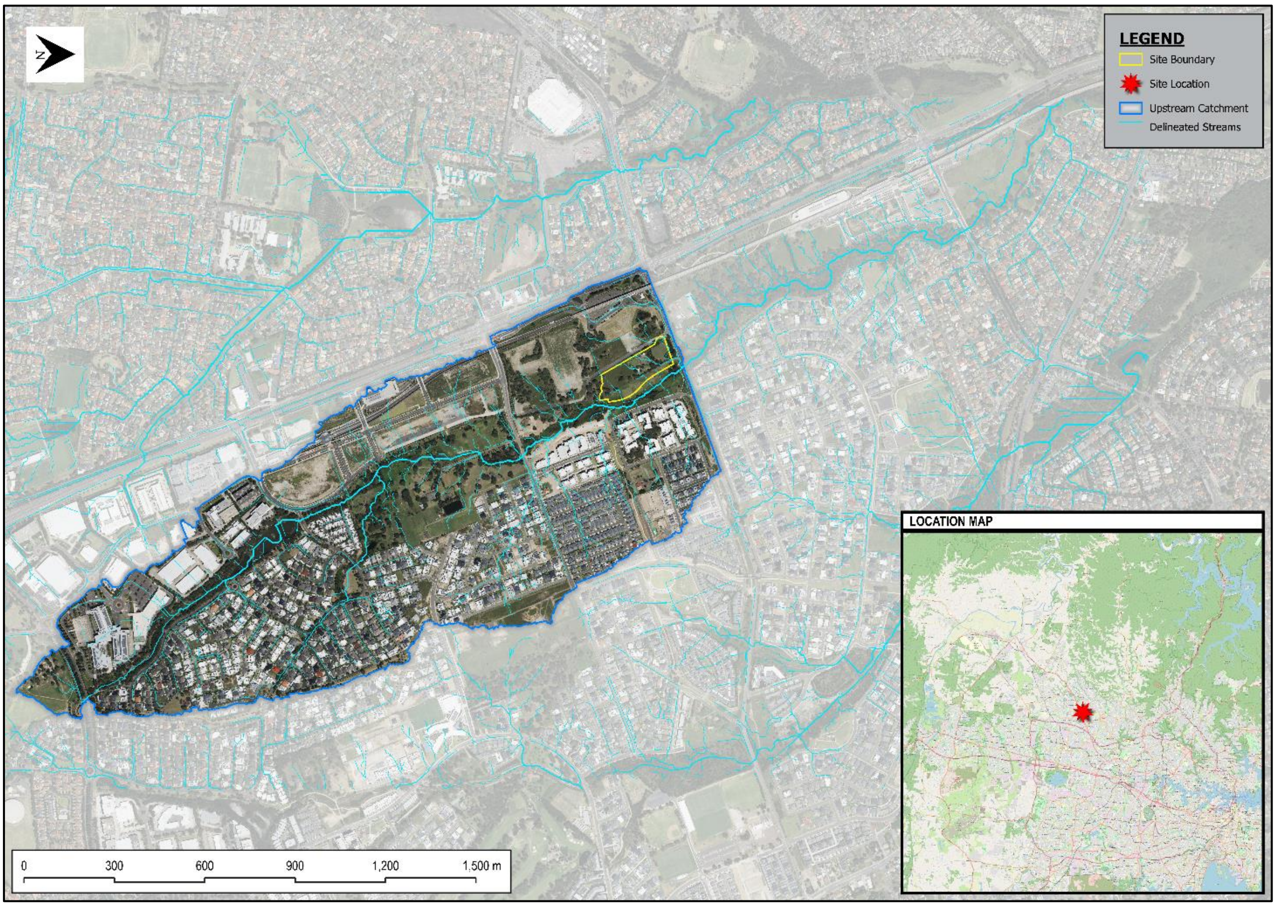

Figure 3 Catchment upstream from 40 Memorial Avenue, Bella Vista

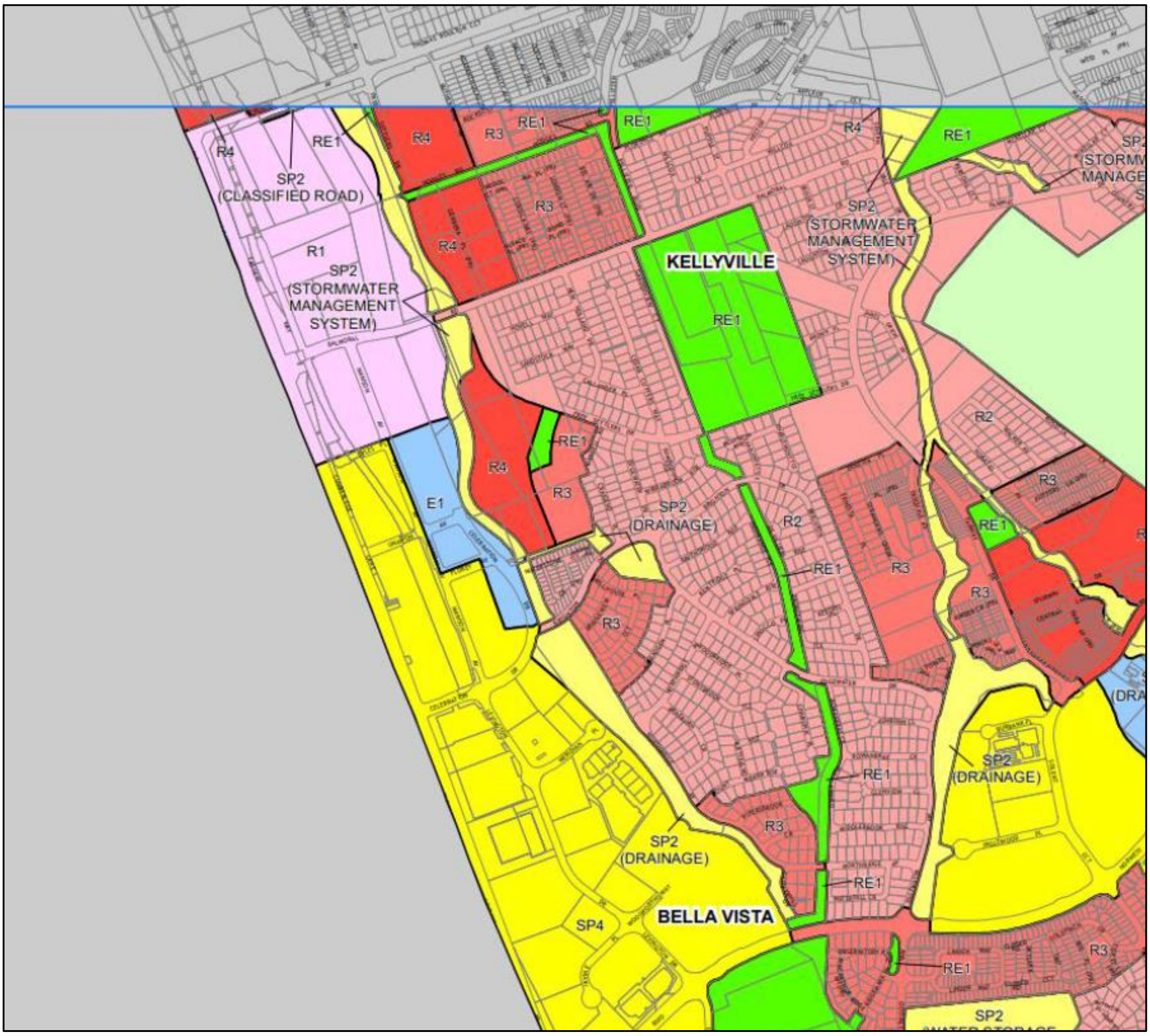

Figure 4 Zoning of catchment upstream from 40 Memorial Avenue, Bella Vista (extracted from The Hill Shire Council Interactive Map – Local Environmental Plan 2019 Land Zoning Map)

2 Planning Secretary's Environmental Assessment Requirements (SEARs)

The following outlines the SEARs in the context of flood risk:

i. Identify the flood planning area and level as set out in the relevant EPI and other supporting documents to determine;
   a. 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
   b. The site access and egress routes
   c. the potential effects of climate change and rare flood events,
   d. any relevant provisions of the NSW Flood Risk Management Manual, and any other relevant guidelines
ii. 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.
iii. 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).

3 Proposed Development

Architectural plans prepared by Turner (Rev 01 – August 2025 for SSDA Submission) indicate that the proposed development is a residential development composed of:

- Two-stage apartment development including 444 dwellings.
- Communal open space.
- Public infrastructure including drainage, services, roads and public parks.

As of the time of writing ***Revision 07*** of this report, the architect has updated the general arrangement plans as per **Figure 5** and **Figure 6**. Refer to Appendix B for an extract of the Lower Ground Floor and Ground Floor Architectural plans.

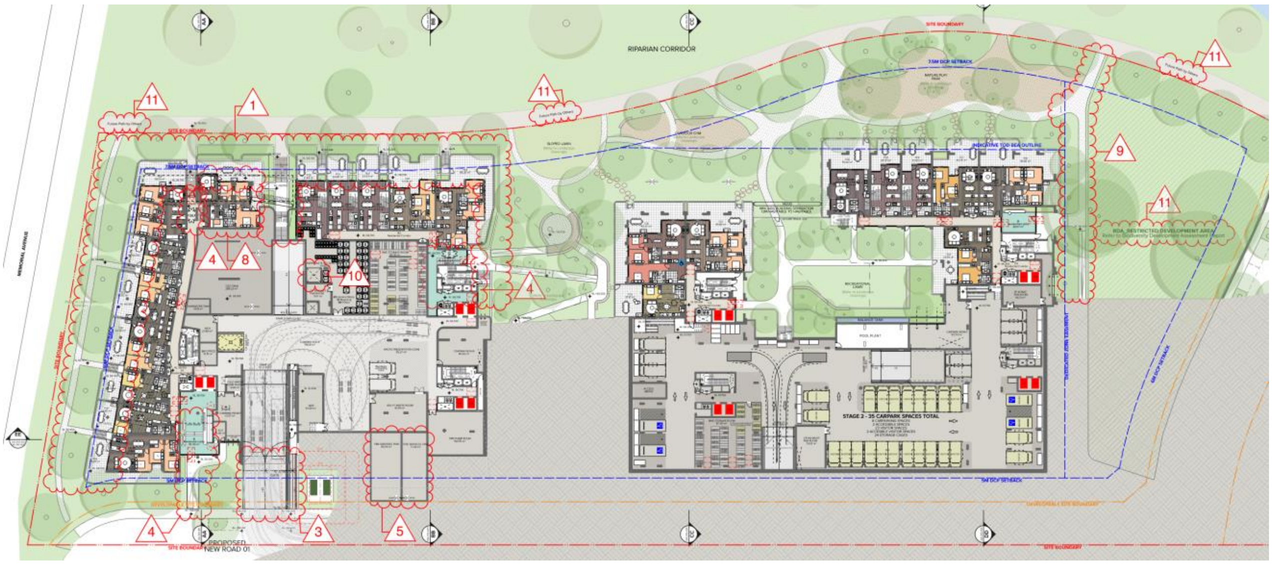

Figure 5 Proposed architectural plan – lower ground level

Figure 6 Proposed architectural plan – ground level

The new proposed architectural layouts have further encroached into the existing 100-year and PMF flood extents since Orion completed the FIRA for DA based on architectural layouts Rev 01 – August 2025 for SSDA Submission by Turner Architects.

The development footprint for the Lower Ground Floor Plan extends into the 10m and 7.5m DCP setback for Buildings C and D to a greater extent than it did previously. While these extensions outside the setback are terraced/landscape in nature and are to be flood compatible.

While the layouts of Buildings A and B have changed, they remain within the original footprint boundary on which we based our initial flood assessment.

3.1 Floor Level Flood Performance

For Buildings A and B, the lowest habitable finished floor level is RL 58.70 mAHD (**Lower Ground Level**)

For Buildings C and D, the lowest habitable finished floor level is RL 58.30 mAHD (**Lower Ground Level**).

To provide additional flood compatibility and resilience the driveway down ramp for buildings A and B has been lifted to an RL of 58.70 which is the same as the PMF water surface levels in the road frontage – to further protect basement levels from significant inundation.

The figure extracts below show critical floor levels relative to a selection of modelled flood levels.

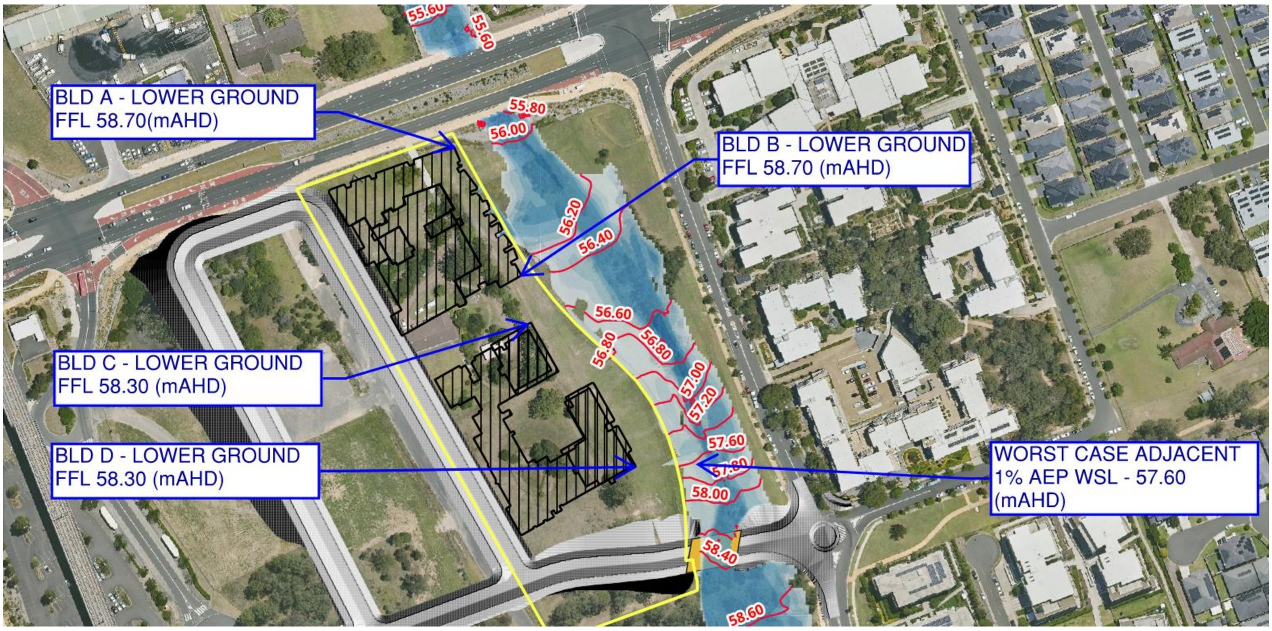

Figure 7 - 1% AEP Interim Flood and Floor Level Comparison

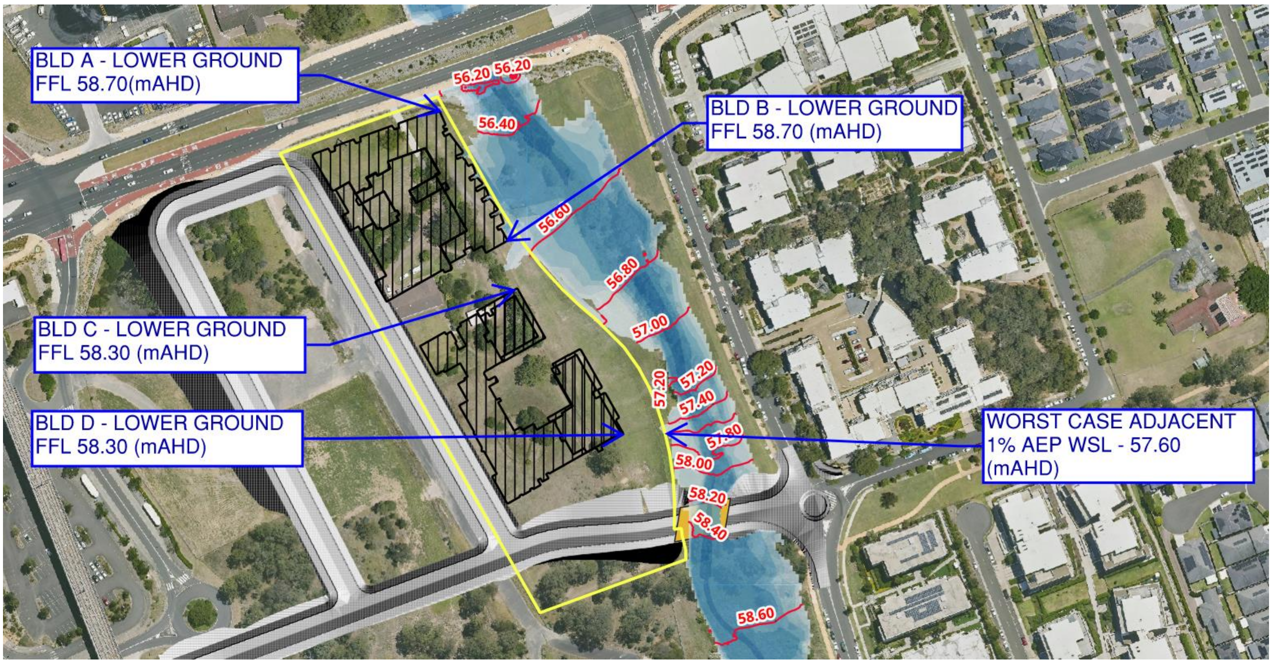

Figure 8 - 1% AEP Ultimate Flood and Floor Level Comparison

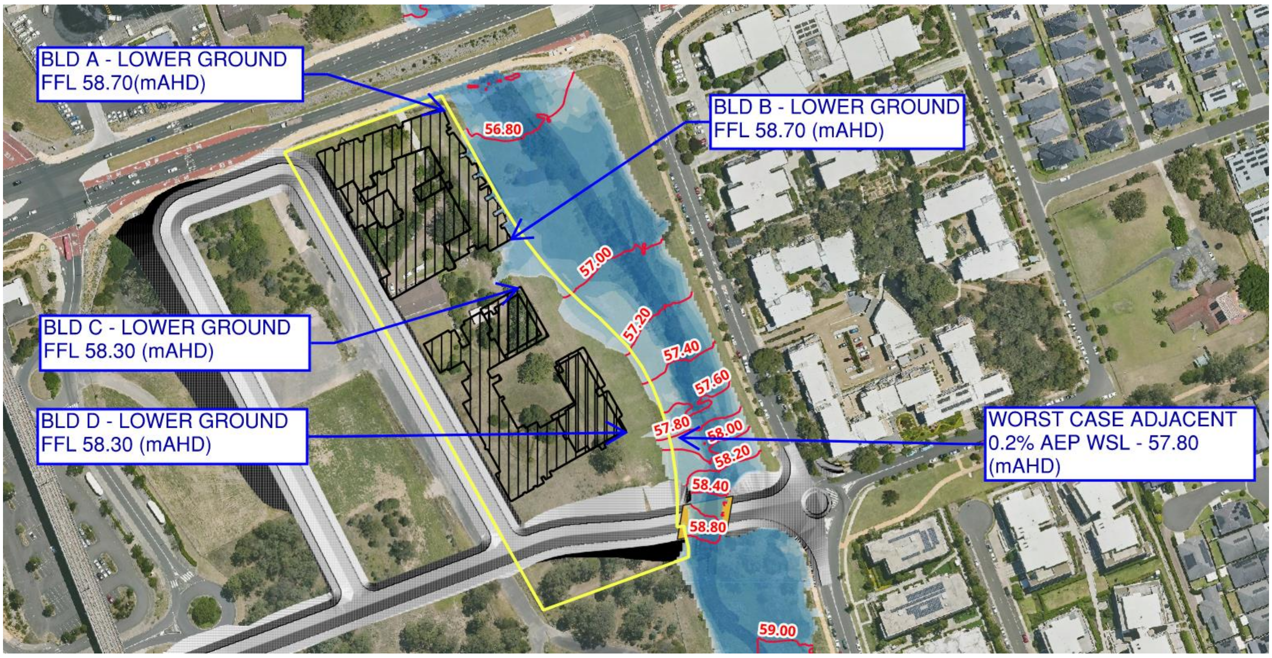

Figure 9 - 0.2% AEP Ultimate Flood Depth and Floor Level Comparison

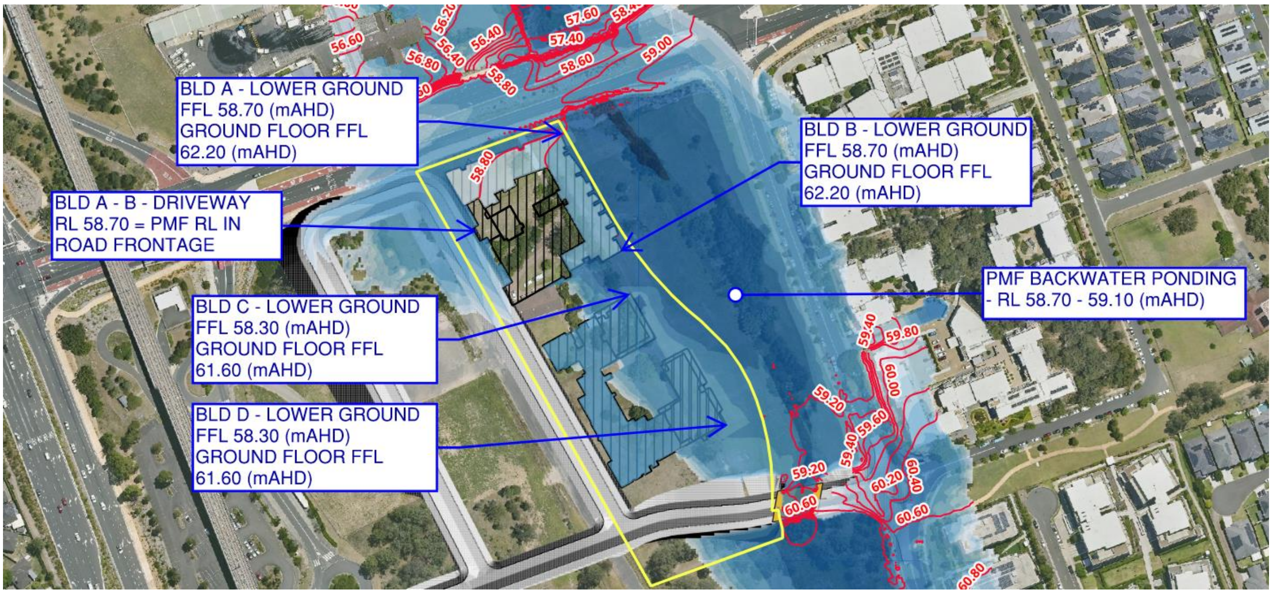

Figure 10 - PMF Interim Flood Depth and Floor Level Comparison

4 Available Data

4.1 Previous studies

4.1.1 Elizabeth Macarthur Creek Trunk Drainage Works - Flood Impact Assessment

The site falls within the Elizabeth MacArthur Creek catchment which is a tributary of Caddies Creek which lies within Cattai Creek catchment and ultimately outfalls to Hawkesbury River catchment. Hills Shire council commissioned WMAwater to undertake a flood study for Rouse Hill in 2014. The study included tributaries of Cattai Creek including Second Ponds Creek, Elizabeth Macarthur Creek, Caddies Creek, Strangers Creek, Smalls Creek and associated floodplain areas.

This hydraulic model (TUFLOW) created for the Rouse Hill Flood Study (RHFS) was inherited by AECOM / Aurecon Joint Venture (AAJV) to undertake a concept design for the Elizabeth MacArthur Creek trunk drainage corridor on behalf of Sydney Water. This study assessed the future concept design which included in-stream works, future fill platforms, future bridge-crossings and local flood management works.

Royal Haskoning DHV (RHDHV) were engaged by Confluence Water to develop an 80% detailed civil design for the rehabilitation of an approximately 2.8km reach of Elizabeth MacArthur Creek. This study area included reaches from Brighton Drive to Samantha Riley Drive (see **Figure 11**). RHDHV inherited the AAJV model in order undertake this assessment.

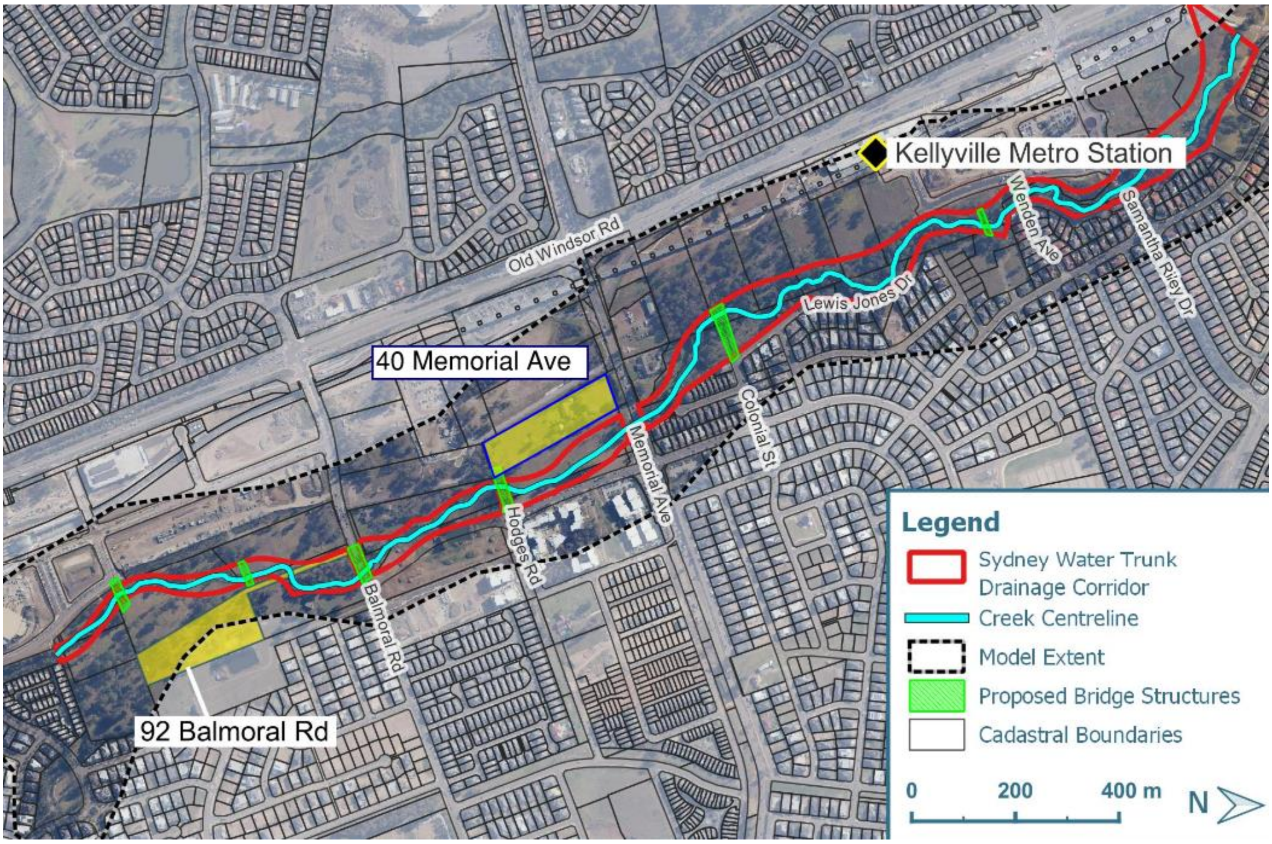

Figure 11 Elizabeth Macarthur Creek Trunk Drainage Works - Flood Impact Assessment - Study Area (Extract of RHDHV, 2024 Figure 1-1 with Subject Site Overlaid)

The proposed rehabilitation works included creek stabilisation and naturalisation, vegetation management, addition and removal of creek structures and site regrading in some areas.

The results from the RHDHV analyses included depth, velocity and bed shear stress maps for the baseline, concept design and detailed design scenario in the 2-year and 1% AEP events. Flood level afflux and velocity afflux maps were also included in the assessment.

It is important to note that ARR 1987 methods were utilised in the AAJV study and were not updated to ARR 2019 for the RHDHV study to enable a like-for-like comparison.

The TUFLOW model input files and results from the Elizabeth Macarthur Creek Trunk Drainage Works Flood Impact Assessment have been provided to Orion to undertake the flood impact assessment for the development at Memorial Avenue and Hodges Road Bridge. The following sections will discuss the model simulation and calibration to the RHDHV results and modelling of proposed works and any associated impacts.

4.2 Survey Data

Much of the survey data that informed the hydraulic modelling was inherited from the RHDHV study. This data included aerial LiDAR survey, topographical surveys of hydraulic structures (bridges, culverts etc), gullies, walls, buildings, roads and drainage channels.

Survey recorded by Orion to facilitate the civil design of this project was used to confirm levels observed in the TUFLOW model elevation data.

The Orion topographical survey was also utilised to further develop the Pre-Development model to better represent current conditions once the calibrated baseline model has been approved.

5 Hydrology

The hydrological model outputs from the RHDHV study for the 1% AEP 120-minute storm were inherited and remained unchanged for the hydraulic model calibration process as detailed in **Section 6.1.8** and **Section 6.3.8**. These hydrological model outputs were originally inherited from the RHFS.

Section 5.1 details the recreation of the XP-RAFTS hydrological model and calibrating to the flows provided by the RHDHV TUFLOW input files. **Section 5.2** details the calculations undertaken to determine PMF flood event flows utilising the calibrated hydrological model

5.1 Hydrological Model Development (XP-RAFTS)

The following subsections details the development of the XP-RAFTS hydrological model using ARR 1987 methodology in order to recreate those flows observed in the RHDHV study. Once the hydrological model has been successfully calibrated to those RHDHV flows, the model can be used to develop PMF flows.

5.1.1 Sub-Catchment Delineation

The sub-catchments have been delineated using LiDAR data as well as known waterway courses, drainage and structures information. The pour points for each sub-catchment were chosen to mimic the locations of the RHDHV TUFLOW flow input locations to remain consistent with the RHDHV study and assist with calibration. QGIS modules were used to delineate the sub-catchments and to output the sub-catchment areas in hectares. See **Figure 12** for sub-catchment delineation.

5.1.2 Sub-catchment Parameterisation

The sub-catchment land use was determined for an ultimate scenario case, i.e. where the total catchment has been fully developed in line with the land zoning as specified in the LEP2019. The ultimate scenario case was chosen for this study to remain consistent with the RHDHV study. Land use zoning maps were used to determine the percentage imperviousness of each subcatchment and input to the DRAINS RAFTS model. Impervious fraction values for each land use were extracted from The Hills Shire Council Design Guidelines for Subdivision/Developments (December 2023). The land use maps and aerial imagery were also used to estimate the manning's n roughness coefficient for the sub-catchments. The sub-catchment slopes were estimated by extracting elevation data from LiDAR along the sub-catchment main drainage line plus any side lines extending to the top of the sub-catchment.

5.1.3 Rainfall Data

5.1.3.1 ARR 1987 Methods

The rainfall data for the DRAINS RAFTS model was generated through DRAINS with input of 9 coefficient from ARR 1987 rainfall intensity-frequency-duration (IFD) table. The rainfall zone was selected as Zone 1 – S.E. Coast and Tasmania. The chosen duration was the 120-minute storm for the 1% AEP flood event similar to the critical duration specified in the RHDHV and RHFS reports.

Table 2 BOM ARR 1987 Rainfall Intensity in mm/h for various durations and return periods

	RETURN PERIOD (YEARS)						
DURATION	**1**	**2**	**5**	**10**	**20**	**50**	**100**
5 mins	79.50	102.00	131.00	147.00	169.00	197.00	218.00
10 mins	60.80	78.20	100.00	113.00	129.00	151.00	167.00
20 mins	44.40	56.90	72.60	81.50	93.50	109.00	121.00
30 mins	36.00	46.20	58.90	66.10	75.80	88.40	97.80
1 hour	24.50	31.40	40.10	45.00	51.70	60.30	66.80
2 hours	16.30	20.90	26.80	30.10	34.60	40.40	44.80
3 hours	12.80	16.40	21.00	23.70	27.30	31.90	35.40
6 hours	8.40	10.80	13.90	15.80	18.20	21.30	23.70
12 hours	5.49	7.09	9.22	10.50	12.10	14.30	15.90
24 hours	3.51	4.57	6.03	6.90	8.03	9.53	10.70
48 hours	2.16	2.83	3.83	4.43	5.20	6.23	7.04
72 hours	1.59	2.09	2.86	3.33	3.93	4.74	5.37

5.1.3.2 ARR 2019 Methods

The rainfall data for the DRAINS RAFTS model was downloaded from BOM ARR2016 rainfall data.

Table 3 BOM ARR 2016 Rainfall Intensity in mm/h for various durations and return periods

	RETURN PERIOD (YEARS)						
DURATION	**1**	**2**	**5**	**10**	**20**	**50**	**100**
5 mins	40.32	96.00	129.60	153.60	176.40	208.80	234.00
10 mins	30.60	76.80	105.60	125.40	145.20	171.60	192.00
20 mins	21.51	54.90	75.30	89.40	103.50	122.10	136.50
30 mins	17.00	43.20	58.80	69.80	80.60	95.00	106.20
1 hour	11.00	27.40	36.70	43.30	49.90	59.00	66.10
2 hours	7.05	17.05	22.65	26.65	30.75	36.50	41.15
3 hours	5.40	13.07	17.33	20.40	23.60	28.13	31.80
6 hours	3.43	8.50	11.38	13.53	15.77	19.00	21.50
12 hours	2.20	5.68	7.83	9.42	11.17	13.50	15.42
24 hours	1.38	3.81	5.42	6.67	8.00	9.71	11.04
48 hours	0.84	2.46	3.63	4.52	5.50	6.60	7.48
72 hours	0.61	1.85	2.74	3.43	4.19	5.01	5.64

5.1.4 Loss Model Parameters

The chosen loss model was an Initial Loss-Continuing Loss (IL-CL) RAFTS model to comply with the requirements of THSC. The loss model parameters are summarised in **Table 4** below:

Table 4 Loss parameters for DRAINS RAFTS hydrological model

Impervious		Pervious	
Initial Loss (mm)	Continuing Loss (mm/hr)	Initial Loss (mm)	Continuing Loss (mm/hr)
0.5	0	10	1.5

The loss parameters were initially determined through research of ARR guidelines, flood studies within the greater Hawkesbury catchment and research papers relating to rainfall losses in New South Wales. These loss values were then altered in order to assist in the calibration process in order to better mimic those flows in the RHDHV study.

In **Revision 7**, the impact of climate change on initial and continuing losses has been considered as the initial and continuing losses have been increased by 5% and 9%, respectively, representing SSP2-4.5 (medium future development) long term (2081-2100) climate change scenario (Australian Rainfall & Runoff Data Hub).

5.1.5 Temporal Patterns

5.1.5.1 ARR 1987 Methods

Temporal patterns are applied based on the rainfall storm burst patterns taken from the manual Australian Rainfall and Runoff (1987). The Zone 1 (S.E. Coast and Tasmania) temporal patterns were applied to the total rainfall depths for the 1% AEP 120-minute storm event.

5.1.5.2 ARR 2019 Methods

The temporal pattern for the median storm of critical duration 120min was determined as 'Storm 1' of the ten temporal patterns used in the analysis.

5.1.6 Areal Reduction Factors

No Areal Reduction Factors were implemented.

5.1.7 Climate Change Factors

As part of ***Revision 06*** of this report to comply with SEARs, Climate change factors were applied to the input rainfall in line with ARR 2019 guidelines with consideration to the Climate Change Book 1, Chapter 6 2024 updates. A factor value of 1.34 representing SSP2-4.5 (medium future development) long term (2081-2100) climate change scenario was used. As the rainfall data obtained from the 2016 IFD portal was derived from historical data from 1961-1990, we also included a climate change factor of 1.16 for our "current scenario" design events for the SSP2-4.5 (medium future development) current and near-term (2021-2040) climate change scenario.

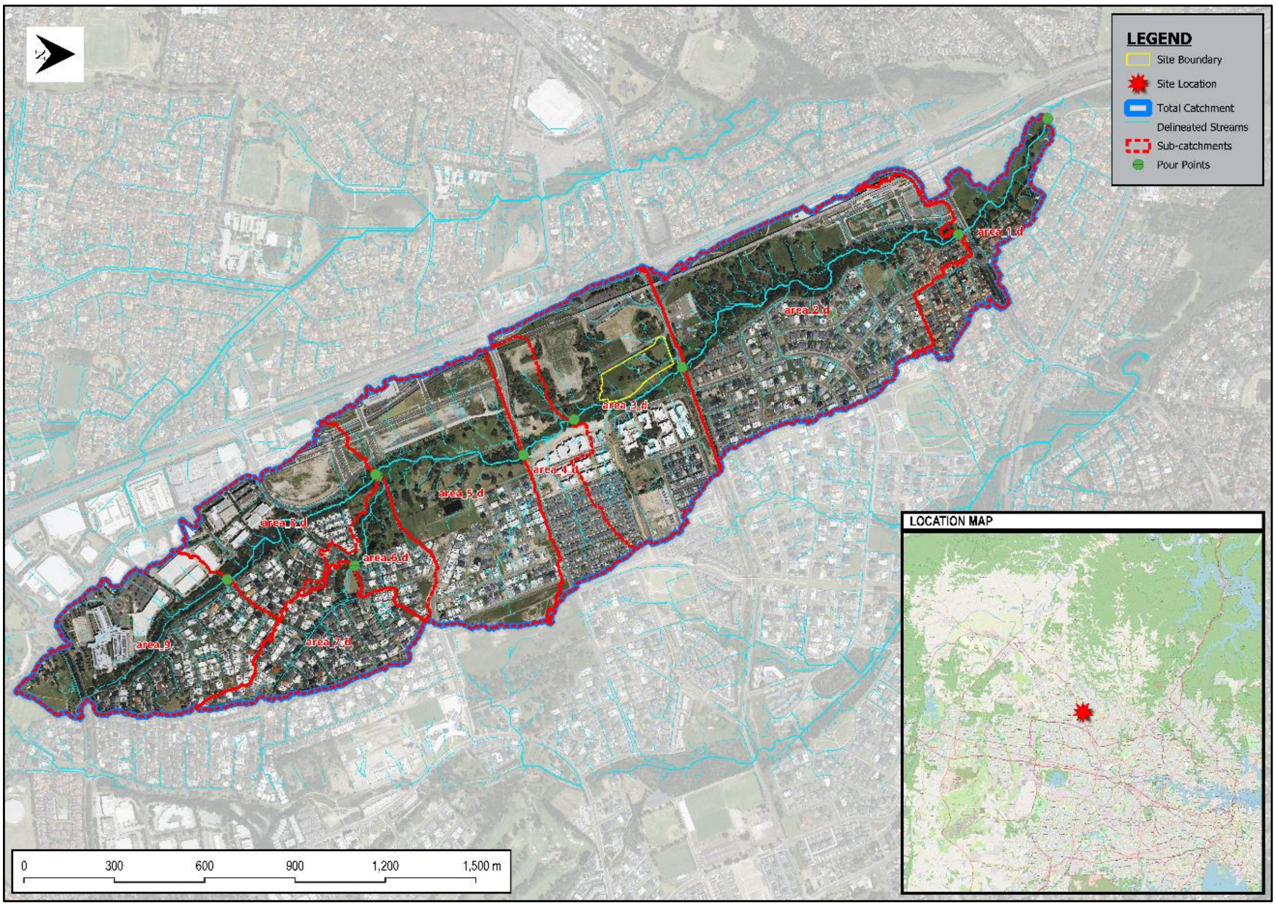

Figure 12 Hydrological model sub-catchment delineation

5.1.8 Hydrological Model Calibration Results

Table 5 below summarises the final flows generated by the calibrated DRAINS RAFTS model.

Table 5 Hydrological model calibration results

OrionCatRef-RHDHVCatRef	Q_{MAX_T}	$tp_{\_T}$	Q_{MAX_O}	$tp_{\_O}$	Q_{MAX_DIFF}	tp_{DIFF}	Q_{T_CUM}	Q_{O_CUM}	Q_{CUM_DIFF}
area_9-32.0|TOTAL	9.63	35.00	11.24	35.20	-16.71%	-0.20	9.63	11.24	-16.71%
area_8-32.01b	5.32	35.00	8.08	35.20	-51.85%	-0.20	14.95	19.32	-29.22%
area_7-40.0a	6.22	35.00	7.10	35.20	-14.11%	-0.20	6.22	7.10	-14.11%
area_6-40.0b	4.15	35.00	3.36	35.20	18.97%	-0.20	10.37	10.46	-0.88%
area_5-32.02|LOCAL	11.48	33.00	15.22	35.20	-32.49%	-2.20	36.80	44.99	-22.26%
area_4-41.0|TOTAL	10.21	33.00	6.55	35.20	35.83%	-2.20	47.01	51.54	-9.64%
area_3-32.03|LOCAL	14.66	33.00	14.77	35.20	-0.74%	-2.20	61.67	66.31	-7.53%
area_2-32.04|LOCAL	24.52	34.00	22.80	35.20	7.01%	-1.20	86.19	89.11	-3.39%
area_1-32.05|LOCAL	9.10	35.00	11.82	35.20	-29.87%	-0.20	95.29	100.93	-5.92%

Q_{MAX_T} = maximum flow inputs to TUFLOW model from RHDHV study
$tp_{\_T}$ = time to peak for inflow hydrograph from RHDHV study
Q_{MAX_O} = maximum flow generated from Orion DRAINS RAFTS model
$Tp_{\_O}$ = time to peak for hydrograph generated from Orion DRAINS RAFTS model

5.2 PMF Hydrological Calculations

The following subsections detail calculations and assumptions made in calculating PMF flows for the study area. The calibrated hydrological model discussed above was used for these calculations.

The PMF flows were generated in line with "The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method" (Bureau of Meteorology, Melbourne, Australia, June 2003). Catchment area, percent rough, elevation of the catchment and moisture adjustment factor were input into DRAINS Utility Spreadsheet which output PMF storms varying from 15 minutes to 6 hours in duration.

The PMF 60-minute storm event was found to the critical duration at the site.

6 Hydraulic Flood Model

TUFLOW software was used to develop a dynamic 1d/2d hydraulic model as part of the study. The hydraulic model input files were inherited from the Elizabeth Macarthur Creek trunk drainage works flood impact assessment model as prepared by RHDHV for Sydney Water.

i. **Section 6.1** outlines the geometry and boundary condition inputs into the RHDHV baseline model, changes made to the model to calibrate Orion's 1% AEP simulations to RHDHV published results and any additions to the baseline model in creating an accurate pre-development model that accurately represents current conditions.

ii. **Section 6.2** outlines the addition of the proposed works to the pre-development model in order to create the interim development model.

iii. **Section 6.3** details the geometry and boundary condition inputs into the RHDHV detailed design model, changes made to the model to calibrate Orion's 1% AEP simulations to RHDHV published results and the addition of the proposed works to the detailed design model to create a Final Development (80% Design) model.

6.1 Baseline RHDHV Model & Pre-Development Model

6.1.1 2D Model Domain

The 2D model domain has been maintained to the same extents of that reported in the RHDHV study. The digital elevation model was created using a combination of 1m resolution Aerial LiDAR Surveys (ALS), topographical spot-level surveys, creek surveys and structure surveys. The hydraulic model extent is shown in **Figure 14**.

6.1.2 Ground Surface Elevations

Ground surface elevations were assigned to grid cells within the TUFLOW model based on the elevation data described above in **Section 4.2**.

6.1.3 Model Cell Size

In the whole catchment area, a square grid was utilised for this study, with the grid size of 1.5m x 1.5m. The grid cell size of 2.25m^2 is sufficiently fine to appropriately represent the variations in topography and land use within the study area. It should be noted that TUFLOW samples elevation points at the cell centres, mid sides, and corners, therefore a 2.25m^2 cell size results in surface elevations being sampled every 0.75m.

6.1.4 Building Footprints

Buildings were represented in the model by polygons with a 2D_code of '0' meaning that the cells in these areas are inactive and excluded from calculations.

6.1.5 Hydraulic Roughness

The hydraulic roughness of a material is an estimate of the resistance to flow and energy loss due to friction between a surface and the flowing water. A higher hydraulic roughness indicates more resistance to the flow. Roughness in TUFLOW is modelled using the Manning's (n) roughness co-efficient.

In **Revision 7**, Manning's zones were based on the RHDHV model data for the existing (pre-development) scenario) as shown in Figure 13.

Figure 13 Existing (pre-development) scenario material layer

6.1.6 1d Model Domain

Detailed culvert and bridge structure data had been incorporated into the 1d network within the RHDHV TUFLOW model as shown in **Figure 14**. The basin and channel at Brighton Drive were also modelled as 1d networks.

6.1.7 Boundary Conditions

Internal 2d inflow Boundary Conditions (BCs) were applied to the 2d domain throughout the model as inflow hydrographs (QT). 1d inflows were also added to the basin area upstream of Brighton Drive as inflow hydrographs (QT). Outflow from the 2d domain was represented by stage-discharge (HQ) 2d BC. Initial Water Levels (IWL) BCs were also applied to the 1d domain to ensure stability at the initialisation of the simulations. Locations of information transfer between 1d and 2d domains were represented by 1d/2d BC connections. These 1d/2d connections include the interaction between 2d domain and culverts and bridges as well as interaction between the 2d domain and 1d domain channels. Model BC locations are illustrated in **Figure 14**.

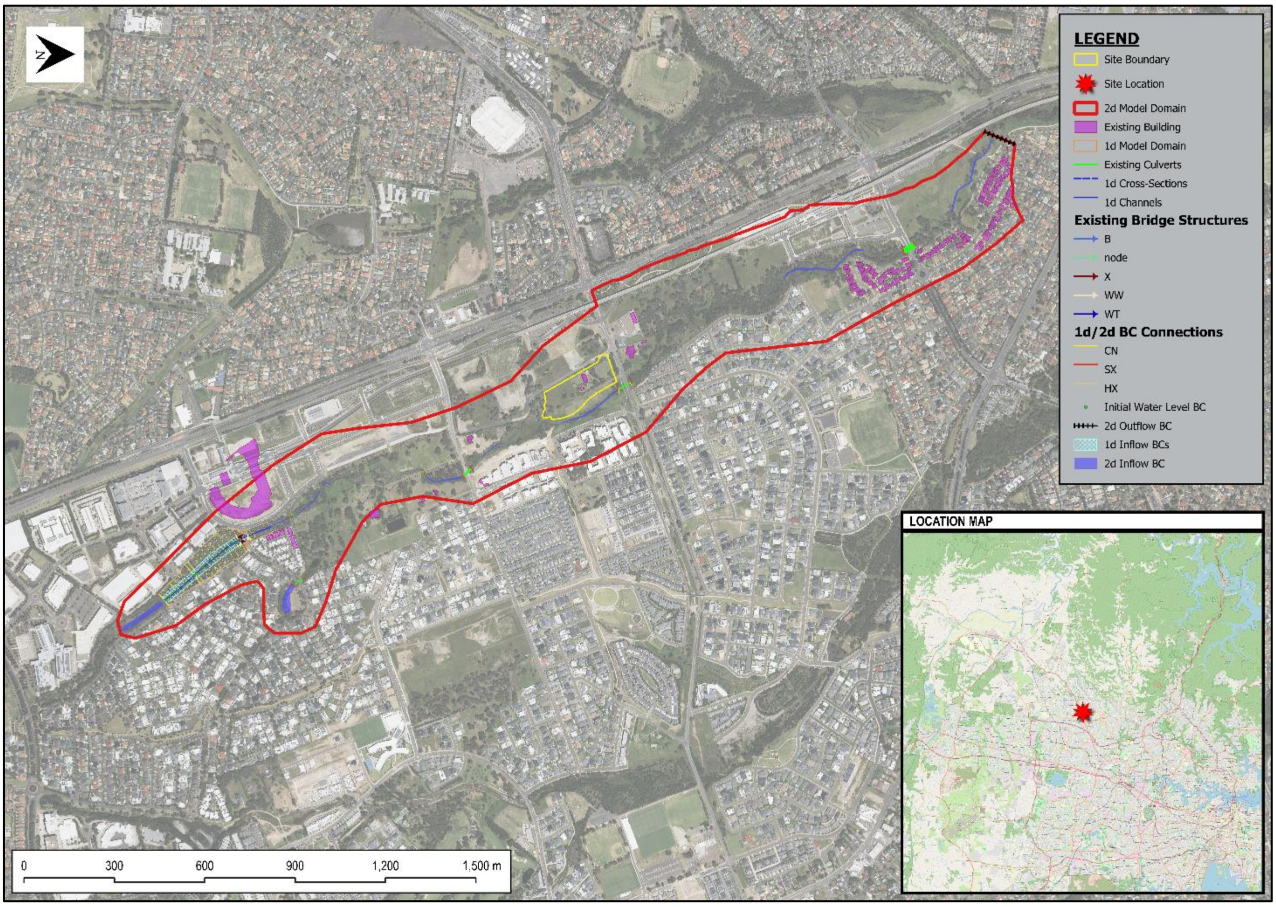

Figure 14 TUFLOW hydraulic model layout – baseline condition

6.1.8 Calibration

The RHDHV TUFLOW baseline model input and results files were provided to Orion by Sydney Water. The baseline model was run for the 120-minute storm for the 1% AEP event. The results from these simulations were then compared with those results maps published as part of the RHDHV.

Upon receipt of the TUFLOW model files, Orion noted that some of the elevation files for the model geometry were missing. It was reported to Orion by RHDHV that some of the original elevation files to inform the digital elevation model were missing and so they had to prepare similar elevation data using TUFLOW simulation result echo files. Fortunately, RHDHV were able to provide these recreated DEM files to Orion in order to complete our assessment.

Initial TUFLOW simulations showed a lot of errors and hydraulic instabilities, and so initially calibration was not possible. The baseline model was run repeatedly for the 1% AEP with iterations with selected suspect elevation files omitted from the geometry control file until the model successfully ran without error and with an allowable level of instability. It became quickly apparent that most of the instabilities were occurring around the detailed survey data recorded around Memorial Avenue.

The problematic elevation files were imported into QGIS, interrogated and improved to reduce the occurrence of sharp increase/decrease of elevation and null data values and then reintroduced to the model geometry one by one.

Additionally, Orion has undertaken a sensitivity analysis regarding the use of TUFLOW model builds from 2013 as per the RHDHV simulations and the more recent 2023 model builds. The results of this sensitivity analysis revealed that the 2023-03-AC-iSP-w64 model build produced results that diverged from those reported in the RHDHV study, outputting water levels 50-100mm lower upstream of the Memorial Avenue bridge. Using the 2013-12-AB-iDP-w64 build output water levels with a max difference of 30mm when compared with the RHDHV model outputs in the same location. It was decided to use the 2013-12-AB-iDP-w64 for this study.

Figure 15 illustrates the water level afflux between the RHDHV and Orion results for the 1% AEP 120-minute event. The afflux raster reported that the Orion results are a maximum of 30mm lower than those reported by RHDHV.

The Hill Shire Council approved the baseline model for use in this assessment on the 14th June 2024. It was recommended that the baseline model be used in preparing an interim post-development model.

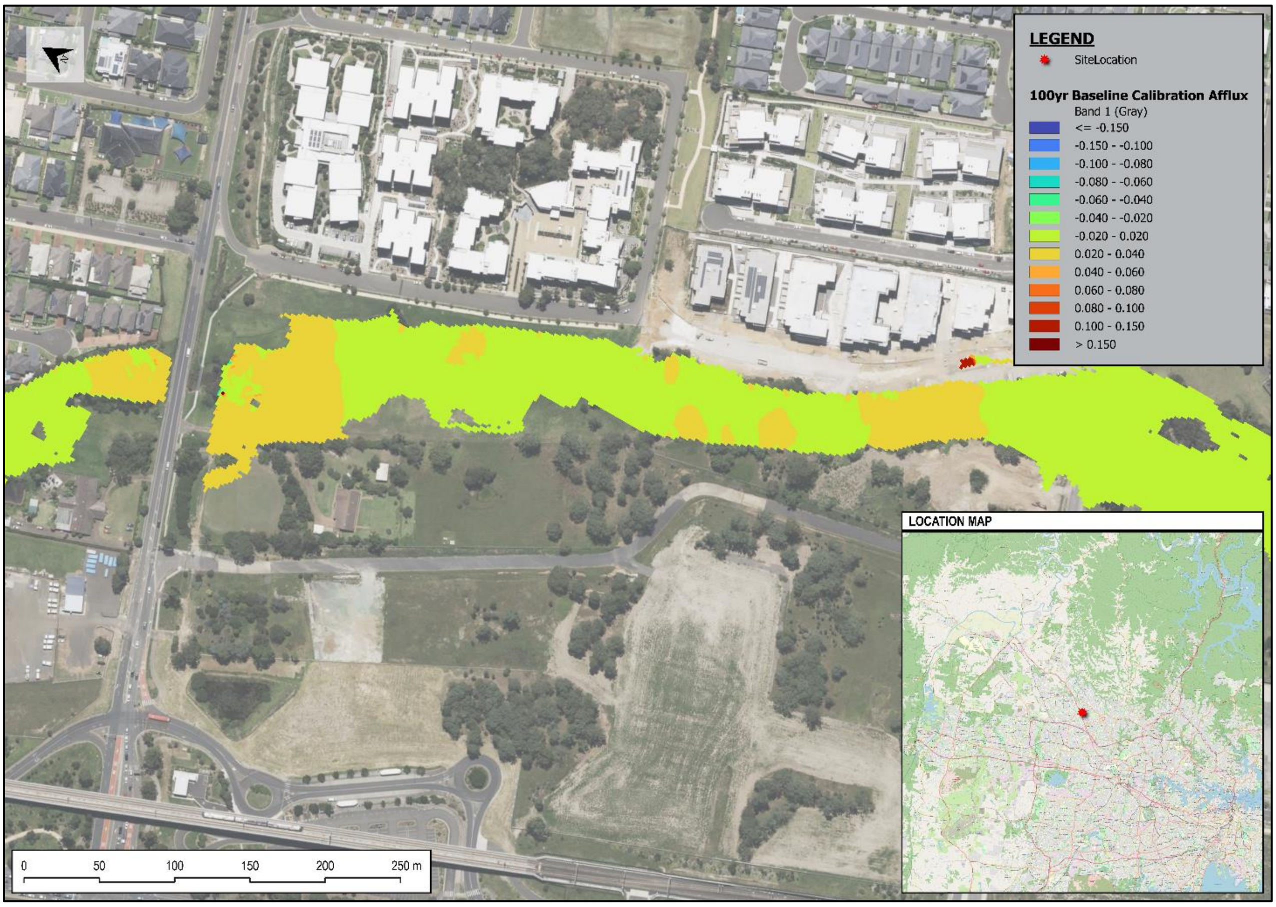

Figure 15 TUFLOW baseline model calibration – 1% AEP 120-minute calibration afflux map

6.1.9 Updated Pre-Development Model

By the request of council, an existing fence line at the site was added to the model in order to assess the impacts on flood levels for two scenarios:

1. The calibrated baseline model with the fence line included with 100% blockage with collapse at time of peak flow in simulation.
2. The calibrated baseline model with the fence line included with 50% blockage with no collapse.

Topographical survey of the site confirmed the position and height of the fence line. A site visit undertaken on 24th May 2024 further validated the location and height of the fence line as well as the culvert arrangement under Memorial Avenue.

These models were approved by council on the 14th June 2024. However, it was recommended to progress the interim post-development model through use of the calibrated baseline model without the inclusion of the fence lines as described above.

For **Revision 07** – the DA approved Hodges Street Bridge and Roundabout (DA/563/2024/ZB) has been added to this scenario to ensure the impact assessment only considers the proposed building development subject to the SSD application.

6.2 Interim Development Model

6.2.1 2D Model Domain

The 2D model domain remains the same as that in the baseline pre-development model.

6.2.2 Ground Surface Elevations

Ground surface elevations were assigned to grid cells within the TUFLOW model based on the elevation data described above in **Section 4.2**.

Proposed surfaces for the buildings finished floor levels (FFLs), associated landscaping, access road and bridge abutments were developed through 12D and Civil 3D and added to the geometry control file.

6.2.3 Model Cell Size

The cell size remains the same as that in the baseline pre-development model in the whole catchment except around the proposed buildings.

In **Revision 7**,and around the proposed buildings, a square grid size of 0.375m x 0.375m was utilised to appropriately capture the site survey data and details of the proposed buildings as shown in **Figure 16** and **Figure 17**.

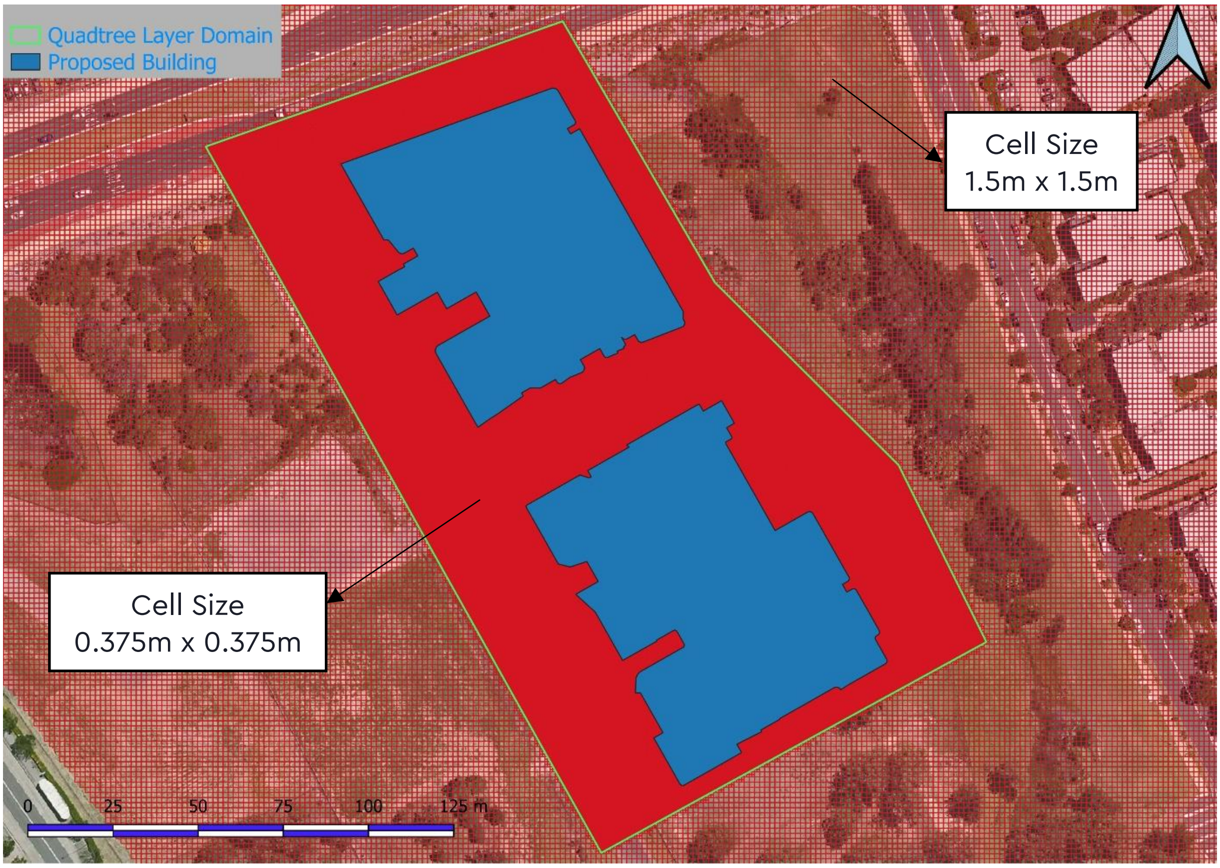

Figure 16 The size of computational cells inside and outside of the study site

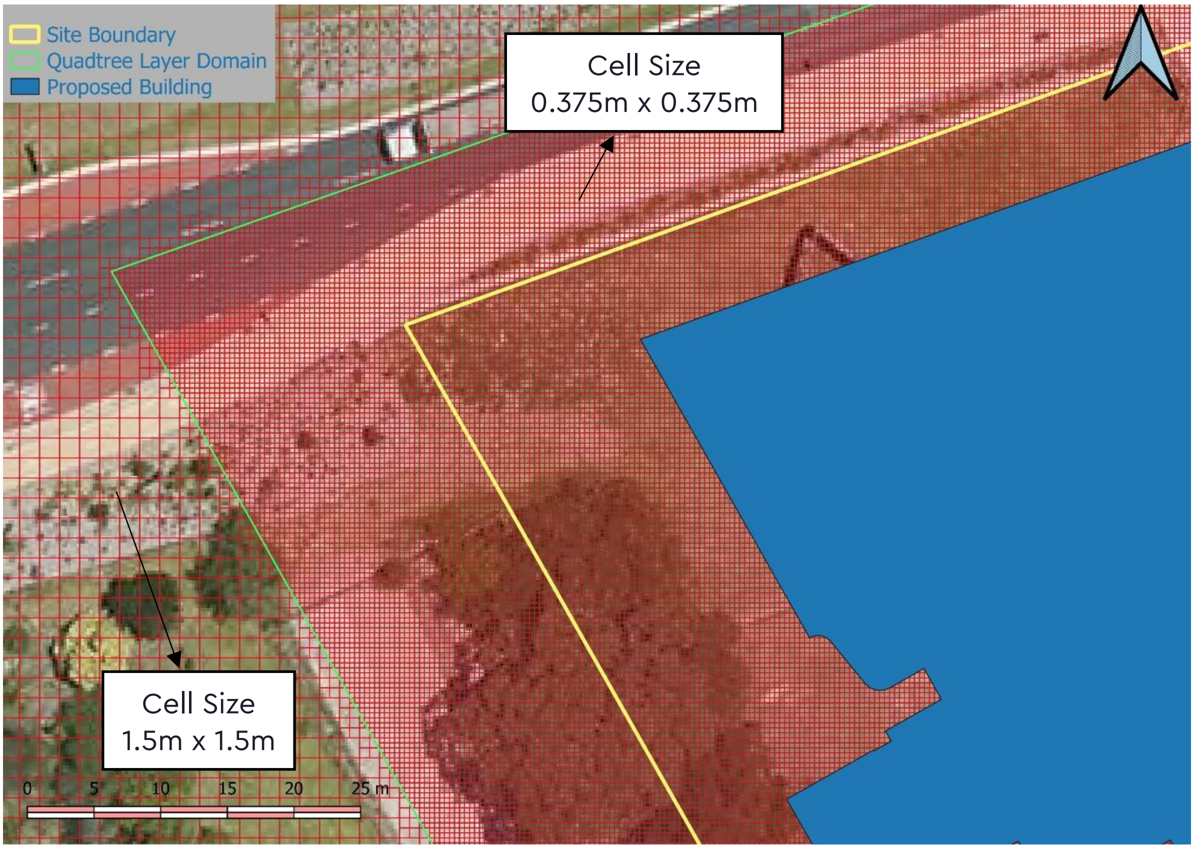

Figure 17 The size of computational cells inside and outside of the study site (close view)

6.2.4 Building Footprints

Buildings were represented in the model by polygons with a 2D_code of '0' meaning that the cells in these areas are inactive and excluded from calculations. The proposed building footprints were included as surfaces raised from the existing ground to the proposed FFLs.

6.2.5 Hydraulic Roughness

The hydraulic roughness of a material is an estimate of the resistance to flow and energy loss due to friction between a surface and the flowing water. A higher hydraulic roughness indicates more resistance to the flow. Roughness in TUFLOW is modelled using the Manning's (n) roughness co-efficient.

In **Revision 7**, Manning's zones were based on the RHDHV model data and has been modified within and around the site to comply with the Interim Development scenario surface as shown in Figure 18.

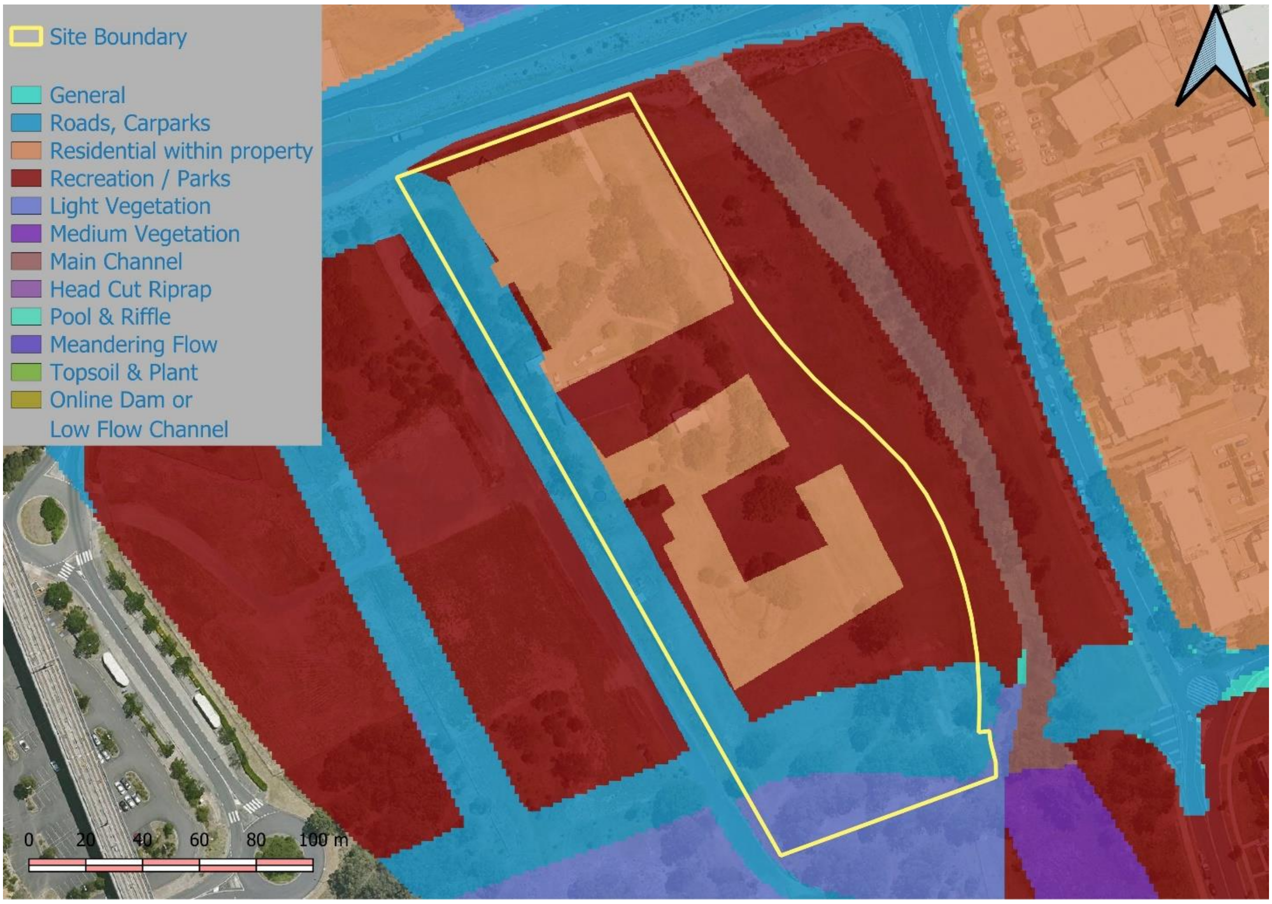

Figure 18 Interim development scenario material layer

6.2.6 1d Model Domain

The 1d model domain remained mostly the same as that included in the baseline pre-development model. The proposed bridge at Hodges Road as part of this development was included in the 1d domain.

6.2.7 Boundary Conditions

The boundary conditions remain the same as those set out in the baseline pre-development model.

6.3 RHDHV Detailed Design Model & Final Development Model

6.3.1 2d Model Domain

The 2d model domain extents remains the same as that applied in the baseline pre-development model.

6.3.2 Ground Surface Elevations

The ground surface elevations were represented by the most recent detailed design surfaces as proposed by RHDHV. These changes included the revised creek horizontal and vertical alignment, cross-sections, roughness parameters, flow diversion channel adjacent to Lewis Jones Drive, seven proposed bridge crossings and filling of the floodplain to the boundary of the trunk drainage corridor.

6.3.3 Model Cell Size

The cell size remains the same as that in the baseline pre-development model in the whole catchment except around the proposed buildings.

In **Revision 7**,and around the proposed buildings, a square grid size of 0.375m x 0.375m was utilised to appropriately capture the site survey data and details of the proposed buildings as shown in **Figure 16** and **Figure 17**.

6.3.4 Building Footprints

There were no updates to the building footprints in the RHDHV detailed design model.

6.3.5 Hydraulic Roughness

The RHDHV detailed design model updated the Manning's hydraulic roughness to represent the changes to the creek channel alignment, geomorphology and vegetation.

In **Revision 7**, the material layer has been modified based on the Ultimate Development scenario surface as shown in Figure 19 per the latest modelling data received for the Elizabeth Macarthur Creek

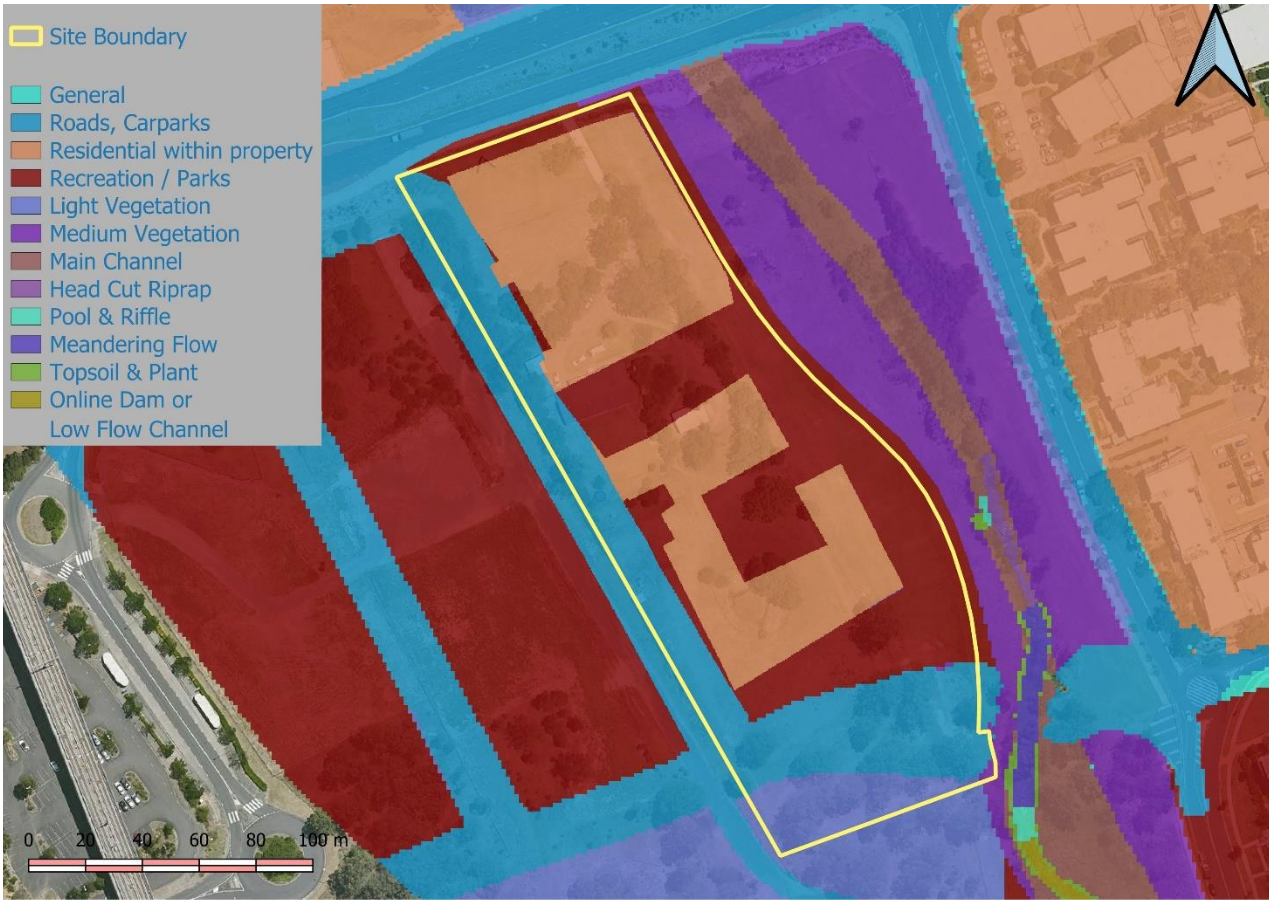

Figure 19 Ultimate development scenario material layer

6.3.6 1d Model Domain

The 1d model domain was largely the same as that in the baseline model but also included the seven new water crossings.

6.3.7 Boundary Conditions

Boundary conditions were largely kept the same as the baseline model with some additional BCs implemented to the updated areas.

6.3.8 Calibration

The RHDHV TUFLOW detailed design model input and results files were provided to Orion by Sydney Water. The detailed design model was run for the 120-minute storm for the 1% AEP event. The results from these simulations were then compared with those results maps published as part of the RHDHV.

Similarly to the baseline model calibration process described in **Section 6.1.8** above, several of the detailed design model elevation files were causing errors in simulations. The problematic elevation files were imported into QGIS, interrogated and improved to reduce the occurrence of sharp increase/decrease of elevation and null data values and then reintroduced to the model geometry one by one.

Figure 20 illustrates the differences in flood extents and water levels for the RHDHV results and the Orion calibrated model results for the 120-minute 1% AEP storm. The two longitudinal profiles and flooding extents show negligible water level afflux between Memorial Avenue and Balmoral Road.

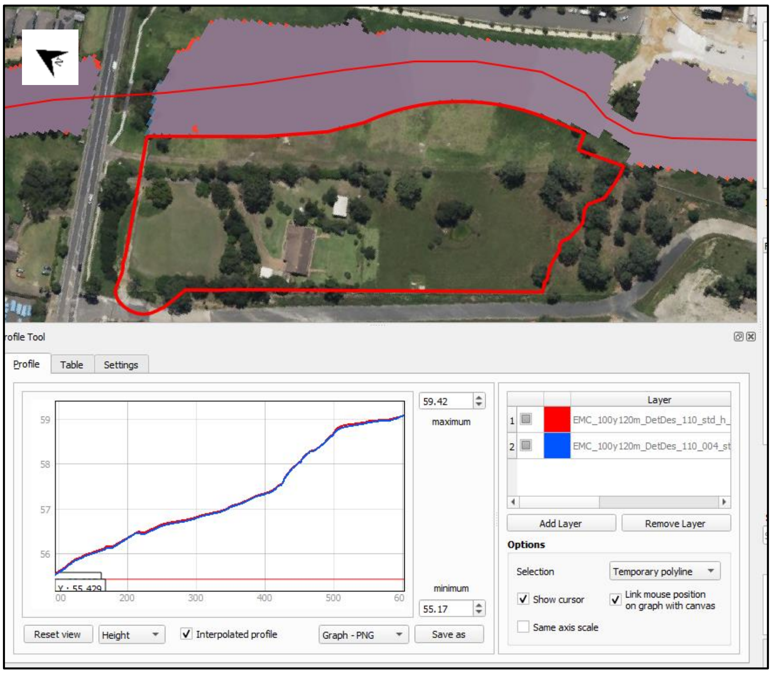

Figure 20 TUFLOW detailed design model calibration – 1% AEP 120-minute results plan and long profile with study area

6.3.9 Final Development Model – Model Updates

The 80% Elizabeth MacArthur Creek Design for the trunk drainage works was used to inform the Final Development model upon agreement with Council.

Proposed surfaces for the buildings finished floor levels (FFLs), associated landscaping, access road and bridge abutments were developed through 12D and Civil 3D and added to the geometry control file.

Changes made to the RHDHV TUFLOW detailed design model scenario include the following:

- Removed the 2d ridge line (previously set at elevation of 100m) within the extents of the development site as the design TIN with the FFLs defines the site geometry interfacing with the watercourse.
- Removed the 2d region modelling bridge abutments for Hodges Road (previously set at elevation of 100m) as the design TIN for Hodges Road defines the road and bridge geometry.

- Hodges Road bridge was modelled as a 2d_lfcsh layer with a bottom of deck level at RL59.52m (an average deck level was adopted, as the bridge was designed with a 0.5% grade along the 18m span between piles). Refer to BG&E 'Hodges Road Bridge' design and Orion's 'Hodges Road Bridge and Roundabout' design.

7 Results

Results of all model scenarios and events can be examined in Appendix A – Flood Maps. The design flood levels will be discussed below in relation to the proposed FFLs of the Lower Ground Floors of Buildings A, B, C and D.

7.1 1% AEP

For the pre-development scenario we see that the flood level at the proposed locations of Buildings A to B is almost 56.2m. The flood level from C to D varies from 57.3m to 57.5m.

The lower ground floor habitable finished levels at Buildings A and B is 58.7m. The lower ground floor habitable finished levels at Buildings C and D is 58.3m.

It is clear from examination of the flood maps and the latest architectural plans that there is sufficient freeboard for the 1%AEP flood level **with all habitable floor levels greater than the 1% AEP + 500mm Freeboard** level.

For the Stage 1 (Interim Development) there is minimal/negligible impact in flood levels in the creek due to the introduction of the proposed development surfaces to the pre-development model.

For the Stage 2 (Ultimate Development) scenario, the flood levels increase to 56.5 to 56.6m adjacent to buildings A and B. The adjacent area to buildings C and D is dry which shows that the buildings C and D are not affected by 1% AEP flood event.

As a result, there is sufficient freeboard to the habitable lower ground levels of the proposed buildings in 1% AEP flood event in the ultimate design scenario.

7.2 1% AEP + CC

For the pre-development scenario we see that the flood level at the proposed locations of Buildings A to B is 56.4m. The flood level from C to D varies from 57.2m to 57.6m. The inclusion of climate change does not have a significant adverse impact on flood levels in the creek, with maximum 200mm increase in the locality of Buildings A and B while water depth in the locality of Buildings C and D increases from zero to 200mm.

The lower ground floor habitable finished levels at Buildings A and B is 58.7m. The lower ground floor habitable finished levels at Buildings A and B is 58.3m.

It is clear from examination of the flood maps and the proposals that there is sufficient freeboard from the 1%AEP + CC flood level.

For the Interim Development, we see that the flood level at the proposed locations of Buildings A to B varies from 56.5m to 56.6m. However, the adjacent area to Buildings C and D is dry which shows that the buildings C and D are not affect by 1% AEP + CC flood event.

For the Ultimate Development scenario the flood levels increase to 56.7 to 56.8m adjacent to buildings A and B. Buildings C and D are still dry in 1% AEP + CC flood event.

As a result, there is still sufficient freeboard to the habitable lower ground levels of the proposed buildings.

7.3 0.5% AEP

For the pre-development scenario we see that the flood level at the proposed locations of Buildings A to B is 56.4m. The flood level from C to D varies from 57.3m to 57.6m. The intensifying of flood occurrence from 1% AEP (100 years) to 0.5% AEP (200 years) flood event does not have a significant adverse impact on flood levels in the creek, with maximum 200mm increase in the locality of Buildings A and B while water depth in the locality of Buildings C and D increases from zero to 200mm with respect to 1% AEP flood event.

The lower ground floor habitable finished levels at Buildings A and B is 58.7m. The lower ground floor habitable finished levels at Buildings A and B is 58.3m.

It clears from examination of the flood maps and the proposals that there is sufficient freeboard from the 0.5%AEP flood level.

For the Interim Development, we see that the flood level at the proposed locations of Buildings A to B varies from 56.5m to 56.6m (similar to the pre-development scenario). Even for 0.5% AEP flood event, however, the adjacent area to Buildings C and D is dry which shows that Buildings C and D are not affected by 0.5% AEP flood event.

For the Ultimate Development scenario, the flood levels increase to 56.7 to 56.8m adjacent to Buildings A and B. Buildings C and D are still dry in 0.5% AEP flood event.

As a result, there is still sufficient freeboard to the habitable lower ground levels of the proposed buildings.

7.4 0.2% AEP

For the pre-development scenario we see that the flood level at the proposed locations of Buildings A to B is 56.5m. The flood level from C to D varies from 57.0m to 57.6m. Consequently, 0.2% AEP (500 years) flood event does not significantly change the flood level in the creek with maximum 300mm increase in the locality of Buildings A and B while water depth in the locality of Buildings C and D increases from zero to 200mm with respect to 1% AEP flood event.

The lower ground floor habitable finished levels at Buildings A and B is 58.7m. The lower ground floor habitable finished levels at Buildings A and B is 58.3m.

It clears from examination of the flood maps and the proposals that there is sufficient freeboard from the 0.2%AEP flood level.

For the Interim Development, we see that the flood level at the proposed locations of Buildings A to B varies from 56.7m to 56.8m. Even for 0.5% AEP flood event, however, the adjacent area to Buildings C and D is dry which shows that Buildings C and D are not affected by 0.2% AEP flood event.

For the Ultimate Development scenario, the flood levels increase to 56.8 to 56.9m adjacent to Buildings A and B. Buildings C and D are still dry in 0.2% AEP flood event.

As a result, there is still sufficient freeboard to the habitable lower ground levels of the proposed buildings.

7.5 PMF

For the pre-development scenario we see that the flood level at the proposed locations of Buildings A to B vary from 59.0m to 59.10m. The flood level from C to D is effectively static at RL 58.90m due to the backwater effects from the crossing under Memorial Avenue.

The lower ground floor habitable finished levels at Buildings A and B is 58.7m. The lower ground floor habitable finished levels at Buildings A and B is 58.3m. While localised afflux is observed within the creek this has a negligible affect on surrounding properties. Due to the possibility of higher risk due to any impacts, a floor level survey of critical buildings along the Frontage of Free Settlers Drive was undertaken to ensure localised impacts do not change the risk profile for any adjoining properties. The survey demonstrates that all existing buildings are well above all PMF modelled events and scenarios. Refer to Section 8.3, FR-07 and Section 8.4 for further information.

While the lower ground habitable areas of the buildings are impacted by the PMF, the flood modelling and architectural designs ensure that all habitable dwellings are at or above the 1% AEP level + 500mm and are resilient to both blockage and climate change sensitivity tests.

8 Risk Assessment

This section presents a Flood Risk Management (FRM) response matrix for the proposed development at 40 Memorial Avenue, Bella Vista to demonstrate compliance with the NSW Flood Risk Management Manual (2023) and associated Floodplain Risk Management Toolkit.

This section is intentionally risk-focused and distinct from evacuation and shelter-in-place planning, which are addressed separately in the Flood Emergency and Evacuation Management Plan (FEEMP). The intent here is to:

- Identify credible flood risks across the full range of flood events
- Classify risks in accordance with NSW flood risk principles (hazard, exposure, vulnerability);
- Demonstrate how risks are avoided, mitigated, or managed through land use planning, design controls, and operational measures;
- Provide a clear audit trail linking risks to adopted controls and residual risk outcomes.

This approach aligns with the Manual's requirement that flood-prone development demonstrate risk-based decision-making, not reliance on a single mitigation measure.

8.1 Flood Risk Management Framework

The NSW Flood Risk Management Manual defines flood risk as a function of:

- Flood Hazard (depth, velocity, rate of rise);
- Exposure (people, buildings, infrastructure);
- Vulnerability (susceptibility to harm, ability to respond).

Consistent with the Manual and Toolkit guidance, this assessment applies the following risk hierarchy and is assessed across the range of modelled events (1% AEP to the PMF):

1. Avoidance – locating critical elements outside high-risk flood environments where practicable;
2. Mitigation – reducing hazard or exposure through design and layout;
3. Management – operational, procedural, and resilience measures where residual risk remains.

8.2 Risk Classification Methodology

The tables below shows how risks have been classified and as shown in the table in section 8.3.

Table 6 - Risk Likelihood Classifications

Likelihood	Description (from ARR derived frequency descriptors)
Extreme(ly Rare)	PMF or extreme events beyond planning level
Very Rare	0.2–0.5% AEP events
Rare	1% AEP + CC
Rare - Likely	1% AEP or more frequent

Table 7 - Risk Consequence Classifications

Consequence	Description
Minor / Low	Inconvenience, no structural damage
Moderate	Property/asset damage, temporary loss of access
Major	Structural damage, unsafe conditions
Severe	Risk to life, reliance on emergency services

8.3 Risk Management Response Matrix

Risk ID	Flood Scenario	Risk Description	Risk Likelihood	Inherent Risk	Risk Management Measures (Avoid / Mitigate / Manage)	Residual Risk	Commentary
FR-01	1% AEP	Inundation of habitable floors	Rare	Moderate	Avoidance: All habitable floor levels set ≥ 1% AEP + 500 mm freeboard	Low	Compliant with Council DCP and NSW Manual planning level principles
FR-02	1% AEP + CC	Reduced freeboard due to climate change	Rare	Moderate	Avoidance: All habitable floor levels are above the 1%AEP + CC	Low	ARR2024 Climate Change Pathways Considered and associated modelling undertaken
FR-03	0.5–0.2% AEP	Increased flood depths adjacent to buildings and non-habitable external landscape areas. Potential risk to habitable floor levels	Very Rare	Moderate to Major	Mitigation: Flood compatible landscaping, controlled flow paths, structural adequacy of development. Avoidance: All habitable floor levels are (already) above the 0.2% AEP water surface levels and risk to habitable levels is removed.	Low–Moderate	Residual risk to non-habitable / landscaped areas only with no loss of emergency access
FR-04	PMF	Inundation of lower ground floor of development	Extremely Rare	Major	Management: Building layout, flood compatible materials, provision of flood emergency evacuation management plan. Mitigation: Revised building design lifted the lower ground floor finished floor levels to reduce the flood hazard of over-floor inundation experienced in the PMF event (to limit hazard to a maximum H1 to H3 hazard banding).	Low-Moderate	Residual risk acknowledged and managed, consistent with NSW Manual. Residents of impacted dwellings that feature over floor inundation have the ability to locally evacuate to floor above and shelter-in-place within building. Hazard of over floor inundation has been lowered by lifting floor levels to lower the risk to life *if for any possible unforeseen reason* localised evacuation is not possible for residents of the lower ground floor.
FR-05	PMF	Unsafe external localised (short duration) flood hazards	Extremely Rare	Major to Severe	Management: A Flood Emergency Evacuation Management Plan (FEEMP) is provided. During such a rare event, residents are required to locally shelter in place per the requirements of the FEEMP.	Moderate	The external-to-building PMF derived flooding risks are rare and residual in nature, due to short duration flash flooding of the existing urban catchment.
FR-06	PMF	Structural damage to buildings	Extremely Rare	Moderate	Mitigation: Structural design certified for PMF impact requirements.	Low–Moderate	Consistent with shelter-in-place design philosophy
FR-07	0.5% AEP - PMF	Increased offsite flood levels	Very Rare - Extremely Rare	Moderate	Mitigation: Afflux - negligible outside drainage corridor or as a function of the proposed development (by design). Floor Level Survey (by registered surveyor) conducted to validate risk profile for any potentially impacted properties	Low	Demonstrated via afflux mapping and floor level survey validation of impacts. Refer to figure below under section 8.4 for floor level data for surrounding properties (by survey). All existing buildings between Memorial Avenue

							and Hodges Road are above the PMF for all modelled scenarios.
FR-08	0.2% AEP - PMF	Floodway obstruction or loss of storage	Very Rare - Extremely Rare	Moderate	Avoidance/Mitigation: Building placement and landscaping minimise flood function impacts. Main conveyance path is maintained for all events and design scenarios and is consistent with the broader Elizabeth Macarthur Creek Upgrate works. Impacts derived by the proposed development in the PMF are understood and do not adversly impact or increase flood risk on any adjacent properties.	Low	Flooding characteristics maintained.

8.4 Floor Level Survey

Figure 21 - Ground Floor Level Surveys of No. 2 Free Settlers Drive (By Registered Surveyor, Orion 11/02/2026)

To validate and understand any risks associated with the localised PMF impacts, a floor levels survey was undertaken for a selected number of units from the footpath reserve of Free Settlers Drive by registered surveyor. The figure 21 above shows these reduced levels by survey for reference.

These floor levels transcribed and are shown in the PMF extract figure below and demonstrates that all existing buildings within the No. 2 Free Settlers Drive frontage are above the PMF flood level.

The buildings with floor levels of RL. 60.47 and 60.39 are above the PMF flood level. The building at the corner of Hodges Road and Free Settlers Drive with floor level 60.03 is shown to have minor PMF affectation within this model in both Pre and Post Development Scenarios with no change in risk or impact due to the proposed development.

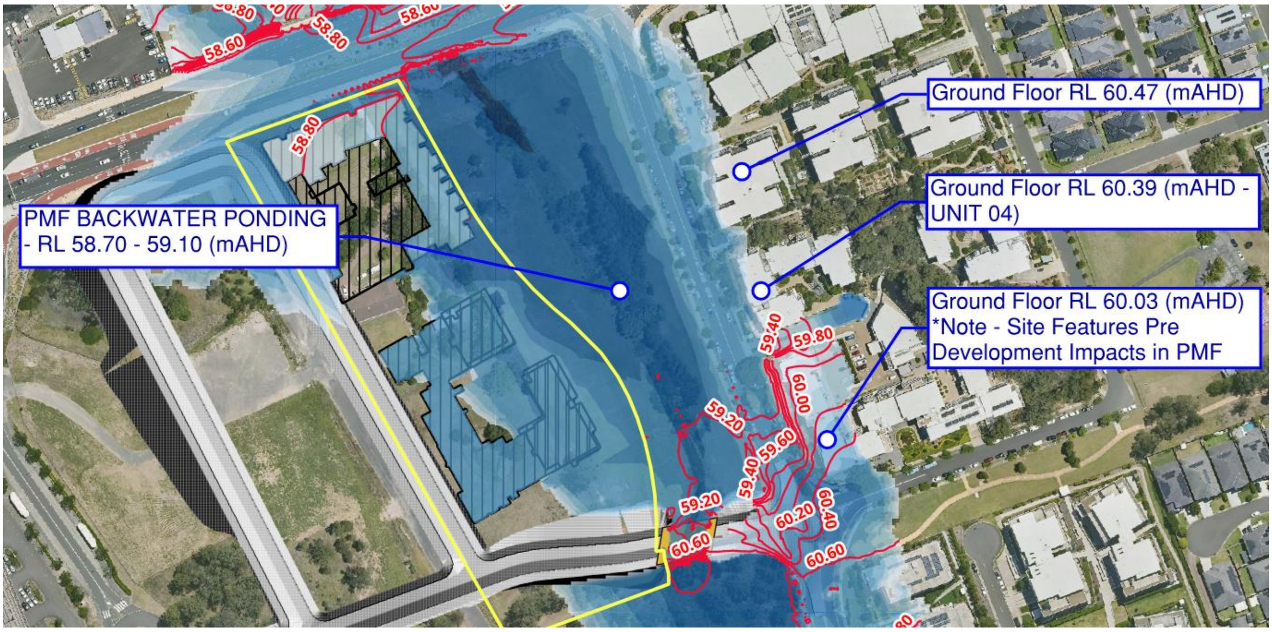

Figure 22 - PMF Interim Flood Depth and Floor Level Comparison for 2 Settlers Drive

9 Conclusion and Recommendations

A detailed hydraulic model has been developed to assess local flood characteristics for the site in the 1% AEP, 1% AEP + CC, 0.5% AEP, 0.2% AEP and PMF events under pre-development, interim development and final development (80% EMC design).

Architectural plans prepared by Turner indicate that the proposed development is a high density residential development composed of four separate buildings.

The site experiences minimal flooding for the 1% AEP event with finished floor levels (FFLs) maintained well above the freeboard required by the Hills Shire Council Development Control Plan. Impacts for this SSDA have been assessed independently of the approved Hodges Road Bridge and Roundabout which is DA approved.

Most of the site is impacted for the PMF event with a backwater effect observed upstream of Memorial Avenue. Flood levels vary from 58.90m to 59.10m in the vicinity of the site for both the pre-development and interim post-development condition. A similar PMF level is observed in the ultimate development scenario.

The final development scenario has been modelled with the 80% Sydney water EMC trunk drainage design. The impacts of the trunk drainage shows improved water levels at the upstream of the trunk drainage alignment, however the narrower floodplain increases the water level at the downstream of the alignment. There are maximum of 350mm increases in water level for the 1%AEP and PMF event along the segment between Hodges Rd and Memorial Avenue. Floor level surveys of existing buildings demonstrate that this localised impact in the PMF event due to the proposed buildings does cause any adverse impacts, with existing ground floor levels being above the adjacent PMF water level.

The baseline, interim and final development scenarios have been modelled to assess the impact of flooding on the proposed development site. In all scenarios, the results indicate that the site is adequately protected in the 1%AEP flood event and complies with Council development controls and flood planning requirements.

Revision 06 of this report has been prepared in order to demonstrate that the proposed development complied with SEARs.

The additional consideration of climate change in line with ARR 2024 Chapter 4 updates has had a negligible impact on flood levels in the creek adjacent to the proposed development.

The consideration of 10% blockage on local culverts/bridges has a negligible impact on flood levels adjacent to the site.

Revision 07 of this report has been prepared in order to respond to concerns raised by CPHR (Ref DOC25/900849) & SES (Ref ID 3429) regarding SSD-80102979.

The additional flood modelling has been undertaken for 0.5% AEP (200 years) and 0.2% AEP (500 years) flood events which shows that the proposed development in the Interim

Development and Ultimate Development scenarios has a negligible impact on flood levels in the creek adjacent to the proposed development.

10 References

Elizabeth Macarthur Creek Trunk Drainage Works - Flood Impact Assessment (Royal HaskoningDHV, 2024)

Australian Rainfall and Runoff (ARR) Data 2019 with ARR 2016 rainfall datasets sourced from Bureau of Methodology (BoM)

ARR 2019 – A Guide to Flood Estimation

The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method (Bureau of Meteorology, Melbourne, Australia, June 2003)

NSW Department of Planning and Environment (2023), Flood Risk Management Manual and associated 'toolkit' guidelines

The Hills Shire Council Development Control Plan (DCP, 2012)

The Hills Shire Council Local Environment Plan (LEP, 2019)

The Hills Shire Council Design Guidelines for Subdivision/Developments (December 2023)

Revision 06: NSW Planning Secretary's Environmental Assessment Requirements (SEARs) for Housing, Version 1 (NSW Department of Planning, Housing and Infrastructure, 2024).