Lot 5 Sealark Road, Callala Bay

Flood Study Report

Project No. 1861
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Prepared for: The Hare Bay Consortia

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1.0 INTRODUCTION

Footprint (NSW) Pt. Ltd. (*Footprint*) has been engaged by 'The Hare Bay Consortia' as owners of Lot 5 Sealark Road, Callala Bay to undertake a flood study to be lodged in support of a planning proposal to re-zone part of the land to enable residential development.

The purpose of the flood study is to address Ministerial Direction 4.3 (flood prone land) issued under Section 9.1 of the EP&A Act and to define flood levels and velocities, flood hazard and hydraulic categories over the land in accordance with the NSW Floodplain Development Manual (2005).

1.1. Scope of Works

The scope of works for the project includes:

1. Review available background information including LiDAR data, topographic maps, existing planning proposal, existing site survey.
2. Undertake a detailed inspection of the site, adjacent watercourses and associated catchments.
3. Undertake hydrologic modelling to determine critical storm durations for the 1% AEP and PMF events only.
4. Undertake two-dimensional hydraulic modelling (using HEC-RAS) to determine the depth and extent of flooding over the proposal area for each of the above rainfall events using a flood envelope approach to account for both riverine and coastal dominated flooding in accordance with NSW OEH guidelines.
5. Consider the impacts associated with climate change on flood behaviour including increased rainfall and sea level rise.
6. Undertake a comparison between ARR1987 and ARR2019 IFD data.
7. Undertake post-development hydraulic modelling to determine the impact of flooding on the proposed development or the impact of the proposed development on flood behaviour.
8. Preparation of a detailed flood study report defining any assumptions, outlining the modelling methodology and presenting the findings of the investigations.

2.0 SUBJECT SITE

2.1. Site Description

The subject site is described as Lot 5 DP 1225356, Sealark Road, Callala Bay and comprises an area of approximately 6.46 hectares.

The subject site adjoins Sealark Road on its' western boundary, the Jervis Bay National Park on its' northern boundary, Wowly Creek (Gully) on its' eastern boundary and existing residential development in Monarch Place to its southern boundary as shown in Figure 1.

Figure 1: Site Locality Plan (source: Six Maps)

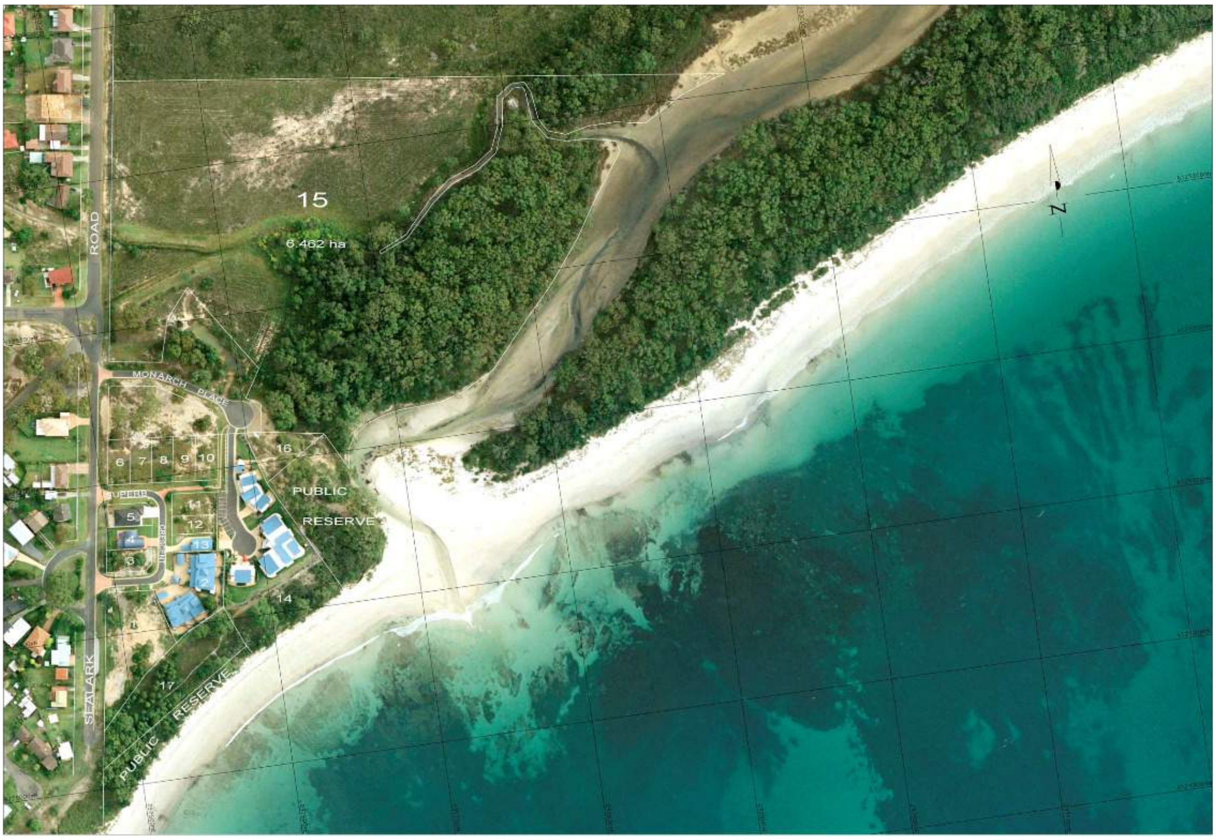


Figure 2: Site Locality Plan with Aerial

The site generally slopes in a north-westly to south-easterly direction towards Wowly Creek. Elevations over the site range from approximately RL6.0m AHD at the north-western corner to approximately RL2.0m AHD along the eastern boundary adjacent to Wowly Creek.

The site is traversed by an open drain which discharges from two stormwater outlets under Sealark Road. This open drain discharges to Wowly Creek near the north-eastern corner of the site.

A copy of the detailed site survey is included in Appendix A.

2.2. Development Proposal

The current proposal consists of rezoning the north-western portion of the land for residential development due to existing site constraints elsewhere on the site including the presence of an Endangered Ecological Community (EEC) and flooding.

A copy of the concept layout plan is included in Appendix B.

3.0 HYDROLOGICAL MODELLING

3.1. Purpose

Hydrological modelling was conducted to inform the HEC-RAS two-dimensional direct rainfall hydraulic model. The primary purposes of the hydrological model were to:

i. determine the critical storm duration for the subject site, and
ii. determine the median storm within the ensemble of modelled storms

such that the hydraulic modelling could be limited to only one storm for each storm event (i.e. 1% AEP, PMF)

3.2. Model Adoption

Hydrological modelling was conducted in DRAINS using a RAFTS storage routing model.

Storage routing models can model larger catchments using a lumped approach by assuming heterogeneity within the sub-catchment to account for the storage and retardence of flows that occurs within the sub-catchment. Such models account for slope and roughness and use a loss model to produce a hydrograph at the sub-catchment outlet.

The RAFTS hydrological model was chosen because it is widely used and accepted across Australia within the industry and has been shown to be insensitive to initial conditions.

3.3. Catchment Areas

The total catchment area contributing to Wowly Creek at the outlet to Jervis Bay is to be approximately 559 hectares and was determined using 1m Digital Elevation Models (DEM's) covering the catchment which were obtained through the Australian Foundation Spatial Data web portal.

The overall catchment was dissected into 7 sub-catchments to represent changes in catchment topography and land-use and ranged in size from approximately 6.6 hectares to 168 hectares as shown in Figure 3.

Parameters adopted for modelling of each sub-catchment are included in Table 1.

Figure 3: Catchment Plan

Table 1: Summary of Catchment Areas

Catchment	Area (ha)	Impervious Percentage	Ave. Slope Gradient (%)	Manning's 'n' [1]
1	125.5	0	3.1	0.100
2	158.1	0	2.7	0.100
3	167.8	0	2.7	0.100
4	67.8	0	3.0	0.100
5	23.5	5	3.6	0.100
6	9.73	40	2.3	0.025
7	6.59	40	2.0	0.025
TOTAL	559.02			

[1] Refer to Section 3.3.1

3.3.1. Manning's Roughness

The adopted Manning's n value specified in Table 1 are consistent with those noted in Tables 6.2.1 and 6.2.2 of Australian Rainfall and Runoff (ARR) 2019.

Table 6.2.1 of ARR2019 specifies a range of Manning's n values of 0.050 to 0.160 for heavily timbered floodplains, with a normal value of 0.10. The adopted value of 0.100 is considered representative of the typically heavily forested areas with the Jervis Bay National Park which covers most of the catchment.

Table 6.2.2 specifies a range of Manning's n values of 0.020 to 0.040 for estuaries and oceans and the adopted value of 0.025 is within this range and is considered representative of the typically sandy bed throughout the estuary.

Further, it is noted that the Currambene Creek and Moona Moona Creek Flood Study (2006) adopted values of 0.030 and 0.120 for the lower part of Currambene and Moona Moona Creeks and the values adopted for this study are consistent with the values the previous study in the adjacent catchment.

3.3.2. Model Configuration

The configuration of the DRAINS hydrological model is shown in Figure 4.

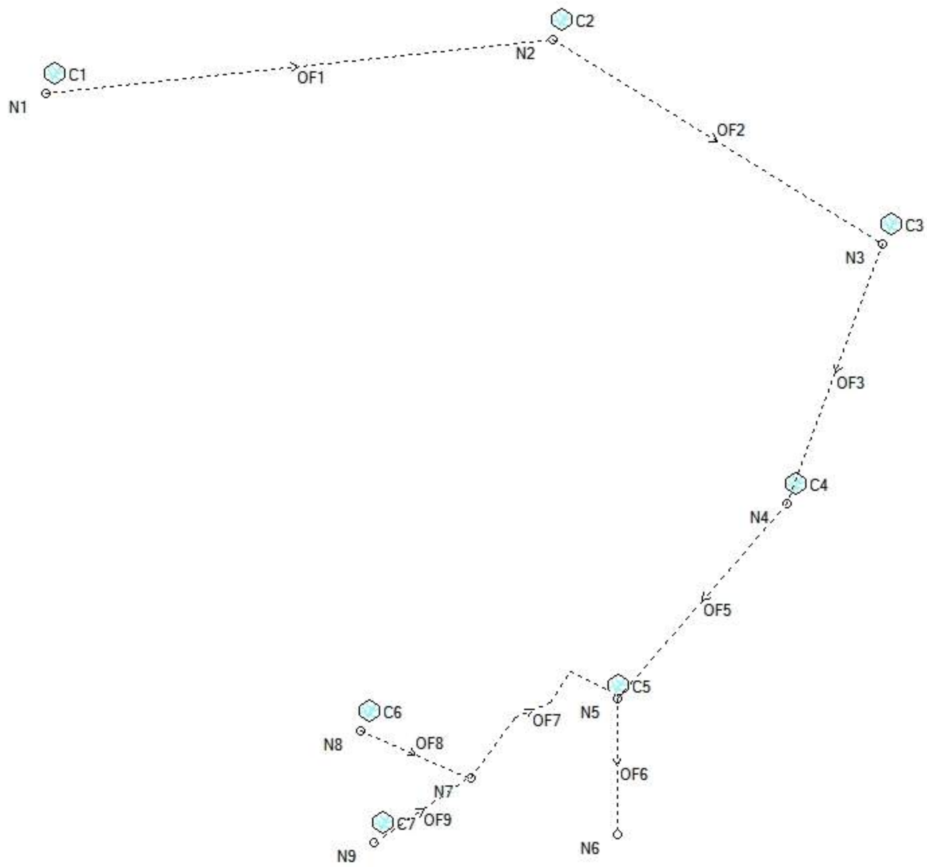


Figure 4: DRAINS Hydrological Model Configuration

3.4. Modelling Input Parameters

The parameters adopted for hydrological modelling are shown in Table 2.

Table 2: Hydrological Parameters Adopted

Parameter	Value Adopted	Justification/Source
Impervious Area Initial Loss (mm)	1	Typical value for urban areas. Only applicable to existing urban area as catchments within the National Park were modelled as 100% pervious.
Impervious Area Continuing Loss (mm/hr)	0	Typical value for urban areas.
Pervious Area Initial Loss (mm)	26	Recommended value from ARR 2019 data hub (refer Appendix C) for non-urban areas. Also adopted for urban area given extent of urban area in the catchment is very low (<3%).
Pervious Area Continuing Loss (mm/h)	1.6	40% of the from ARR 2019 data hub (refer Appendix C) as recommended for NSW.
BX	1	RAFTS Default
Sub-catchment Area (ha)	Varies	As per Figure 3 & Table *1*
Impervious Area (%)	0	Based on aerial photography
Sub-catchment Slope (%)	Varies	As per Table 1
Manning's n	Varies 0.025 (urban) to 0.100 (forest)	As per Table 1 and Section 3.3.1. 0.025 consistent with urban catchment. 0.10 consistent with heavily forested catchment areas.

3.5. Flow Routing

The routing of flows through the Wowly Creek catchment (OF1 to OF6) was undertaken by adopting a parabolic cross-sectional profile (200m wide x 10m deep) and applying this to each overflow route (link). For OF1 a Manning's n value of 0.1 was adopted representing flows through a heavily forested catchment, whilst for OF2 to OF6 a value of 0.025 was adopted representing flows within the sand-based estuary.

The routing of flows through the subject site from Catchments 6 and 7 was undertaken by adopting a typical cross section from the detailed site survey for each channel and adopting a Manning's n value of 0.06.

Flows were routed along each link using the DRAINS premium hydraulic model which applies the full S.t Venant equations of unsteady flow to overland flow routes. This allows water levels along these routes to be determined accurately, allowing for varied water surface flow profiles, including subcritical and supercritical flows. It also accounts for storage effects in overland flow routes.

3.6. Rainfall Data

3.6.1. Design Rainfall

IFD design rainfall depth data and temporal pattern was derived in accordance with Australian Rainfall and Runoff (2019) using the Bureau of Meteorology's Rainfall IFD on-line Data System.

The temporal patterns for the Southern Slopes (Vic/NSW) region was used as these cover the subject site (latitude -34.984, longitude 150.723).

It was found that no variation in rainfall intensity occurred over the catchment area and therefore single point rainfall intensities were adopted.

A copy of the rainfall depths for the range of storm durations used can be found in Appendix D.

Storm probabilities in ARR2019 are now classified in two ways: Very Frequent storms, quantified as 'Exceedances per Year' (EY), and both Frequent and Infrequent storms given as Annual Exceedance Probability (AEP). The 'very frequent' storms have only been used for the 1EY, 0.5EY and the 0.2EY as these are equivalent to the former classifications of 1 in 1 year, 1 in 2 year and 1 in 5 year storms respectively (ARR 2019 state that the 50% AEP and the 20% AEP do not correspond statistically to the 1 in 2 year and 1 in 5 year storms, but rather are equivalent to the 1 in 1.44 year and 1 in 4.48 year storms respectively).

3.6.2. Pre-Burst Rainfall

NSW transformation pre-burst rainfall depths derived from ARR 2019 data hub (refer Appendix C were adopted in the model.

In the absence of pre-burst rainfall depths for the 4.5 hour (270 minute) and 9 hour (540 minute) storm in the ARR Data these values were determined by linear interpolation.

Pre-burst rainfall depths adopted in the modelling for various events and durations are shown in Table E1 in Appendix E.

3.6.3. Probable Maximum Precipitation

The PMF is the response of the catchment to the probable maximum precipitation (PMP) and is the largest flood event that can reasonably be expected to occur at a location.

Estimates of PMP were made using the Generalised Short Duration Method (GSDM) presented in Bureau of Meteorology (2003) and are provided in Table 3. This method is appropriate for estimating extreme rainfall depths for catchments up to 1000km^2 in area and storm durations up to 6 hours and is therefore considered appropriate for the subject catchment.

Table 3: Estimate of PMP

Duration (Hours)	PMP Estimate (mm)
0.25	150
0.50	220
0.75	270
1.0	320
1.5	370
2.0	410
3.0	460
4.5	520*
6.0	570

* interpolated from 4 and 5 hour depths

Due to the inability of DRAINS (and HEC-RAS) to model spatially variable rainfall no adjustment to the point values above where made.

Notwithstanding, an assessment was undertaken to determine how much of the catchment would fall between the ellipses in Figure 6 of the GSDM and the results are provided in Table 4.

Given the relatively small size of the catchment (5.6km^2) the assessment indicates that only a very small reduction (in the order of 10%) in rainfall would apply over a little more than half of the catchment that lies between the A and B ellipses.

The hydrological results obtained through modelling point PMP values in lieu of spatially variable PMP values would therefore be slightly higher than actual flows and therefore conservative.

Table 4: Assessment of PMP Spatial Distribution

Ellipse	Approximate Area (km²)
A	2.4
A-B	3.2
B-C	0

3.7. Results

The DRAINS model was run in 'premium' mode for storm durations ranging from 10 minutes to 3 hours for the 1% AEP event and 15 minutes to 6 hours for the PMF event with the downstream boundary set to 0.6m (approximating neap tide level).

A summary of relevant peak flows at the outlet of Wowly Creek are shown in Table 5 for the critical storm duration and the critical storm either side of the critical duration.

Table 5: Peak Flows at outlet of Wowly Creek (critical values in bold)

Event (AEP)	Critical Duration (hours)	Storm No. in Ensemble	Peak Flow Rate (m^3/s)
5% AEP	4.5	Storm 6	29.6
	6.0	**Storm 6**	**30.3**
	9.0	Storm 7	29.0
1% AEP	3.0	Storm 7	42.1
	4.5	**Storm 8**	**46.3**
	6.0	Storm 7	40.2
PMF	1.5	N/A	238
	2	**N/A**	**254**
	3	N/A	238

4.0 HYDRAULIC MODELLING

Hydraulic modelling was conducted using an unsteady direct rainfall two-dimensional HEC-RAS model (Version 5.0.7) which covered the entire catchment draining to the proposal area, except for the existing residential area to the west of Sealark Road. For this area inflow hydrographs were applied to the edge of the two-dimensional domain in lieu of using direct rainfall to better represent the urban catchment rainfall-runoff characteristics.

4.1. Two-Dimensional Domain

A digital elevation model (DEM) of the catchment area was established using the following elevation data:

i. a series of 1m gridded digital elevation models sourced from www.elevation.fsdf.org.au
ii. a 5m gridded DEM of bathymetry for Jervis Bay, including the Wowly Creek estuary, obtained from the NSW Office of Environment and Heritage
iii. detailed site survey over the subject site.

Although the bathymetry data extended approximately 1.2km up Wowly Creek from its outlet into Jervis Bay, the data was only used to define bed levels within Jervis Bay below RL0.00m AHD as it was found that the 1m gridded data provided a more accurate three dimensional representation of the estuary than the coarser 5m bathymetry data. Further the 1m data was found to compare favourably to the 5m bathymetry data in terms of elevation to the bed of the estuary as shown in Figure 5, which is perhaps an indication that the estuary had very little water at the time the 1m gridded data was surveyed (April 2011).

The elevation data from each source was imported into HEC-RAS and used as the basis for development of a 10m x 10m terrain model over most of the catchment, whilst a 5m x 5m grid was defined over the subject site. The DEM grid was further refined where required by applying breaklines to enforce abrupt changes in geometry, such as along existing banks.

The extent of the two-dimensional domain used in HEC-RAS is shown in Figure 6.

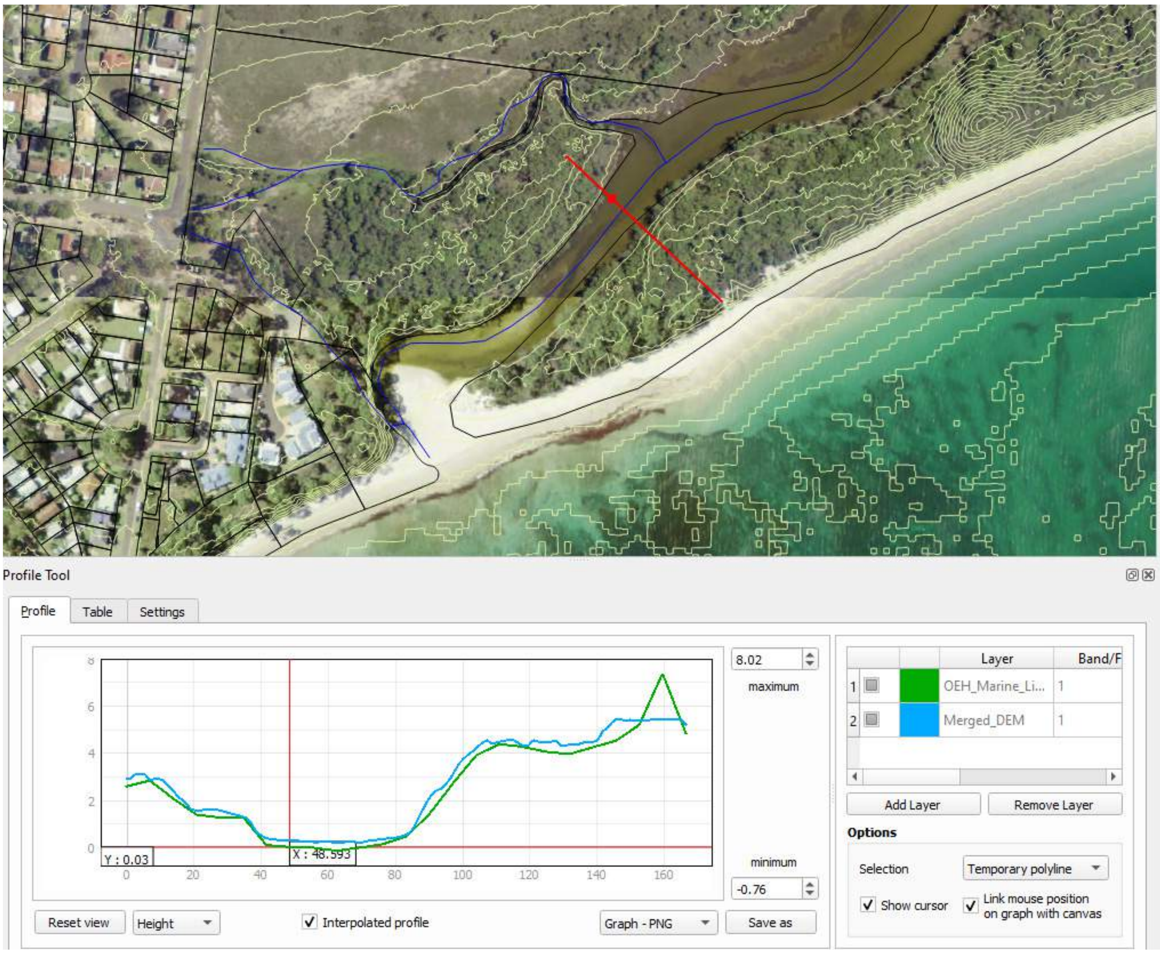


Figure 5: Comparison of 1m DEM (blue) versus 5m Bathymetry DEM (green)

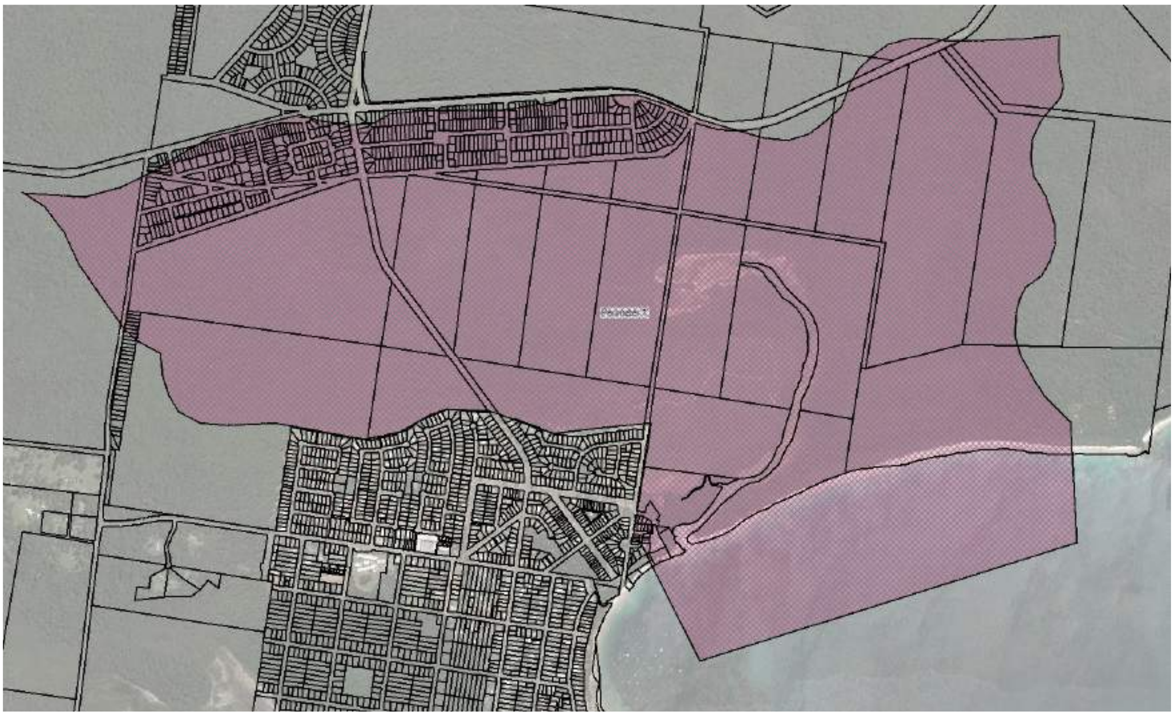


Figure 6: Extent of Two-Dimensional Domain

4.2. Manning's Roughness

The two-dimensional domain was assigned a default Manning's n value of 0.1 which is considered representative of the heavily forested areas within the Jervis Bay National Park. The Manning's n value was decreased to 0.025 within the estuary and Jervis Bay to account for the typically sandy bed, and decreased to 0.025 within the grassed area of the subject site and the existing residential area off Monarch Place. Within the existing drainage channel through the site the Manning's value was reduced to 0.06 and 0.04 on the right overbank area.

Manning's n override regions are shown in Figure 7.

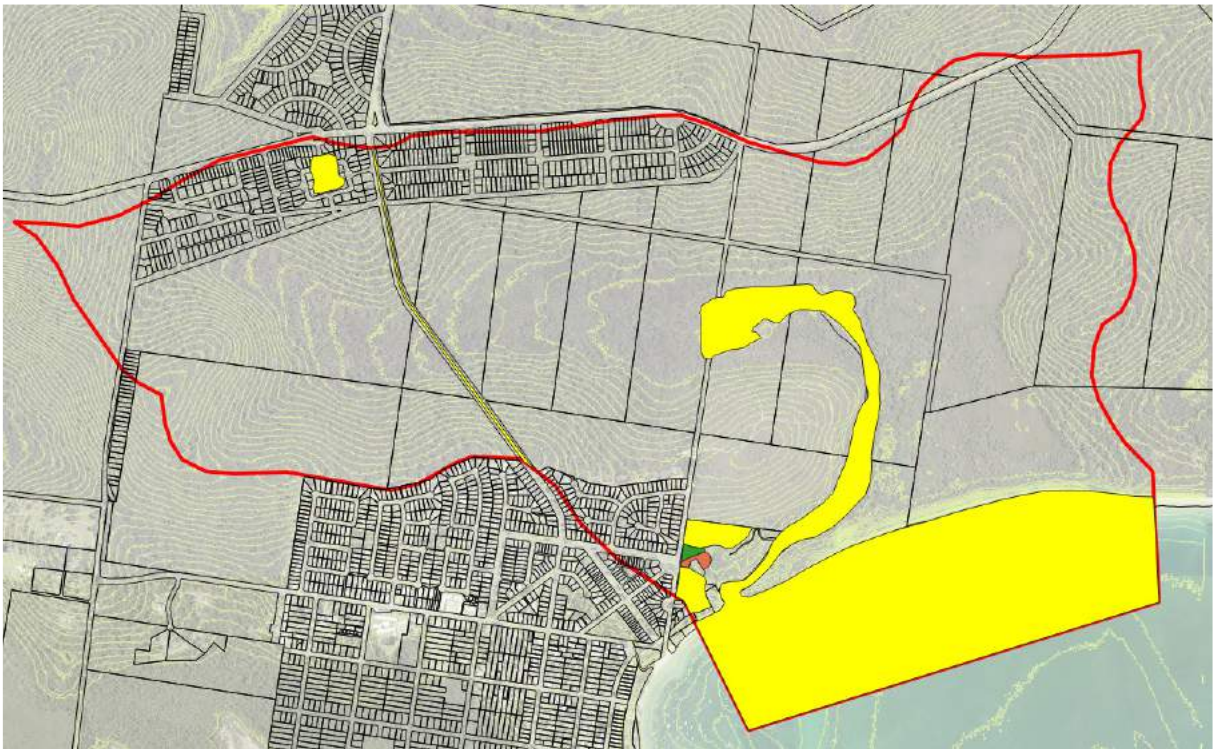


Figure 7: Manning's n Override Regions (Yellow 0.025, Orange 0.04, Green 0.06)

4.3. Boundary Conditions

4.3.1. Direct Rainfall

The direct rainfall boundary condition applies precipitation directly to the surface of the grid to perform two-dimensional hydraulic calculations.

The current limitation of HEC-RAS means that precipitation can only be used to apply rainfall excess (rainfall minus losses due to interception/infiltration) directly to the two-dimensional grid.

Rainfall excess hyetographs for the median storm in the ensemble for the critical duration storm events shown in Table 5 were generated by subtracting initial losses plus pre-burst rainfall (refer to Table 2) from the design rainfall data starting from the beginning of the data set. An example of this for the 1% AEP, 4.5 hour storm event is shown in Figure 8.

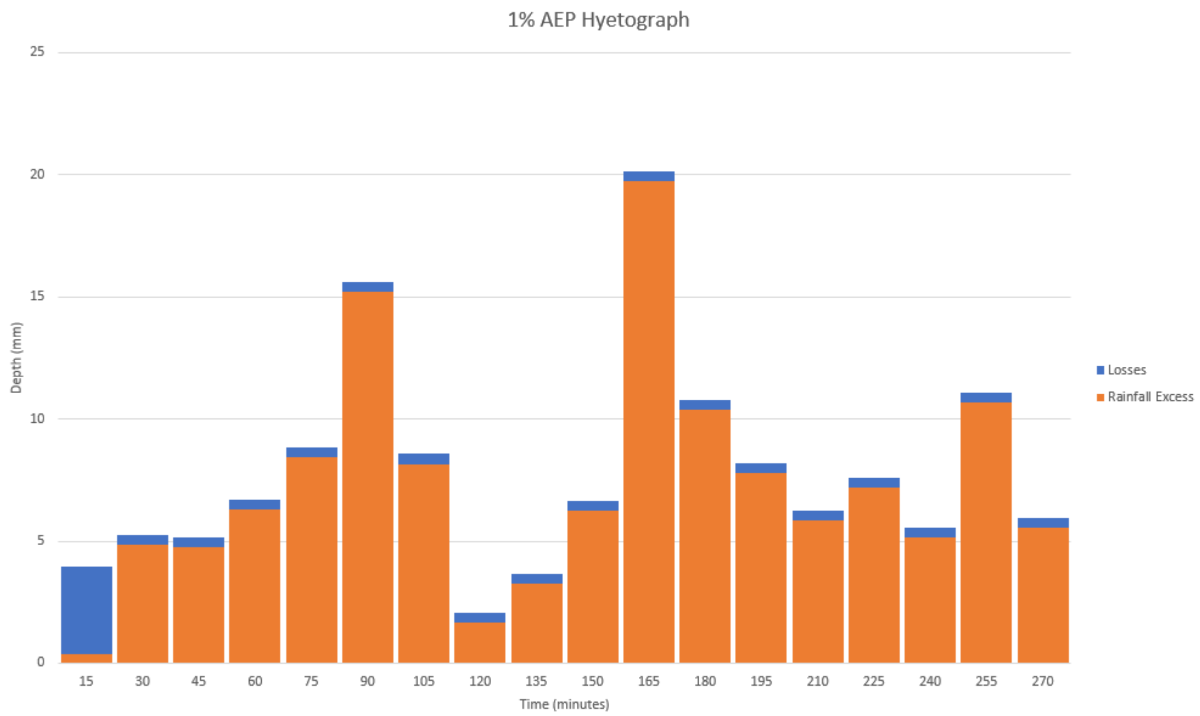


Figure 8: 1% AEP Rainfall Excess Hyetograph

4.3.2. Upstream Boundary Conditions

Flow hydrographs were used to define the upstream boundary condition for both Catchments 6 and 7 to represent flows emanating from the existing residential development west of Sealark Road. The hydrographs adopted for the modelling were those of the median storm in the ensemble for the critical duration of each catchment, rather than those of the critical duration of the entire catchment.

4.3.3. Downstream Boundary Conditions

A stage hydrograph boundary was adopted as the downstream boundary condition for each storm event to represent downstream ocean levels within Jervis Bay. Stage hydrographs were extracted from the event time series shown in the NSW Office of Environment and Heritage, Floodplain Risk Management Guide: Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways. The timing of each time series was adjusted such that peak ocean levels were coincidental with relevant peak flows from the catchment (refer to Table 5) as shown in Figure 9.

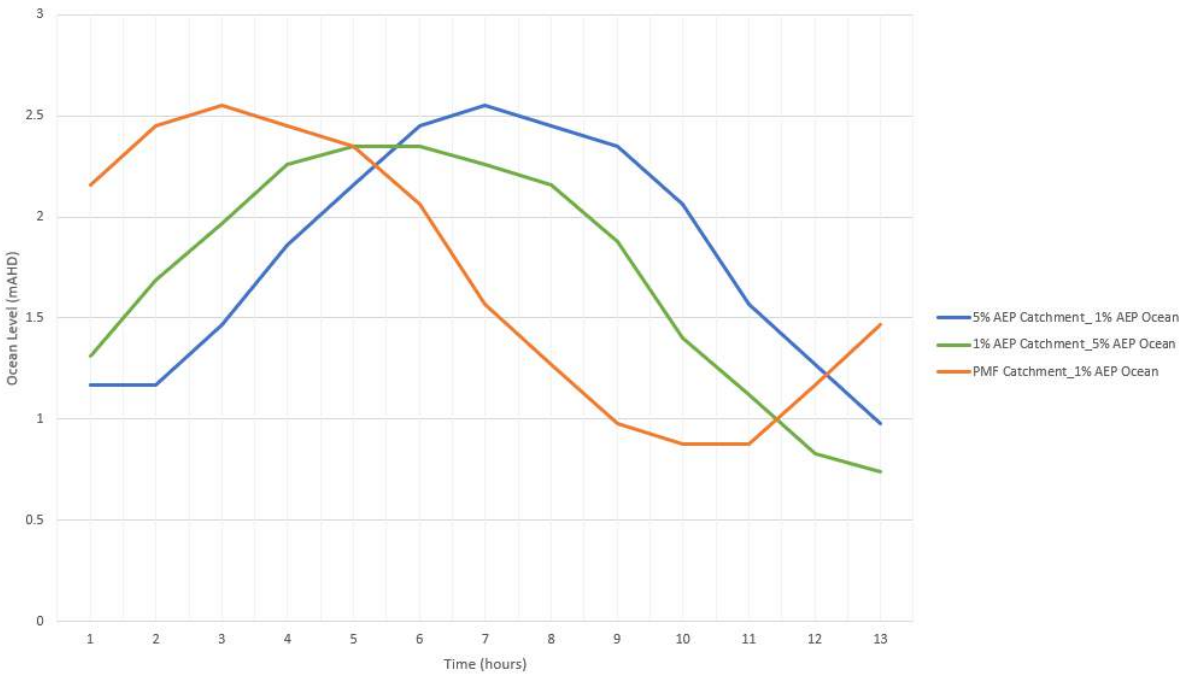


Figure 9: Downstream Ocean Boundary Time Series

A summary of design peak ocean levels used in the model is shown in Table 6.

Table 6: Summary of Design Peak Ocean Levels

Design Ocean Event	NSW OEH Guideline Figure	Peak Ocean Level (m AHD)
1% AEP	Figure A.3	2.55
5% AEP	Figure A.4	2.35

4.4. Hydraulic Model Verification

4.4.1. Comparison between models

Validation of the HEC-RAS hydraulic model was undertaken by comparing hydrographs and volume accumulation for the 5% AEP and 1% AEP events at the Wowly Creek entrance between those generated in DRAINS and those generated in HEC-RAS. For each event the downstream boundary was set at a fixed elevation of 0.6m which approximates a neap tide elevation.

The results of the validation are shown in Table 7 and Figure 10.

Table 7: Results of Hydraulic Model Validation

Event	DRAINS		HEC-RAS	
	Peak Flow (m^3/s)	Volume (m^3)	Peak Flow (m^3/s)	Volume (m^3)
5% AEP	30.3	481,076	24.7	448,229
1% AEP	46.3	679,520	37.2	620,413

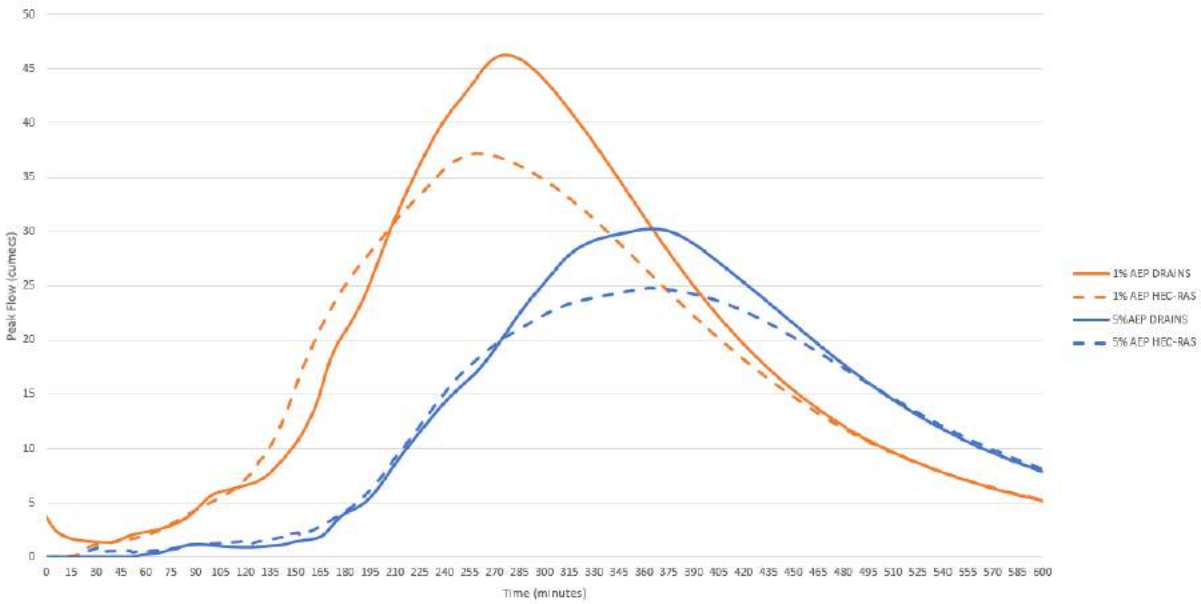


Figure 10: Comparison of DRAINS and HEC-RAS Hydrographs

The results of the validation show:

i. that peak flows generated in DRAINS are in the order of 19% higher than those generated in HEC-RAS. This is expected as the DRAINS model used simplistic link routing (refer to Section 3.5) and did not represent the significant wetland storage area to the east of Wowly Creek which would contribute towards the reduction in peak flows observed in the HEC-RAS model.

ii. volume accumulation in DRAINS is in the order of 8% lower than volume accumulation in HEC-RAS over the same storm duration. Once again, the reduction in volumes can be explained by the simplistic routing applied in DRAINS and the presence of the wetland storage area in HEC-RAS.

iii. the overall shape of the hydrographs the timing of peak flows between the two models are very similar.

4.4.2. Comparison to critical duration

Due to the differences between peak runoff rates observed between the DRAINS and HEC-RAS models the median storm event from the ensemble for the duration either side of the critical duration (as shown in Table 5) was modelled in HEC-RAS in order to ensure that the correct critical duration had been adopted for modelling purposes.

The results of this comparison are shown in Figure 10 for the 5% AEP, Figure 11 for the 1% AEP and Figure 12 for the PMF event.

The results show that the critical storm duration storm adopted generates the maximum peak flow across all events, except for the 5% AEP event for which all storms produce peak flows of very similar magnitude (i.e. all within 0.6m^3/s).

This analysis validates that the critical durations for each of the events adopted in Table 5 produce the highest peak flows and are therefore acceptable for adoption in design event modelling.

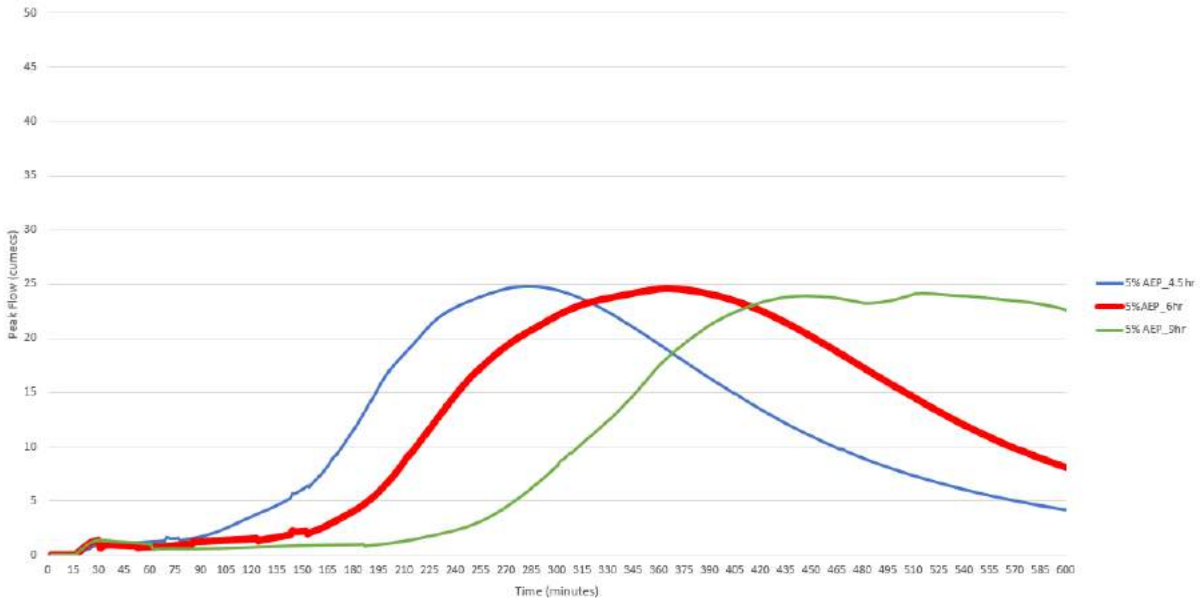


Figure 11: Comparison of Hydrographs for 5% AEP storms (critical storm in red)

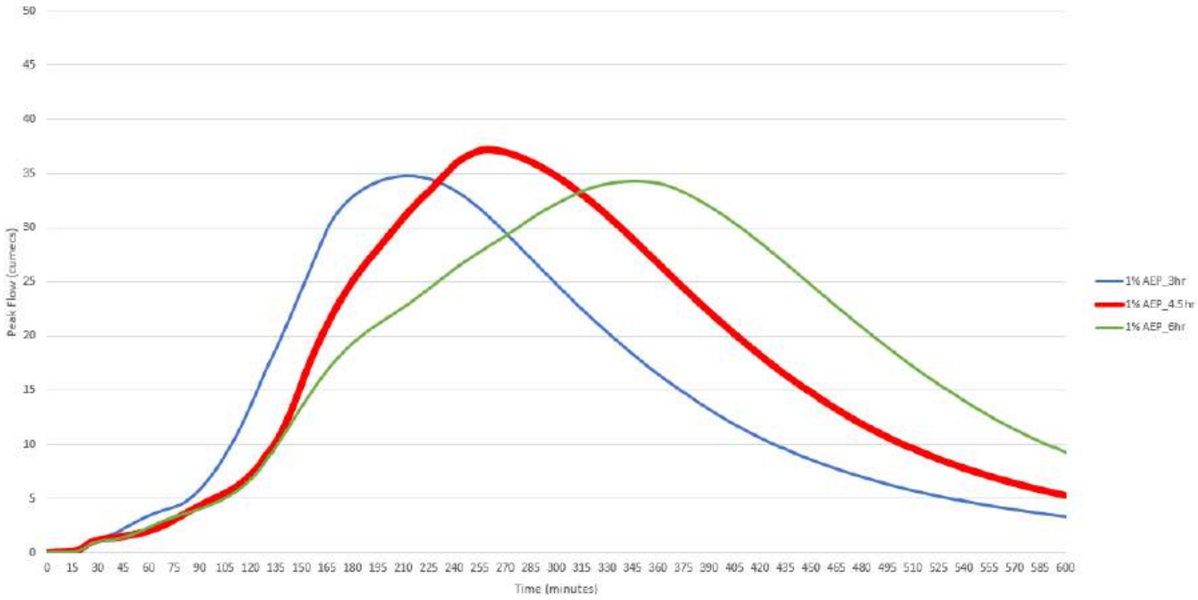


Figure 12: Comparison of Hydrographs for 1% AEP storms (critical storm in red)

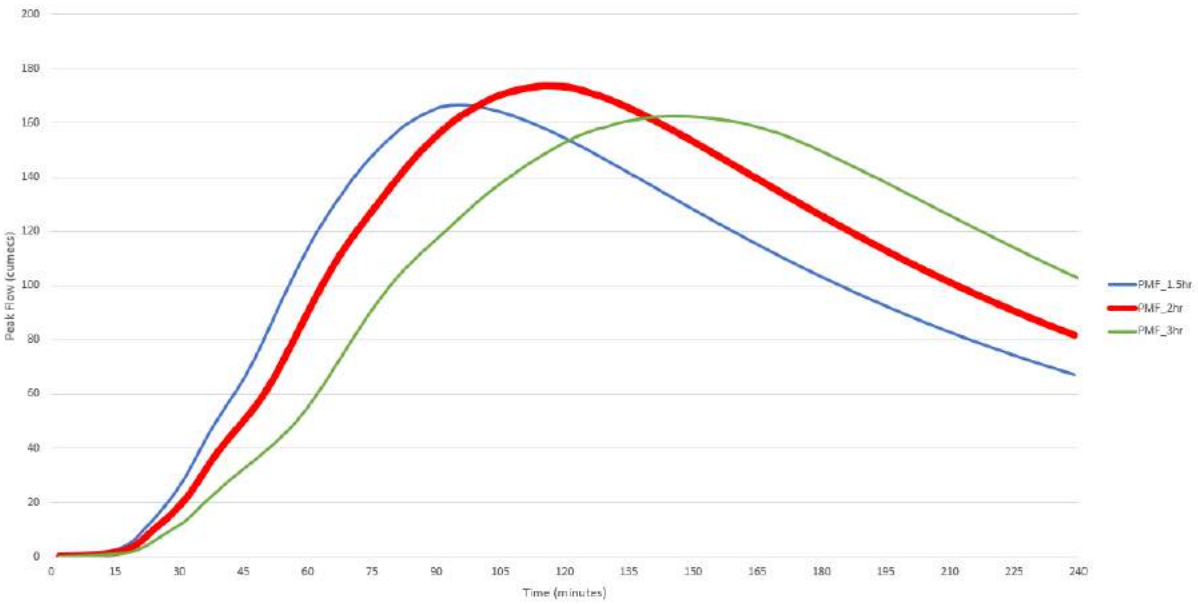


Figure 13: Comparison of Hydrographs for PMF storms (critical storm in red)

4.4.3. Comparison to Regional Flood Frequency Estimation Model

A comparison of peak flows for the 1% and 5% AEP events from both DRAINS and HEC-RAS were compared to the peak flows obtained through the Regional Flood Frequency Estimation (RFFE) Model and the results are shown in Table 8 and Figure 14.

Table 8: Comparison to RFFE Model

AEP	Peak Flow Rate (cumecs)				
	DRAINS	HEC-RAS	Regional Flood Frequency Estimation Model		
			Discharge	Lower (5%)	Upper (95%)
1%	46.3	37.2	122	44.5	33.9
2%	-	-	93.5	34.9	255
5%	30.3	24.7	63.1	24.1	168
10%	-	-	44.7	17.2	118

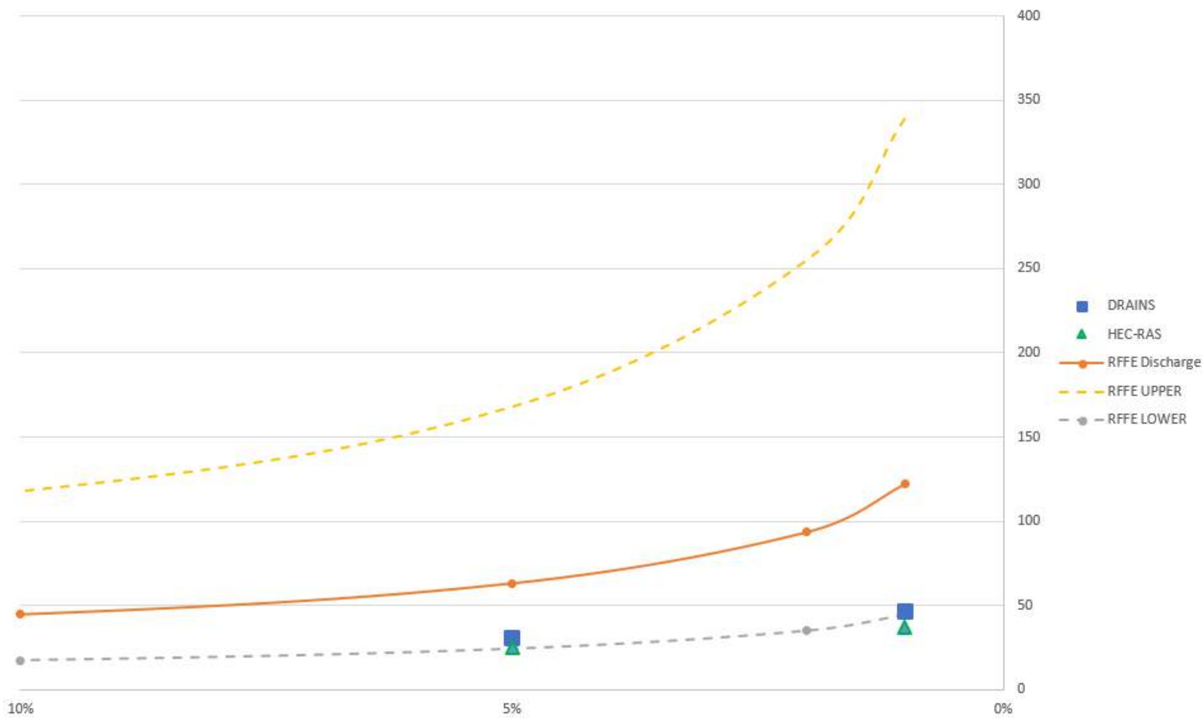


Figure 14: Comparison to RFFE Model

The comparison shows that the modelled flows lie close to the lower confidence limit (5%).

This is not unexpected as most of the subject catchment comprises National Park and is located adjacent to the coast, whereas most of the catchments used in the derivation of results are located further away from the coast and/or in less densely vegetated areas.

The RFFE method results are included in Appendix F and show that the subject catchment is typically an order of magnitude less than most of the catchments used in the derivation of the results (i.e. the majority are in excess of 100km^2). The subject site catchment also has a shape factor of 0.42 whilst the majority of the comparison catchments have shape factors between 0.5 and 1. In this regard the RFFE results includes a statement that the catchment has unusual shape and the results have a lower accuracy and may therefore may not be directly applicable in practice.

4.5. Design Event Modelling

Design floods events are hypothetical floods used for planning and floodplain management purposes. They are based on having a probability of occurrence specified as either:

- Annual Exceedance Probability (AEP) expressed as a percentage; or
- Average Recurrence Interval (ARI) expressed in years.

This report uses the AEP terminology. Table 9 provides the approximate equivalent for ARI and AEP events.

Table 9: Design Flood Terminology

ARI	AEP
100 years	1%
20 years	5%
10 years	10%
5 years	20%

Design flood conditions are derived from the application of design rainfall parameters (refer to Section 4.3.1) and design downstream ocean boundary levels (refer to Section 4.3.3)

Flooding in tidal waterways may occur due to a combination of ocean and catchment flooding derived from the same storm cell and therefore the risk of flooding from both sources may vary significantly depending on the location, distance from the ocean and the level of the ocean.

The NSW Governments Flood Risk Management Guide: Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways (DECCW, 2015) recommends that flood planning areas in tidal waterways consider the interaction of catchment and coastal flooding from the selection of peak flood levels from an envelope of scenarios such as:

- 1% AEP ocean flooding with 5% AEP catchment flooding with coincident peaks

- 5% AEP ocean flooding with 1% AEP catchment flooding with coincident peaks

On the above basis design event modelling was undertaken for the suite of events shown in Table 10.

Table 10: Design Model Runs

Design AEP for Peak Flood Levels	Catchment Flood Scenario	Ocean Water Boundary Scenario
Design Model Runs		
1% AEP Envelope	5% AEP	1%AEP
	1% AEP	5% AEP
PMF Catchment	PMF	1% AEP

4.6. Impact of Climate Change

The impact of climate change on flooding was assessed for both an increase in sea level and an increase in rainfall intensity in accordance with the sensitivity model runs shown in Table 11, with an explanation of the factors adopted provided in Section 4.6.1 and Section 4.6.2 respectively.

Table 11: Summary of Climate Change Design Model Runs

Design AEP for Peak Flood Levels	Catchment Flood Scenario	Ocean Water Boundary Scenario
Climate Change Scenarios		
1% CC Ocean Envelope	5% AEP	1% AEP + CC
	1% AEP	5% AEP + CC
1% CC Catchment Envelope – RCP4.5	5% AEP + RCP4.5	1% AEP
	1% AEP + RCP4.5	5% AEP
1% CC Catchment Envelope – RCP8.5	5% AEP + RCP8.5	1% AEP
	1% AEP + RCP8.5	5% AEP
PMF CC	PMF	1% AEP + CC
1% Combined Catchment (RCP8.5) & 1% Ocean Envelope	1% AEP + RCP8.5	5% AEP + CC
	5% AEP + RCP8.5	1% AEP + CC

4.6.1. Sea Level Rise

Shoalhaven City Council adopted the following sea level rise projections in February 2015.

Table 12: Summary of SCC Sea Level Rise Projections

Planning Horizon	Projected Sea Level Rise (mm)
2030	100mm
2050	230mm
2100	360mm

As the proposed development consists of the subdivision of land which has a design life in excess of 100 years the 2100 planning horizon was adopted with a sea level rise projection of 360mm.

For modelling purposes, the downstream boundary levels described in Section 4.3.3 were increased by 360mm, to reflect the rise in sea level.

4.6.2. Increased Rainfall Intensity

ARR2019 currently provides advice on changes in projected rainfall intensity (or equivalent depth) due to climate change. Note, that due to little available information, no adjustment due to climate change is considered for projected changes in rainfall frequency, duration and temporal patterns, antecedent wetness and baseflow (Flood Plain Risk Management Guide, NSW Office of Environment and Heritage, 2019).

ARR2019 recommends the use of the Representative Concentration Pathway (RCP) 4.5 and RCP8.5 values in assessing climate change effect on flooding. Interim climate change factors can be found on the ARR Data Hub, as provided in Appendix C, and are represented as a percentage increase in design rainfall depths that should be applied for a given future year (up to 2090). These values correspond to the percentage increase that considers a 5% increase in rainfall intensity for every 1˚C of projected warming in the subject region.

As the proposed development consists of the subdivision of land which has a design life in excess of 100 years the 2090 planning horizon was adopted.

Table 13: Summary of Adopted Increases in Rainfall Intensity

Planning Horizon	Increase in Rainfall Intensity RCP4.5	Increase in Rainfall Intensity RCP8.5
2090	7.6%	16.3%

To reflect the increase in rainfall intensity the HEC-RAS model was adjusted as follows:

i. Direct Rainfall Boundary: Rainfall depths for each critical storm event were increased by the percentages in Table 13 and the resultant rainfall excess applied as the direct rainfall boundary.
ii. Upstream Boundary Condition: The increase in rainfall intensities were applied to the DRAINS hydrological model and the resultant hydrographs for Catchments 6 and 7 were applied to the model.

4.7. Pre-Development Results

The HEC-RAS model was run in unsteady mode with variable timestep controlled by Courant condition for a typical duration of 10 hours for the 1% AEP event and 6 hours for the PMF event. The results are provided in Appendix G and include the mapping shown in Table 14. For those figures demonstrating the change in flood level the comparison flood surface relates to the flood surface in the absence of any climate change impacts (i.e. those shown on Figures 1.1 and 2.1).

The results include the mapping of flood hazard vulnerability in accordance with Book 6, Chapter 7 of Australian Rainfall and Runoff (2019).

Table 14: Schedule of Pre-Development Results Mapping

Figure	Description
Figure 1.1	Envelope of Maximum Flood Levels and Depths – 1% AEP
Figure 1.2	Envelope of Maximum Flood Velocities – 1% AEP
Figure 1.3	Envelope of Maximum Flood Hazard – 1% AEP
Figure 1.4	Source of Maximum Flood Envelope Level – 1% AEP
Figure 2.1	Maximum Flood Levels and Depths – PMF
Figure 2.2	Maximum Flood Velocities – PMF
Figure 2.3	Maximum Flood Hazard – PMF
Figure 3.1	Envelope of Maximum Flood Levels and Depths – 1% AEP + Sea Level Rise (0.36m)
Figure 3.2	Change in Maximum Flood Level – 1% AEP + Sea Level Rise (0.36m)
Figure 4.1	Maximum Flood Levels and Depths – PMF + Sea Level Rise (0.36m)
Figure 4.2	Change in Maximum Flood Level – PMF + Sea Level Rise (0.36m)
Figure 5.1	Envelope of Maximum Flood Levels and Depths – 1% AEP+ RCP4.5 Climate Change
Figure 5.2	Change in Maximum Flood Level – 1% AEP + RCP4.5 Climate Change
Figure 6.1	Envelope of Maximum Flood Levels and Depths – 1% AEP+ RCP8.5 Climate Change
Figure 6.2	Change in Maximum Flood Level – 1% AEP + RCP8.5 Climate Change
Figure 7.1	Envelope of Maximum Flood Levels and Depths – 1% AEP+ RCP8.5 Rainfall Increase + Sea Level Rise (0.36m)

Figure 7.2	Envelope of Maximum Flood Velocities – 1% AEP+ RCP8.5 Rainfall Increase + Sea Level Rise (0.36m)
Figure 7.3	Envelope of Maximum Flood Hazard – 1% AEP+ RCP8.5 Rainfall Increase + Sea Level Rise (0.36m)
Figure 7.4	Change in Maximum Flood Level – 1% AEP+ RCP8.5 Rainfall Increase + Sea Level Rise (0.36m)

4.8. Pre-Development Results Discussion

The results show that:

i. flooding in the lower reaches of Wowly Creek is dominated by ocean derived flooding rather than catchment derived flooding. This is particularly evident in Figure 1.4 which shows that ocean derived flood dominates over an area extending approximately 2.3km upstream for the inlet.
ii. flooding within the investigation area on the subject site are typically dominated by catchment derived runoff from the adjacent residential development.
iii. flood hazard within the investigation area of the subject site is typically H1 for the 1% AEP and H1 to H3 for the PMF event, except for flows within the existing drainage channel which are classified at up to H5 in both events.
iv. a projected increase in sea level of 360mm results in similar increases in flood levels over a large portion of the estuary for the 1% AEP event and increases of between 200 and 300mm in the PMF event although these increases do typically not project far into the investigation area on the subject site due to the change in topography.
v. The increase in rainfall intensity has very little impact on flood levels (less than 10mm) within the estuary due to the significant storage volume within the estuary.

4.9. Comparison to ARR1987 IFD Data

A comparison of 1987 and 2019 IFD data for the 5% AEP, 6 hour storm and 1% AEP, 4.5 hours storm (see Table 15) shows the 1987 IFD data to be 19% and 26% higher than the 2019 data.

Table 15: Comparison of 1987 and 2019 IFD Data

Event	Rainfall Intensity (mm/hr)		% Difference
	2019	1987	
5% AEP, 6hr	20.3	24.2	+19%
1% AEP, 4.5hr	31.6	39.9	+26%

The hydraulic modelling conducted for the assessment of the impact of an increase in rainfall intensity showed that, due to the large storage area of the estuary in comparison to the catchment, that the flood level within the estuary is insensitive to increases in rainfall, with an increase in rainfall of 16% resulting in an increase in flood level of less than 10mm.

Given this insensitivity the increase in flood levels associated with ARR1987 IFD data was not modelled and is likely to be in the order to 10-15mm.

4.10. Post Development Modelling

The impact of flooding on the proposed development and the impact of the proposed development on flooding was assessed by incorporating indicative road and lot filling platforms and adjusting the Manning's n value over the proposed development area (refer to Figure 15).

Preliminary civil design plans are shown in Drawings 1861-C01-C07 in Appendix H and incorporate the following elements:

- Perimeter road linking Sealark Road to Monarch Place raised to typically be above the 1% AEP flood level.
- Culvert crossing over the existing drainage channel comprising 4 No. 2100 x 600 reinforced concrete box culverts
- Widening of the existing drainage channels to achieve nominal base dimensions of 5m each and 10m when combined
- Filling of proposed lots to typically be above the 1% AEP flood level plus 500mm freeboard (i.e. above the flood planning level)

Figure 15: Post Development Manning's n Override Regions (Light Blue 0.015, Yellow 0.025, Orange 0.04, Green 0.06)

4.11. Post Development Results

The HEC-RAS model was again run in unsteady mode with variable timestep controlled by Courant condition for a typical duration of 10 hours for the 1% AEP event and 6 hours for the PMF event. The results are provided in Appendix I and include the mapping shown in Table 16. For those figures demonstrating the change in flood level the comparison flood surface relates to the pre-development flood surface for the corresponding design event model run (i.e. for the 1% AEP the RCP8.5 rainfall increase and 360mm sea level rise as shown in Figure 7.1 and for the PMF inclusive of 360mm sea level rise as shown in Figure 4.1).

The results include the mapping of flood hazard vulnerability in accordance with Book 6, Chapter 7 of Australian Rainfall and Runoff (2019).

Table 16: Schedule of Post Development Results Mapping

Figure	Description
Figure 8.1	Post Development Envelope of Maximum Flood Levels and Depths – 1% AEP+ RCP8.5 Rainfall Increase + Sea Level Rise (0.36m)
Figure 8.2	Post Development Envelope of Maximum Flood Velocities – 1% AEP+ RCP8.5 Rainfall Increase + Sea Level Rise (0.36m)
Figure 8.3	Post Development Envelope of Maximum Flood Hazard – 1% AEP+ RCP8.5 Rainfall Increase + Sea Level Rise (0.36m)
Figure 8.4	Post Development Change in Maximum Flood Level – 1% AEP+ RCP8.5 Rainfall Increase + Sea Level Rise (0.36m)
Figure 8.5	Post Development 1% AEP Flood Planning Area
Figure 9.1	Post Development Maximum Flood Levels and Depths – PMF + Sea Level Rise (0.36m)
Figure 9.2	Post Development Maximum Flood Velocities – PMF + Sea Level Rise (0.36m)
Figure 9.3	Post Development Maximum Flood Hazard – PMF + Sea Level Rise (0.36m)
Figure 9.4	Post Development Change in Maximum Flood Level – PMF + Sea Level Rise (0.36m)

4.12. Post Development Results Discussion

The results show that:

i. the proposed channelisation of flows through the proposed development site and elevation of the roads and lots the 1% AEP flooding is shown to be largely confined to those areas that are not proposed to be rezoned (Figure 8.1). It should be noted that minor flood depths shown on Lots A and B and the proposed road is a result of rainfall on grid (direct rainfall) modelling and such flows would be appropriately managed through a network of pits, pipes and overland flow paths and are therefore not representative of actual flow behaviour in these locations.

ii. there is predicted to be a decrease in 1% AEP flood level over the upper part of the widened drainage channels to a maximum of approximately 300mm because of increasing the capacity of these channels. This decrease in flood levels within the channels would result in a reduction in flood levels within Sealark Road which anecdotally occurs due to the current restricted outlet channels (for both dimension and overgrown vegetation). The reduction in flooding within Sealark Road would result in serviceability benefits to the wider Callala Bay community.

iii. The proposed development is not anticipated to result in any adverse flooding impacts in the 1% AEP design event.

iv. the proposed area of residential rezoning (Lots A and B) is outside the 1% AEP flood planning area when incorporating RCP8.5 rainfall increases and 0.36m seal level rise (i.e. worst case climate change impacts) as shown in Figure 8.5.

5.0 CONCLUSION

The modelling undertaken demonstrates that flooding within the Wowly Creek estuary is dominated by oceanic flooding rather than catchment derived flooding.

Within the investigation area on the subject site flooding occurs predominately from the runoff derived from the existing residential catchments to the west of the site which discharge onto the site via two separate culverts under Sealark Avenue. Currently these flows exceed the capacity of the existing channel and cause flooding of variable depth within the overbanks.

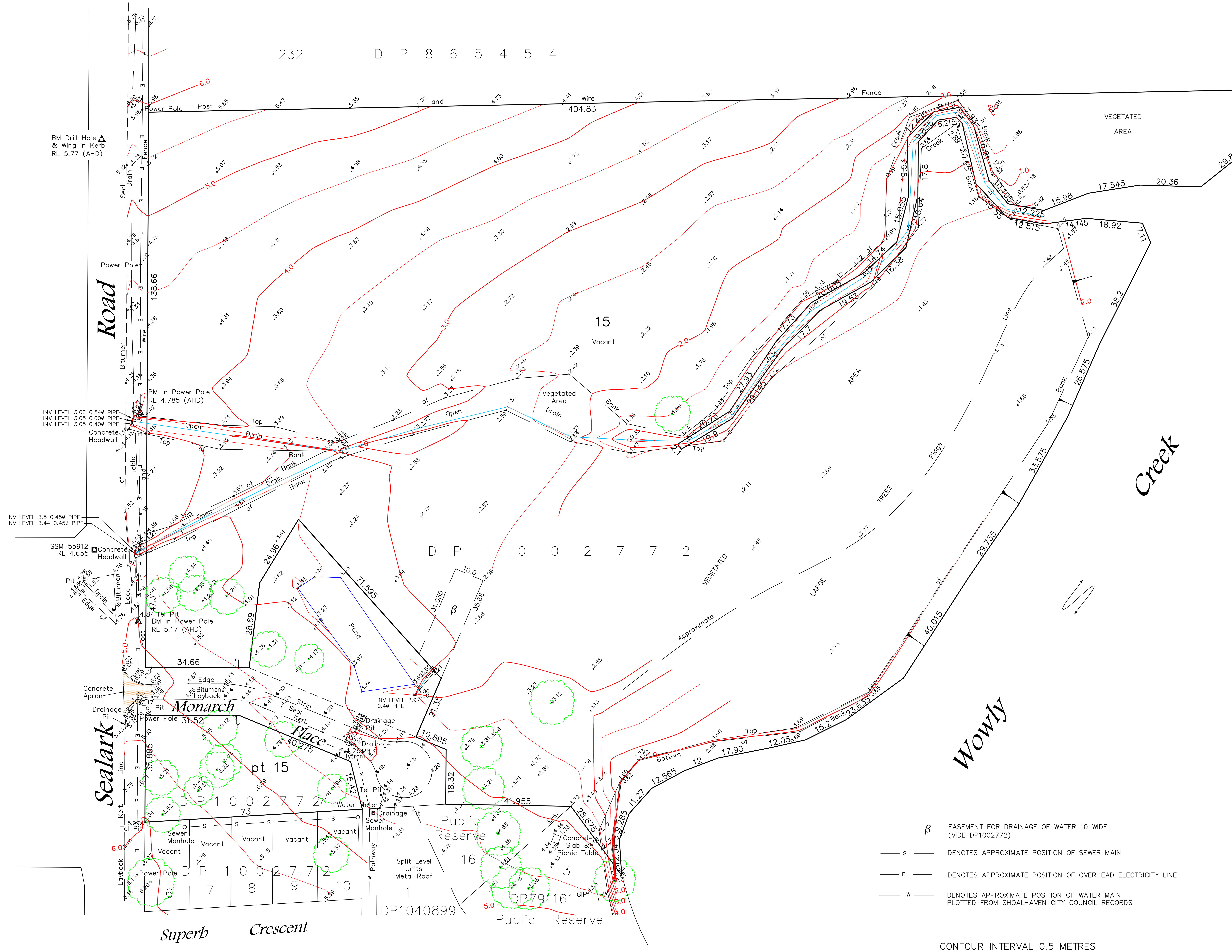
Except for overbank flooding from the above drainage channels the investigation area is relatively free from flooding and is therefore considered suitable for residential development.

Post development modelling showed that increasing the capacity of these drainage channels combined with floodplain filling would minimize the area of land inundated by flooding and that suitable flood free land above the flood planning level can be made available for residential development.

Further, the post development modelling showed that 1% AEP flood levels within the upper part of the drainage channels is likely to decrease by up to 300mm, which in turn is anticipated to result a reduction in flooding and increased serviceability within Sealark Road to the benefit of the wider community.

APPENDIX A

Detailed Site Survey



CAUTION

1. Please note that no boundary definition survey has been undertaken for this plan and no boundaries have been marked.

   The boundary position and dimensions as shown on the plan have only been taken from a copy of the deposited plan and not verified by field survey. The dimensions can only be verified by undertaking a comprehensive boundary definition survey to establish the available dimensions of the property.

2. All visible evidence of utility services has been located at the time of field survey, as shown on the plan.

   No record search or sub-surface investigation as to the location of any utility services or other structures (such as footings or foundations) has been undertaken.

   We recommend that prior to any demolition, excavation or construction work on the site, the relevant service authorities should be contacted for sub-surface utility service location information. In addition any sub-surface footings or foundations adjacent to any boundaries may need to be exposed to establish their extent and location.

3. Services shown hereon have been located where possible by field survey. If not able to be so located, services have been plotted from the records of relevant authorities where available and have been noted accordingly on this plan. Where such records either do not exist or are inadequate a notation has been made hereon.

   Prior to any demolition, excavation or construction on the site, the relevant authority should be contacted for possible location of further underground services and detailed locations of all services. In addition any sub-surface footings or foundations adjacent to any boundaries may need to be exposed to establish their extent and location.

4. The north point orientation shown hereon has been taken from cadastral plans and other available information. No attempt has been made to determine its exact relationship to either current magnetic north or true north. It should be regarded as approximate only.

5. The contours shown give an approximate representation only of the shape and level of the ground surface. They do not represent the exact level at any particular point except where a spot level is shown.

6. The tree spreads shown are indicative only and may need to be investigated further if required for purposes other than this topographical survey.

RATIO:	DATUM:	SURVEY	GH	AMENDMENTS	BY	DATE
1 : 600	AUSTRALIAN HEIGHT DATUM	DESIGN				
	ORIGIN: SSM 55912 RL 4.655 AHD	DRAWN	AVS			
		CHECK'D				
	DATE OF PLAN: 16/12/04	CADD FILE	24340 DETAIL			

ALLEN, PRICE & ASSOCIATES
LAND AND DEVELOPMENT CONSULTANTS
75 PLUNKETT STREET, NOWRA, NEW SOUTH WALES, 2541
Phone: (02) 4421 6544 Fax: (02) 4422 1821 DX 5310

PLAN SHOWING CONTOURS AND DETAIL
OVER PART OF LOT 15 DP1002772
AT SEALARK ROAD AND MONARCH PLACE
CALLALA BAY FOR HARE BAY DEVELOPMENT
CONSORTIUM C/O MERLOT CONSTRUCTIONS PTY LTD

REF. No. 24340

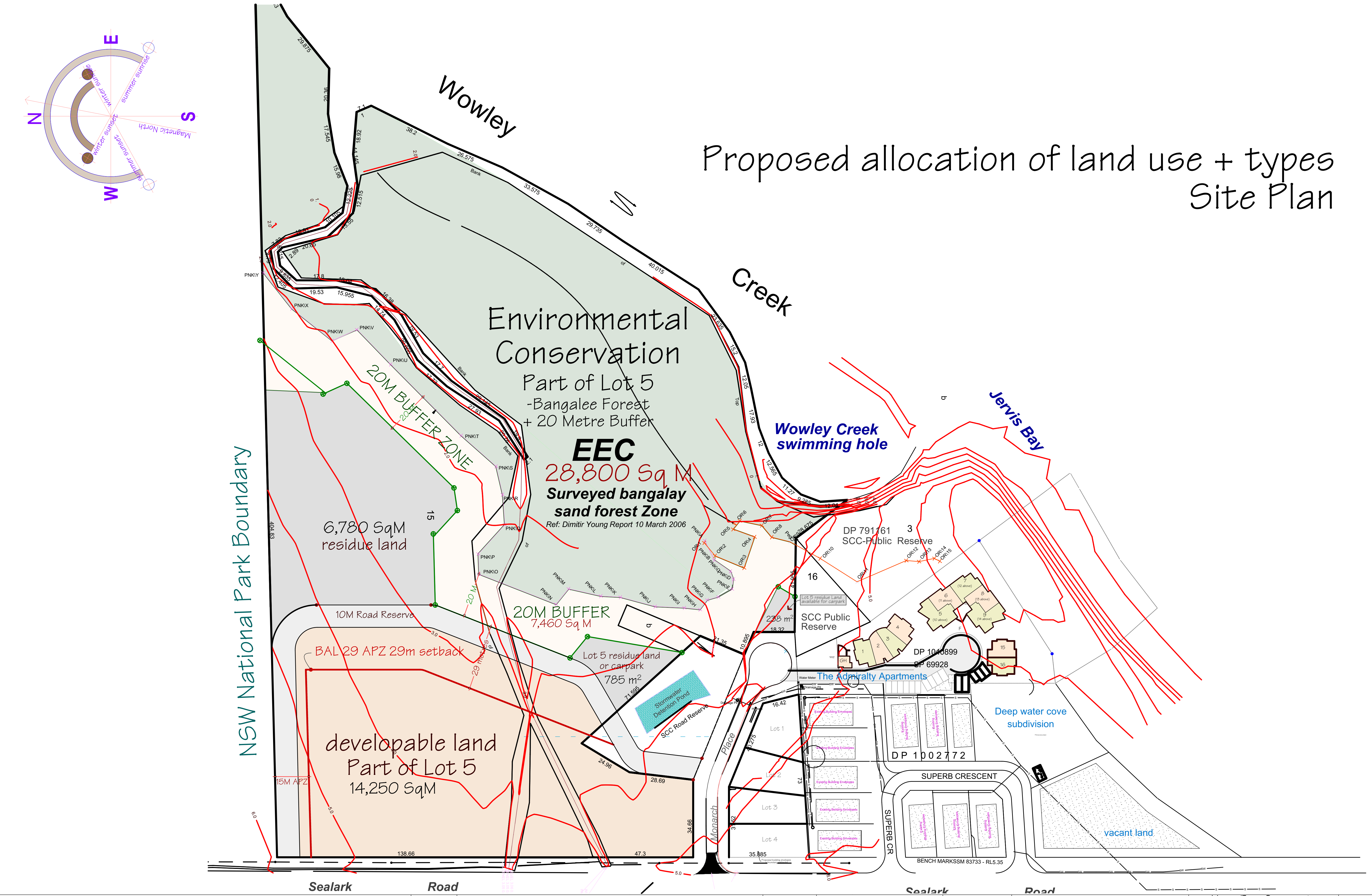
SHEET 1 OF 1 SHEETS

AMENDMENT

APPENDIX B

Concept Layout Plan

Proposed allocation of land use + types Site Plan



Dwg Issue:	Revision Notes:	Date Issued:
PRM 303A	Release for consultative Final Reports	16th July 2020

General Notes:
1. COPYRIGHT: The drawings & design remain the property & copyright of the architect. Reproduction of any drawing,the design and/or any design element may only occur with the architect's written permission.
2. DIMENSIONS: Written dimensions take precedence, do not scale drawings. Double check all dimensions on site and prior to construction. Verify any discrepancies with the project architect prior to proceding with any work.

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Hare Bay Consortia
Lot 5 DP 1225356
Sealark Road, Callala Bay

Sheet: 303 A

Drawing: Proposed Land allocation + ring road layout PLAN

Issue: PP

Drawn: cad | Check: prm | Issue Date: 16July2020 | Scale: 1:1,500 | Job No

APPENDIX C

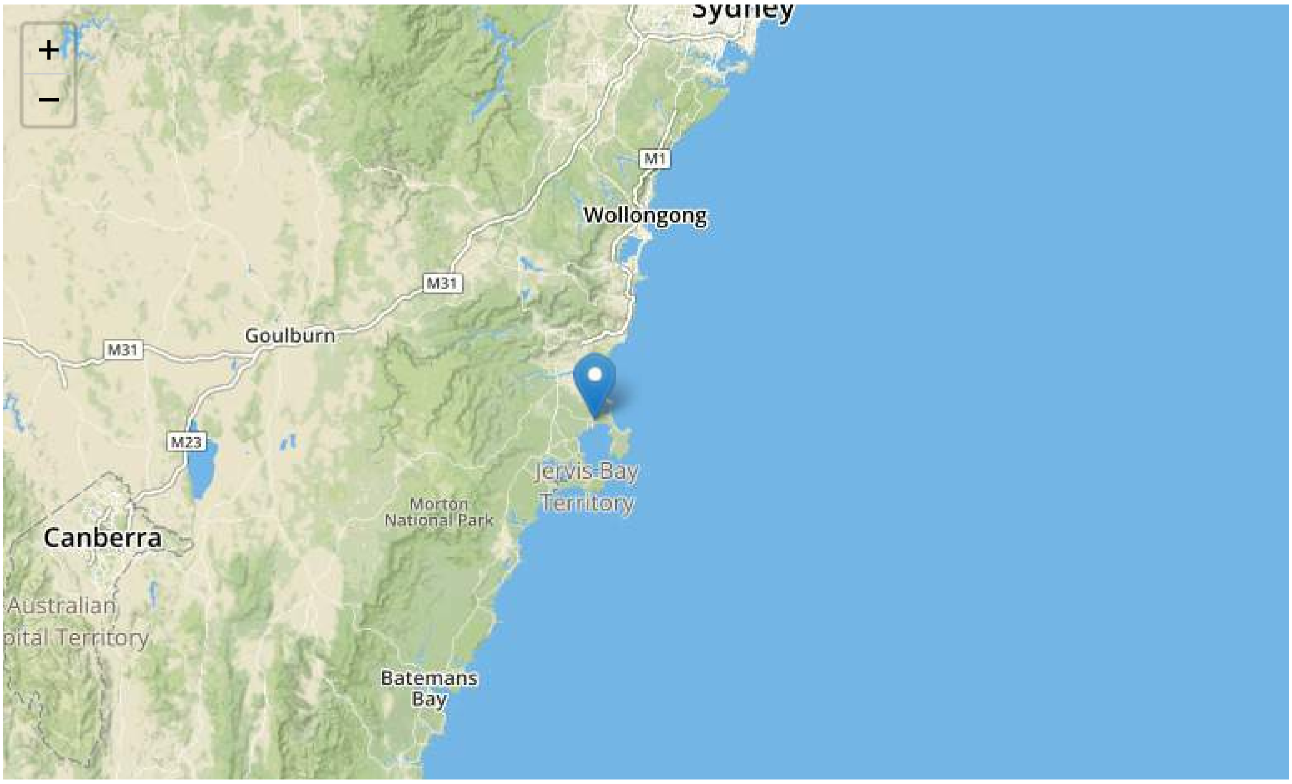
ARR Data Hub Output

ATTENTION: This site was updated recently, changing some of the functionality. Please see the changelog (./changelog) for further information

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	150.723
Latitude	-34.984
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Probability Neutral Burst Initial Loss (./nsw_specific)	show



Data

River Region

Division	South East Coast (NSW)
River Number	16
River Name	Clyde River-Jervis Bay

Layer Info

Time Accessed	05 August 2019 01:29PM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
SE Coast	0.06	0.361	0.0	0.317	8.11e-05	0.651	0.0	0.0	0.0

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26 \text{ x } 10^{-3} \text{ x } Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141 \text{ x } Area^{0.213} \text{ x } 10^{-0.021\frac{(Duration-180)^2}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	05 August 2019 01:29PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. The continuing storm loss information from the ARR Datahub provided below should only be used where relevant under the loss hierarchy (level 5) and where used is to be multiplied by the factor of 0.4.

ID	14817.0
Storm Initial Losses (mm)	26.0
Storm Continuing Losses (mm/h)	4.0

Layer Info

Time Accessed	05 August 2019 01:29PM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/SSmainland.zip)

code	SSmainland
Label	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	05 August 2019 01:29PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_SSmainland.zip)

code	SSmainland
arealabel	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	05 August 2019 01:29PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-34.984323464&longitude=150.72253611&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	05 August 2019 01:29PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	2.1 (0.072)	2.6 (0.066)	3.0 (0.062)	3.3 (0.059)	1.9 (0.028)	0.9 (0.011)
90 (1.5)	7.0 (0.209)	6.7 (0.144)	6.5 (0.117)	6.3 (0.096)	3.6 (0.045)	1.5 (0.016)
120 (2.0)	14.9 (0.390)	12.1 (0.229)	10.2 (0.161)	8.4 (0.114)	4.9 (0.055)	2.3 (0.023)
180 (3.0)	7.8 (0.171)	8.1 (0.128)	8.2 (0.109)	8.3 (0.095)	10.5 (0.100)	12.1 (0.102)
360 (6.0)	12.5 (0.195)	21.2 (0.241)	27.0 (0.257)	32.5 (0.267)	21.9 (0.151)	13.9 (0.085)
720 (12.0)	6.6 (0.074)	13.8 (0.110)	18.5 (0.124)	23.1 (0.134)	28.9 (0.142)	33.3 (0.146)
1080 (18.0)	5.9 (0.055)	9.7 (0.064)	12.2 (0.067)	14.5 (0.069)	23.4 (0.094)	30.0 (0.108)
1440 (24.0)	1.9 (0.015)	6.2 (0.036)	9.0 (0.044)	11.8 (0.049)	17.8 (0.062)	22.3 (0.069)
2160 (36.0)	0.0 (0.000)	2.2 (0.011)	3.6 (0.015)	5.0 (0.017)	7.1 (0.021)	8.7 (0.023)
2880 (48.0)	0.0 (0.000)	0.1 (0.000)	0.1 (0.001)	0.2 (0.001)	2.3 (0.006)	3.9 (0.009)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	05 August 2019 01:29PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	05 August 2019 01:29PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.8 (0.022)	0.8 (0.015)	0.8 (0.012)	0.7 (0.010)	0.3 (0.004)	0.0 (0.000)
180 (3.0)	0.1 (0.002)	0.1 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.5 (0.008)	0.3 (0.003)	0.1 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	1.1 (0.004)	2.0 (0.007)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	05 August 2019 01:29PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	32.3 (1.138)	32.8 (0.832)	33.2 (0.696)	33.5 (0.596)	32.8 (0.480)	32.3 (0.412)
90 (1.5)	40.9 (1.214)	41.9 (0.900)	42.6 (0.761)	43.2 (0.658)	40.5 (0.509)	38.5 (0.424)
120 (2.0)	45.9 (1.202)	53.2 (1.011)	58.1 (0.921)	62.7 (0.849)	50.5 (0.567)	41.3 (0.407)
180 (3.0)	47.5 (1.033)	48.8 (0.773)	49.6 (0.658)	50.4 (0.574)	70.9 (0.673)	86.2 (0.722)
360 (6.0)	49.3 (0.768)	69.8 (0.791)	83.3 (0.793)	96.4 (0.790)	98.1 (0.678)	99.3 (0.611)
720 (12.0)	30.0 (0.334)	47.6 (0.381)	59.2 (0.398)	70.4 (0.407)	84.0 (0.411)	94.1 (0.413)
1080 (18.0)	24.2 (0.224)	40.8 (0.269)	51.8 (0.285)	62.3 (0.295)	68.3 (0.274)	72.8 (0.261)
1440 (24.0)	17.8 (0.146)	26.7 (0.155)	32.6 (0.157)	38.2 (0.158)	50.4 (0.176)	59.5 (0.186)
2160 (36.0)	7.8 (0.055)	20.7 (0.102)	29.2 (0.119)	37.4 (0.130)	40.8 (0.119)	43.5 (0.113)
2880 (48.0)	5.0 (0.032)	9.5 (0.042)	12.4 (0.046)	15.3 (0.048)	18.1 (0.047)	20.3 (0.047)
4320 (72.0)	0.0 (0.000)	1.2 (0.005)	1.9 (0.006)	2.7 (0.007)	22.0 (0.050)	36.4 (0.073)

Layer Info

Time Accessed	05 August 2019 01:29PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	95.4 (3.357)	109.7 (2.779)	119.2 (2.502)	128.4 (2.286)	119.7 (1.752)	113.2 (1.445)
90 (1.5)	99.0 (2.937)	114.7 (2.462)	125.1 (2.234)	135.0 (2.055)	132.1 (1.661)	130.0 (1.429)
120 (2.0)	98.1 (2.568)	132.2 (2.512)	154.7 (2.453)	176.4 (2.389)	160.0 (1.797)	147.7 (1.456)
180 (3.0)	84.4 (1.836)	123.2 (1.952)	148.9 (1.975)	173.6 (1.975)	174.9 (1.661)	175.9 (1.474)
360 (6.0)	79.4 (1.238)	117.3 (1.330)	142.4 (1.356)	166.5 (1.365)	173.7 (1.201)	179.1 (1.102)
720 (12.0)	82.0 (0.912)	103.4 (0.828)	117.6 (0.789)	131.2 (0.759)	159.5 (0.782)	180.7 (0.793)
1080 (18.0)	56.7 (0.525)	85.2 (0.562)	104.1 (0.573)	122.2 (0.579)	147.2 (0.590)	165.9 (0.595)
1440 (24.0)	64.6 (0.529)	74.5 (0.432)	81.0 (0.391)	87.3 (0.361)	107.0 (0.374)	121.8 (0.380)
2160 (36.0)	52.8 (0.372)	63.2 (0.311)	70.0 (0.286)	76.6 (0.267)	92.6 (0.270)	104.6 (0.272)
2880 (48.0)	21.0 (0.135)	35.0 (0.156)	44.2 (0.163)	53.1 (0.166)	69.9 (0.182)	82.4 (0.191)
4320 (72.0)	10.4 (0.060)	19.2 (0.077)	25.0 (0.082)	30.5 (0.084)	78.4 (0.178)	114.2 (0.229)

Layer Info

Time Accessed	05 August 2019 01:29PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	RCP 8.5
2030	**0.648 (3.2%)**	0.687 (3.4%)	**0.811 (4.0%)**
2040	**0.878 (4.4%)**	0.827 (4.1%)	**1.084 (5.4%)**
2050	**1.081 (5.4%)**	1.013 (5.1%)	**1.446 (7.3%)**
2060	**1.251 (6.3%)**	1.229 (6.2%)	**1.862 (9.5%)**
2070	**1.381 (7.0%)**	1.460 (7.4%)	**2.298 (11.9%)**
2080	**1.465 (7.4%)**	1.691 (8.6%)	**2.719 (14.2%)**
2090	**1.496 (7.6%)**	1.906 (9.7%)	**3.090 (16.3%)**

Layer Info

Time Accessed	05 August 2019 01:29PM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	12.8	8.8	9.0	8.8	9.6	6.5
90 (1.5)	11.8	8.3	9.2	9.0	8.9	5.3
120 (2.0)	10.4	7.8	8.3	8.3	8.7	5.5
180 (3.0)	12.1	9.1	9.5	8.9	8.3	2.9
360 (6.0)	11.9	8.0	8.4	8.1	9.1	2.8
720 (12.0)	15.4	10.7	11.4	9.0	10.2	3.0
1080 (18.0)	17.1	12.4	13.3	11.0	12.0	3.6
1440 (24.0)	19.3	15.1	15.4	13.2	14.1	4.3
2160 (36.0)	22.2	16.8	17.1	15.2	16.8	8.7
2880 (48.0)	24.8	20.4	20.0	20.7	20.0	10.2
4320 (72.0)	27.3	24.1	24.8	24.4	23.1	7.6

Layer Info

Time Accessed	05 August 2019 01:29PM
Version	2018_v1

Note As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.

Download TXT (downloads/30fd0218-eb31-4c6a-9753-a0270413312d.txt)

Download JSON (downloads/d079fcc2-1baf-456c-898a-ad1d668a6373.json)

Generating PDF... (downloads/11af4468-b57d-4fcc-ba73-6679d1feb8af.pdf)

APPENDIX D

ARR 2019 IFD Data

Australian Government
Bureau of Meteorology

Location

Label: Sealark Rd, Callala Bay

Easting: 292188

Northing: 6126324

Zone: 56

Latitude: Nearest grid cell: 34.9875 (S)

Longitude: Nearest grid cell: 150.7125 (E)

IFD Design Rainfall Intensity (mm/h)

Issued: 24 September 2019

Rainfall intensity for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP).
FAQ for New ARR probability terminology

	Annual Exceedance Probability (AEP)						
Duration	**63.2%**	**50%#**	**20%***	**10%**	**5%**	**2%**	**1%**
1 min	128	145	204	247	293	358	411
2 min	110	124	171	205	241	294	338
3 min	101	114	157	189	223	272	312
4 min	93.4	106	147	177	209	255	293
5 min	87.3	99.0	138	167	197	241	276
10 min	66.7	75.9	107	130	154	188	216
15 min	54.8	62.4	88.0	107	127	155	179
20 min	47.1	53.6	75.5	91.7	109	133	153
25 min	41.6	47.3	66.5	80.8	95.8	117	135
30 min	37.5	42.6	59.8	72.6	86.0	105	121
45 min	29.7	33.6	47.0	56.8	67.1	81.9	94.1
1 hour	25.1	28.4	39.5	47.7	56.2	68.3	78.4
1.5 hour	19.9	22.5	31.0	37.3	43.8	53.0	60.6
2 hour	16.9	19.1	26.3	31.5	36.9	44.5	50.7
3 hour	13.6	15.3	21.0	25.1	29.3	35.1	39.8
4.5 hour	11.0	12.4	17.0	20.3	23.6	28.1	31.6
6 hour	9.44	10.7	14.7	17.5	20.3	24.1	27.1
9 hour	7.65	8.69	12.0	14.3	16.6	19.6	22.0
12 hour	6.57	7.49	10.4	12.4	14.4	17.0	19.0
18 hour	5.24	6.01	8.43	10.1	11.7	13.9	15.5
24 hour	4.42	5.09	7.19	8.64	10.1	11.9	13.3
30 hour	3.85	4.44	6.31	7.60	8.89	10.6	11.8
36 hour	3.42	3.94	5.64	6.81	7.98	9.52	10.7
48 hour	2.80	3.24	4.66	5.66	6.67	8.00	9.01
72 hour	2.07	2.40	3.48	4.26	5.04	6.10	6.92

96 hour	1.65	1.91	2.79	3.42	4.06	4.95	5.64
120 hour	1.37	1.59	2.33	2.86	3.41	4.16	4.75
144 hour	1.18	1.37	2.00	2.46	2.94	3.59	4.11
168 hour	1.04	1.21	1.76	2.17	2.59	3.16	3.61

Note:
The 50% AEP IFD **does not** correspond to the 2 year Average Recurrence Interval (ARI) IFD. Rather it corresponds to the 1.44 ARI.
* The 20% AEP IFD **does not** correspond to the 5 year Average Recurrence Interval (ARI) IFD. Rather it corresponds to the 4.48 ARI.

This page was created at **12:11 on Tuesday 24 September 2019 (AEST)**

APPENDIX E

Pre-Burst Rainfall Depths

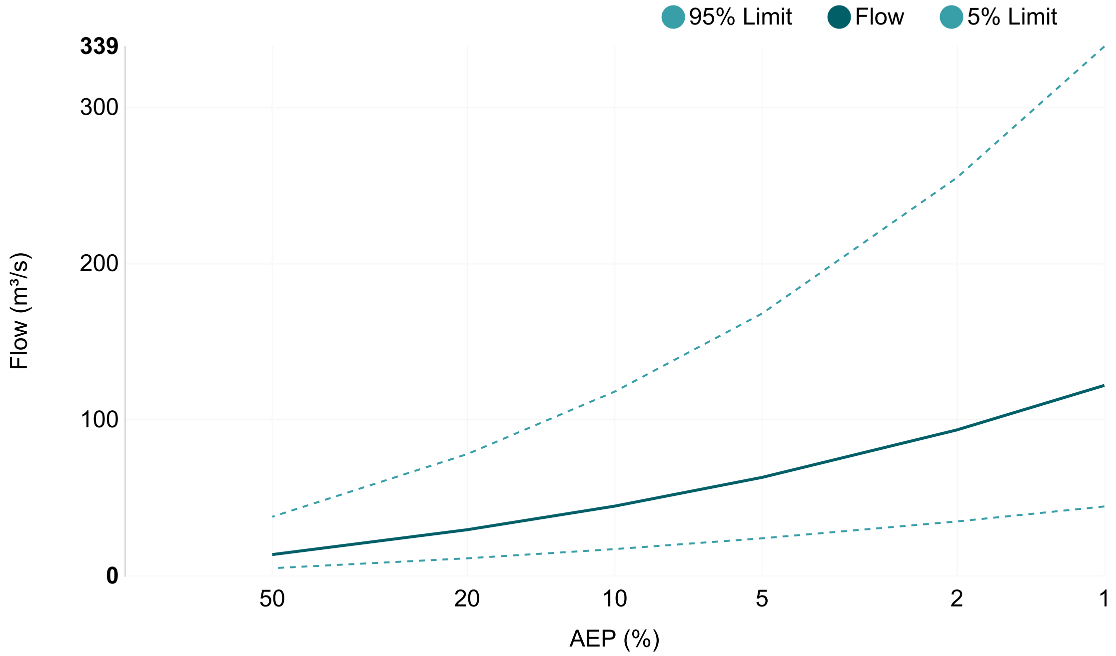
Table E1: NSW Transformation Pre-Burst Rainfall Depths (bold values interpolated)

Storm Duration		Pre-Burst Rainfall Depth (mm)					
		AEP (%)					
min	**hrs**	**50**	**20**	**10**	**5**	**2**	**1**
60	1	12.8	16.8	16.6	16.8	16	19.1
90	1.5	13.8	17.3	16.4	16.6	16.7	20.3
120	2	15.2	17.8	17.3	17.3	16.9	20.1
180	3	13.5	16.5	16.1	16.7	17.3	22.7
270	**4.5**	**13.6**	**17.1**	**16.7**	**17.1**	**16.9**	**22.8**
360	6	13.7	17.6	17.2	17.5	16.5	22.8
540	**9**	**12.0**	**16.3**	**15.7**	**17.1**	**16.0**	**22.7**
720	12	10.2	14.9	14.2	16.6	15.4	22.6
1080	18	8.5	13.2	12.3	14.6	13.6	22
1440	24	6.3	10.5	10.2	12.4	11.5	21.3
2160	36	3.4	8.8	8.5	10.4	8.8	16.9
2880	48	0.8	5.2	5.6	4.9	5.6	15.4
4320	72	0	1.5	0.8	1.2	2.5	18

APPENDIX F

RFFE Method Output

Results | Regional Flood Frequency Estimation Model



*The catchment has unusual shape. Results have lower accuracy and may not be directly applicable in practice.

AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	13.7	4.97	37.9
20	29.6	11.3	78.0
10	44.7	17.2	118
5	63.1	24.1	168
2	93.5	34.9	255
1	122	44.5	339

Statistics

Variable	Value	Standard Dev
Mean	2.460	0.646
Standard Dev	0.896	0.162
Skew	0.091	0.027

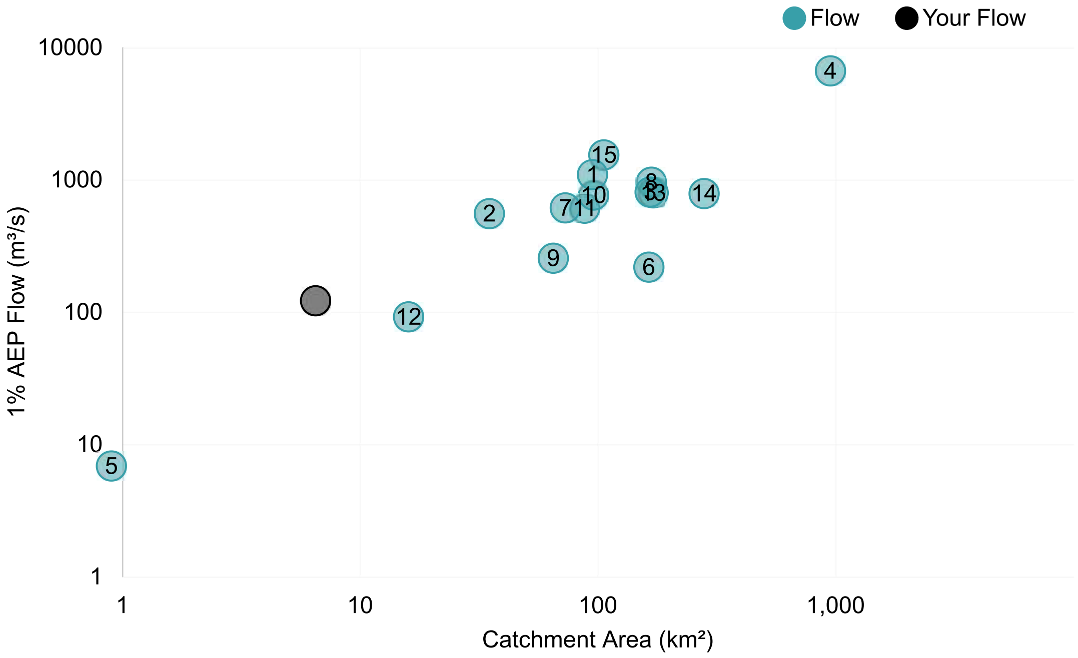
Note: These statistics come from the nearest gauged catchment. Details.

Correlation

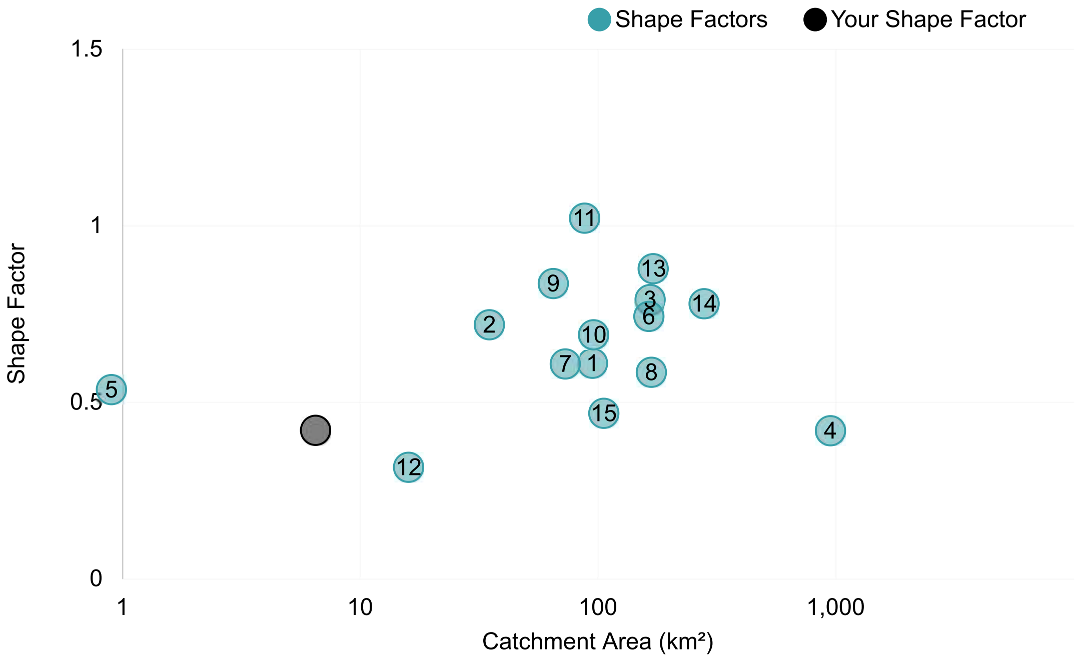
1.000		
-0.330	1.000	
0.170	-0.280	1.000

Note: These statistics are common to each region. Details.

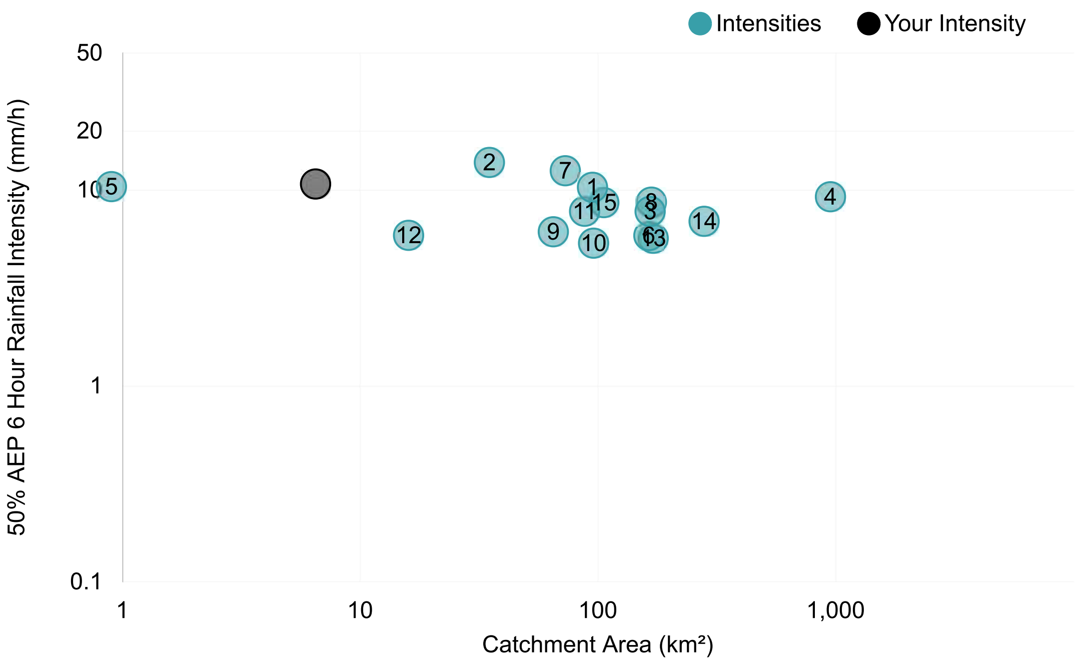
1% AEP Flow vs Catchment Area



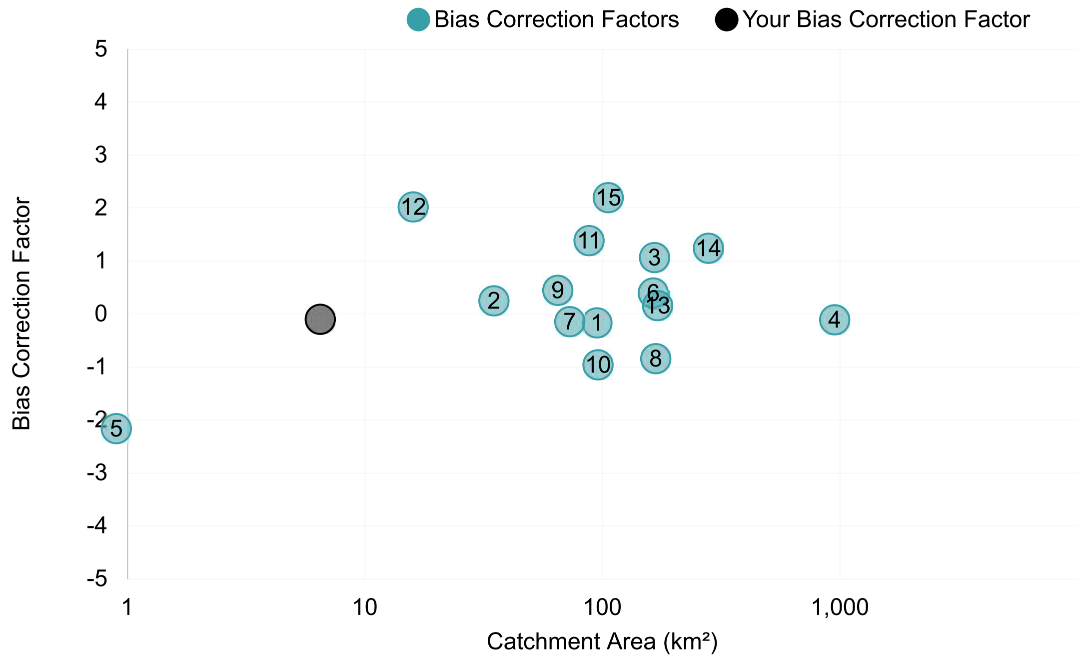
Shape Factor vs Catchment Area



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area



Download

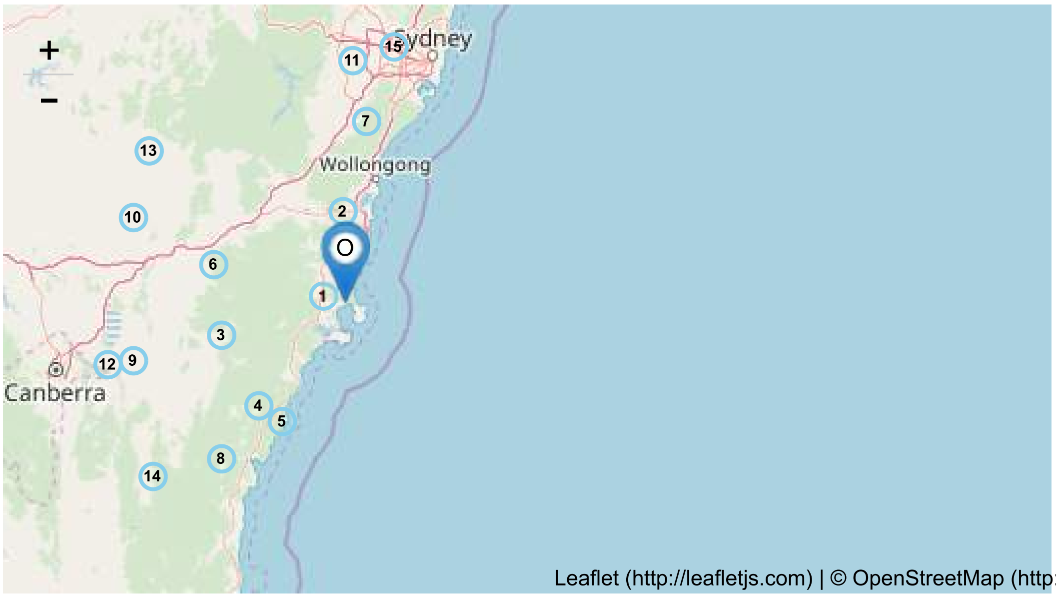
TXT Nearby JSON

Input Data

Date/Time	2019-08-05 16:19
Catchment Name	Wowly
Latitude (Outlet)	-34.99499
Longitude (Outlet)	150.72876
Latitude (Centroid)	-34.98533
Longitude (Centroid)	150.727794
Catchment Area (km^2)	6.5
Distance to Nearest Gauged Catchment (km)	12.21
50% AEP 6 Hour Rainfall Intensity (mm/h)	10.724723
2% AEP 6 Hour Rainfall Intensity (mm/h)	24.131247
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast

Input Data

Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	0.42*
Interpolation Method	Natural Neighbour
Bias Correction Value	-0.104



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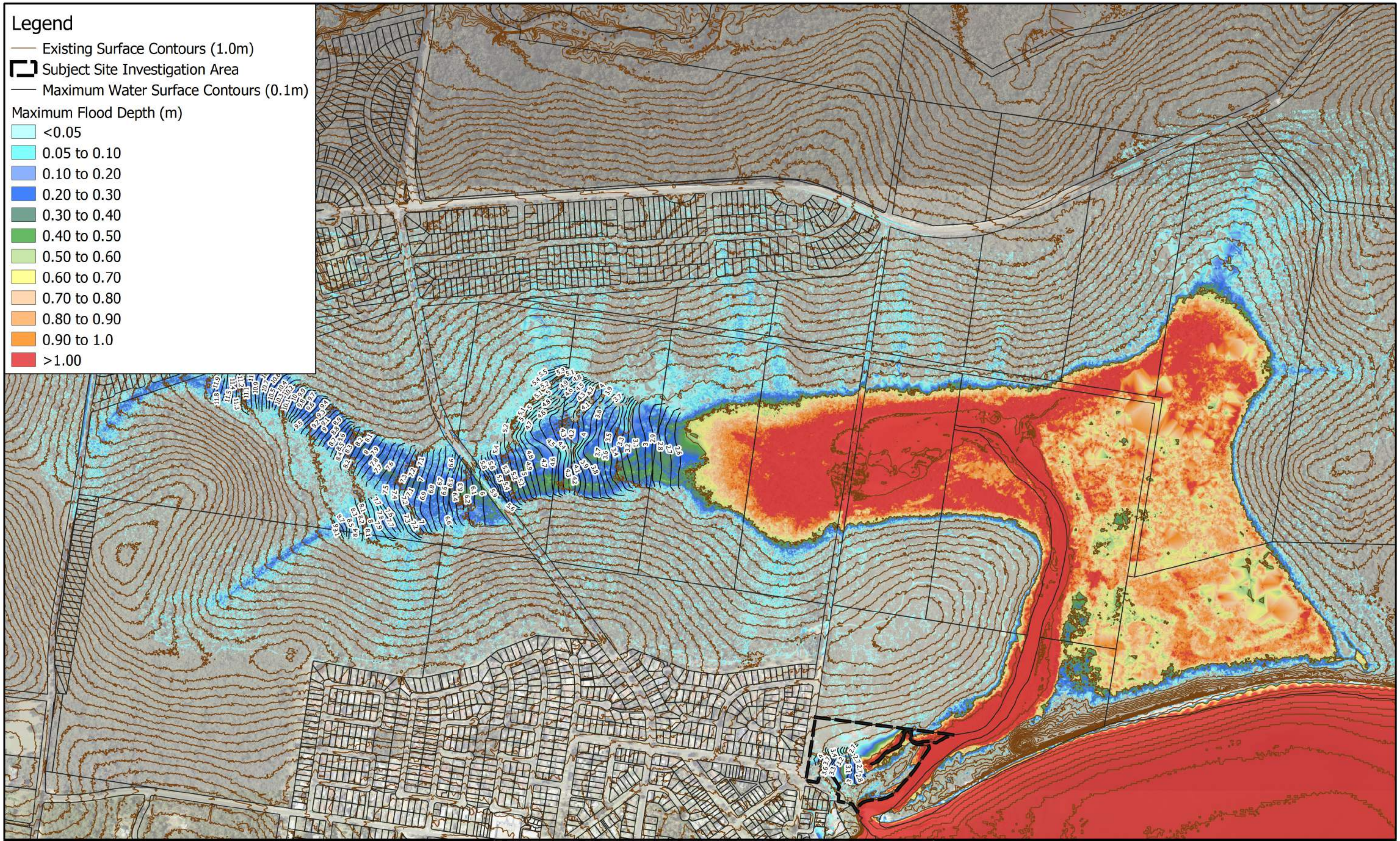
Method by Dr Ataur Rahman and Dr Khaled Haddad from Western Sydney University for the Australian Rainfall and Runoff Project. Full description of the project can be found at the project page (http://arr.ga.gov.au/revision-projects/project-list/projects/project-5) on the ARR website. Send any questions regarding the method or project here (mailto:admin@arr-software.org).

ENGINEERS AUSTRALIA (http://www.engineersaustralia.org.au)

WESTERN SYDNEY UNIVERSITY (http://www.uws.edu.au)

APPENDIX G

Pre-Development Modelling Results



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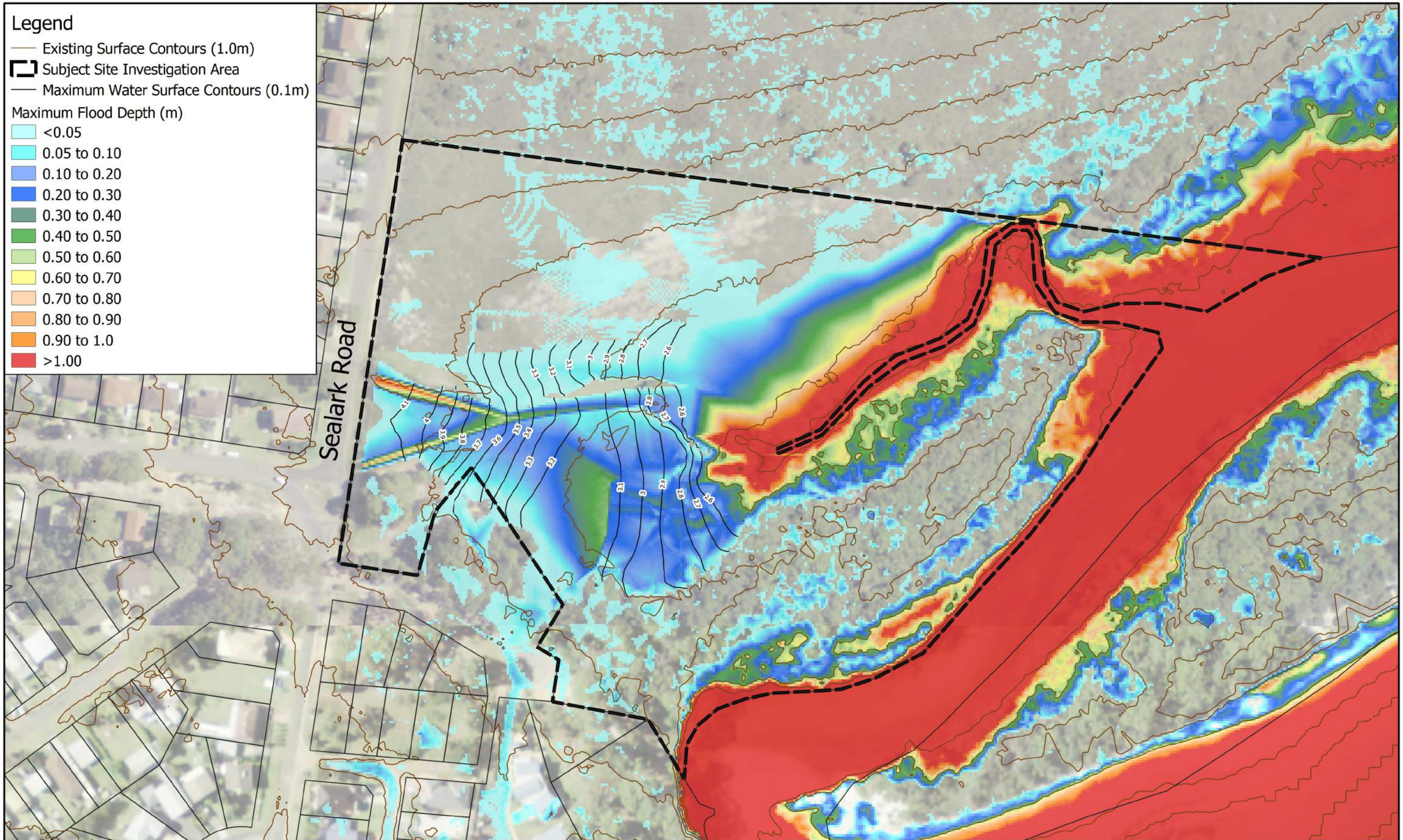
LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 1.1A

ENVELOPE OF MAXIMUM FLOOD LEVELS AND DEPTHS

1% AEP

Rev 2 - 20 October 2020



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LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 1.1B

ENVELOPE OF MAXIMUM FLOOD LEVELS AND DEPTHS

1% AEP

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LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 1.2A

ENVELOPE OF MAXIMUM FLOOD VELOCITIES

1% AEP

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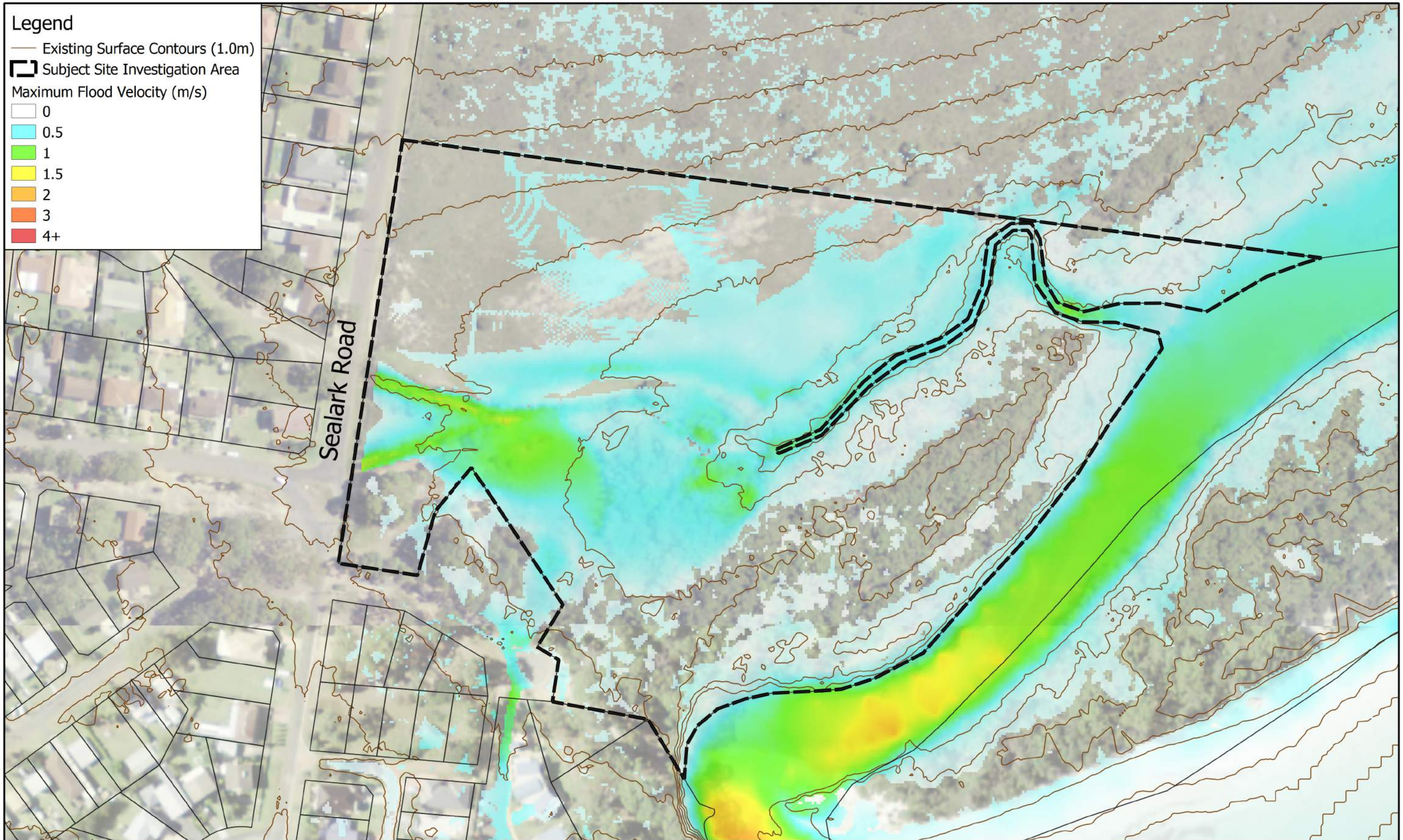

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25 0 25 50 m

Scale 1:1,500 at A3

LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 1.2B

ENVELOPE OF MAXIMUM FLOOD VELOCITIES

1% AEP

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200 0 200 m

Scale 1:10,000 at A3

LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 1.3A

ENVELOPE OF MAXIMUM FLOOD HAZARD

1% AEP

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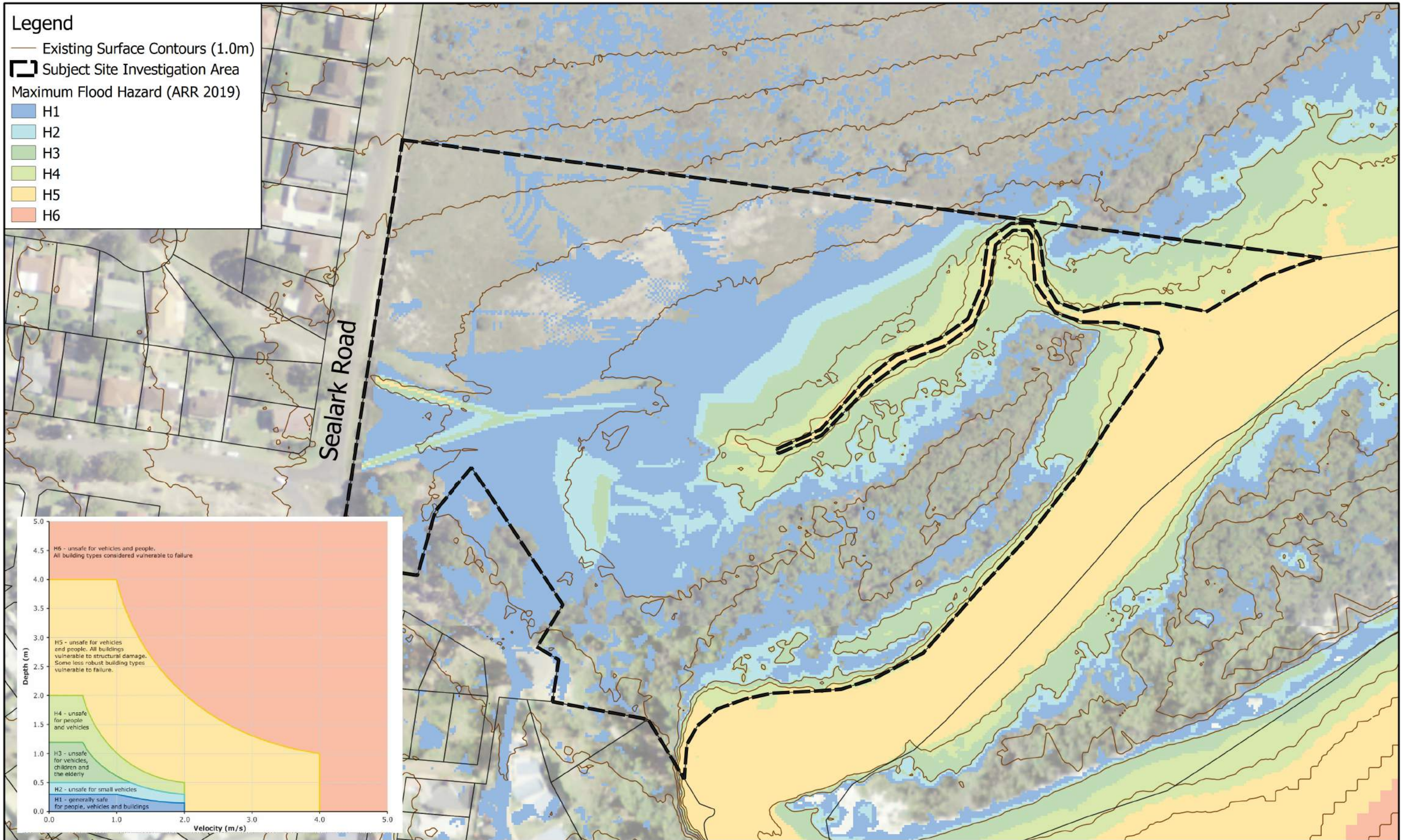

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25 0 25 50 m

Scale 1:1,500 at A3

LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 1.3B
ENVELOPE OF MAXIMUM FLOOD VELOCITIES
1% AEP

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LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 1.4A

SOURCE OF MAXIMUM FLOOD ENVELOPE LEVEL

1% AEP

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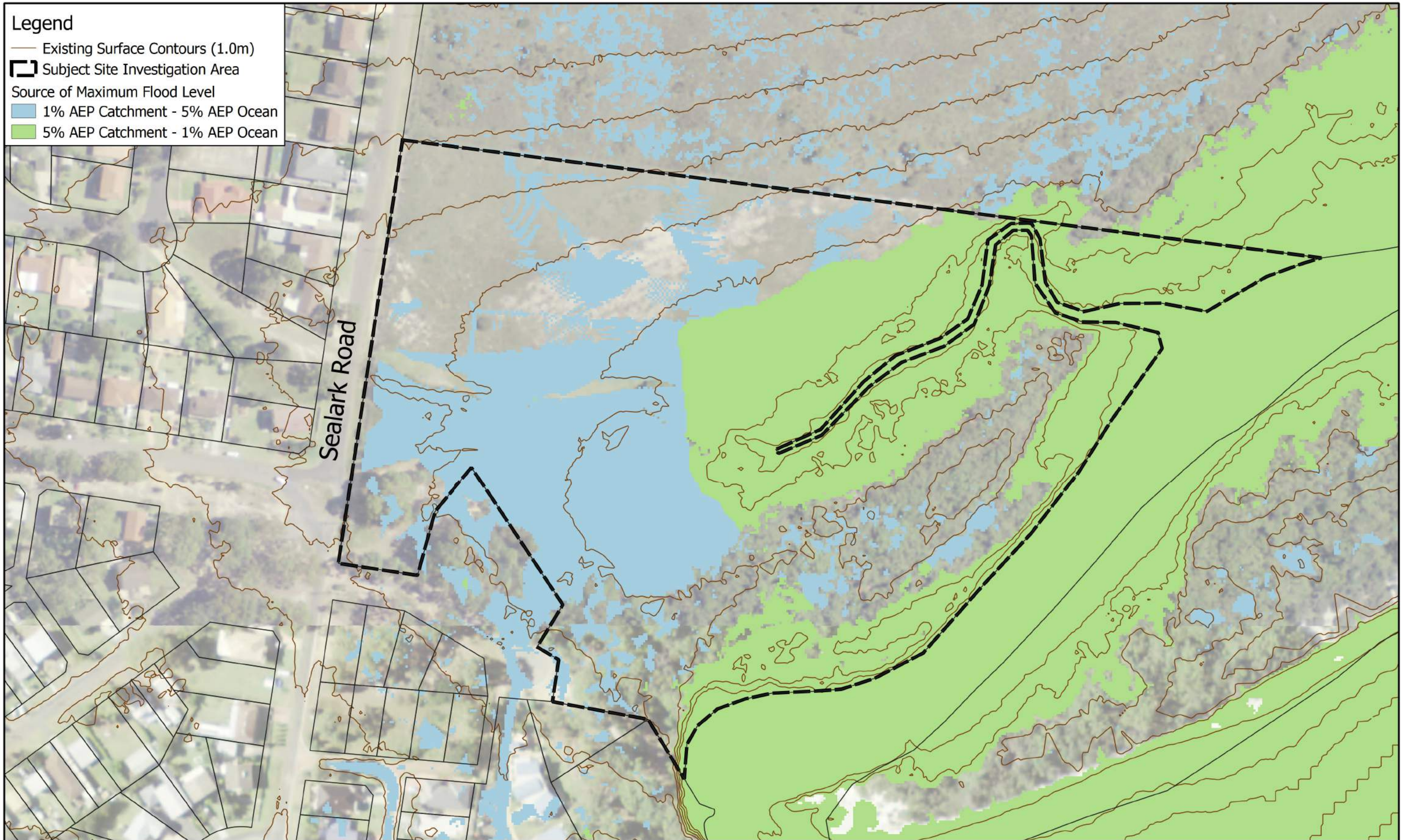

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25 0 25 50 m

Scale 1:1,500 at A3

LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 1.4B

SOURCE OF MAXIMUM FLOOD ENVELOPE LEVEL

1% AEP

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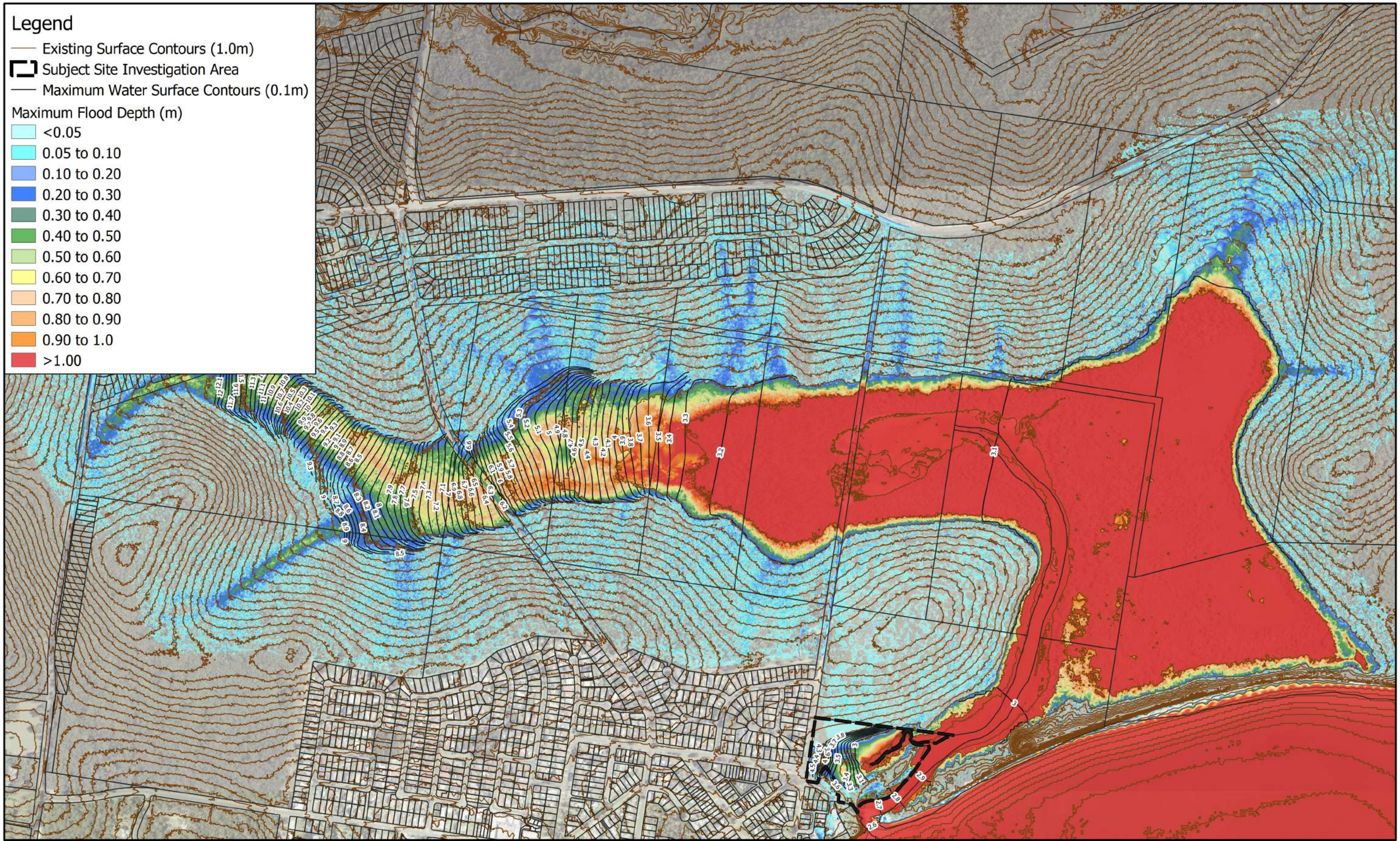

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200 0 200 m

Scale 1:10,000 at A3

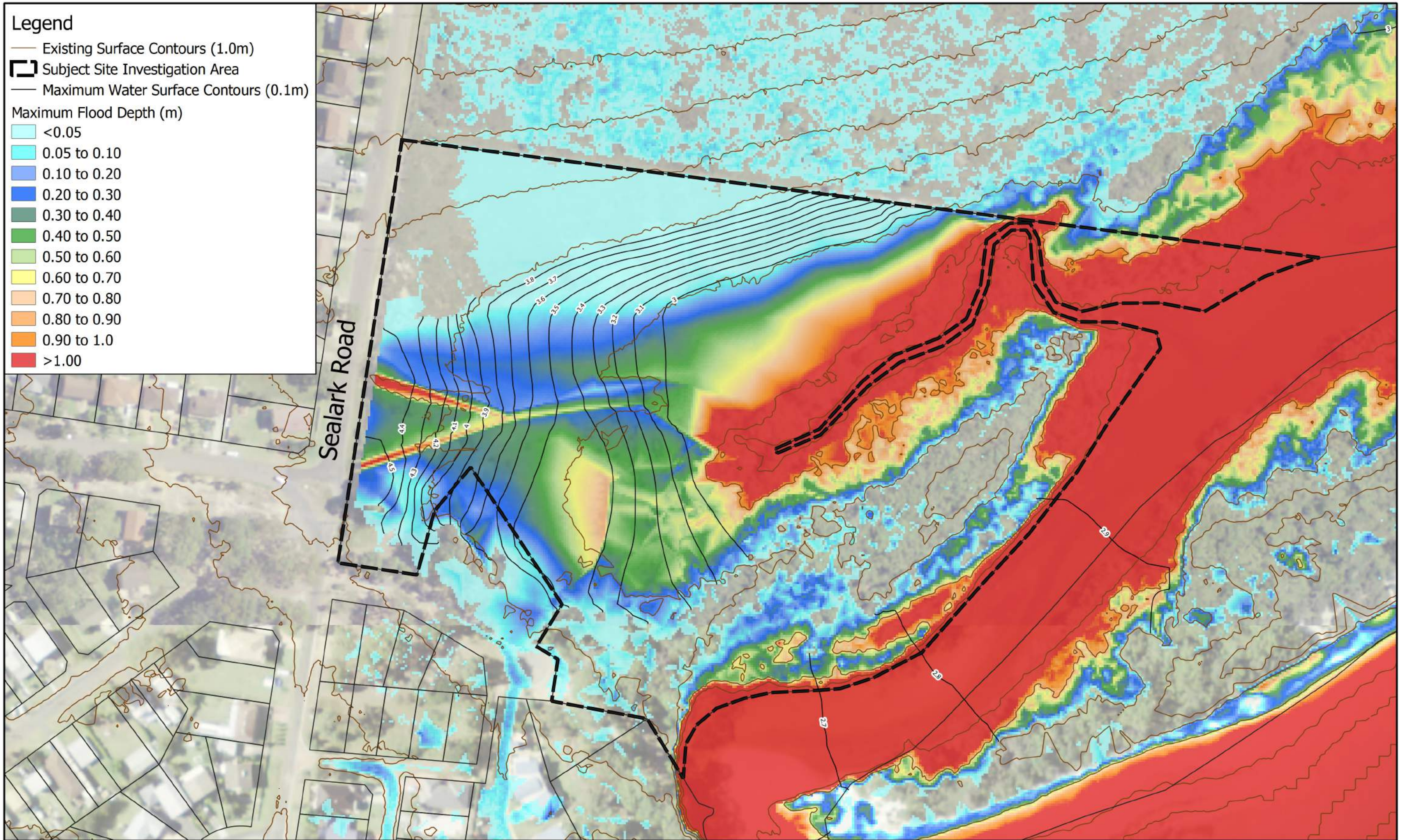
LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 2.1A

MAXIMUM FLOOD LEVELS AND DEPTHS

PMF

Rev 2 - 20 October 2020



footprint.
sustainable engineering.
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nsw 2533 p: (02) 4237 6770

25 0 25 50 m

Scale 1:1,500 at A3

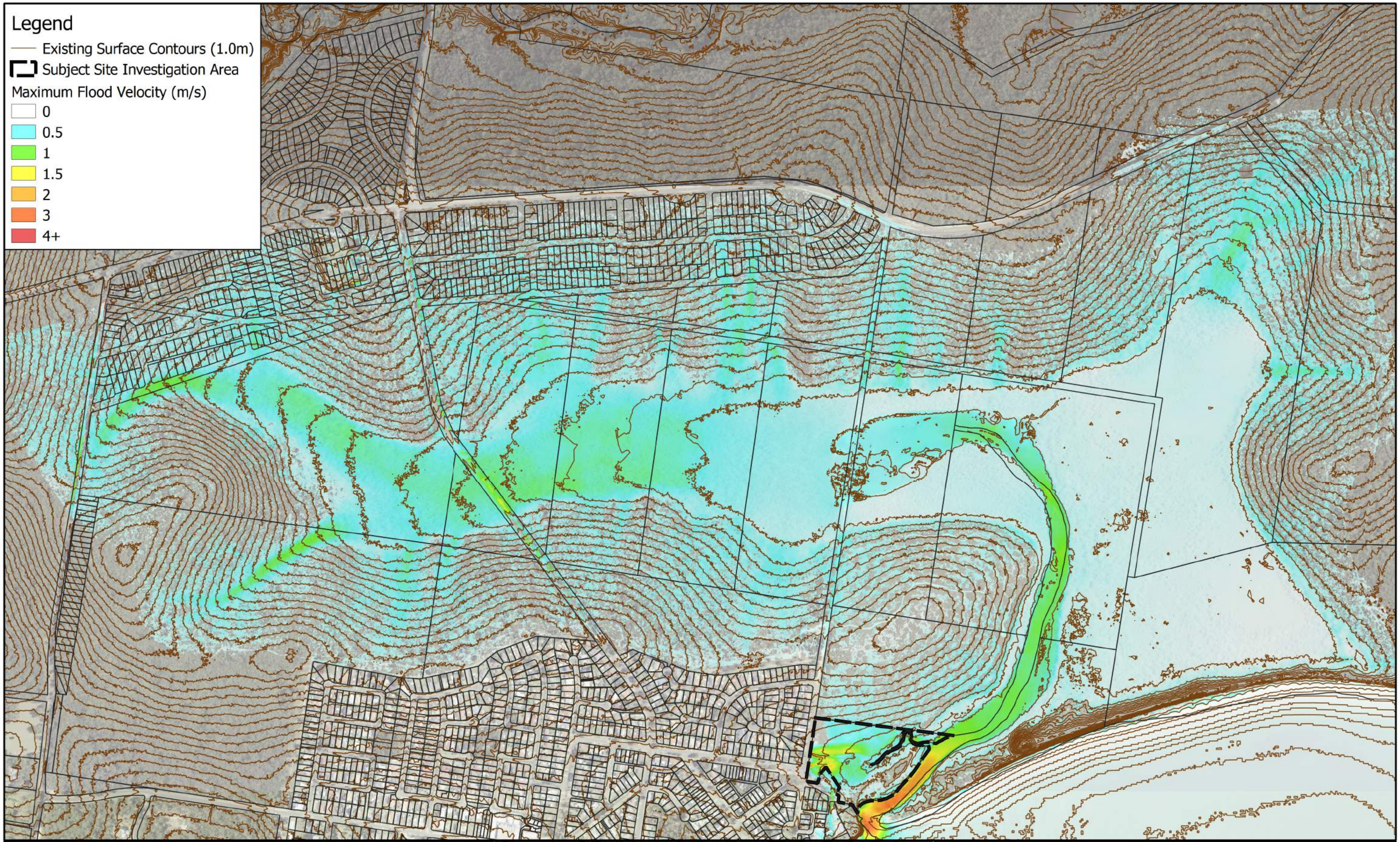
LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 2.1B

MAXIMUM FLOOD LEVELS AND DEPTHS

PMF

Rev 2 - 20 October 2020



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sustainable engineering.

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200 0 200 m

Scale 1:10,000 at A3

LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 2.2A
MAXIMUM FLOOD VELOCITIES
PMF

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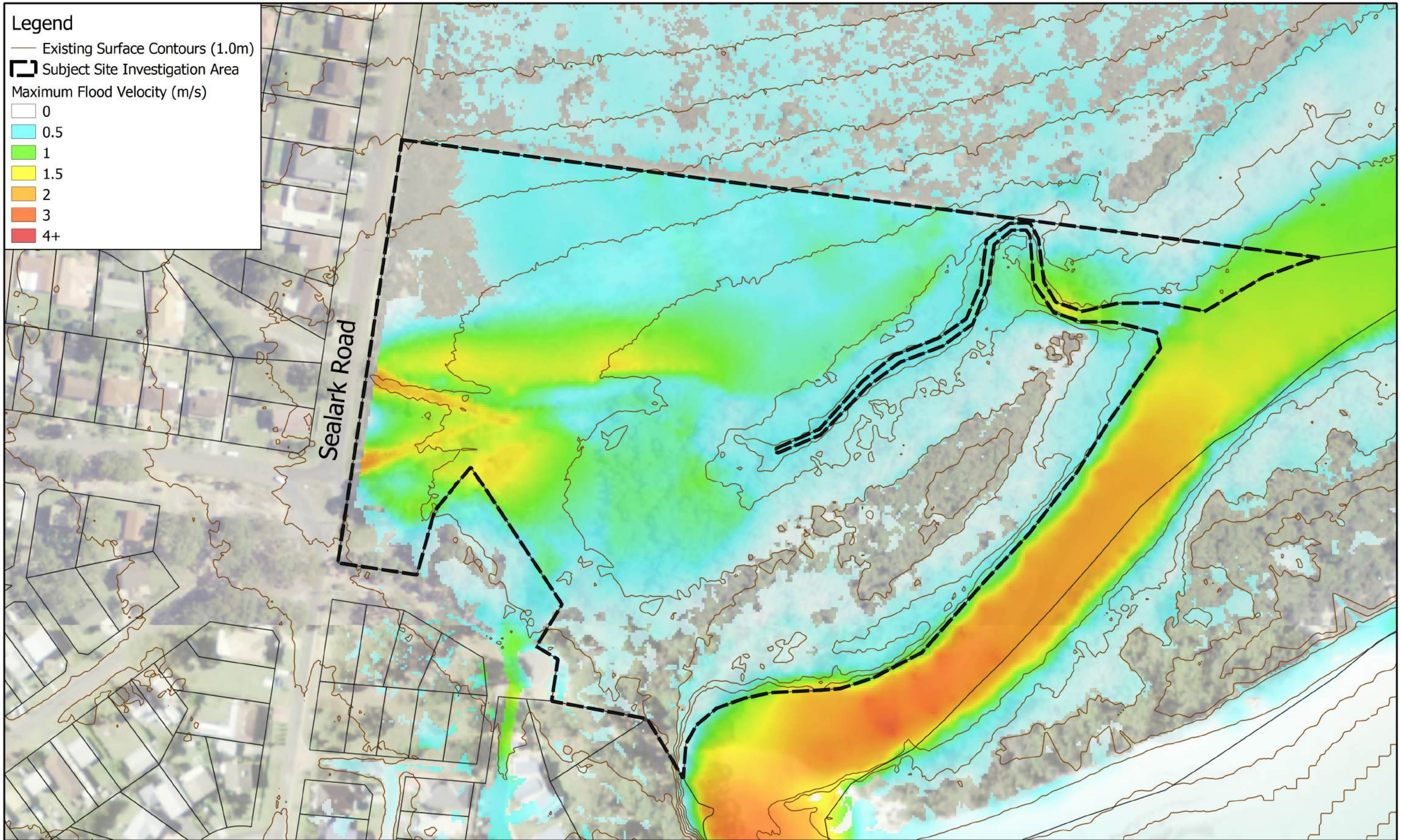

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sustainable engineering.

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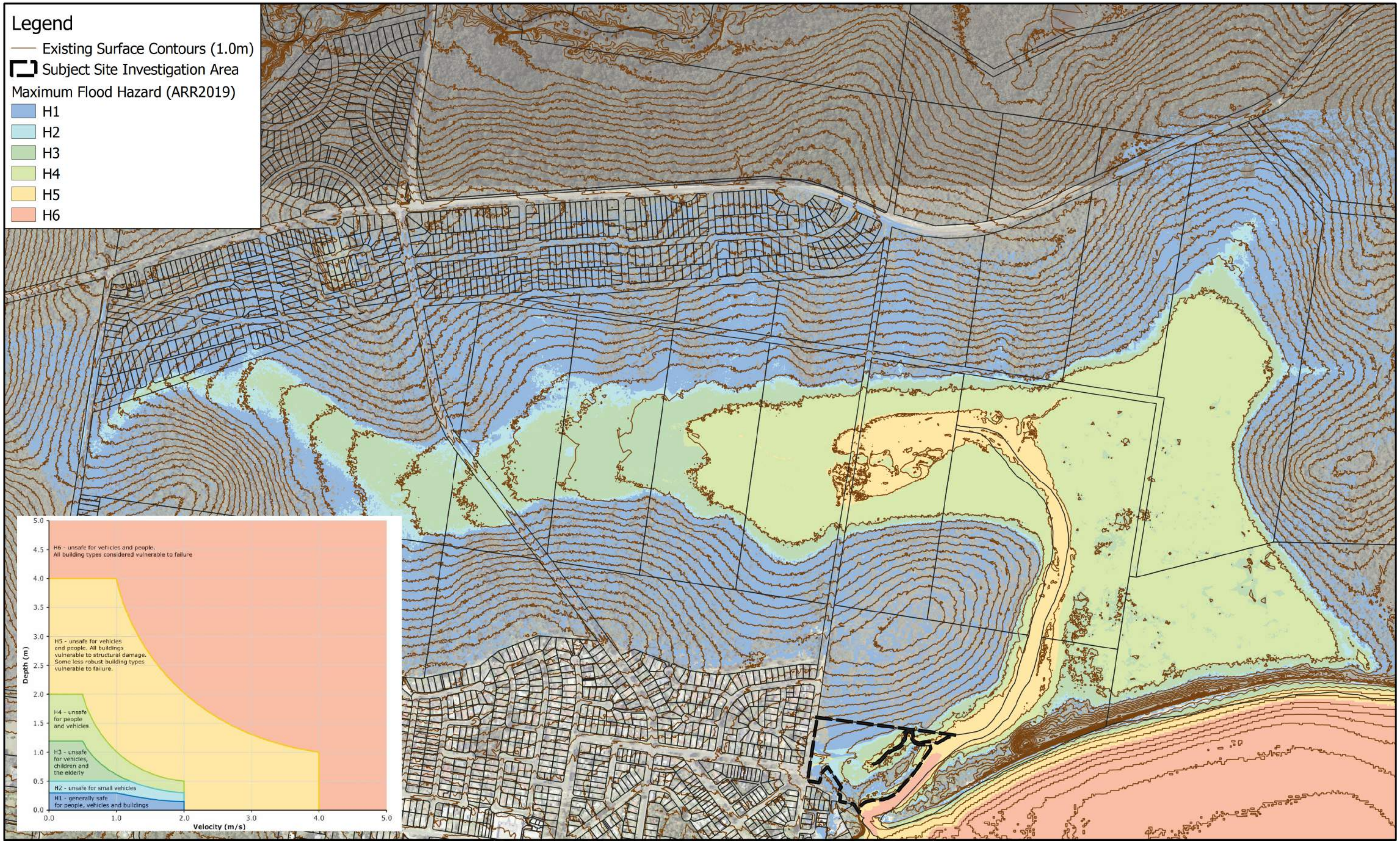
25 0 25 50 m

Scale 1:1,500 at A3

LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 2.2B
MAXIMUM FLOOD VELOCITIES
PMF

Rev 2 - 20 October 2020



footprint.
sustainable engineering.
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200 0 200 m

Scale 1:10,000 at A3

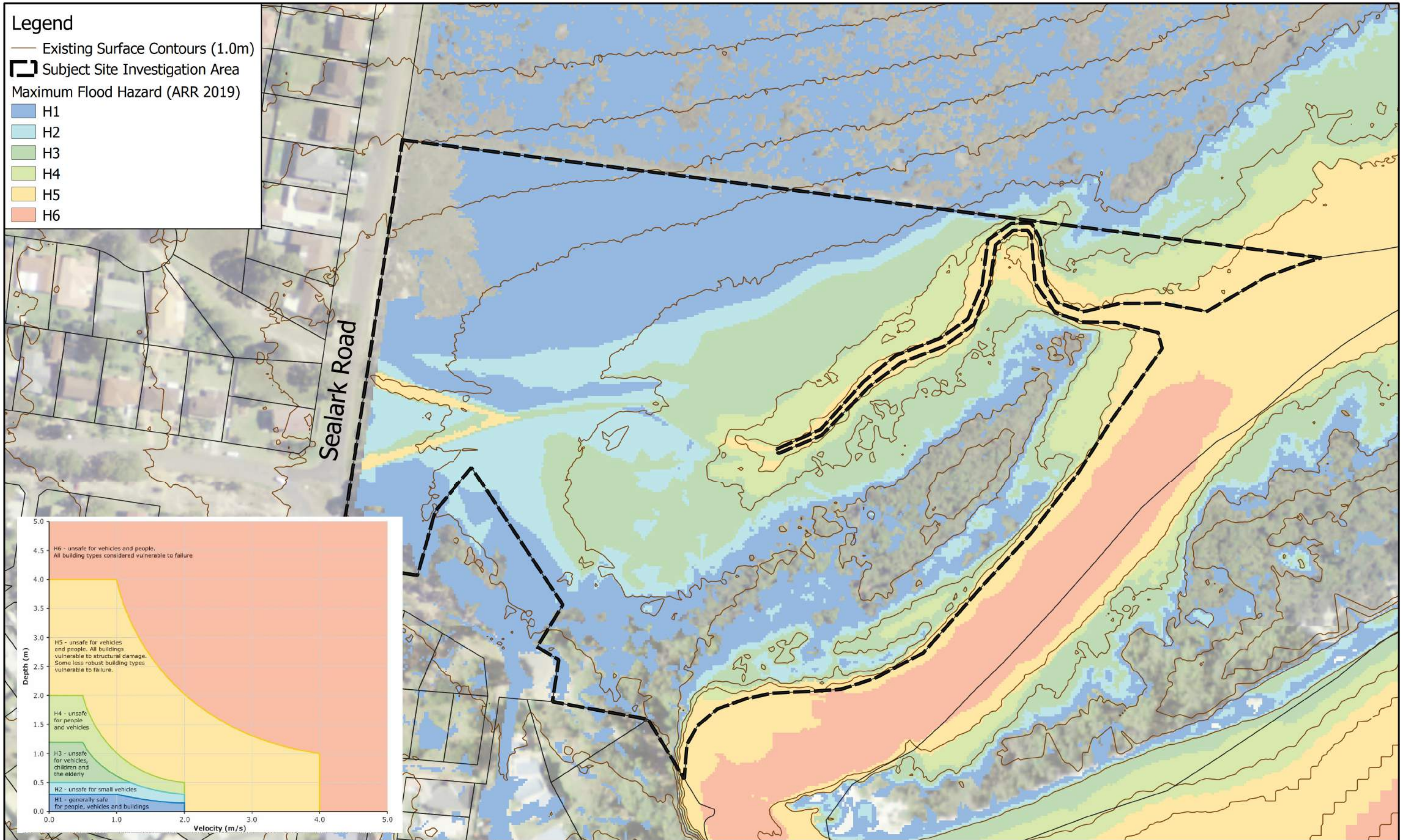
LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 2.3A

MAXIMUM FLOOD HAZARD

PMF

Rev 2 - 20 October 2020



footprint.
sustainable engineering.

15 meehan drive, kiama downs,
nsw 2533 p: (02) 4237 6770

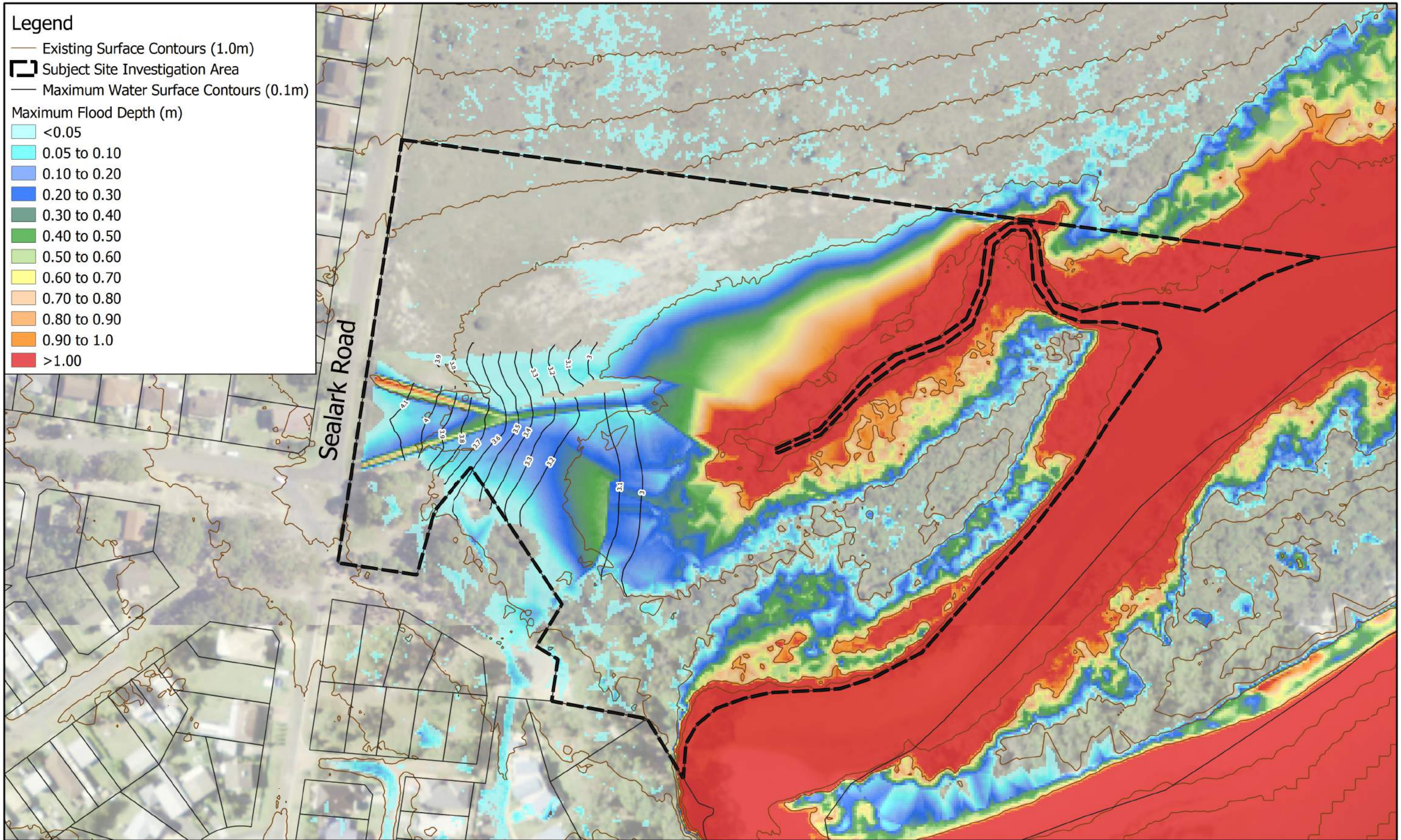
25 0 25 50 m

Scale 1:1,500 at A3

LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 2.3B
MAXIMUM FLOOD VELOCITIES
PMF

Rev 2 - 20 October 2020



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sustainable engineering.
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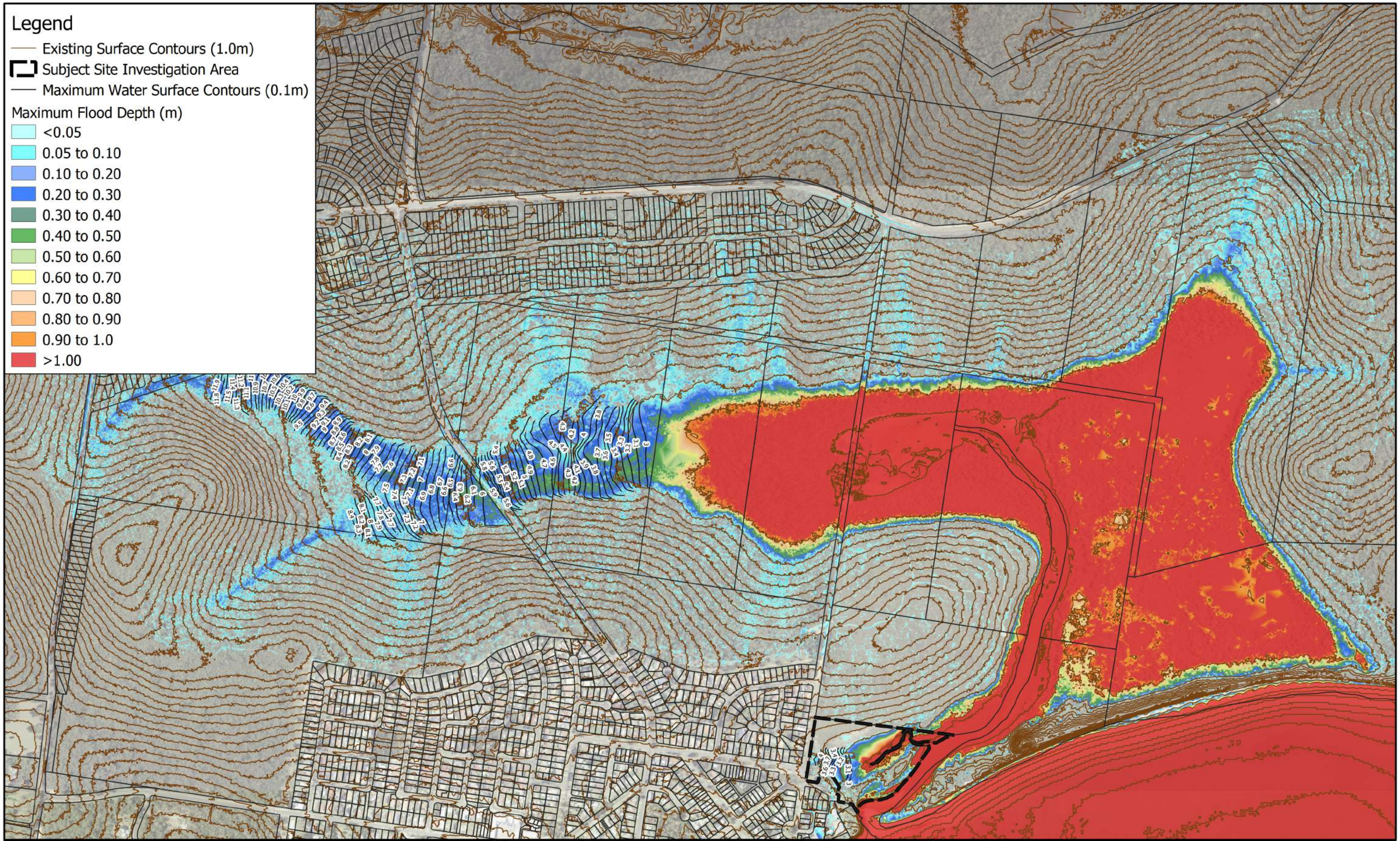
LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 3.1B
ENVELOPE OF MAXIMUM FLOOD LEVELS AND DEPTHS
1% AEP + SEA LEVEL RISE (0.36m)

Rev 2 - 20 October 2020



footprint.
sustainable engineering.
15 meehan drive, kiama downs, nsw 2533 p: (02) 4237 6770

200 0 200 m

Scale 1:10,000 at A3

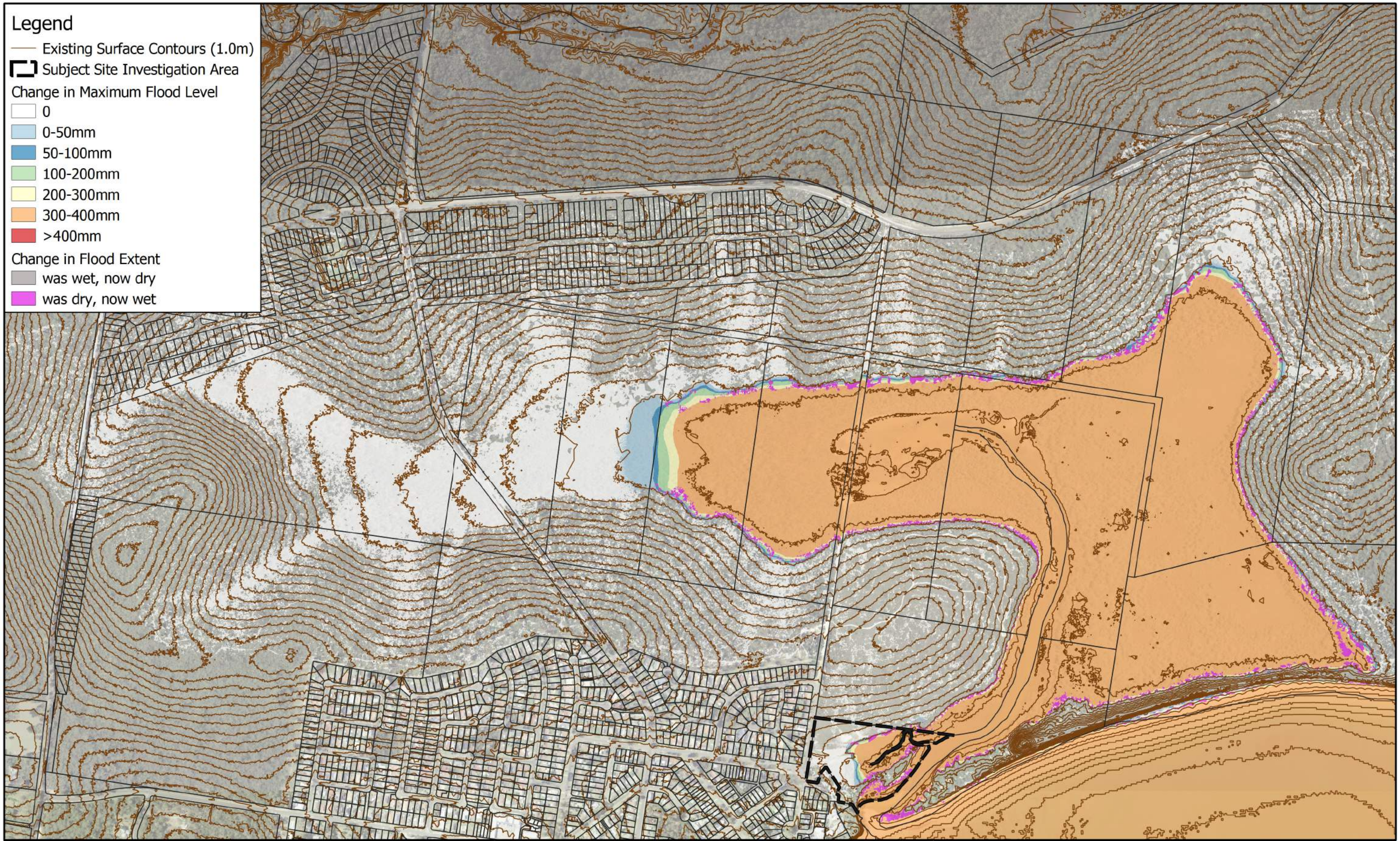
LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 3.1A

ENVELOPE OF MAXIMUM FLOOD LEVELS AND DEPTHS

1% AEP + SEA LEVEL RISE (0.36m)

Rev 2 - 20 October 2020



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sustainable engineering.
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nsw 2533 p: (02) 4237 6770

200 0 200 m

Scale 1:10,000 at A3

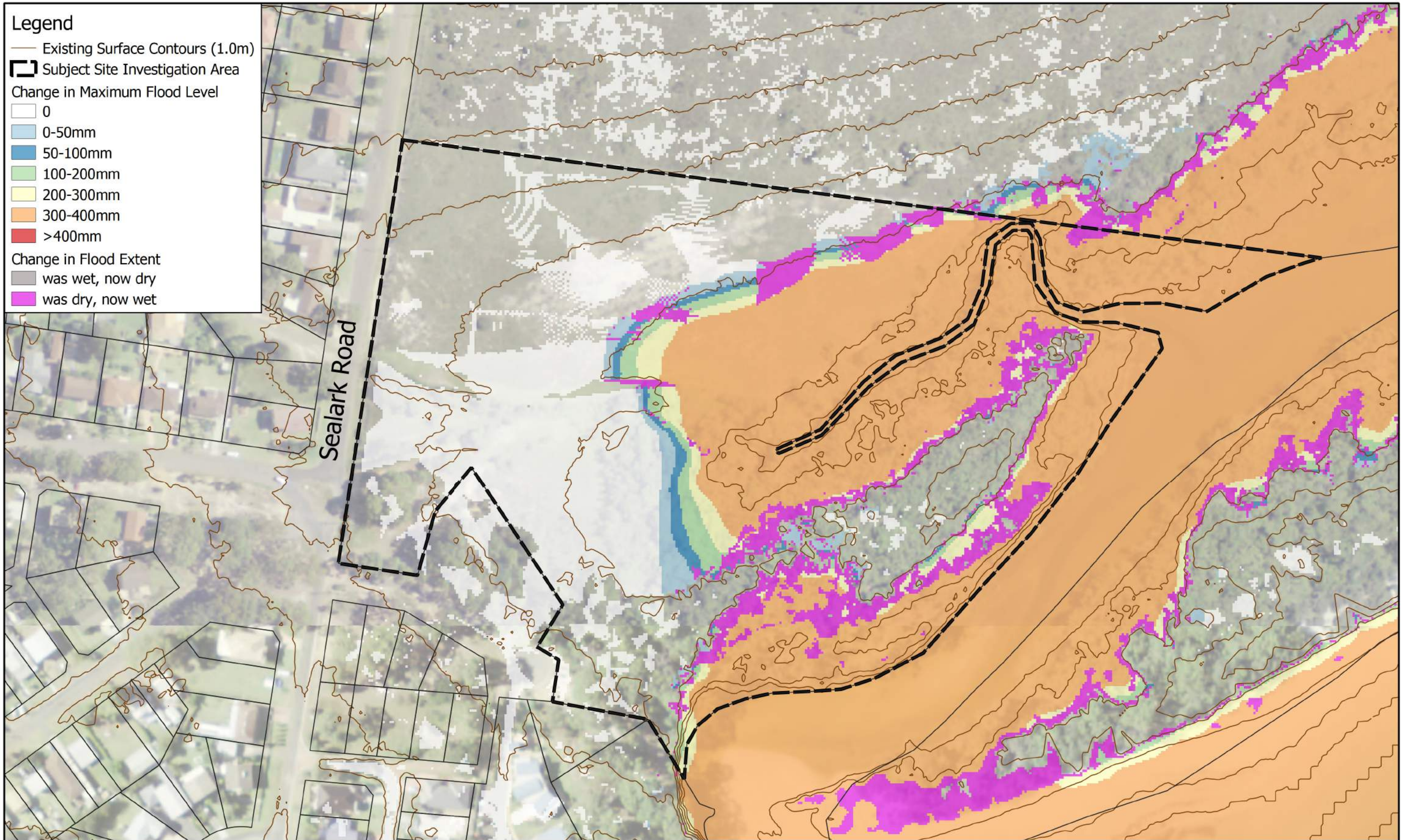
LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 3.2A

CHANGE IN MAXIMUM FLOOD LEVEL

1% AEP + SEA LEVEL RISE (0.36m)

Rev 2 - 20 October 2020



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LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 3.2B
CHANGE IN MAXIMUM FLOOD LEVEL
1% AEP + SEA LEVEL RISE (0.36m)

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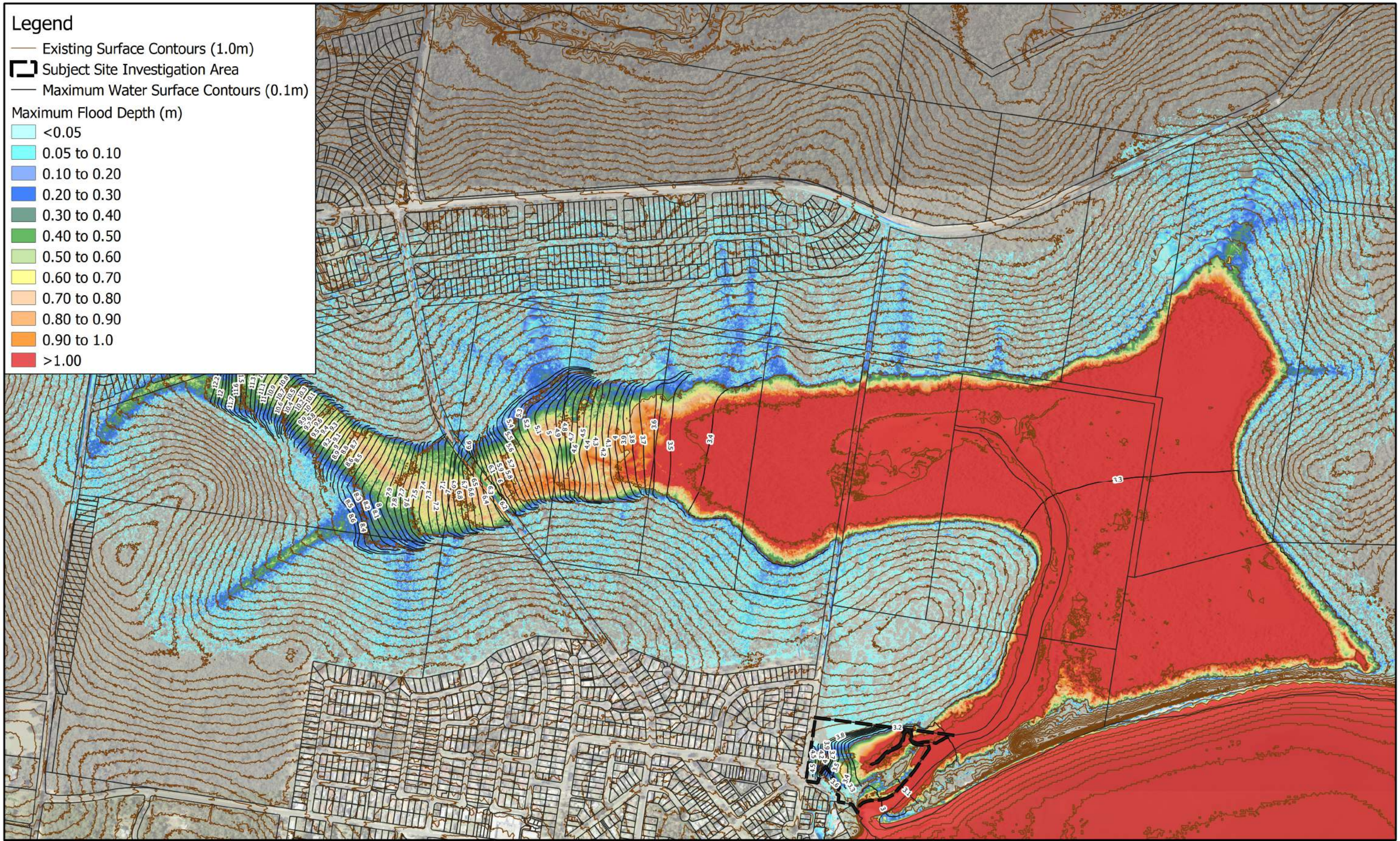

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nsw 2533 p: (02) 4237 6770

200 0 200 m

Scale 1:10,000 at A3

LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 4.1A
MAXIMUM FLOOD LEVELS AND DEPTHS
PMF + SEA LEVEL RISE (0.36m)

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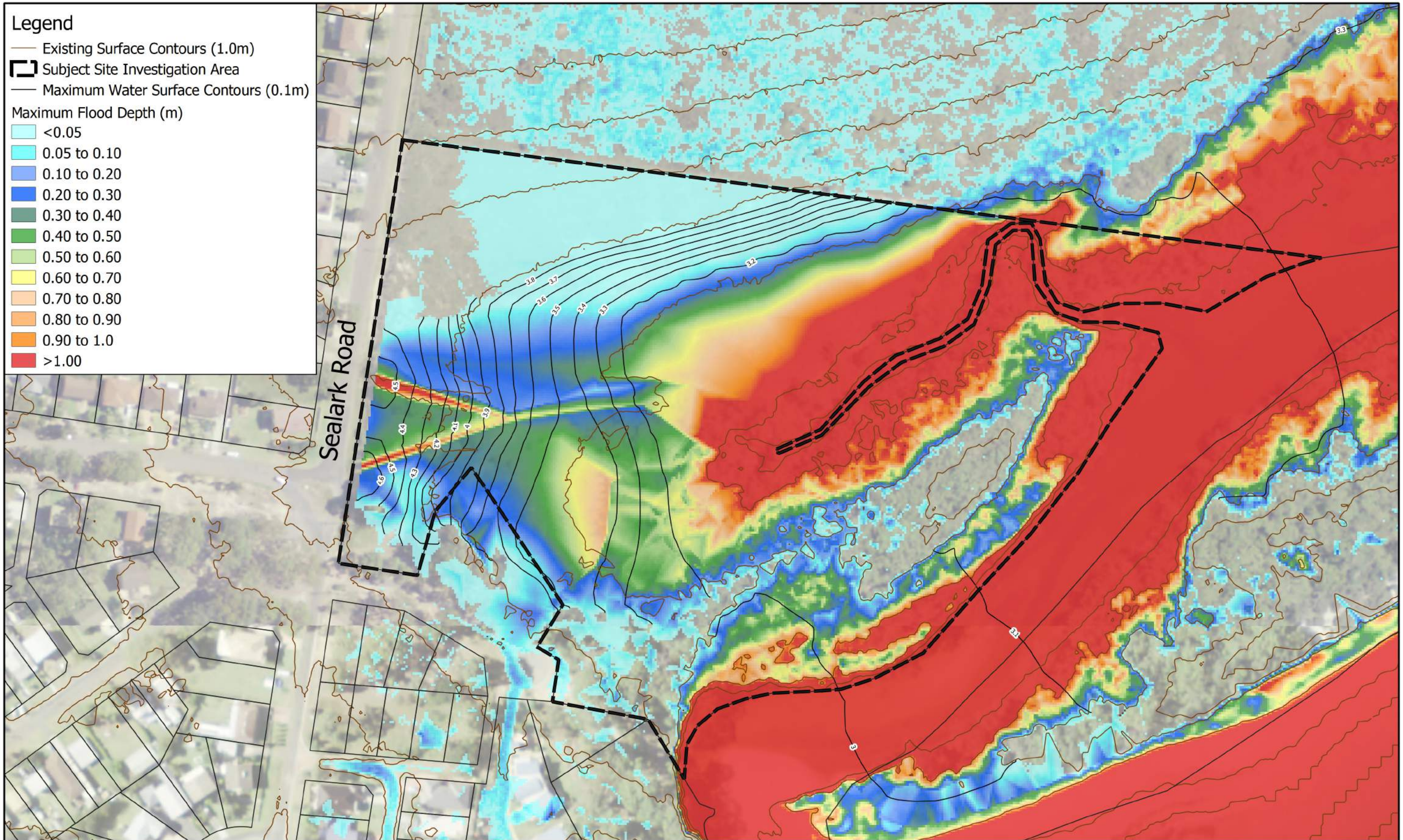

Scale 1:1,500 at A3

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LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 4.1B
MAXIMUM FLOOD LEVELS AND DEPTHS
PMF + SEA LEVEL RISE (0.36m)

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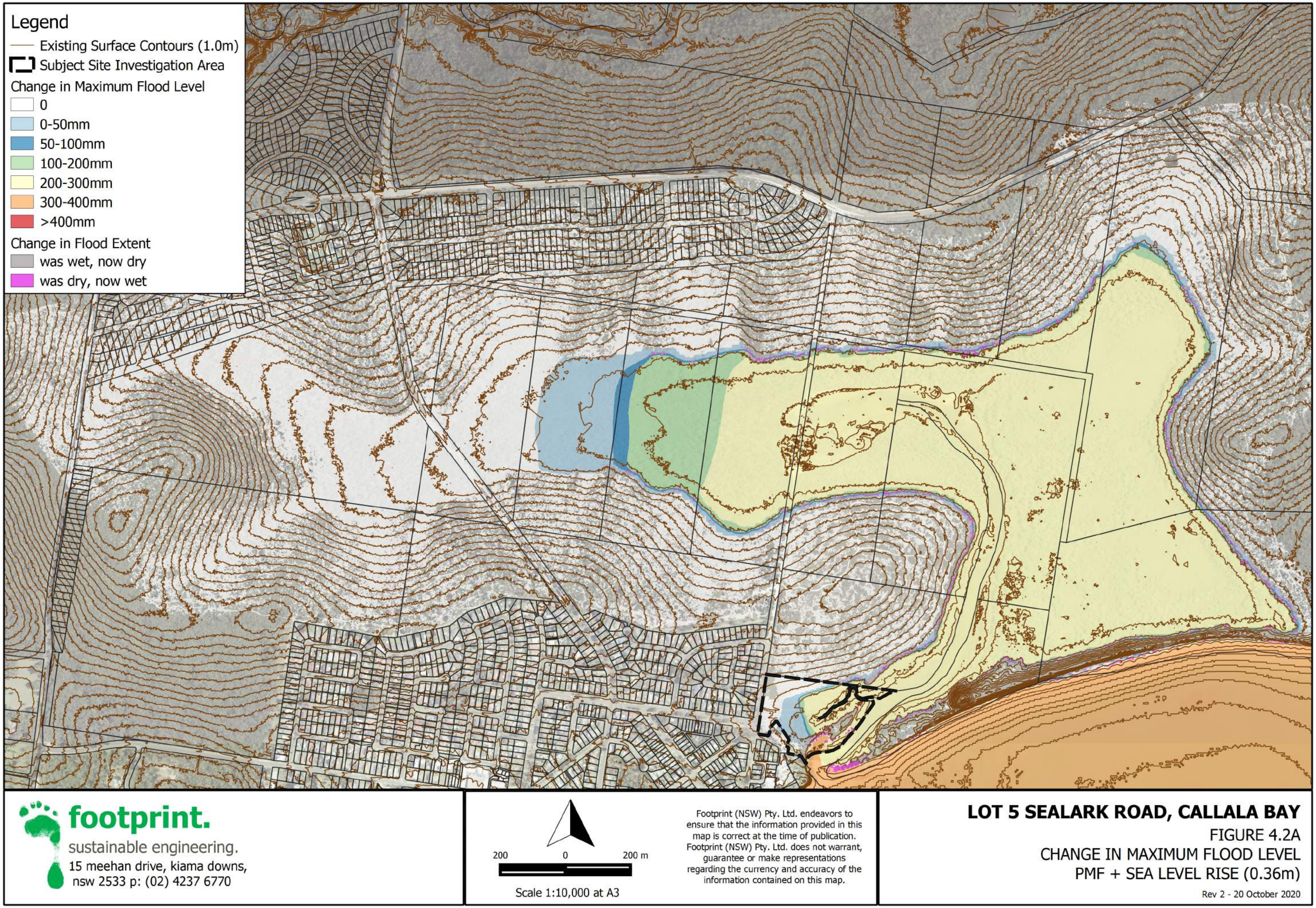

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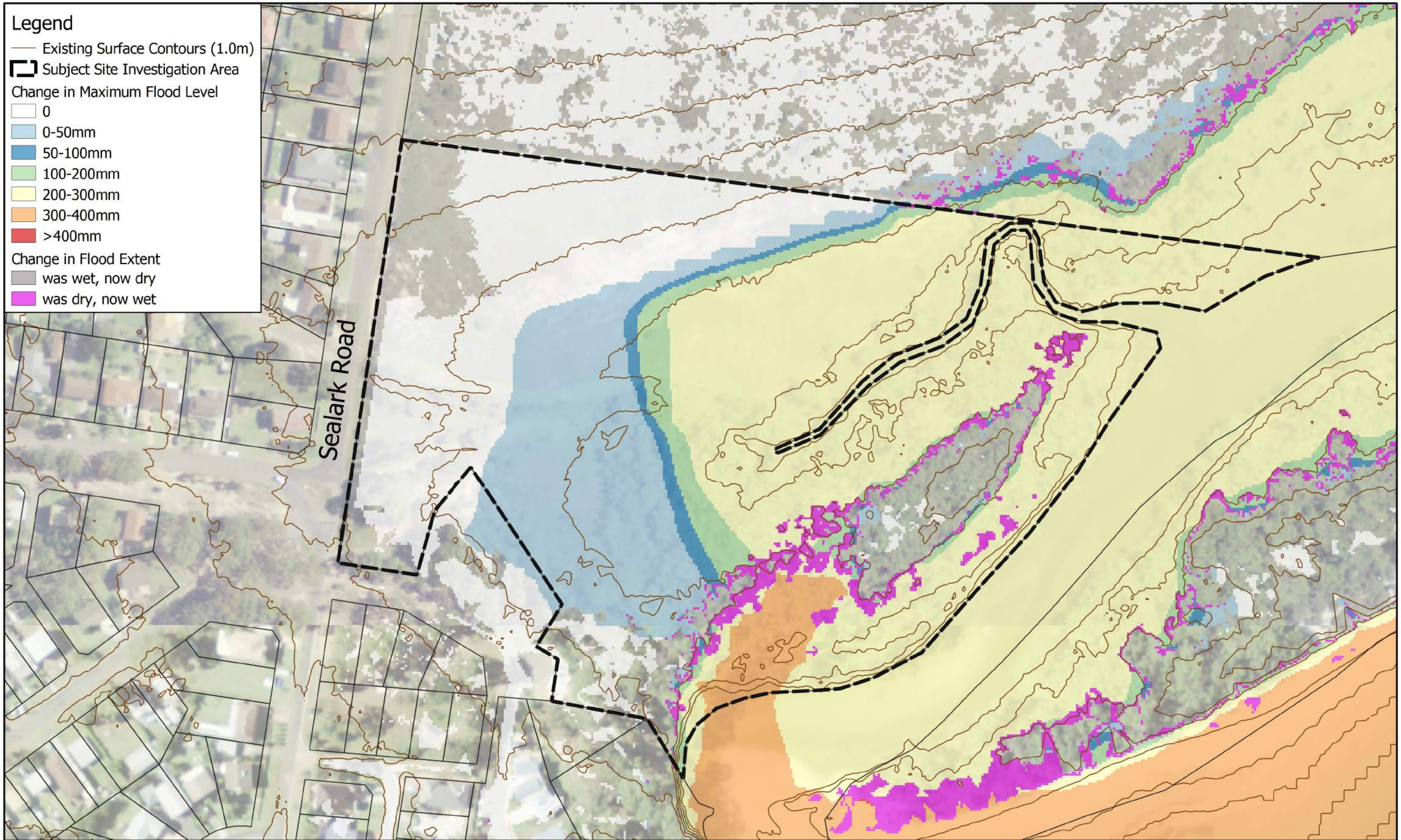
LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 4.2A

CHANGE IN MAXIMUM FLOOD LEVEL

PMF + SEA LEVEL RISE (0.36m)

Rev 2 - 20 October 2020



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LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 4.2B
CHANGE IN MAXIMUM FLOOD LEVEL
PMF + SEA LEVEL RISE (0.36m)

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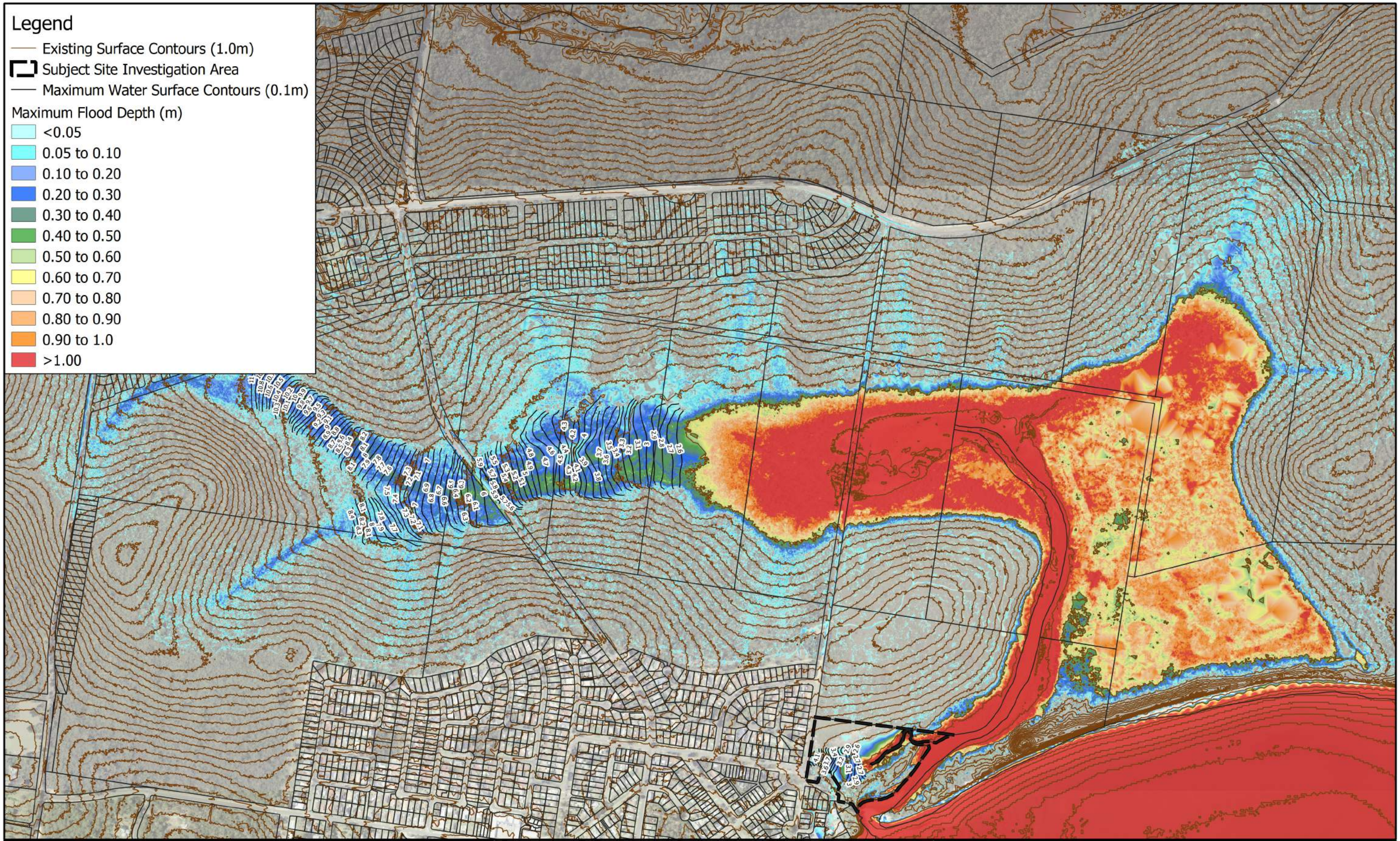

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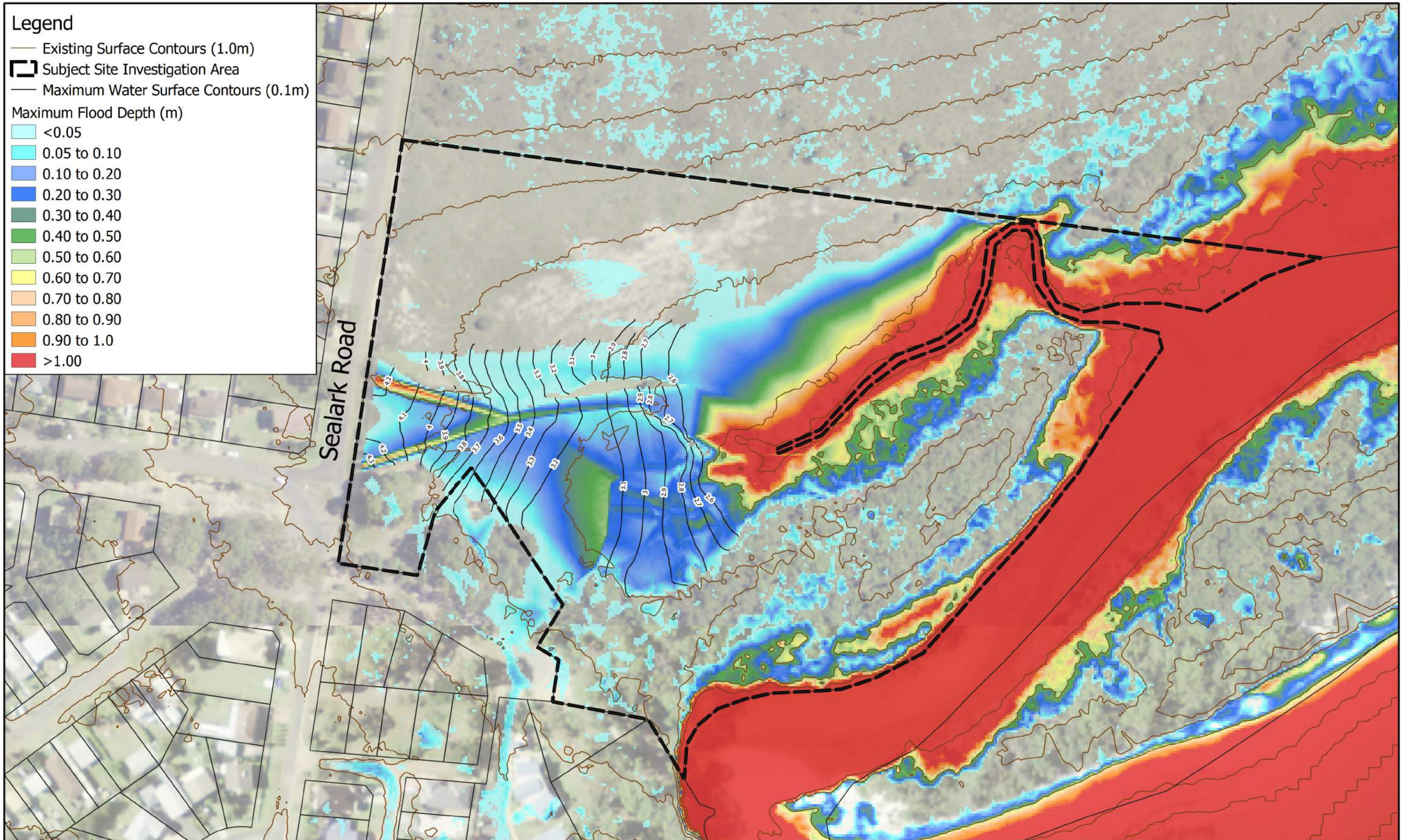
LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 5.1A

ENVELOPE OF MAXIMUM FLOOD LEVELS AND DEPTHS

1% AEP + RCP4.5 RAINFALL INCREASE

Rev 2 - 20 October 2020



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nsw 2533 p: (02) 4237 6770

25 0 25 50 m
Scale 1:1,500 at A3

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LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 5.1B
ENVELOPE OF MAXIMUM FLOOD LEVELS AND DEPTHS
1% AEP + RCP4.5 RAINFALL INCREASE

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LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 5.2A
CHANGE IN MAXIMUM FLOOD LEVEL
1% AEP + RCP4.5 RAINFALL INCREASE

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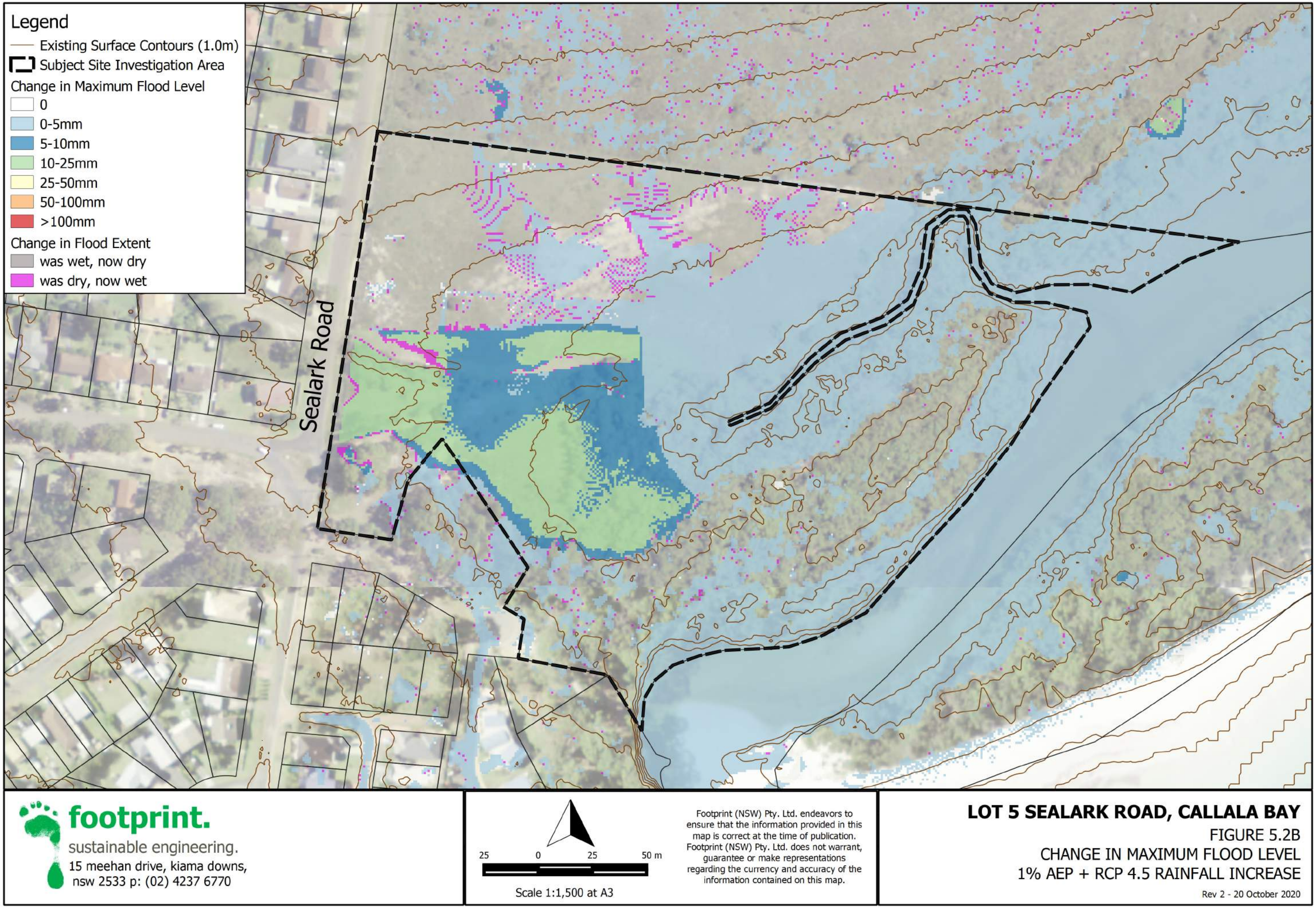

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LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 5.2B
CHANGE IN MAXIMUM FLOOD LEVEL
1% AEP + RCP 4.5 RAINFALL INCREASE

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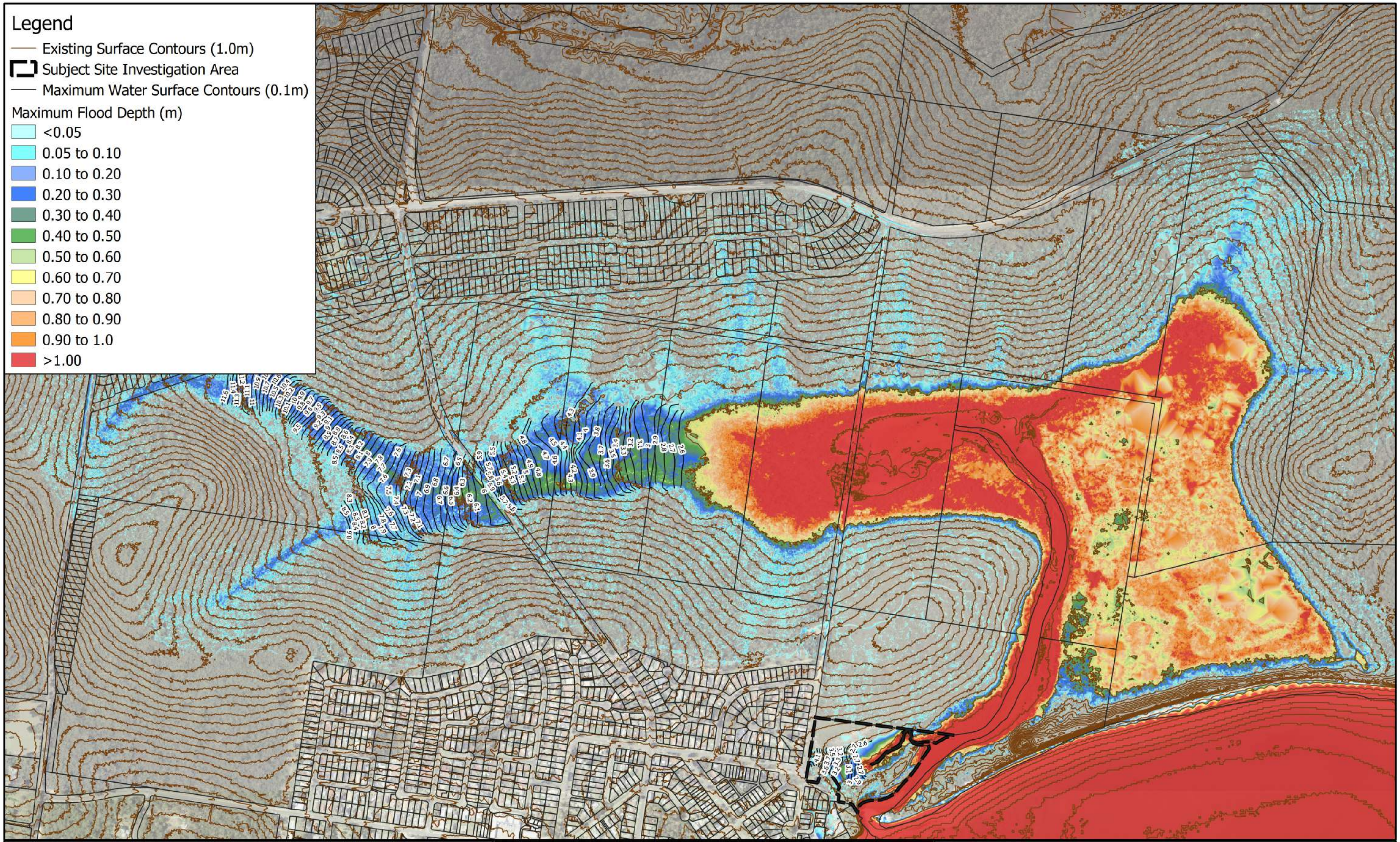

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nsw 2533 p: (02) 4237 6770

200 0 200 m

Scale 1:10,000 at A3

LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 6.1A

ENVELOPE OF MAXIMUM FLOOD LEVELS AND DEPTHS

1% AEP + RCP8.5 RAINFALL INCREASE

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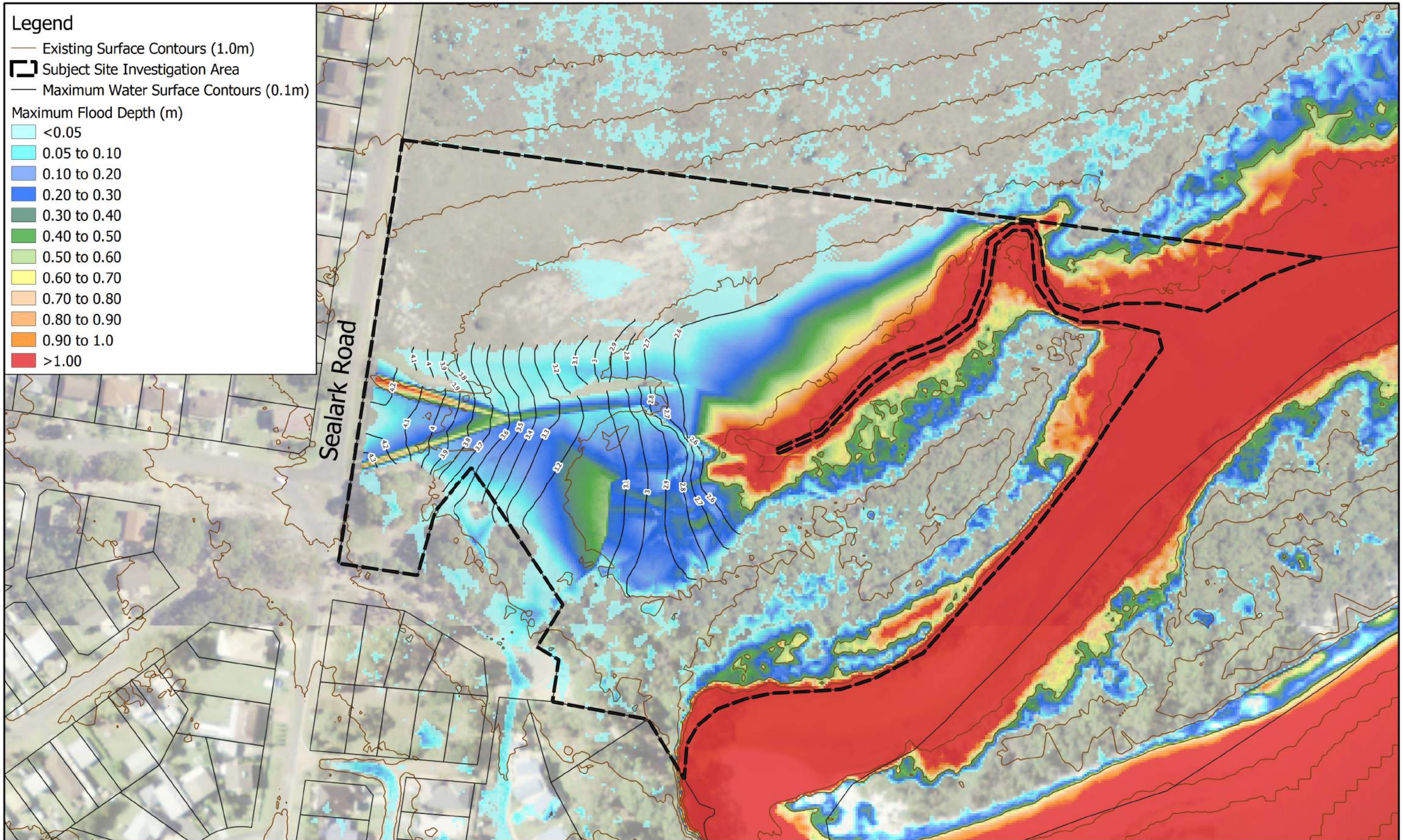

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nsw 2533 p: (02) 4237 6770

25 0 25 50 m

Scale 1:1,500 at A3

LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 6.1B

ENVELOPE OF MAXIMUM FLOOD LEVELS AND DEPTHS
1% AEP + RCP8.5 RAINFALL INCREASE

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LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 6.2A

CHANGE IN MAXIMUM FLOOD LEVEL

1% AEP + RCP8.5 RAINFALL INCREASE

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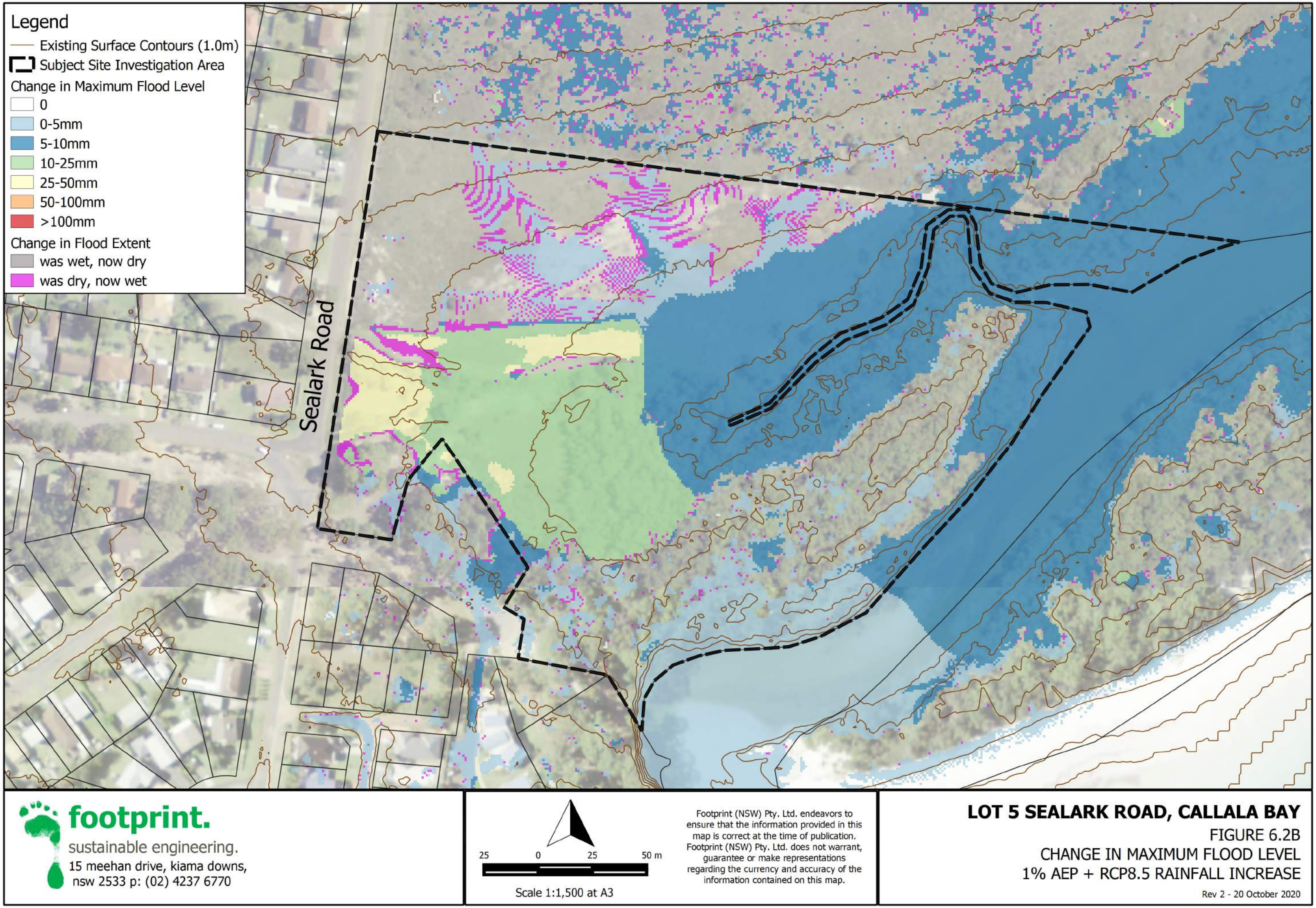

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LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 6.2B
CHANGE IN MAXIMUM FLOOD LEVEL
1% AEP + RCP8.5 RAINFALL INCREASE

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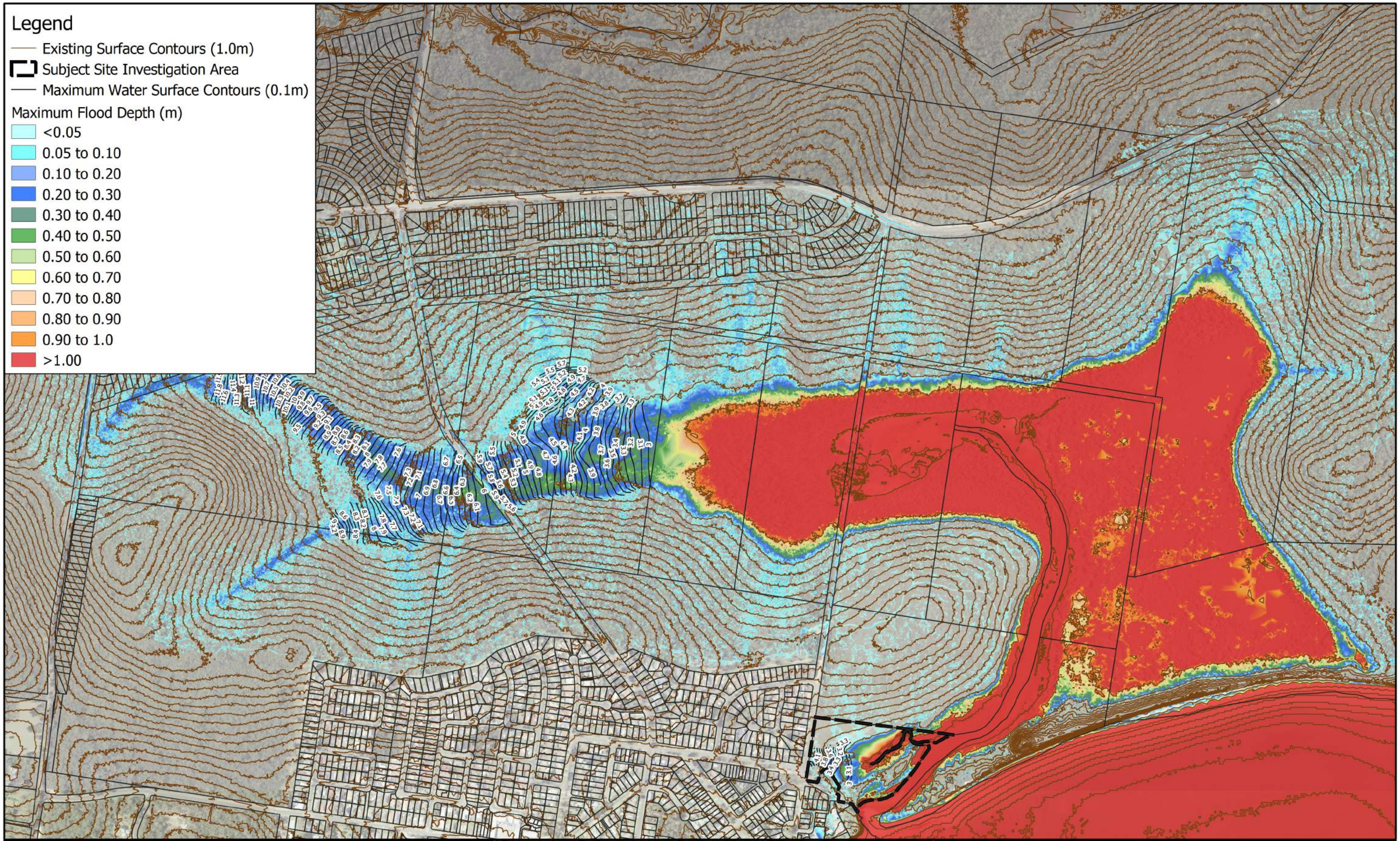

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LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 7.1A

ENVELOPE OF MAXIMUM FLOOD LEVELS AND DEPTHS
1% AEP + RCP8.5 RAINFALL INCREASE + SLR (0.36m)

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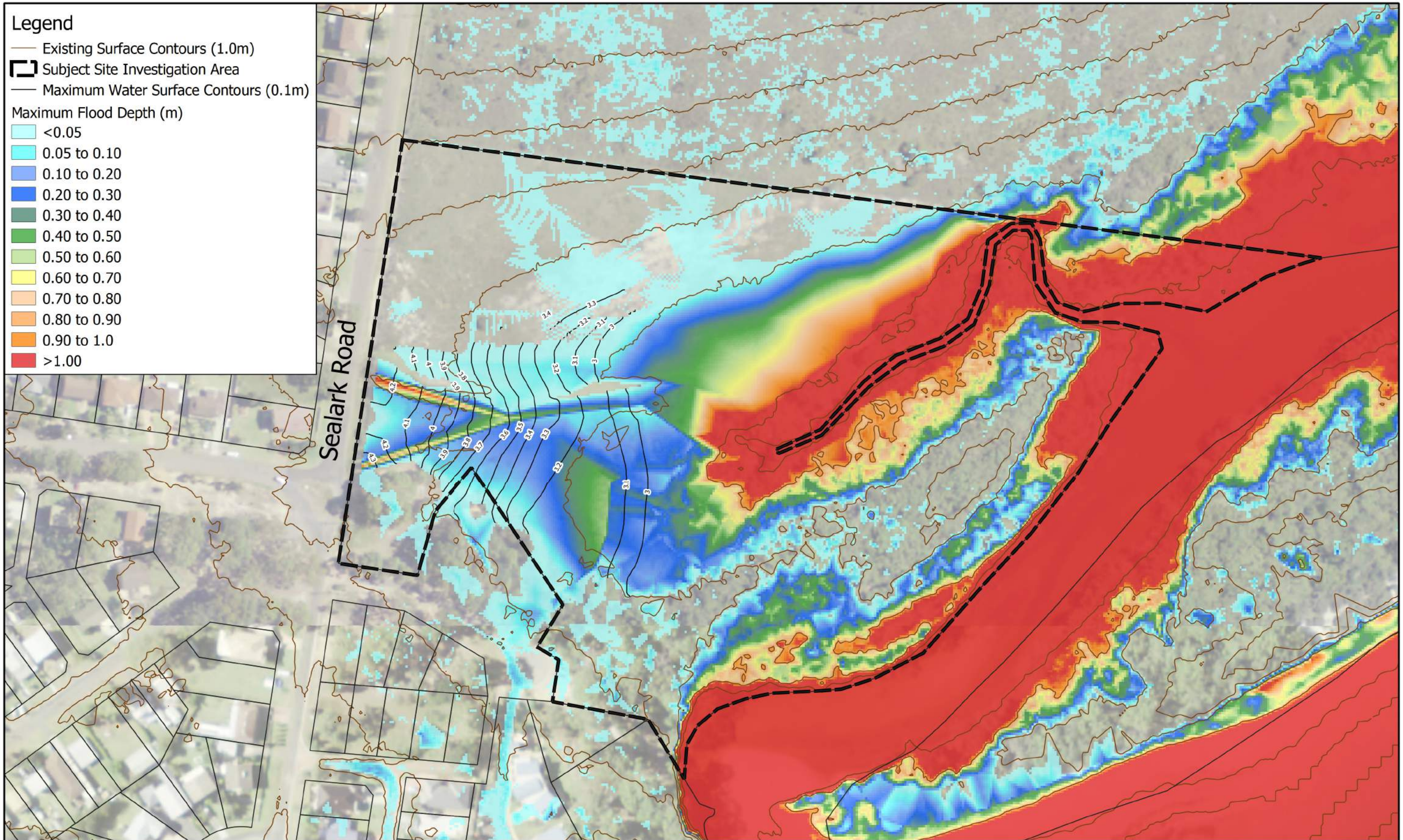

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nsw 2533 p: (02) 4237 6770

25 0 25 50 m

Scale 1:1,500 at A3

LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 7.1B
ENVELOPE OF MAXIMUM FLOOD LEVELS AND DEPTHS
1% AEP + RCP8.5 RAINFALL INCREASE + SLR (0.36m)

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15 meehan drive, kiama downs,
nsw 2533 p: (02) 4237 6770

200 0 200 m

Scale 1:10,000 at A3

LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 7.2A

ENVELOPE OF MAXIMUM FLOOD VELOCITIES

1% AEP + RCP8.5 RAINFALL INCREASE + SLR (0.36m)

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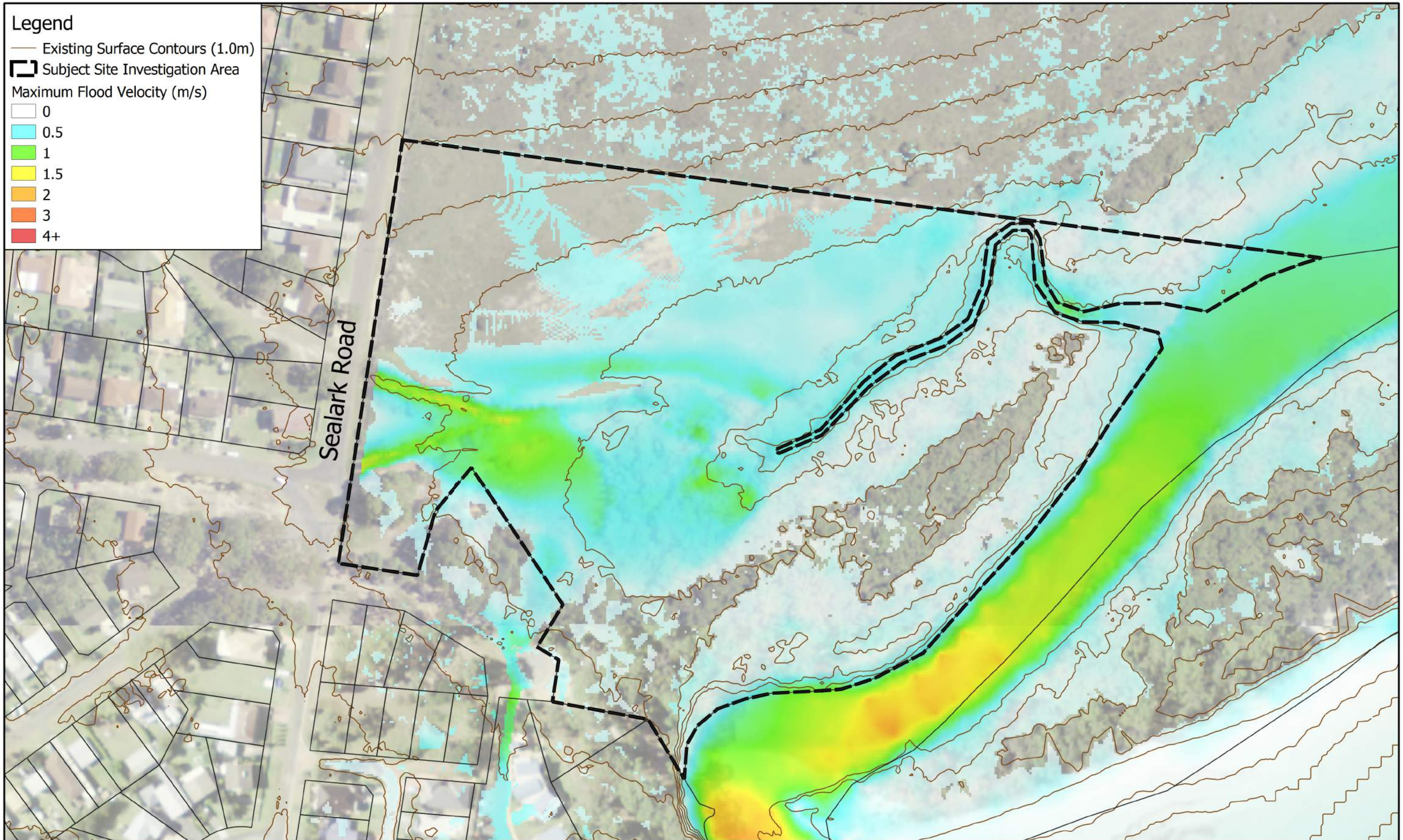

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LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 7.2B

ENVELOPE OF MAXIMUM FLOOD VELOCITIES

1% AEP + RCP8.5 RAINFALL INCREASE + SLR (0.36m)

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200 0 200 m

Scale 1:10,000 at A3

LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 7.3A

ENVELOPE OF MAXIMUM FLOOD HAZARD

1% AEP + RCP8.5 RAINFALL INCREASE + SLR (0.36m)

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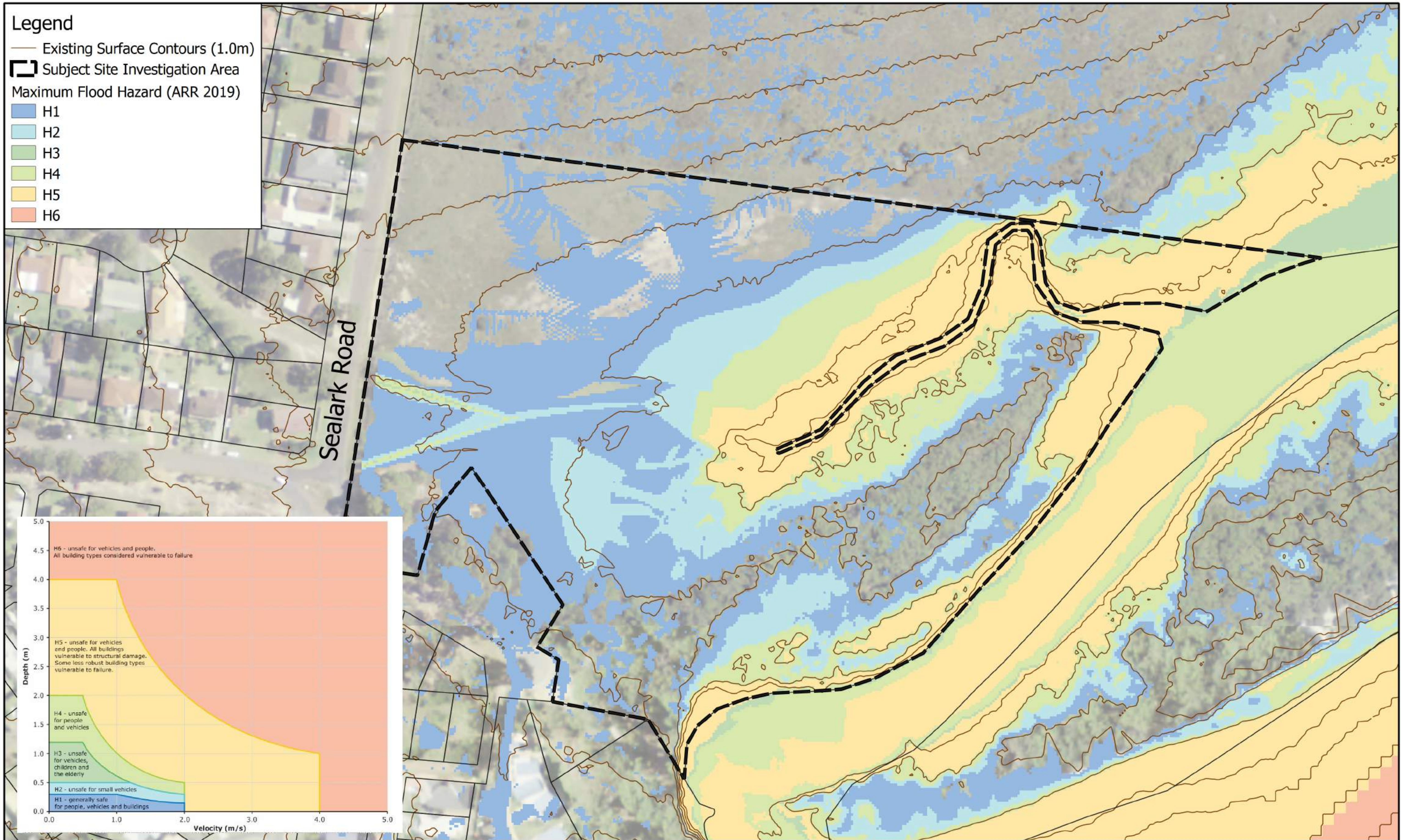

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25 0 25 50 m

Scale 1:1,500 at A3

LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 7.3B

ENVELOPE OF MAXIMUM FLOOD VELOCITIES

1% AEP + RCP8.5 RAINFALL INCREASE + SLR (0.36m)

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200 0 200 m

Scale 1:10,000 at A3

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LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 7.4A

CHANGE IN MAXIMUM FLOOD LEVEL

1% AEP + RCP8.5 RAINFALL INCREASE + SLR (0.36m)

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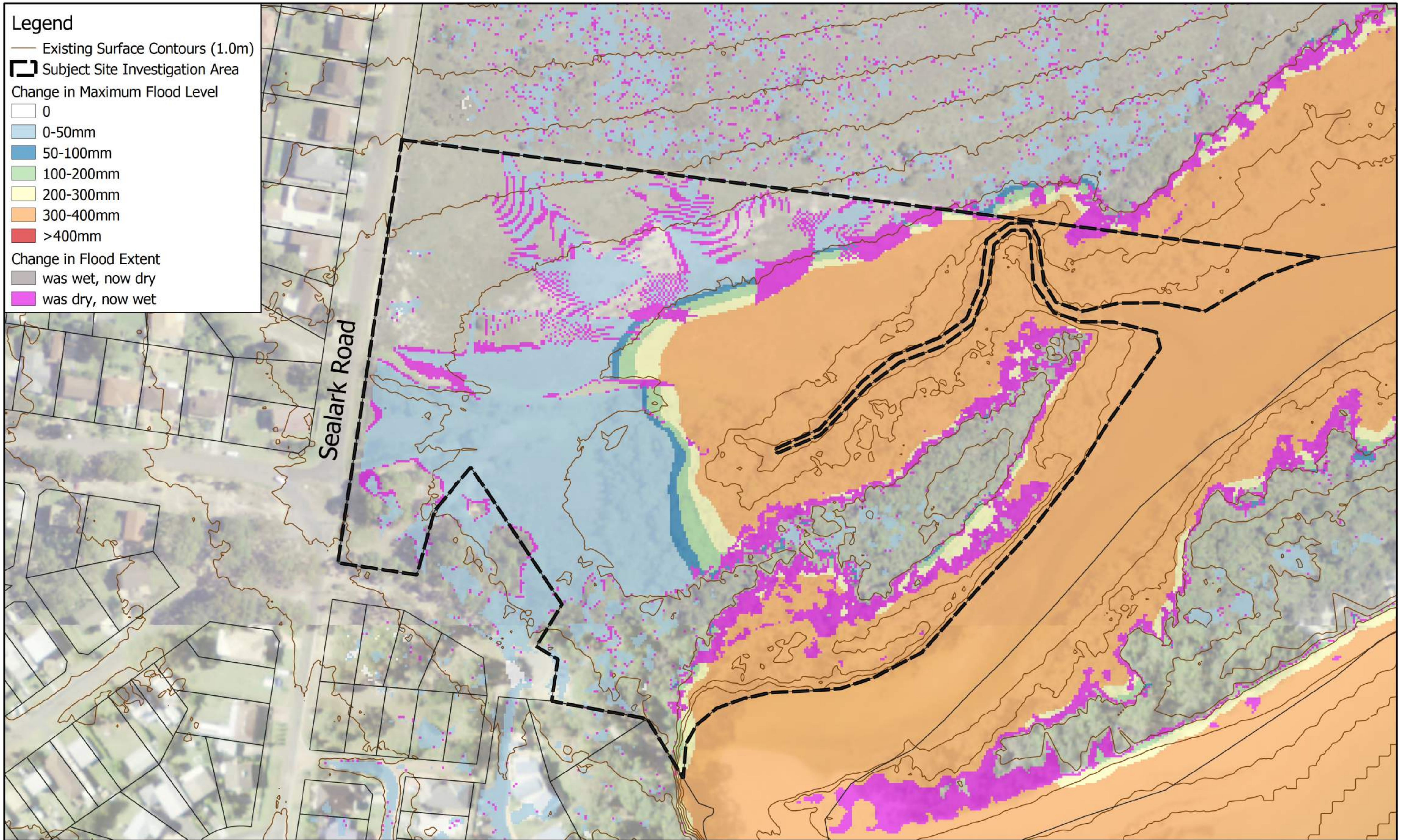

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25 0 25 50 m

Scale 1:1,500 at A3

LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 7.4B

CHANGE IN MAXIMUM FLOOD LEVEL

1% AEP + RCP8.5 RAINFALL INCREASE + SLR (0.36m)

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APPENDIX H

Preliminary Civil Design Drawings

LOT 5 SEALARK ROAD, CALLALA BAY
PLANNING PROPOSAL

PRELIMINARY CIVIL DESIGN DRAWINGS

LOCALITY PLAN
NOT TO SCALE

SHEET INDEX

DRAWING No.	DESCRIPTION
1861–C01	TITLE SHEET
1861–C02	GENERAL ARRANGEMENT PLAN
1861–C03	PRELIMINARY EARTHWORKS PLAN
1861–C04	ROAD LONGITUDINAL SECTION & CROSS SECTIONS – SHEET 1 OF 2
1861–C05	ROAD CROSS SECTIONS SHEET 2 OF 2
1861–C06	PRELIMINARY STORMWATER MANAGEMENT PLAN
1861–C07	WATER QUALITY PRE AND POST DEVELOPMENT LAND USE PLAN

ISSUE	DESCRIPTION	DATE
3	RE–ISSUED FOR PLANNING PROPOSAL	22/11/21
2	RE–ISSUED FOR PLANNING PROPOSAL	18/10/21
1	FOR PLANNING PROPOSAL	30/10/20

FOR PLANNING PROPOSAL
NOT FOR CONSTRUCTION

FOOTPRINT (NSW) PTY. LTD. AUTHORISE THE USE OF THIS DRAWING ONLY FOR THE PURPOSE DEMONSTRATED BY THE STATUS STAMP SHOWN ABOVE.

SCALES	ORIGINAL
N.T.S	A3

CLIENT: HARE BAY CONSORTIA

SURVEYOR:	ALLEN PRICE
DATUM:	AHD
AZIMUTH:	GDA 94, MGA56
DRAWN:	AB
DESIGNED:	AB
DESIGNED DATE:	OCT '20
CHECKED:	AB

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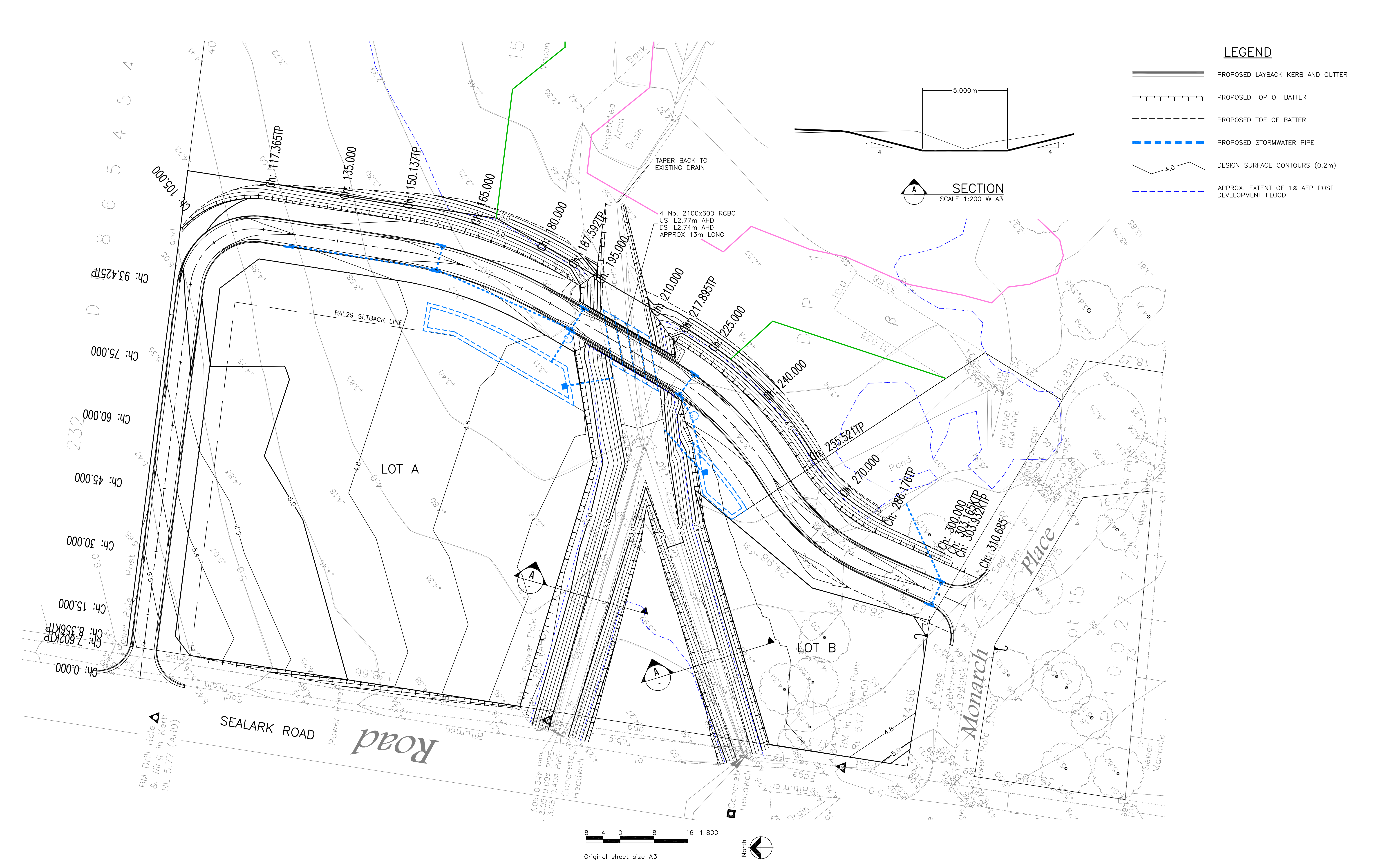
sustainable engineering
a. 15 meehan drive
kiama downs nsw 2533
p. 02 4237 6770
f. 02 4237 8962

LOT 5 SEALARK ROAD, CALLALA BAY
PLANNING PROPOSAL
PRELIMINARY CIVIL DESIGN
TITLE SHEET

DRAWING NO. 1861-C01
ISSUE. 3
SHEET 1 OF 7



ISSUE	DESCRIPTION	DATE
3	RE-ISSUED FOR PLANNING PROPOSAL	22/11/21
2	RE-ISSUED FOR PLANNING PROPOSAL	22/11/21
1	FOR PLANNING PROPOSAL	22/10/20

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SCALES	ORIGINAL
1:800	A3

CLIENT: HARE BAY CONSORTIA

SURVEYOR:	ALLEN PRICE
DATUM:	AHD
AZIMUTH:	GDA 94, MGA56
DRAWN:	AB
DESIGNED:	AB
DESIGNED DATE:	OCT '20
CHECKED:	AB

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f. 02 4237 8962

LOT 5 SEALARK ROAD, CALLALA BAY

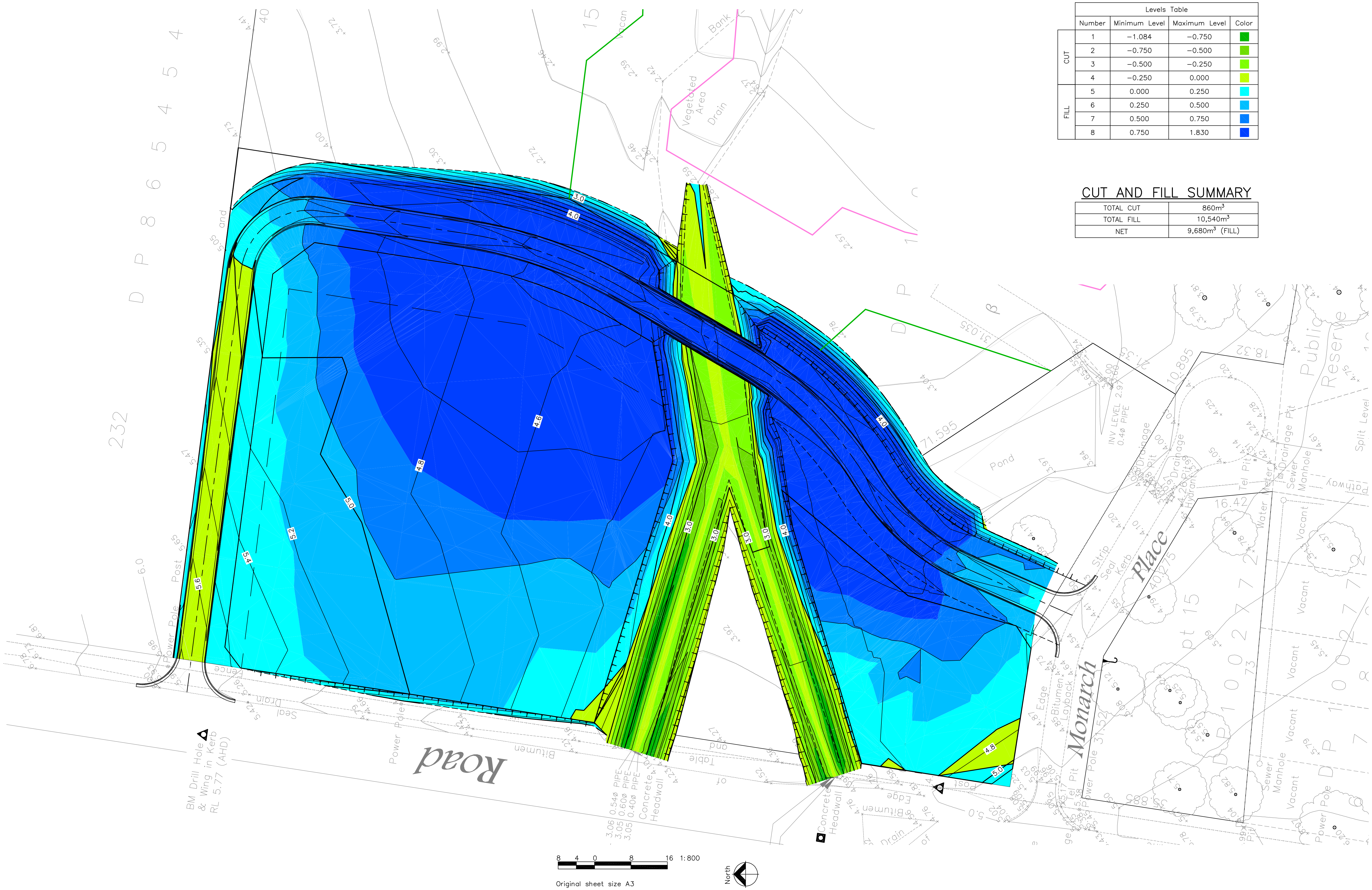
PLANNING PROPOSAL
PRELIMINARY CIVIL DESIGN
STORMWATER MANAGEMENT PLAN

DRAWING NO. 1861-C06
ISSUE. 3
SHEET 6 OF

Levels Table				
	Number	Minimum Level	Maximum Level	Color
CUT	1	−1.084	−0.750	
	2	−0.750	−0.500	
	3	−0.500	−0.250	
	4	−0.250	0.000	
FILL	5	0.000	0.250	
	6	0.250	0.500	
	7	0.500	0.750	
	8	0.750	1.830	

CUT AND FILL SUMMARY

TOTAL CUT	860m³
TOTAL FILL	10,540m³
NET	9,680m³ (FILL)



ISSUE	DESCRIPTION	DATE
3	RE-ISSUED FOR PLANNING PROPOSAL	22/11/21
2	RE-ISSUED FOR PLANNING PROPOSAL	22/11/21
1	FOR PLANNING PROPOSAL	30/10/20

FOR PLANNING PROPOSAL

NOT FOR CONSTRUCTION

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SCALES	ORIGINAL
1:800	A3

CLIENT: HARE BAY CONSORTIA

SURVEYOR:	ALLEN PRICE
DATUM:	AHD
AZIMUTH:	GDA 94, MGA56
DRAWN:	AB
DESIGNED:	AB
DESIGNED DATE:	OCT '20
CHECKED:	AB

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p. 02 4237 6770
f. 02 4237 8962

LOT 5 SEALARK ROAD, CALLALA BAY

PLANNING PROPOSAL

PRELIMINARY EARTHWORKS PLAN

GENERAL ARRANGEMENT PLAN

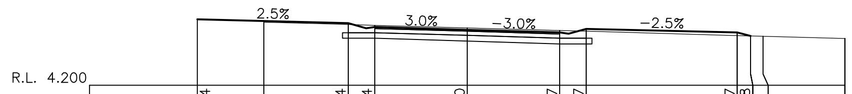
DRAWING NO. 1861-C03

ISSUE. 3

Chainage	Design Levels	Existing Levels
0.000	5.820	5.820
7.602	5.744	5.806
8.356	5.737	5.797
15.000	5.670	5.720
30.000	5.520	5.545
45.000	5.370	5.394
60.000	5.220	5.274
71.554	5.105	5.218
75.000	5.072	5.200
79.054	5.039	5.158
86.554	4.992	5.060
90.000	4.975	5.014
93.425	4.958	4.969
105.000	4.900	4.678
117.365	4.838	4.240
120.000	4.825	4.154
135.000	4.750	3.674
150.000	4.675	3.342
150.137	4.674	3.339
165.000	4.600	3.059
180.000	4.525	2.957
187.592	4.487	2.909
195.000	4.450	3.019
209.225	4.521	2.824
210.000	4.525	2.890
213.743	4.506	3.134
225.000	4.450	3.011
240.000	4.525	3.161
255.000	4.600	3.377
255.521	4.603	3.386
270.000	4.675	3.523
276.952	4.710	3.725
285.000	4.670	4.163
286.176	4.664	4.180
300.000	4.595	4.344
303.165	4.579	4.386
303.932	4.575	4.391
310.685	4.541	4.541

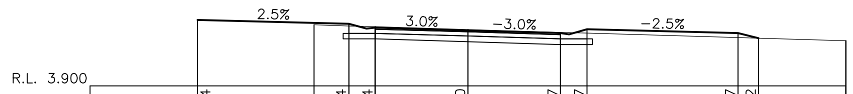
ROAD LONGITUDINAL SECTION

SCALES H 1:1000
V 1:100



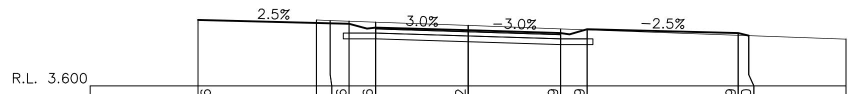
Offset	Design Surface	Existing Surface
−7.150	5.944	
−5.384		5.873
−3.150	5.844	5.810
−2.450	5.744	5.790
0.000	5.670	5.720
2.450	5.597	5.651
3.150	5.697	5.631
7.150	5.597	5.518
7.505	5.508	5.508
7.828		5.499
10.000		5.436

Ch 15.000



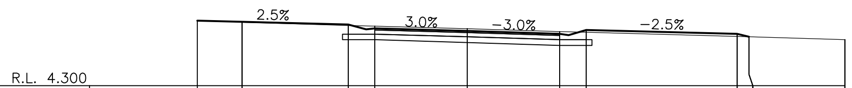
Offset	Design Surface	Existing Surface
−7.150	5.644	
−4.066		5.517
−3.150	5.544	5.490
−2.450	5.444	5.468
0.000	5.370	5.394
2.450	5.297	5.320
3.150	5.397	5.299
7.150	5.297	5.178
7.689	5.162	5.162
10.000		5.092

Ch 45.000



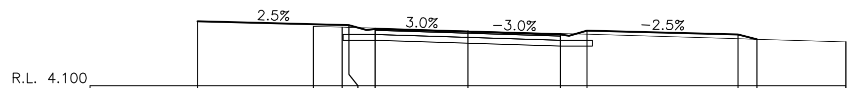
Offset	Design Surface	Existing Surface
−7.150	5.346	
−4.018		5.345
−3.653		5.333
−3.150	5.246	5.315
−2.450	5.146	5.289
0.000	5.072	5.200
2.450	4.999	5.111
3.150	5.099	5.085
7.150	4.999	4.940
7.426	4.930	4.930
10.000		4.836

Ch 75.000



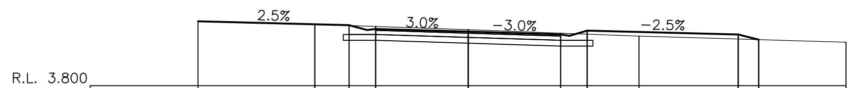
Offset	Design Surface	Existing Surface
−7.150	6.010	
−5.958		5.966
−3.150	5.910	5.886
−2.450	5.810	5.866
0.000	5.737	5.797
2.450	5.663	5.728
3.150	5.763	5.708
7.150	5.663	5.595
7.459	5.586	5.586
10.000		5.514

Ch 8.356



Offset	Design Surface	Existing Surface
−7.150	5.794	
−4.086		5.663
−3.322		5.641
−3.150	5.694	5.636
−2.450	5.594	5.616
0.000	5.520	5.545
2.450	5.447	5.474
3.150	5.547	5.453
7.150	5.447	5.337
7.647	5.322	5.322
10.000		5.254

Ch 30.000



Offset	Design Surface	Existing Surface
−7.150	5.494	
−4.059		5.421
−3.150	5.394	5.388
−2.450	5.294	5.363
0.000	5.220	5.274
2.450	5.147	5.184
3.150	5.247	5.159
4.525		5.109
7.150	5.147	5.029
7.684	5.013	5.013
10.000		4.943

Ch 60.000

ISSUE	DESCRIPTION	DATE
3	RE-ISSUED FOR PLANNING PROPOSAL	22/11/21
2	RE-ISSUED FOR PLANNING PROPOSAL	22/11/21
1	FOR PLANNING PROPOSAL	30/10/20

FOR PLANNING PROPOSAL
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SCALES	ORIGINAL
1:200 NAT	A3

CLIENT: HARE BAY CONSORTIA

SURVEYOR:	ALLEN PRICE
DATUM:	AHD
AZIMUTH:	GDA 94, MGA56
DRAWN:	AB
DESIGNED:	AB
DESIGNED DATE:	OCT '20
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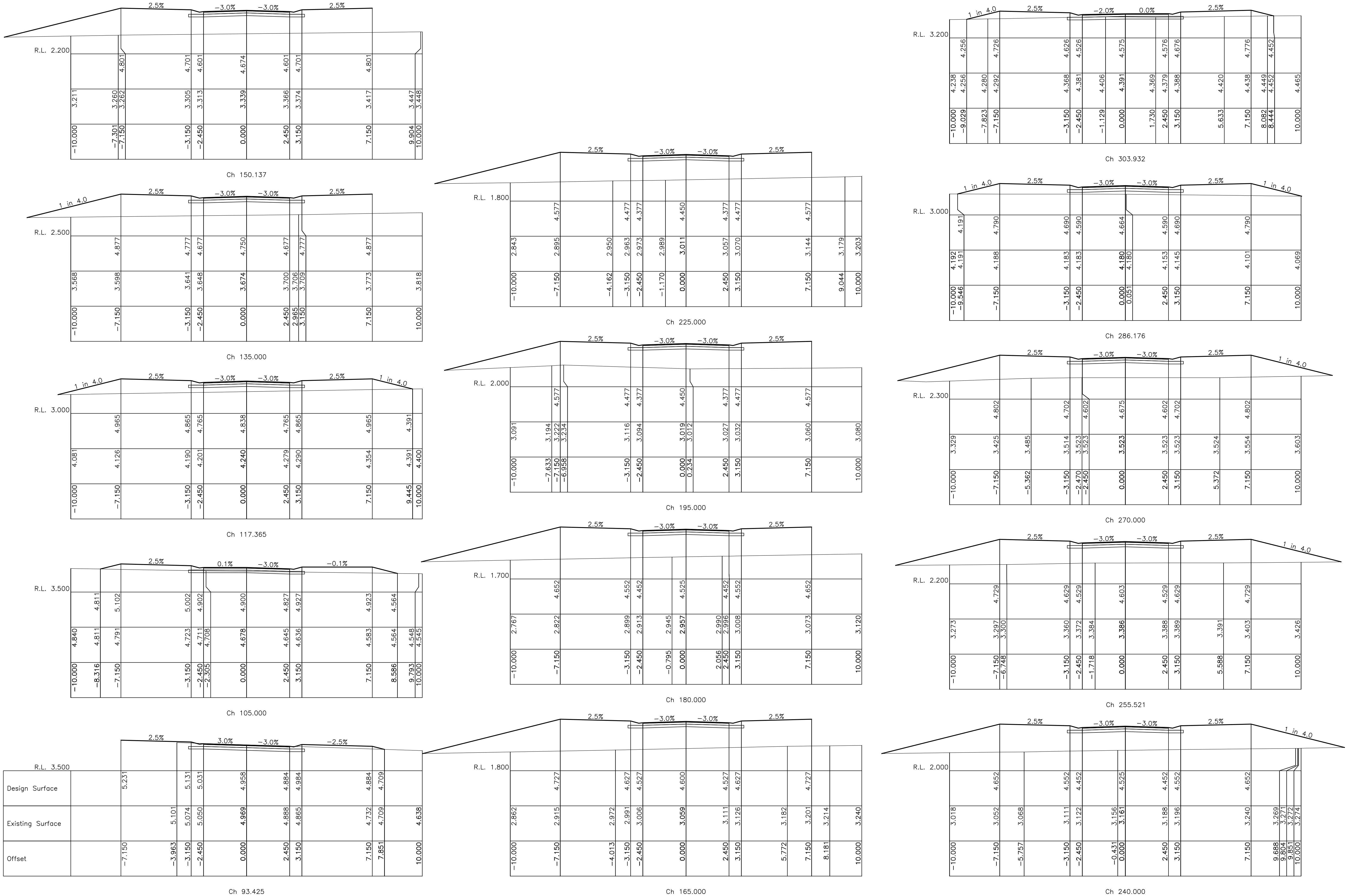
LOT 5 SEALARK ROAD, CALLALA BAY

PLANNING PROPOSAL
PRELIMINARY CIVIL DESIGN
ROAD LONGITUDINAL SECTION & CROSS SECTIONS - SHEET 1 OF 2

DRAWING NO. 1861-C04
ISSUE. 3



ISSUE	DESCRIPTION	DATE
3	RE-ISSUED FOR PLANNING PROPOSAL	22/11/21
2	RE-ISSUED FOR PLANNING PROPOSAL	22/11/21
1	FOR PLANNING PROPOSAL	30/10/20

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SCALES	ORIGINAL
1:200 NAT	A3

CLIENT: HARE BAY CONSORTIA

SURVEYOR:	ALLEN PRICE
DATUM:	AHD
AZIMUTH:	GDA 94, MGA56
DRAWN:	AB
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DESIGNED DATE:	OCT '20
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LOT 5 SEALARK ROAD, CALLALA BAY

PLANNING PROPOSAL

PRELIMINARY CIVIL DESIGN

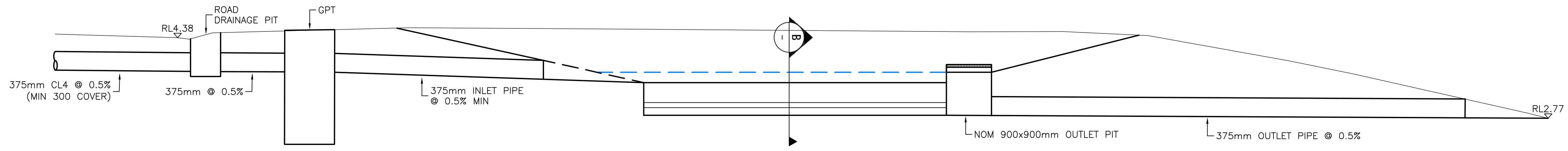
ROAD CROSS SECTIONS - SHEET 2 OF 2

DRAWING NO. 1861-C05

ISSUE. 3

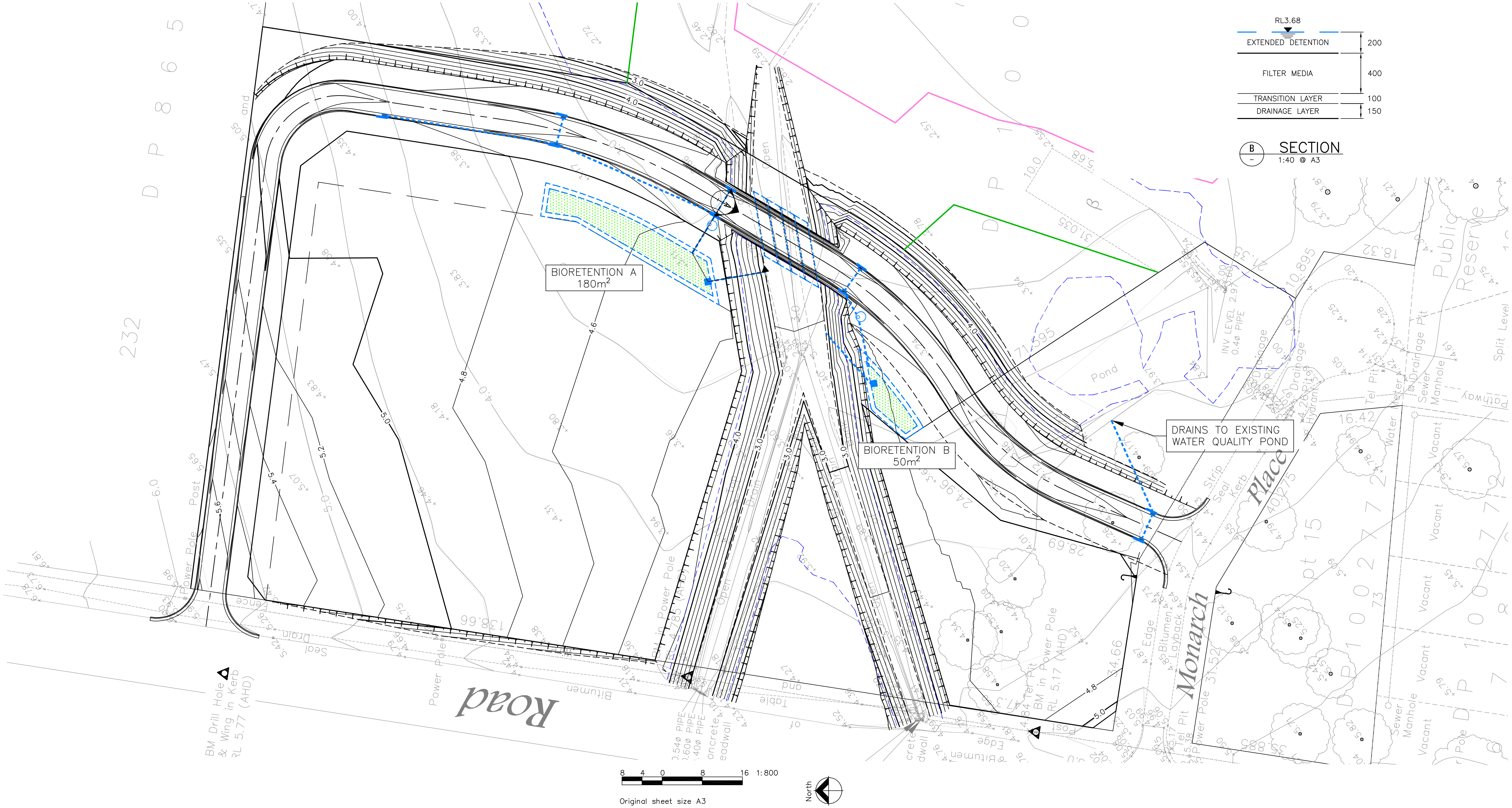
LEGEND

- PROPOSED BIORETENTION BASIN
- PROPOSED TOP OF BATTER
- PROPOSED TOE OF BATTER
- PROPOSED STORMWATER PIPE
- DESIGN SURFACE CONTOURS (0.2m)
- APPROX. EXTENT OF 1% AEP POST DEVELOPMENT FLOOD



A SECTION
1:100 @ A3

B SECTION
1:40 @ A3



ISSUE	DESCRIPTION	DATE
3	RE-ISSUED FOR PLANNING PROPOSAL	22/11/21
2	RE-ISSUED FOR PLANNING PROPOSAL	22/11/21
1	FOR PLANNING PROPOSAL	30/10/20

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SCALES	ORIGINAL
1:800	A3

CLIENT: HARE BAY CONSORTIA

SURVEYOR:	ALLEN PRICE
DATUM:	AHD
AZIMUTH:	GDA 94, MGA56
DRAWN:	AB
DESIGNED:	AB
DESIGNED DATE:	OCT '20
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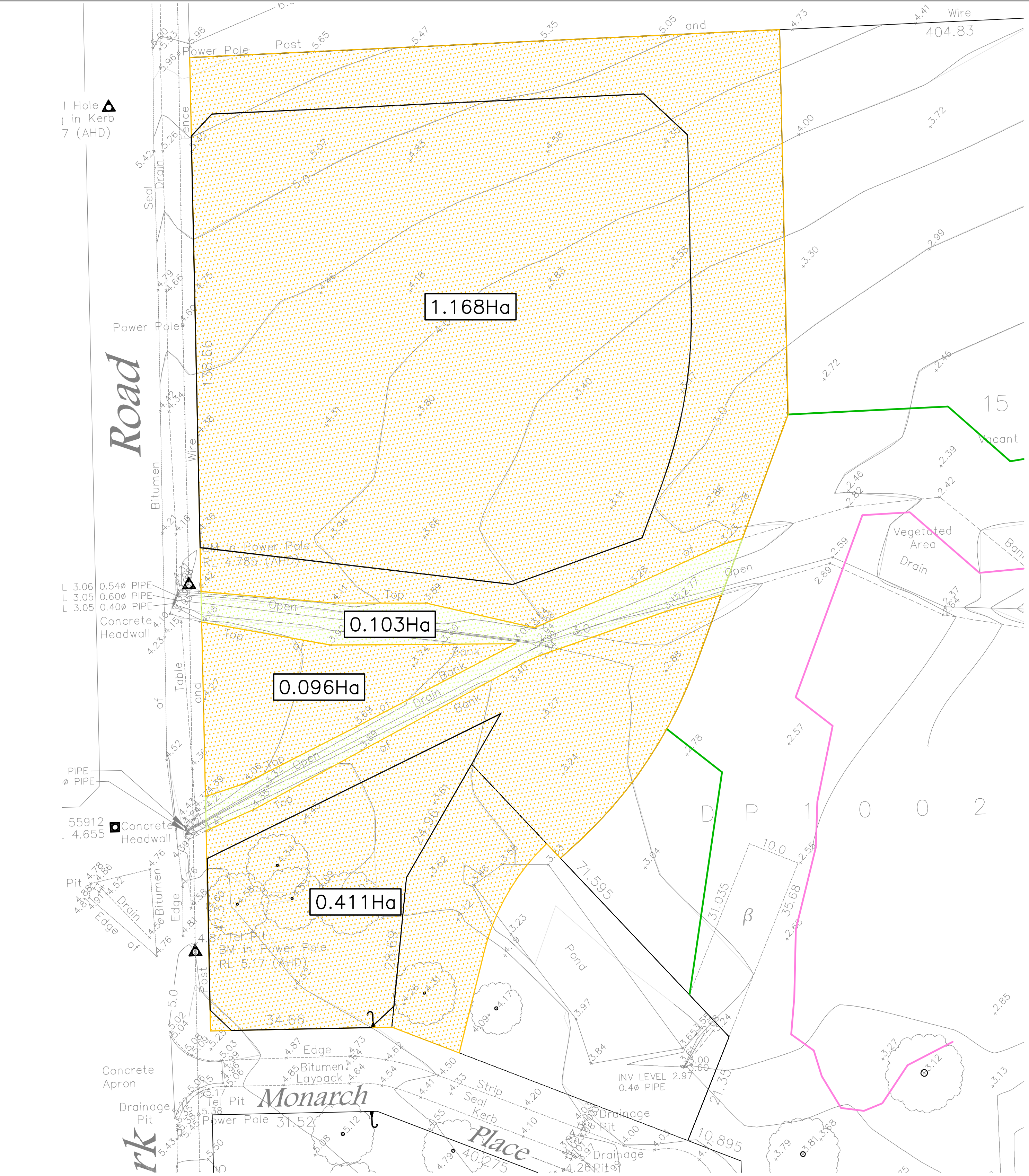
LOT 5 SEALARK ROAD, CALLALA BAY

PLANNING PROPOSAL
PRELIMINARY CIVIL DESIGN
PRELIMINARY STORMWATER MANAGEMENT PLAN

DRAWING NO. 1861-C06
ISSUE. 3

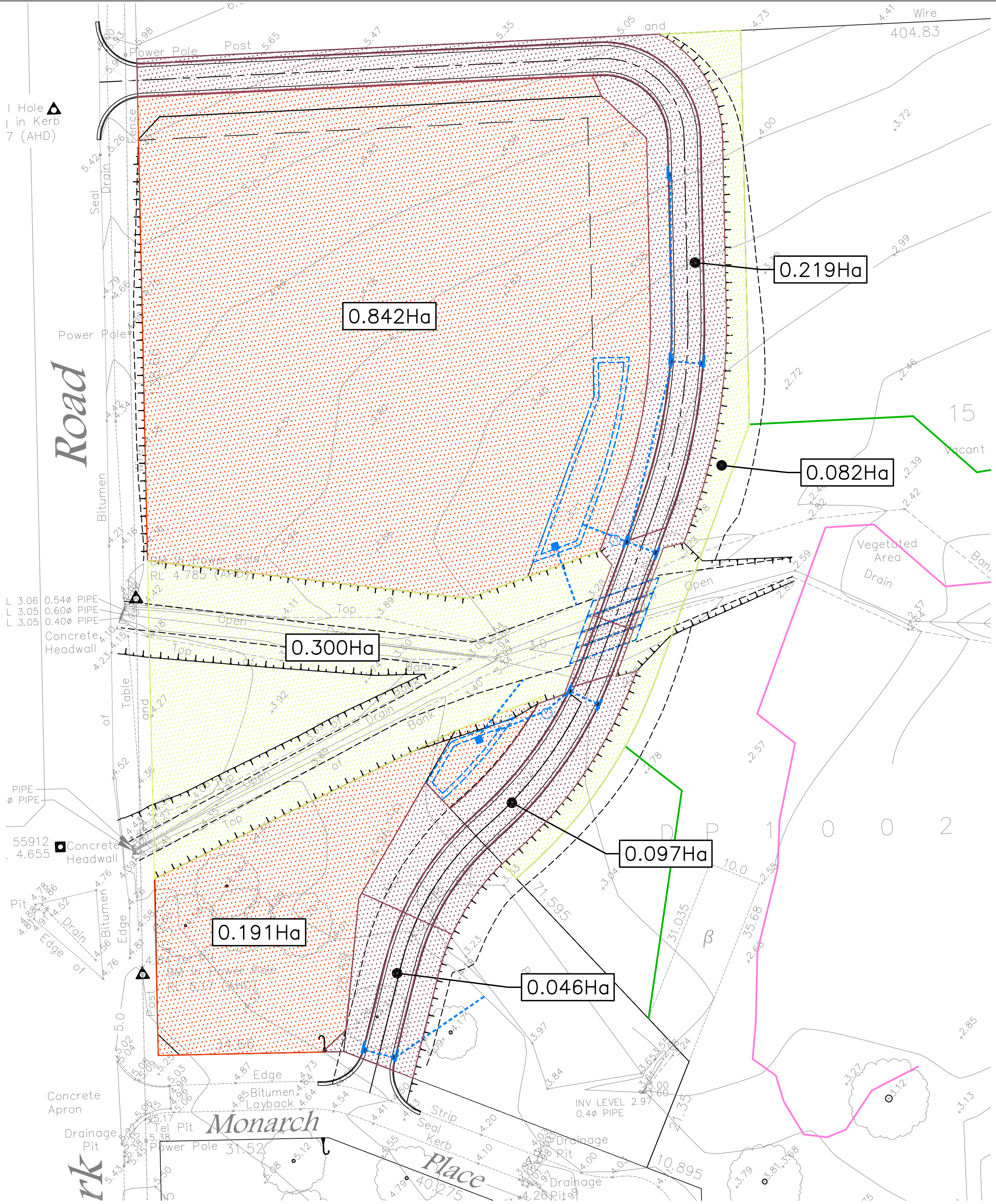


PRE–DEVELOPMENT – SUB–CATCHMENTS

LEGEND

NATURAL AREAS

DISTURBED LAND USE



POST–DEVELOPMENT – SUB–CATCHMENTS

LEGEND

NATURAL AREAS

PROPOSED MEDIUM DENSITY LAND USE

PROPOSED ROAD RESERVE

8 4 0 8 16 1:800

Original sheet size A3

North

ISSUE	DESCRIPTION	DATE
3	RE–ISSUED FOR PLANNING PROPOSAL	22/11/21
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SCALES	ORIGINAL
1:800	A3

CLIENT: HARE BAY CONSORTIA

SURVEYOR:	ALLEN PRICE
DATUM:	AHD
AZIMUTH:	GDA 94, MGA56
DRAWN:	AB
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DESIGNED DATE:	OCT '20
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LOT 5 SEALARK ROAD, CALLALA BAY

PLANNING PROPOSAL

PRELIMINARY CIVIL DESIGN

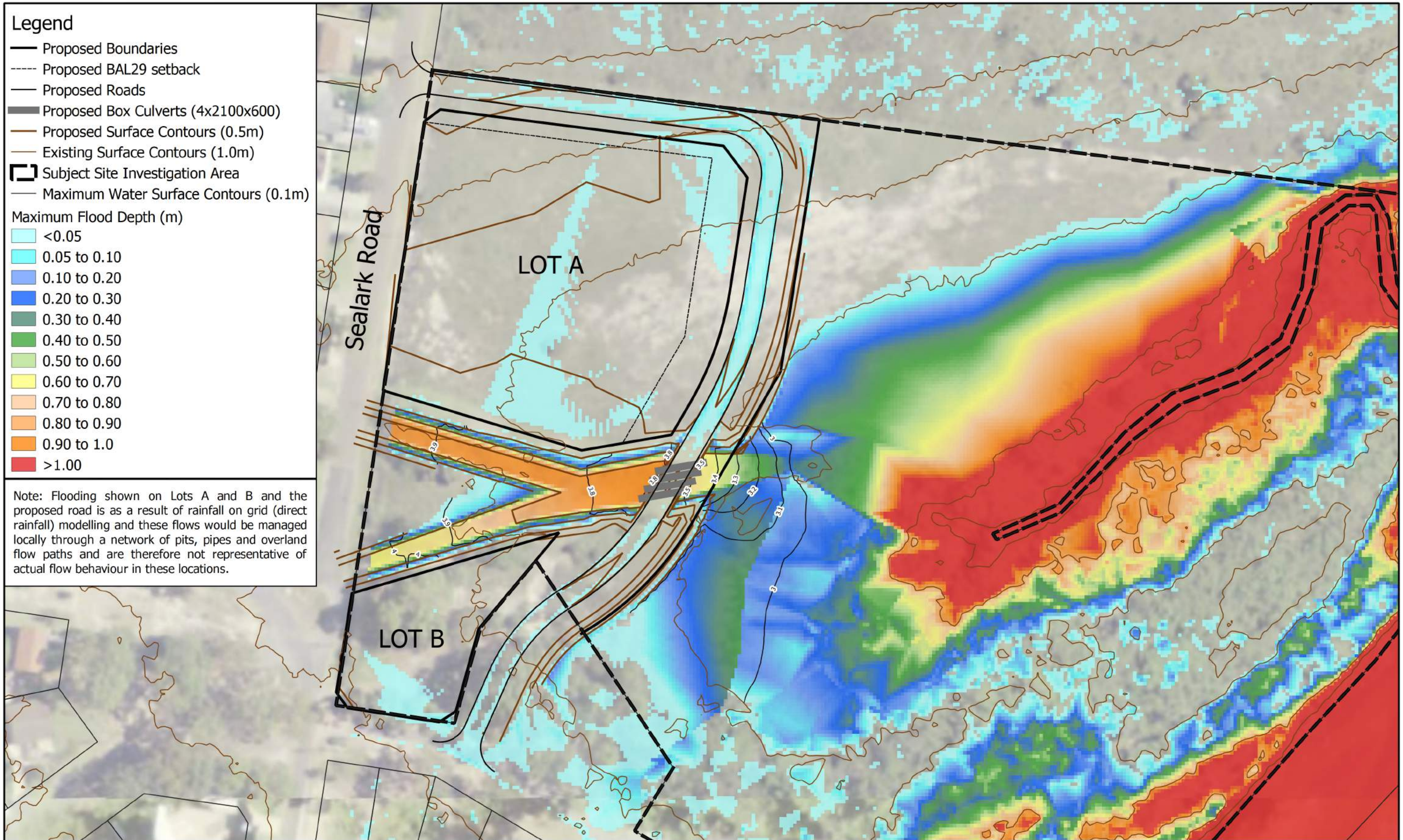
WATER QUALITY PRE AND POST DEVELOPMENT LAND USE PLAN

DRAWING NO. 1861-C07

ISSUE. 3

APPENDIX I

Post Development Modelling Results



Note: Flooding shown on Lots A and B and the proposed road is as a result of rainfall on grid (direct rainfall) modelling and these flows would be managed locally through a network of pits, pipes and overland flow paths and are therefore not representative of actual flow behaviour in these locations.

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LOT 5 SEALARK ROAD, CALLALA BAY

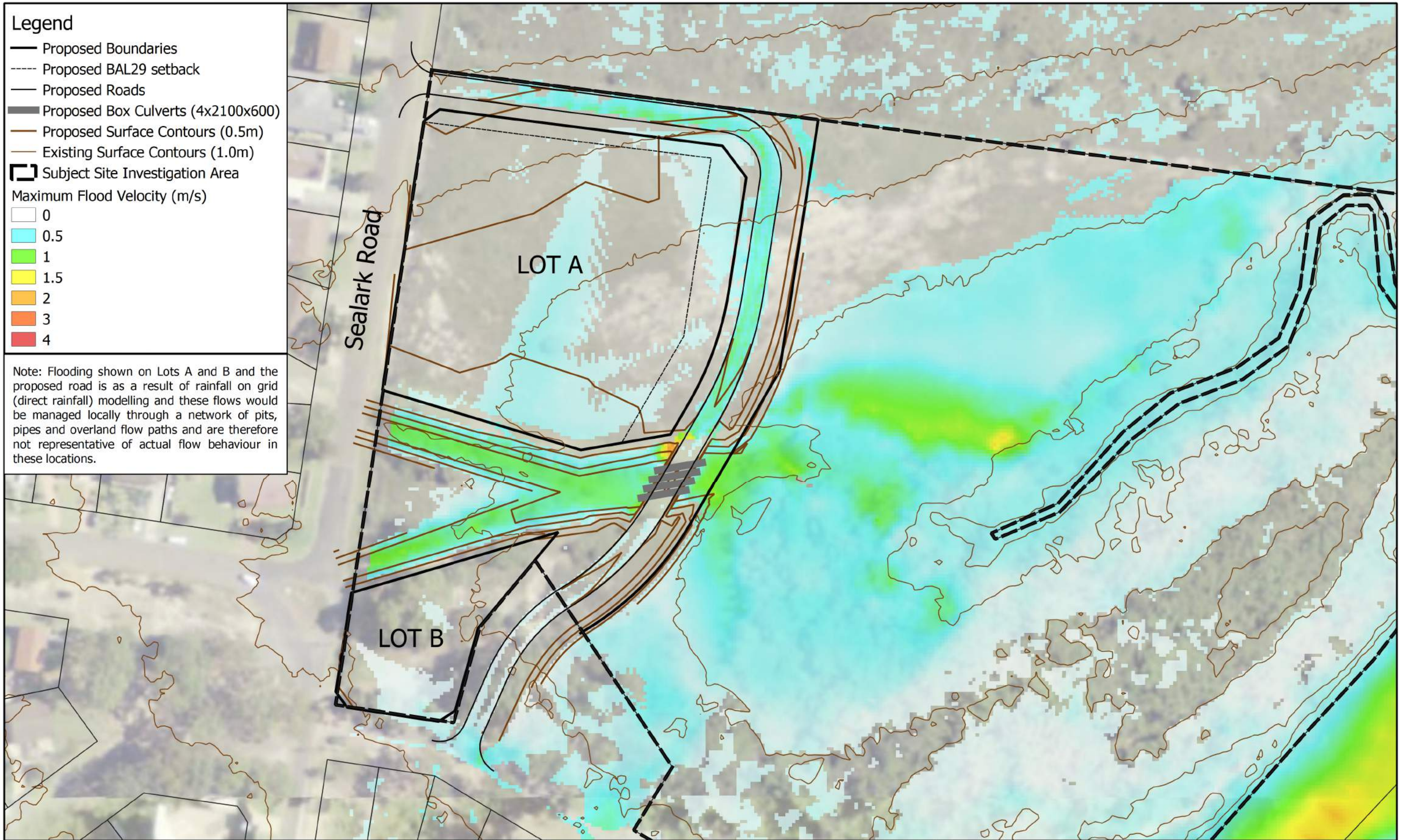
FIGURE 8.1

POST DEVELOPMENT

ENVELOPE OF MAXIMUM FLOOD LEVELS AND DEPTHS

1% AEP + RCP8.5 RAINFALL INCREASE + SLR (0.36m)

Rev 2 - 18 November 2021



Note: Flooding shown on Lots A and B and the proposed road is as a result of rainfall on grid (direct rainfall) modelling and these flows would be managed locally through a network of pits, pipes and overland flow paths and are therefore not representative of actual flow behaviour in these locations.

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25 0 25 m

Scale 1:1,000 at A3

LOT 5 SEALARK ROAD, CALLALA BAY

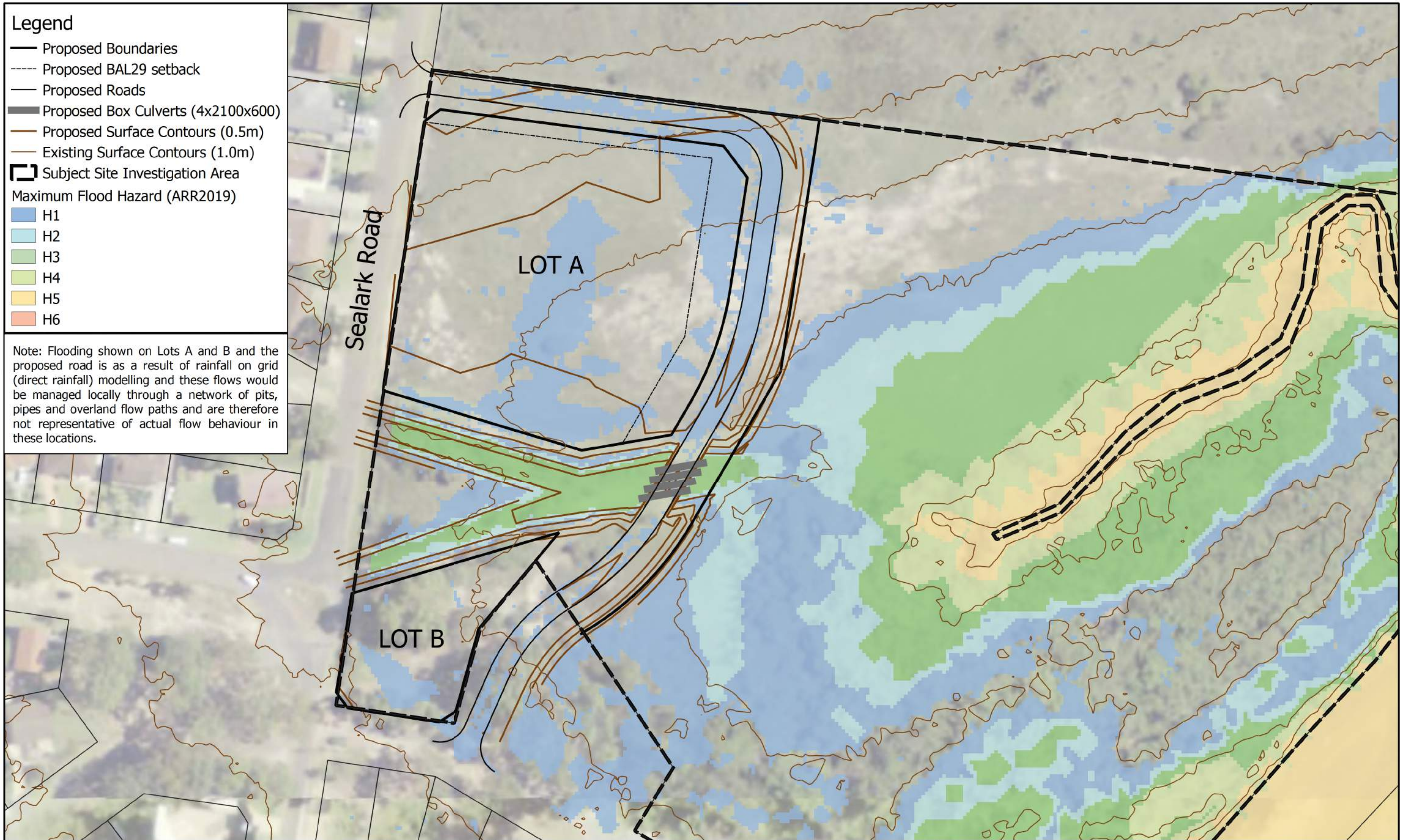
FIGURE 8.2

POST DEVELOPMENT

ENVELOPE OF MAXIMUM FLOOD VELOCITIES

1% AEP + RCP8.5 RAINFALL INCREASE + SLR (0.36m)

Rev 2 - 18 November 2021



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25 0 25 m

Scale 1:1,000 at A3

LOT 5 SEALARK ROAD, CALLALA BAY

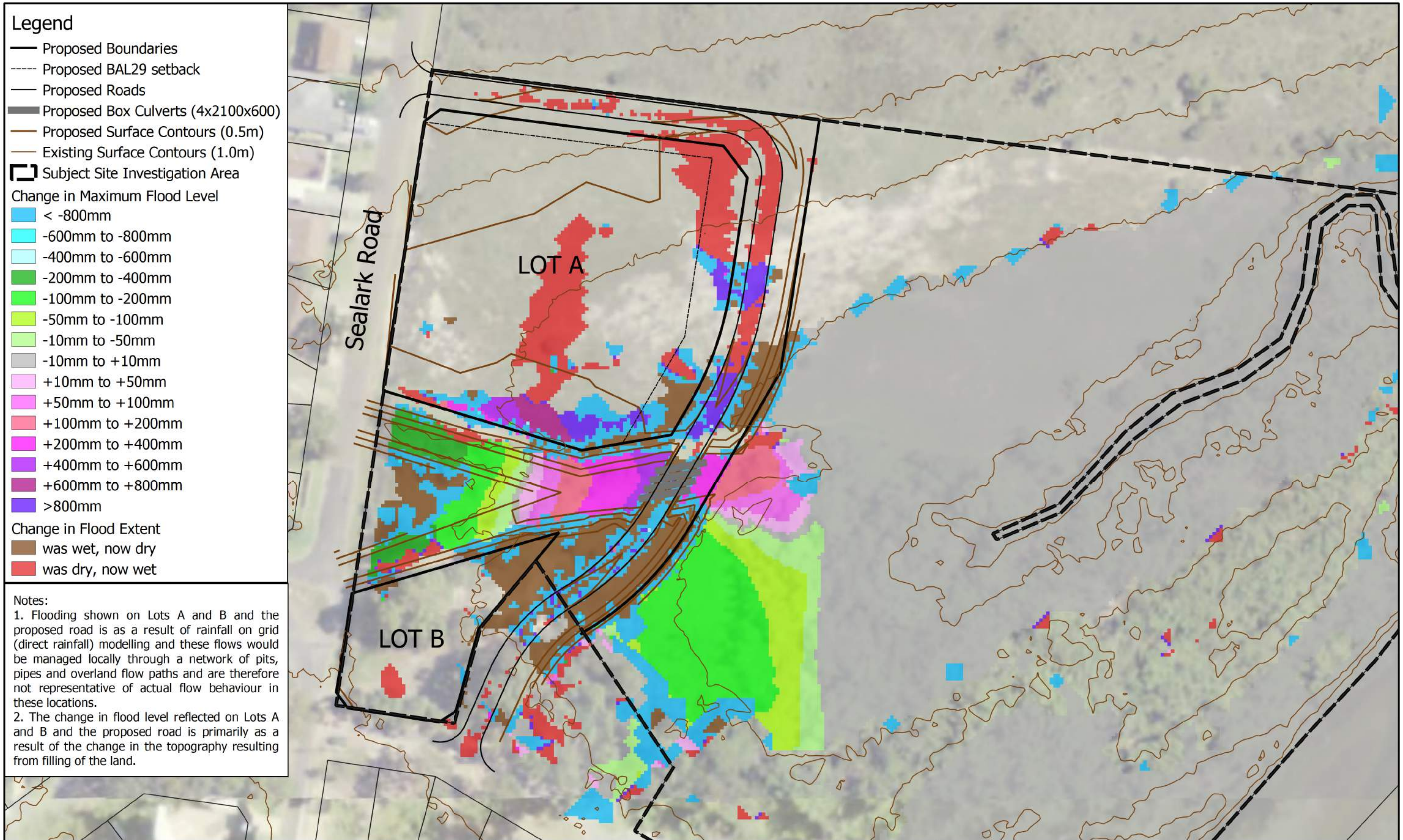
FIGURE 8.3

POST DEVELOPMENT

ENVELOPE OF MAXIMUM FLOOD HAZARD

1% AEP + RCP8.5 RAINFALL INCREASE + SLR (0.36m)

Rev 2 - 18 November 2021



Notes:

1. Flooding shown on Lots A and B and the proposed road is as a result of rainfall on grid (direct rainfall) modelling and these flows would be managed locally through a network of pits, pipes and overland flow paths and are therefore not representative of actual flow behaviour in these locations.
2. The change in flood level reflected on Lots A and B and the proposed road is primarily as a result of the change in the topography resulting from filling of the land.

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25 0 25 m

Scale 1:1,000 at A3

LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 8.4

POST DEVELOPMENT

CHANGE IN MAXIMUM FLOOD LEVEL

1% AEP + RCP8.5 RAINFALL INCREASE + SLR (0.36m)

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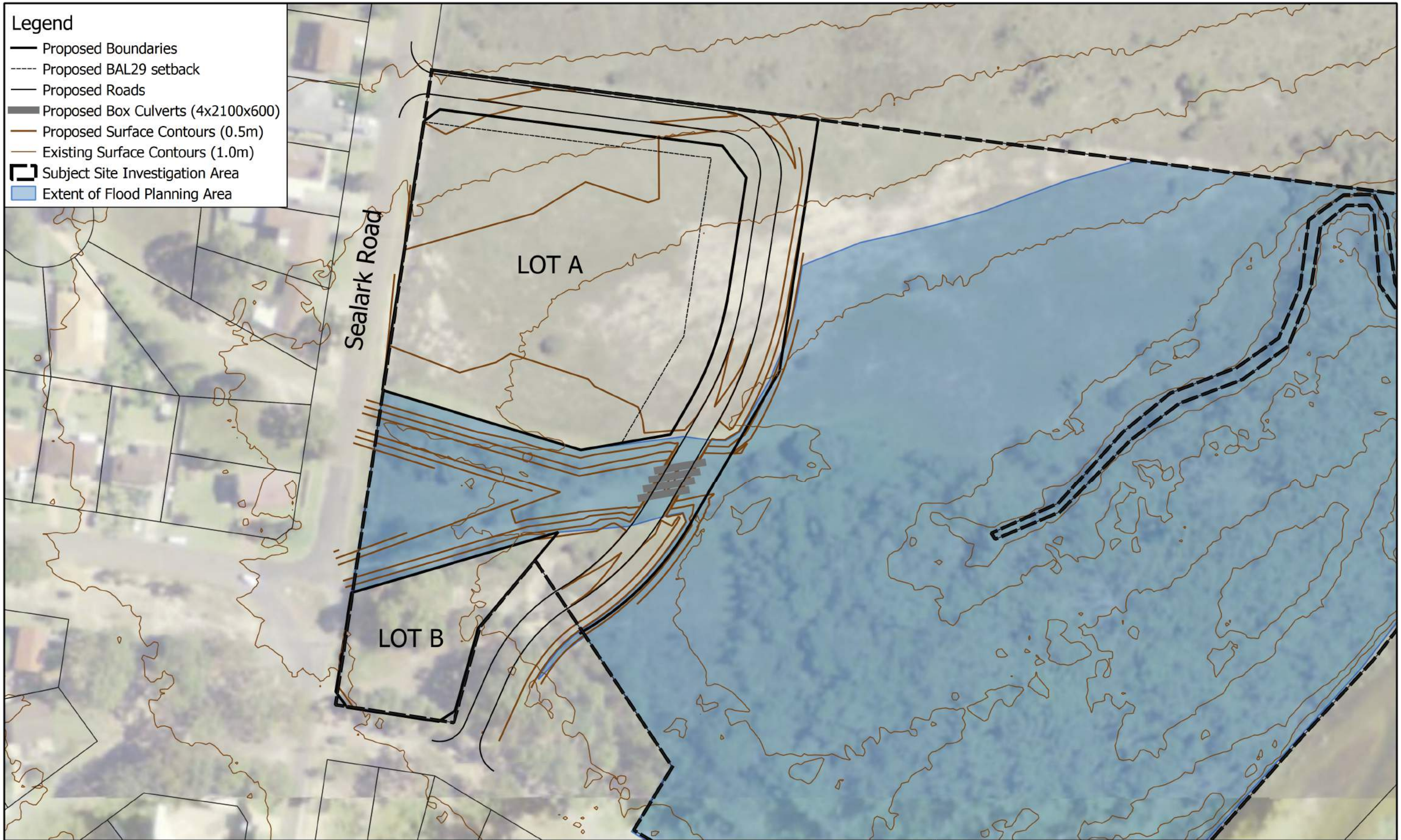

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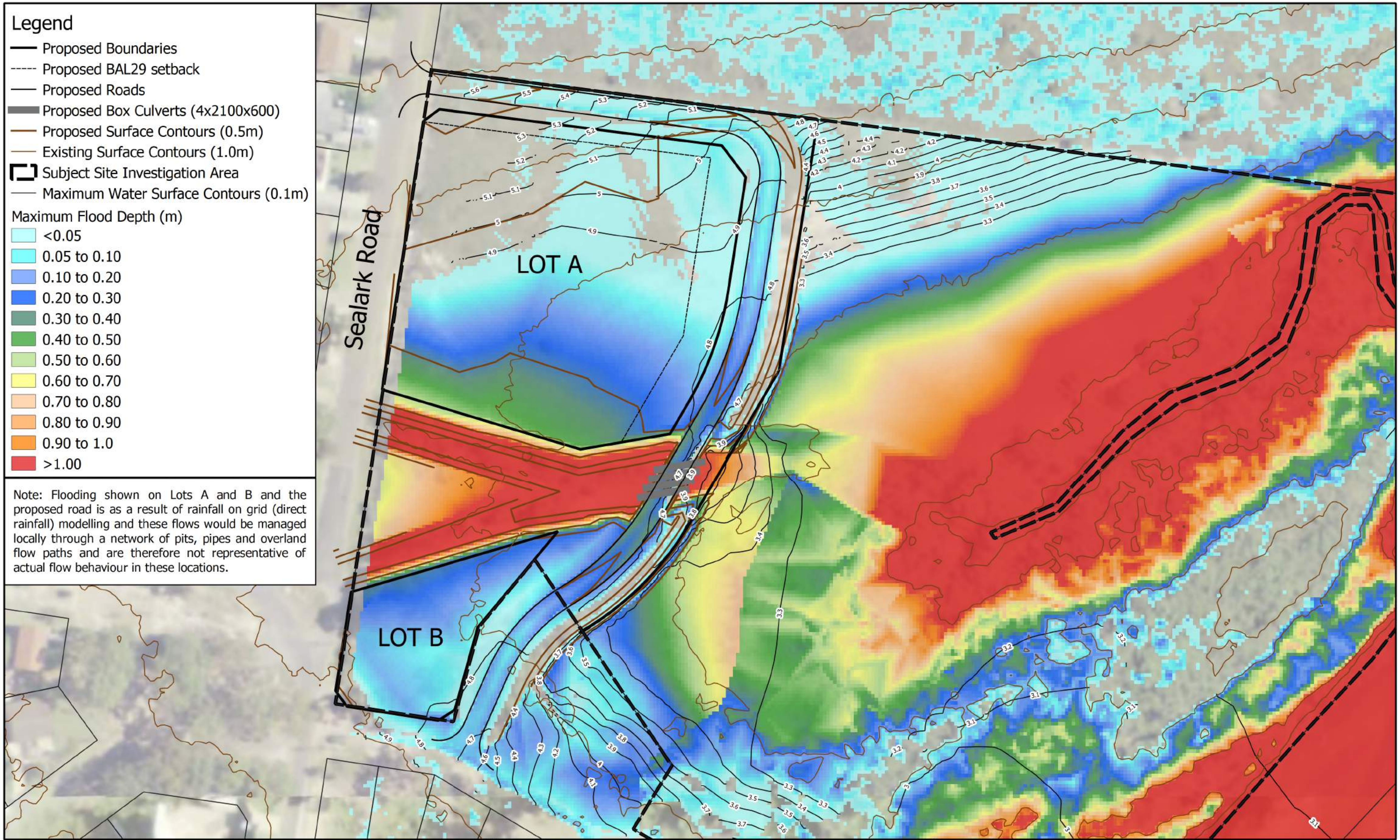
Scale 1:1,000 at A3

LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 8.5

EXTENT OF POST DEVELOPMENT FLOOD PLANNING AREA
1% AEP + RCP8.5 (RAINFALL INCREASE) + SLR (0.36m)

Rev 2 - 18 November 2021



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25 0 25 m

Scale 1:1,000 at A3

LOT 5 SEALARK ROAD, CALLALA BAY

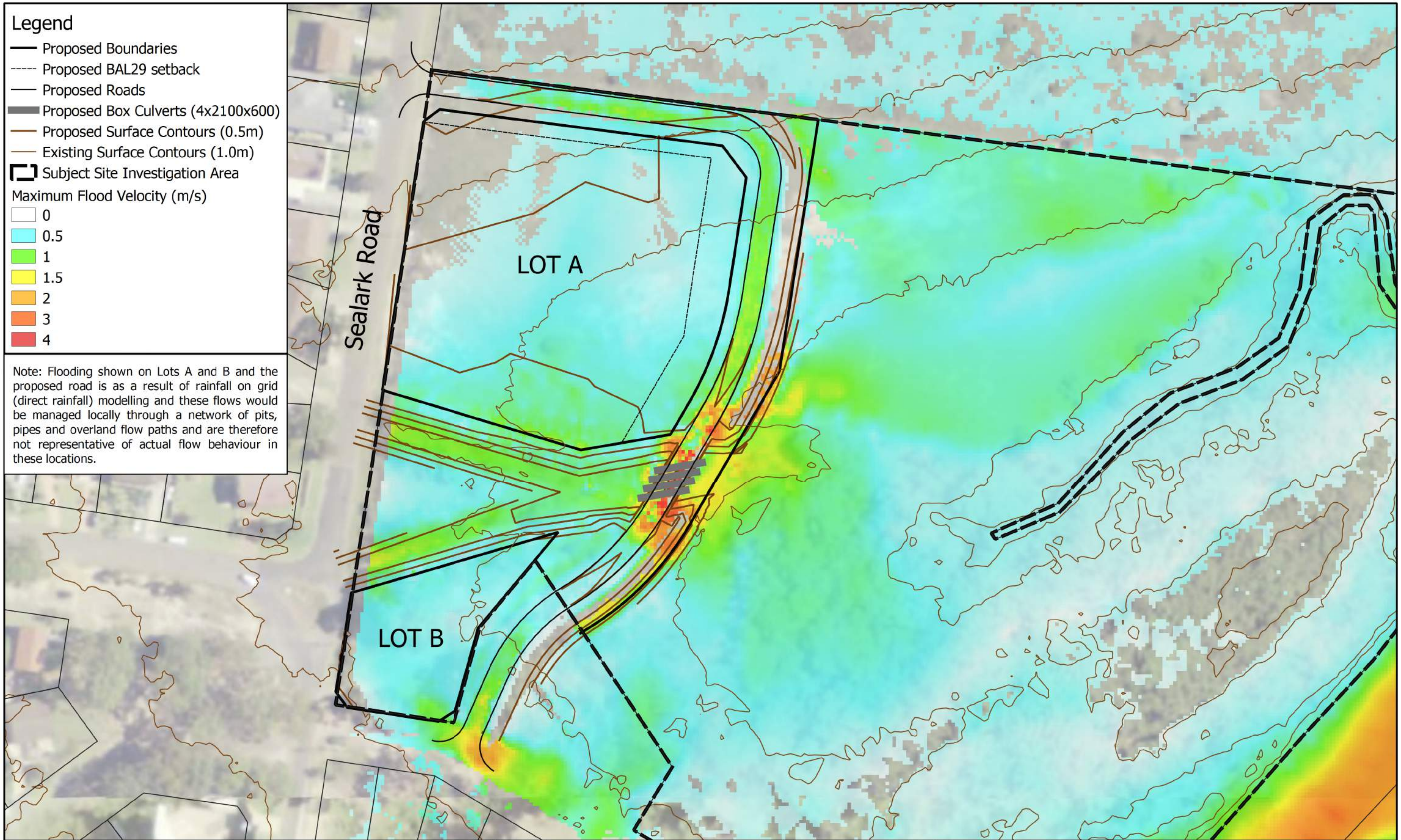
FIGURE 9.1

POST DEVELOPMENT

MAXIMUM FLOOD LEVELS AND DEPTHS

PMF + SEA LEVEL RISE (0.36m)

Rev 2 - 18 November 2021



Note: Flooding shown on Lots A and B and the proposed road is as a result of rainfall on grid (direct rainfall) modelling and these flows would be managed locally through a network of pits, pipes and overland flow paths and are therefore not representative of actual flow behaviour in these locations.

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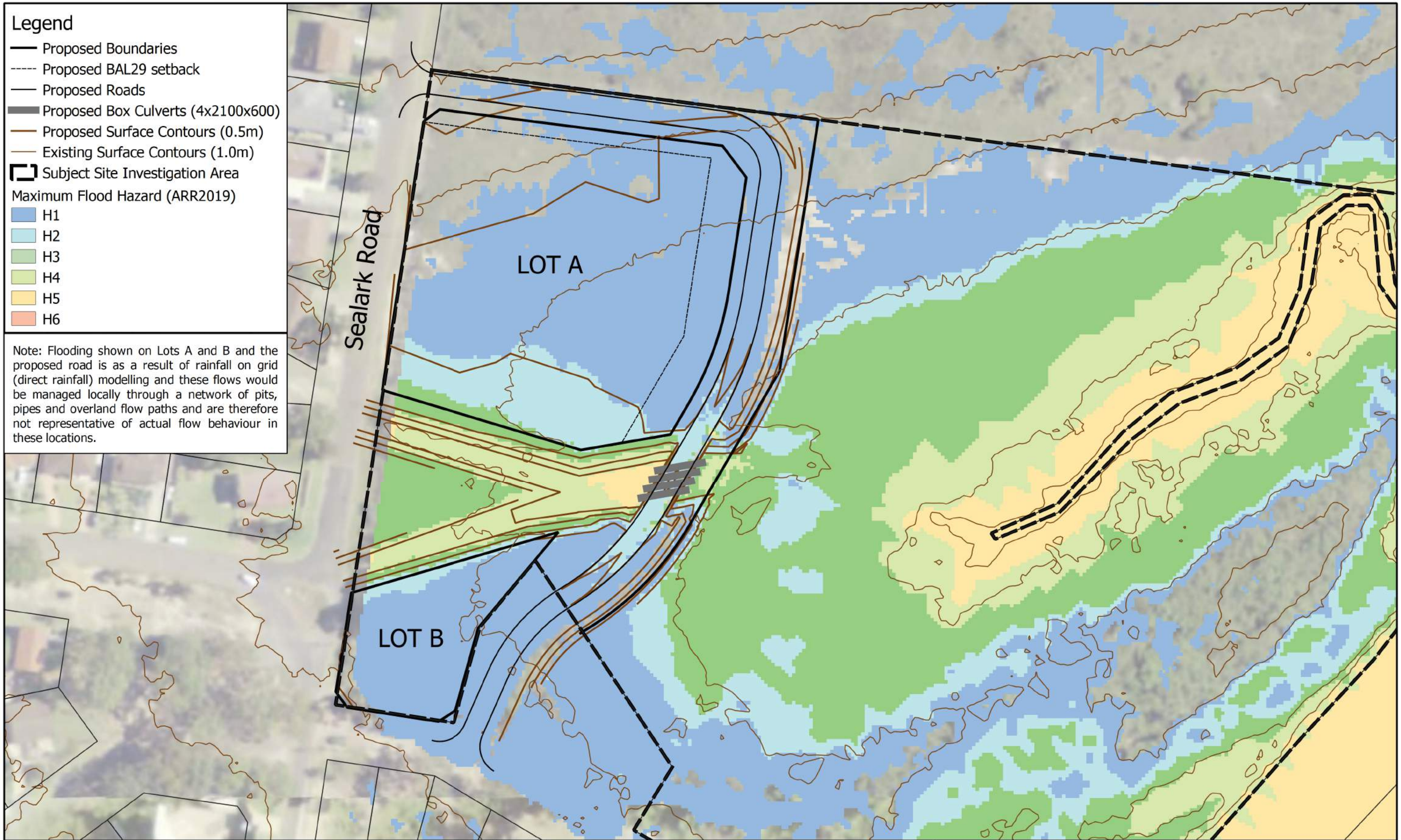
LOT 5 SEALARK ROAD, CALLALA BAY
FIGURE 9.2
POST DEVELOPMENT
MAXIMUM FLOOD VELOCITIES
PMF + SEA LEVEL RISE (0.36m)
Rev 2 - 18 Novemebr 2021



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LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 9.3

POST DEVELOPMENT

MAXIMUM FLOOD HAZARD

PMF + SEA LEVEL RISE (0.36m)

Rev 2 - 18 November 2021

Legend

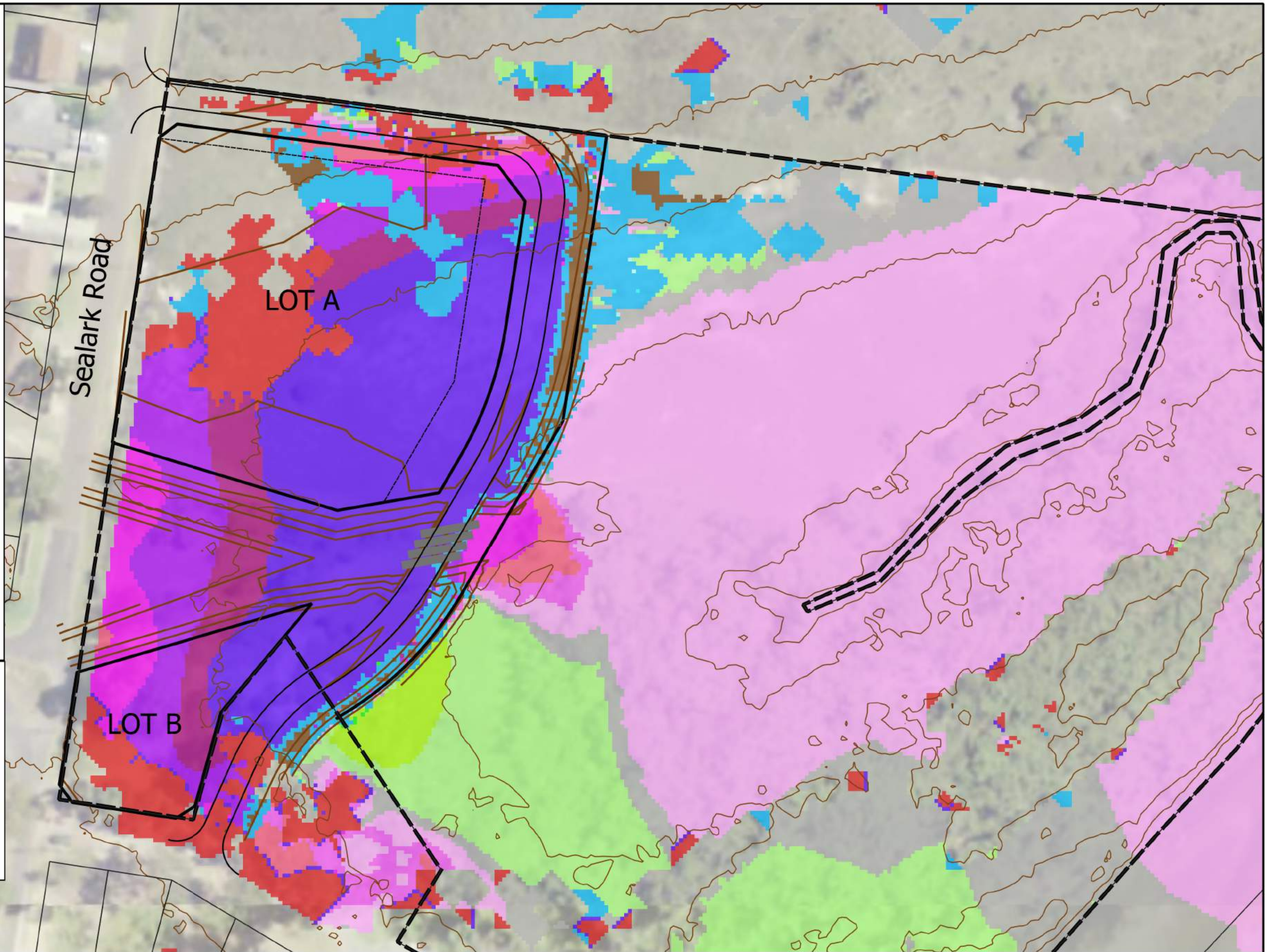
- Proposed Boundaries
- Proposed BAL29 setback
- Proposed Roads
- Proposed Box Culverts (4x2100x600)
- Proposed Surface Contours (0.5m)
- Existing Surface Contours (1.0m)
- Subject Site Investigation Area

Change in Maximum Flood Level

- < -800mm
- -600mm to -800mm
- -400mm to -600mm
- -200mm to -400mm
- -100mm to -200mm
- -50mm to -100mm
- -10mm to -50mm
- -10mm to +10mm
- +10mm to +50mm
- +50mm to +100mm
- +100mm to +200mm
- +200mm to +400mm
- +400mm to +600mm
- +600mm to +800mm
- >800mm

Change in Flood Extent

- was wet, now dry
- was dry, now wet



Notes:

1. Flooding shown on Lots A and B and the proposed road is as a result of rainfall on grid (direct rainfall) modelling and these flows would be managed locally through a network of pits, pipes and overland flow paths and are therefore not representative of actual flow behaviour in these locations.
2. The change in flood level reflected on Lots A and B and the proposed road is primarily as a result of the change in the topography resulting from filling of the land.

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25 0 25 m

Scale 1:1,000 at A3

LOT 5 SEALARK ROAD, CALLALA BAY

FIGURE 9.4

POST DEVELOPMENT

CHANGE IN MAXIMUM FLOOD LEVEL

PMF + SEA LEVEL RISE (0.36m)

Rev 2 - 18 November 2021