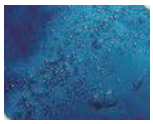
Moonee Parklands Trust
C/-JW Planning Pty Ltd

Flood Assessment: Proposed Sub-division, Lot 1 DP1097743 and Lot 6 DP252223, Pacific Highway, Moonee Beach, NSW.

martens consulting engineers

ENVIRONMENTAL

WATER



WASTEWATER

GEOTECHNICAL

CIVIL

PROJECT MANAGEMENT

P1002663JR08V01
March 2013

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All enquiries regarding this project are to be directed to the Project Manager.

Contents

1 Overview

1.1 Study Overview

Martens & Associates Pty Ltd has prepared this flood assessment for Moonee Parklands Trust C/- JW Planning Pty Ltd to form a Part 3A Environmental Assessment for a proposed residential sub-division yielding up to 160 lots at Lot 1 DP 1097743 and Lot 6 DP252223, Pacific Hwy, Moonee Beach, NSW.

This report comprises a desktop review of previous flood assessments completed for the local area to identify key issues, as well as a flood assessment detailing hydrological and hydraulic flood modelling completed for existing and developed conditions.

1.2 Project Scope

The report provides the following:

- Summarises previous flood assessments conducted for the lower part of Moonee Creek in the vicinity of the subject site.
- Assessment of the existing site flood levels, velocities and hazards arising from the 1 in 100 year Average Recurrence Interval (ARI) and Probable Maximum Precipitation (PMP) critical duration storm events.
- Assessment of the changes to existing flood behaviour arising from the development of the site.
- Assessment of the likely impacts of climate change on flooding behaviour at the site.
- Provide comment and recommendations with respect to flood emergency and evacuation responses for the development.

1.3 Proposed Development

The development proposal involves the sub-division of land zoned predominantly for residential purposes and part conservation purposes.

The implementation of the concept subdivision is proposed to occur in 4 construction stages beginning in the north west corner. The construction stages will be divided further in into 10 sales stages which may be adjusted in size at the time of release to suit marketing requirements. Preliminary staged works are as follows:

1. Stage 1:
    a. Bulk earthworks for the entire 101 lots to reduce costs and impact on adjoining residents.
    b. The court approved collector road running along the western edge of Moonee Parklands links the approved Glades development to the north with Moonee Beach Village to the south and will be constructed prior to development and release of lots in the Glades development.
    c. Connections to power, water and telecommunication infrastructure to be located within the collector road.
    d. Construction of vehicular access to the proposed sewer pump station as well as to stormwater treatment and detention Basin 1.
    e. Services extended as required and access to the existing residence maintained.
2. Stage 2:
    a. Extension of Roads 4, 5 and 6 with associated services.
3. Stage 3:
    a. Construction of stormwater Basin 2.
    b. Extension of Road 3 & 6 and the partial construction of Road 2 with associated services.
4. Stage 4:
    a. Connection of Road 1 and Road 2 as well as complete Roads 4 & 5 and associated services.

The proposed staging plan aims to provide a cost effective construction sequence that seeks to minimise the impact on any local residents. Whilst subject to possible variation via more detailed construction certificate investigation, design and market considerations as well as land owner circumstances, the proposed staging is practical and logical.

1.4 Policy and Objectives

A number of planning controls and principles have been considered and implemented in the development of site flooding assessment. The objectives of these are summarised below:

1.4.1 Coffs Harbour City Council DCP (2012)

This document addresses minimum requirements for flood management and mitigation measures for development sites to ensure no adverse impacts to upstream and downstream properties and infrastructure.

Specific objectives of Council's DCP (2012) considered pertinent to this study include:

- To reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods where possible.
- Avoidance or minimisation of flood risk using appropriate planning controls. Where this is not feasible, flood risk mitigation using appropriately designed and constructed measures.
- With respect to water conservation measures, provision of necessary flood immunity for infrastructure and buildings, and resilience to potential climate change flooding, while seeking to maintain natural water balance, flow regime and water quality.
- Ensure no increase in the frequency and adversity of flooding.
- Ensure that public health and safety is maintained.

1.4.2 NSW Department of Environment and Climate Change (2007) Floodplain Risk Management Guideline Practical Consideration of Climate Change

This guideline summarises minimum requirements for flood assessment modelling with respect to modelling the impacts of climate change including suggested increases in sea level and rainfall intensities.

1.4.3 NSW Department of Environment Climate Change and Water (2010) Draft Flood Risk Management Guide: Incorporating sea level rise benchmarks in flood risk assessments

This guideline provides information on applying climate change sea level rise in floodplain risk management planning and assessment for development projects. It provides updated sea level rise figures from DECC (2007) guidelines. The document also details suggested flood assessment techniques that should be modelled to determine the 1 in 100 year flood effects including establishing a peak flood envelope based on model ocean level and ARI of rainfall event and a summary of typical ocean boundary conditions depending on the catchment entrance condition.

1.4.4 Coffs Harbour City Council (2009) Engineering Development Specification Design – 0074 Stormwater drainage Design

This document summarises the engineering requirements for stormwater and drainage measures for proposed development within the Coffs

Harbour LGA. Specific objectives and specifications considered to be pertinent to this study include the following:

- To ensure that inundation of private and public buildings located in flood prone areas occurs only on rare occasions and that, in such events, surface flow routes convey floodwaters below the prescribed velocity/depth limits.

2 Site Description

2.1 Location and Site Description

The subject site is located between Pacific Highway and Moonee Creek at Moonee Beach, approximately 12 km north of Coffs Harbour and is within the Coffs Harbour City Council Local Government Area (Figure 1).

Bucca Creek, a tributary of the Moonee Creek, is located at the northern side of the subject site. Cunningham Creek dissects the lot adjacent to the southern site boundary and joins Moonee Creek approximately 300m south of the south-eastern corner of the site.

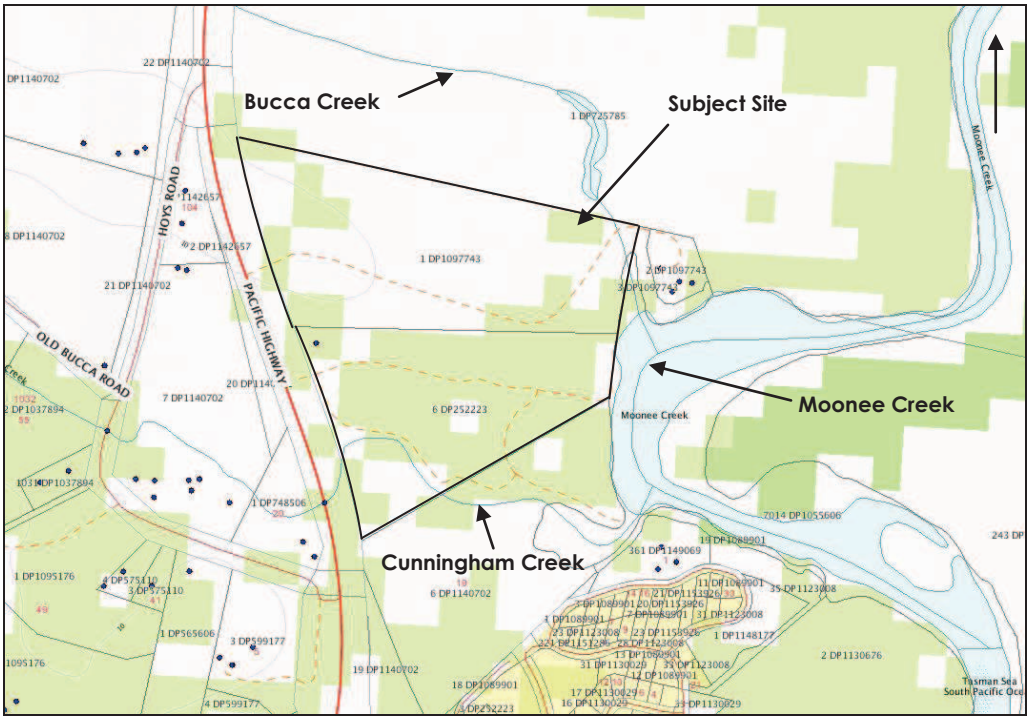

Figure 1: Location of the subject site within its local context.

Lot 6 has an area of 10.073 ha while Lot 1 is 12.93 ha in area, giving the site a total area of approximately 23 ha. The site is in an area of low density rural development approximately 500 m north of a commercial area and existing residential areas of Moonee Beach. The site is partly cleared with stands of remnant trees remaining. There is a caravan and detachable house in the eastern portion and a caravan and stables in the north-west corner of Lot 6 and unsealed access roads on both properties. Otherwise, the site is undeveloped.

2.2 Field Investigations

Site investigations were undertaken 26 – 28 July 2010 for a range of engineering services, including a walkover inspection of the site to assess existing site conditions, surface waters on the site and inspection of the surrounding creeks.

2.3 Topography

The site is located in an area of gently to moderately undulating hills and flatter low-lying alluvial plains associated with Moonee Creek. Site elevation ranges between approximately 18 mAHD in the west of Lot 1 and 2 mAHD along the banks of Moonee Creek in the east with slopes of up to 8 degrees in the west and relatively flat (generally less than 5%) across low-lying areas in the east.

2.4 Geology

The Coffs Harbour 1:250,000 Geological Sheet (NSW Dept. of Mines, 1970) identifies the site as being on the boundary of Coramba Beds comprising mudstone, siltstone and greywacke with minor intervals of volcanic rock, and Quaternary alluvium comprising silt, clay, fluvial sand, marine sand and gravel.

2.5 Hydrology

Moonee Creek catchment is drained by a series of small intermittent drainage lines, draining into four main creeks. Moonee Creek originates in the north, flowing south until it discharges into the ocean at Moonee Beach. There are three main tributaries of Moonee Creek being: Skinners Creek; Cunninghams Creek, and Sugar Mill Creek (Figure 2). Skinners Creek flows east until it joins Moonee Creek. Cunninghams Creek is similar to Skinner Creek but located further south. Sugar Mill Creek is the southernmost creek and flows north and joins Moonee Creek immediately upstream of its outlet with the Pacific Ocean (Moonee Beach).

Cunninghams Creek dissects the adjacent lot to the south of the site and another minor tributary, Bucca Creek dissects the north eastern corner of the site.

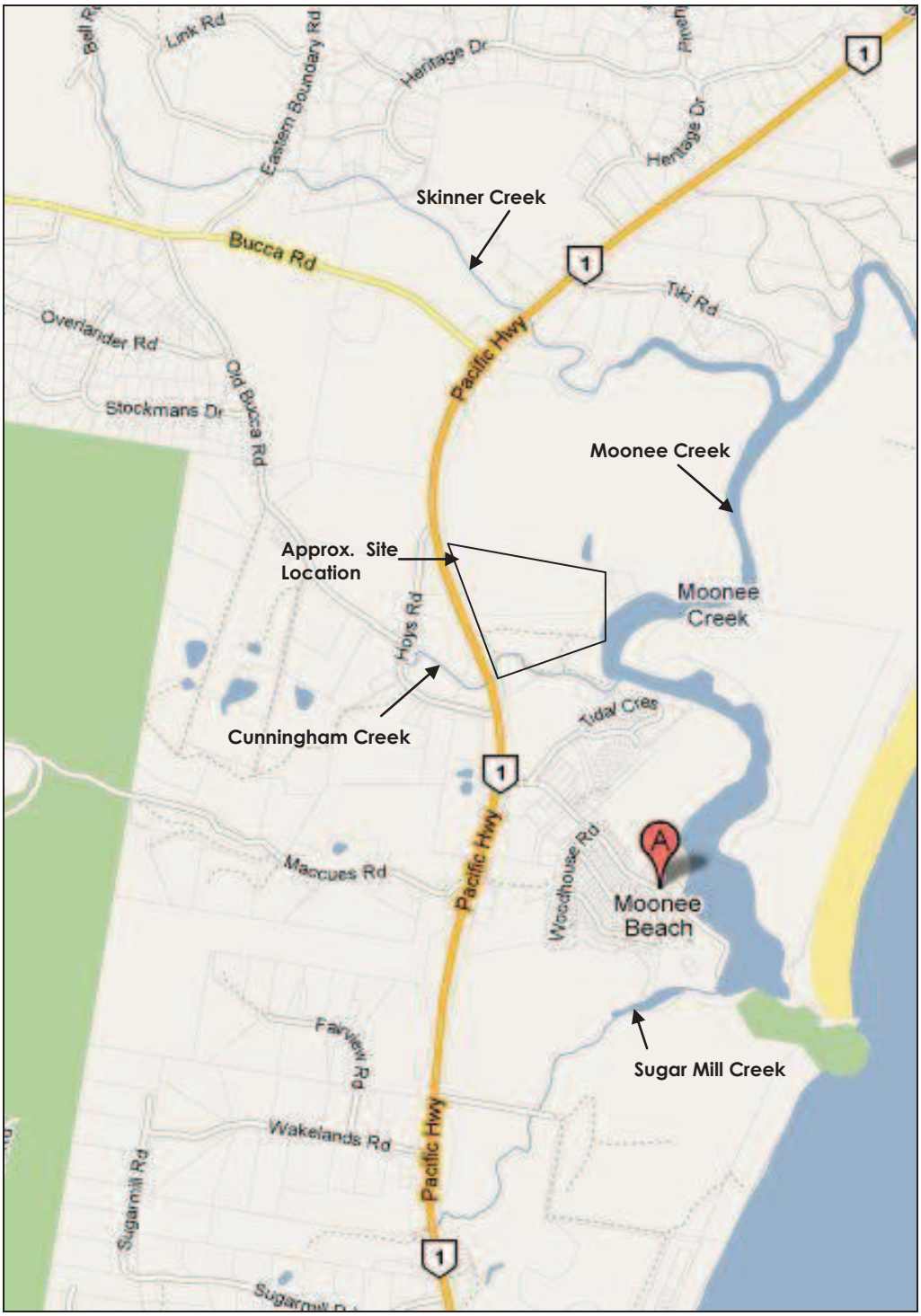

Figure 2: Moonee Creek and its main tributaries.

3 Flood Risk Assessment

3.1 Previous Flood Studies Desktop Assessment

Previous flood studies completed for Moonee Creek are considered in this section.

3.1.1 Moonee Creek Flood Study (GHD 1994).

This study assessed flood behaviour in Moonee Creek for the "Heritage Park" development located approximately 2 km to the north of the subject site. This assessment utilised a 1D hydraulic model (HEC-2) to determine flood levels. Flood levels in Moonee Creek from this study are summarised in Table 1, with Figure 3 showing the position of cross-sections used in the study which are relevant to this study.

Table 1: HEC-2 Flood levels results in GHD Moonee Creek Flood Study for 1 in 100 year ARI.

HEC-2 Section	Existing Flood Levels mAHD		Flood Levels After Development m AHD 100 year ARI
	20 year ARI	100 year ARI	
7	2.80	3.23	3.24
8	2.91	3.36	3.36
9	3.08	3.53	3.53

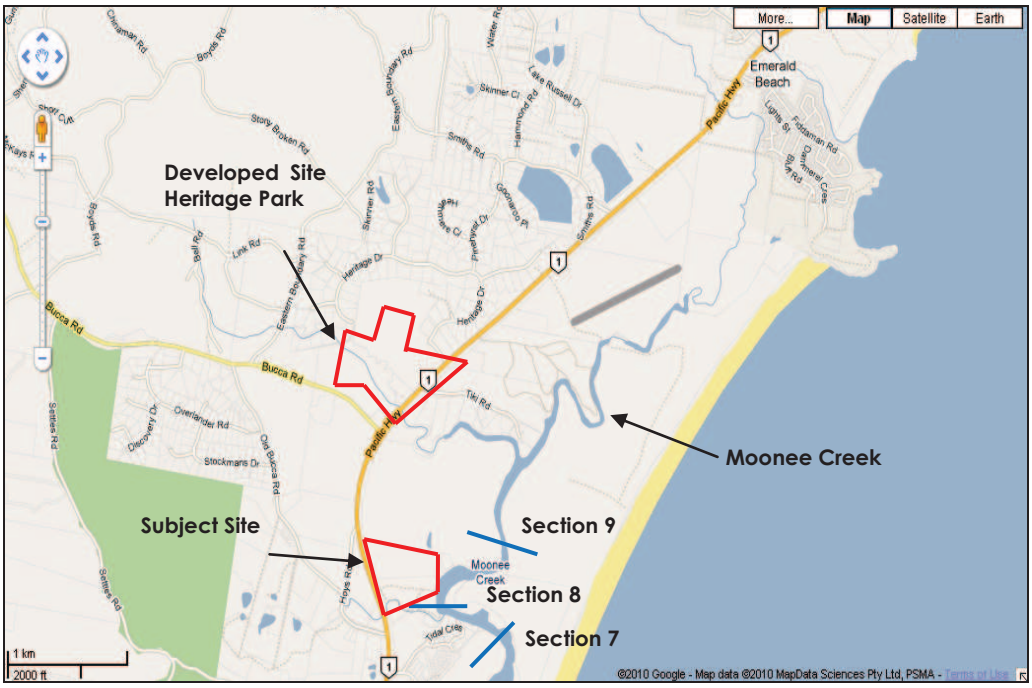

Figure 3: HEC-2 Section location map in GHD Moonee Creek Flood Study.

3.1.2 Moonee Creek Flood Study (Paterson Consultants 1998).

Prepared for Council, this assessment utilised a MIKE 11 model of Moonee Creek and its tributaries. Peak flood levels for varying durations during the 1 in 100 year ARI flood for Moonee Creek and Cunninghams Creek in the vicinity of the site are summarised in Table 2.

Table 2: Summary of 1 in 100 year ARI flood levels per storm duration for Moonee Creek and Cunninghams Creek (Paterson, 1998).

Location	Storm Duration (hrs)					
	2	3	4.5	6	9	12
Moonee Creek						
at Cunninghams Creek	2.64	2.50	2.62	2.62	(2.69)[1]	2.62
Cunninghams Creek						
u/s Pacific Highway	(2.83)[1]	2.67	2.71	2.67	2.76	2.74

A series of flood maps showing flood characteristics for the 1 in 100 year ARI flood (heights and hazards) were produced that show a peak flood level of approximately 2.8 mAHD in Moonee Creek adjacent to the site and levels ranging from 2.8 mAHD to approximately 4.0 mAHD along the northern site boundary in Bucca Creek. Hazard mapping showed the subject site to be largely outside of existing 1 in 100 year ARI flood extents, with some portions of the site identified as having a "Low Hazard" rating. Both figures are reproduced below.

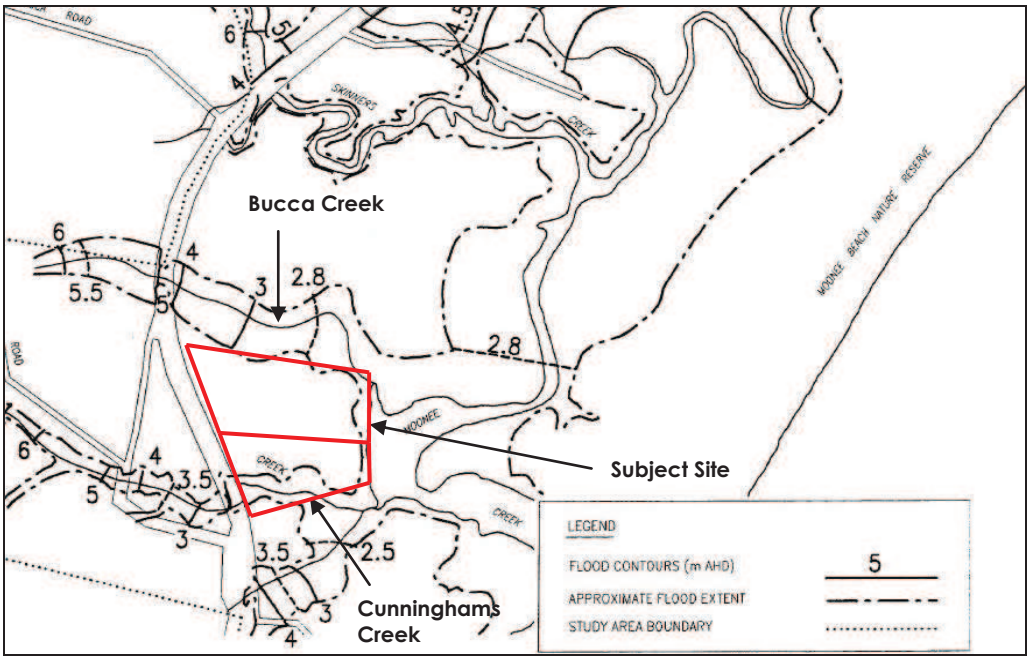

Figure 4: 1 in 100 year ARI flood extents map for Moonee Creek, Cunningham's Creek and Bucca Creek in the vicinity of the subject site (Paterson Consultants, 1998).

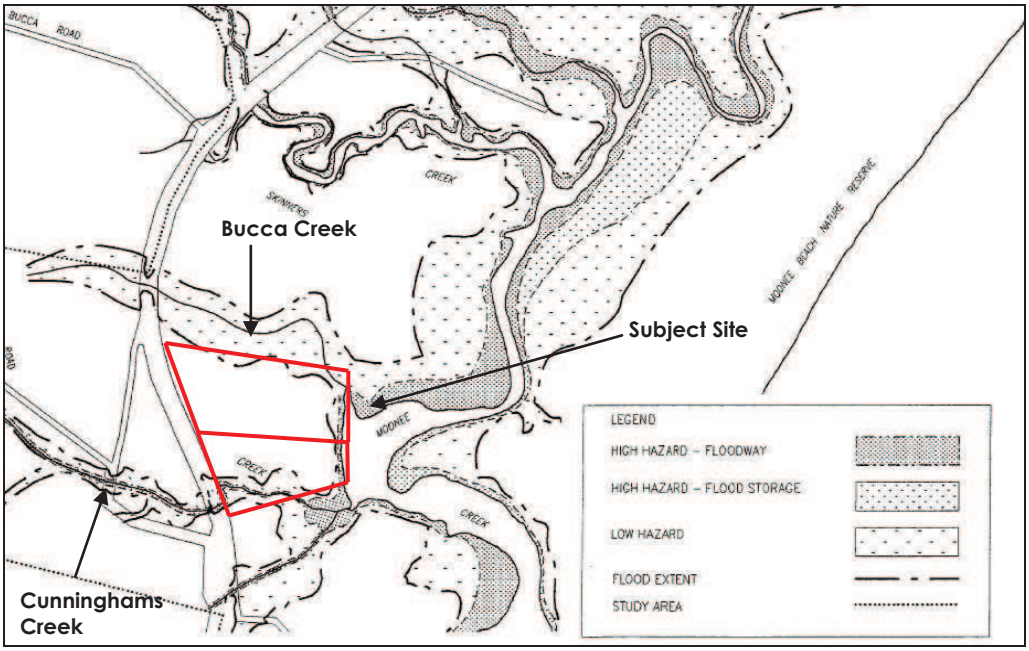

Figure 5: 1 in 100 year ARI flood hazard map for Moonee Creek, Cunningham's Creek and Bucca Creek in the vicinity of the subject site (Paterson Consultants, 1998).

3.1.3 Coffs Creek Floodplain Risk Management Plan (Bewsher Consulting, 2005)

This assessment was completed by Bewsher Consulting on behalf of Coffs Harbour City Council and provides details a floodplain risk

management plan for Coffs Creek. Whilst Moonee Creek and its tributaries were not included in this assessment, a flooding and hazard extents map was prepared for areas to the north of Coffs Creek, based on the previous assessment conducted by Paterson Consultants (1998). This map shows that a portion of the site is affected by the 1 in 100 year ARI peak flood extents and that the area affected is considered to be a 'low flood extent' area.

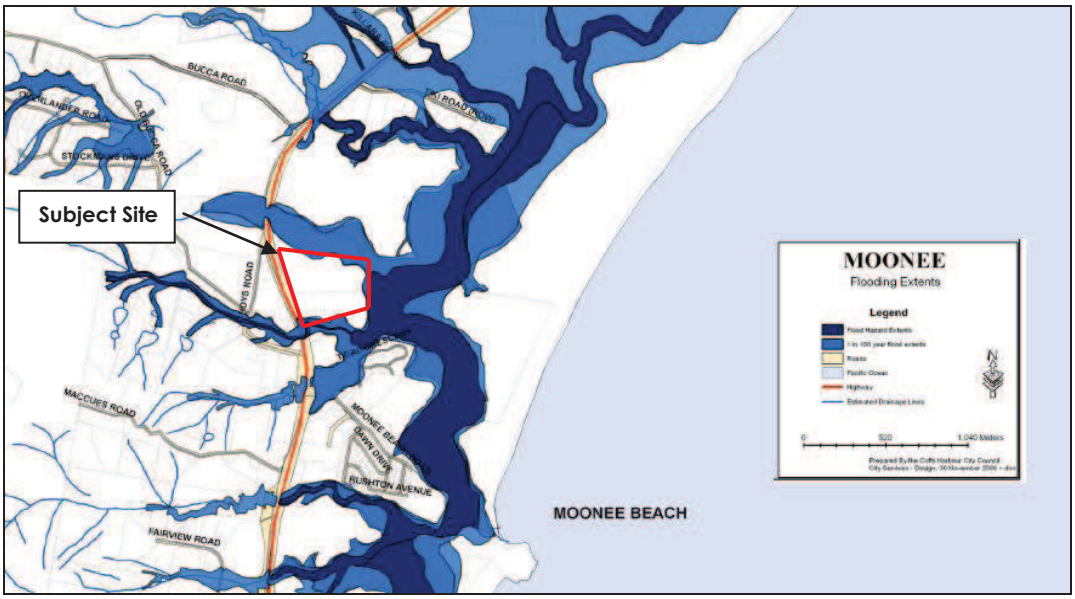

Figure 6: Flood extents mapping for Moonee Creek and tributaries (Bewsher Consulting, 2005).

3.1.4 Moonee Creek Estuary Process Study (WBM Oceanics, 2005)

This assessment determined hydraulic characteristics (tidal movement and water levels) for Moonee Creek. The assessment used levels recorded by the NSW Department of Commerce Manly Hydraulic Laboratory (MHL) for a site located approximately 1.9 km from the mouth of Moonee Creek and approximately 0.8 km from the subject site. Recorded water levels are summarised below in Table 3.

Table 3: Summary of water levels in Moonee Creek (WBM Oceanics, 2005).

Water Levels	Moonee Creek	Ocean (Coffs Harbor)
Maximum Water Level	1.17m AHD	1.23m AHD
Minimum Water Level	-0.1m AHD	-0.18m AHD
Median Water Level	0.24m AHD	-0.04m AHD
Median High Water Level	0.56m AHD	0.56m AHD
Median Low Water Level	0.11m AHD	-0.59m AHD

3.1.5 The Glades, Moonee Beach – Hydraulic Assessment (Cardno Lawson Treloar, 2007)

This assessment details hydraulic modelling conducted for "The Glades" sub-division (Lots 1 and 2 DP 725785) located adjacent to and north of the subject site for existing and developed conditions. This assessment utilised the MIKE – 11 model developed for Coffs Harbour City Council in the *Moonee Creek Flood Study* (Paterson 1998), updated to the latest version and supplemented with additional cross-sections and the addition of the Pacific Highway bridge over Skinners Creek to improve model accuracy in the vicinity of the development.

The assessment considered three flood simulations (i.e. flood envelope) to determine the 1 in 100 year flood event envelope curve as follows:

- 1 in 100 year flood event flows with normal high tide level as boundary conditions (0.6 mAHD).
- 1 in 20 year flood event flows with 1 in 20 year tide level as boundary conditions (adopted as 2.3 mAHD).
- 1 in 5 year flood event flows with 1 in 100 year tide level as boundary conditions (adopted as 2.6 mAHD).

The development was modelled by assuming that all developed areas would be filled to be above the 1 in 100 year ARI flood level.

Modelling results for flood levels showed that the effects of the adjacent development on local flooding levels were contained within the relevant site (Lot 1 DP 725785). Flood hazard mapping showed that there are some small areas of Lot 1 DP 1097743 closest to Moonee Creek that are classified as "High Flood Risk Precinct", indicating that the land is subject to high hydraulic hazard. Modelling results indicated

that downslope of Moonee Creek section 6580 (upslope of the subject site), peak flood levels resulted from the high tailwater scenarios rather than the peak flood flow scenario.

Report figures showing model layouts and flood risk precincts are reproduced in Attachment D. Flood level results of the assessment for sections close to the subject site are summarised in Table 4.

Table 4: Summary of peak flood levels in Moonee Creek and Bucca Creek in the vicinity of the site (CLT, 2007).

Creek / Model Branch	Section Chainage	1 in 100 Year ARI Water Surface Level Envelope (mAHD)	
		Existing Conditions	Developed Conditions
Moonee Creek	6900	2.69	2.69
	7200	2.65	2.65
	7280	2.64	2.64
	7400	2.64	2.64
Bucca Creek	800	3.92	3.98
	810	3.91	3.98
	840	3.85	3.97
	866	3.77	3.81
	900	3.71	3.77
	1030	3.46	3.51
	1100	3.22	3.34
	1270	3.01	3.03
	1350	2.84	2.87
	1520	2.68	2.68
	1800	2.65	2.65

3.2 Flood Assessment Methodology and Assumptions

3.2.1 Overview

The flood assessment was only undertaken for proposed development at Lot 1 DP1097743 only.

The purpose of the flood assessment is to provide details of flood heights and extents for the 1 in 100 year ARI and Probable Maximum Flood (PMF) events for existing and developed conditions in accordance with Council requirements. The assessment makes use of the SMS Tuflow two-dimensional hydraulic modelling package and results of hydrological modelling undertaken using the RAFTS program to determine flood characteristics for existing and proposed conditions.

3.2.2 *Objectives*

The objectives of the flooding assessment are as follows:

- Determine existing site flood characteristics during the 1 in 20, 1 in 100 year ARI and PMF events, including peak flood heights, velocities, hazard classification and direction of flows.
- Determine changes to site flood characteristics for post-development conditions during the modelled flood events, with investigation of the effects of proposed site filling on flood behaviour on adjacent properties.
- Preparation of flood extents and depth maps.

3.2.3 *Methodology and Assumptions*

In accordance with the NSW Department of Environment and Climate Change (2010) Draft Flood Risk Management Guideline, the following scenarios have been assessed to determine the peak 1 in 100 year ARI flood characteristics for Moonee Creek and Bucca Creek at the site:

- Scenario 1 – 1 in 100 year ARI ocean level with 1 in 20 year ARI catchment flooding with coincident peaks.
- Scenario 2 – 1 in 100 year ARI catchment flooding with 1 in 20 year ARI ocean level with coincident peaks.
- Scenario 3 – 1 in 100 year ARI catchment flooding with neap tide cycle with coincident peaks.

The flood characteristics of the PMF have been assessed assuming PMF catchment flooding coinciding with peak neap tide.

The effects of climate change on results are also assessed as detailed in Section 3.5.

The study used the following computer models to determine site flood characteristics:

- RAFTS hydrological modelling package to determine existing and post-development peak flow rates and sub-catchment hydrographs for the critical duration 1 in 20 year; 1 in 100 year ARI and Probable Maximum Precipitation (PMP) storms for use in the flood modelling (Section 3.4). Design rainfall data used in the model were sourced from NSW Bureau of Meteorology and are considered to be consistent with figures provided by Council.
- Tuflow 11.0.10 1D / 2D hydraulic modelling package to determine existing and post-development flood characteristics

and potential effects of proposed development on adjacent properties and infrastructure.

Models used a conceptual design layout and surveyed site levels provided by the Client as well as LiDAR data and drainage information provided by Council. Plans showing the concept layout and existing and proposed site contours are provided in Attachment A. Key assumptions used in the modelling are detailed below:

3.2.4 RAFTS Model Assumptions

- Storm durations from 10 minutes to 24 hours were assessed for the 1 in 20 year ARI; 1 in 100 year ARI storm and PMP rainfall events to determine the critical duration storm events.
- Post-development flood hydrographs were assumed to be as per existing conditions as it is expected that any (minor) additional flows from the site that might otherwise increase the peak flow rate for the overall catchment will be discharged on the rising limb of the hydrograph for Moonee Creek.
- Sub-catchments were split into land use categories based on zoning maps and aerial photos. Pervious and impervious area used in the model are summarised in Table 5.
- Sub-catchment boundaries were determined on the basis of the 1:25,000 Moonee Beach topographic map. Existing stormwater pit and pipe networks (e.g. road drainage) were not considered in determining model sub-catchments for both existing and proposed conditions.
- Initial and continuing losses used in the modelling are based on values given in AR&R (1987) and are considered to be appropriate for this development.
- Sub-catchments were split into two sub-catchments within the model, consisting of pervious and impervious areas.
- PERN roughness coefficients used assumed a weighted value for pervious areas based on percentage of forested, pasture and urban pervious areas.

3.2.5 Tuflow Model

- Existing and proposed conditions models used survey data and design levels provided by the Client and LiDAR data provided by Council. Survey data was fenced and merged with design contours using the 12D surveying and design package.

- Ground levels did not include proposed earthworks for the adjacent "Glades" development to the north of the subject site.

- Model boundaries were set at the Pacific Highway, upslope of the confluence of Moonee Creek and Skinners Creek and approximately at the mouth of Moonee Creek (i.e. at the ocean).

- Developed site conditions were modelled by assuming the "developed portion of the site" was filled to a nominal level of 20 mAHD to simulate proposed earthworks to lift site developed areas above the flood planning level.

- Individual buildings such as dwellings, garages, sheds *etc*. were not included in the model. Urban areas downslope of the site were given a high Mannings Roughness (0.2) to simulate obstructions.

- Model used a 10 m x 10 m grid cell for existing and proposed conditions, based on existing and proposed tin levels calculated using 12D.

- Existing site stormwater culverts were not included in the model. This will give a conservative result as it assumes that all site stormwater and run-on will flow over existing accesses.

- Model used sub-catchment hydrographs for the 9 hour storm events for all average recurrence intervals modelled, calculated from the hydrological modelling for existing and proposed conditions.

- Manning's Roughness was based on aerial photography of the site and site inspections. Details of Manning's Roughness used in existing and proposed conditions models are provided in Attachment C.

- Proposed site water quality basins were not included in post-development analyses as these are within the "developed portion of the site" as noted above and these areas were modelled as filled to a nominal level of 20 mAHD.

- Site downslope boundary conditions were set at peak ocean levels as provided by Council.

3.3 Hydrological Modelling

RAFTS modelling conducted for this study used sub-catchment data as summarised in Table 5 and Table 6. Catchment plans are provided in

Attachment A. Results (in terms of total peak flow discharged from the sub-catchments) are summarised in Table 7. General comments about the hydrological modelling are as follows:

- The critical storm duration for the overall catchment is the 9 hour storm event for the 1 in 20 year ARI, 1 in 100 year ARI and PMP events. Sub-catchment hydrographs for these event were used in the hydraulic model.

- Peak flows obtained from the model for the 1 in 100 year ARI and 1 in 20 year ARI are comparable to the results obtained in the CLT (2007) flood assessment for "The Glades" development using the calibrated MIKE-11 model.

Table 5: Summary of sub-catchments used in RAFTS hydrological modelling.

Catchment	Area (ha)	Impervious Area (ha)	Pervious Area (ha)	Impervious PERN	Pervious PERN	Slope (%)
Sugar Mill Ck	926.9	70.4	856.6	0.015	0.075	6.3
Moonee Lower	224.4	16.7	207.7	0.015	0.087	0.3
Cunninghams Ck	360.6	28.5	332.1	0.015	0.078	4.4
Bucca Ck	78.6	13.5	65.1	0.015	0.062	2.0
Skinners Ck	785.6	21.7	763.9	0.015	0.089	3.8
Moonee Upper	1,804.9	38.4	1,766.4	0.015	0.089	2.2
Total	4,181.0	189.2	3,991.8	0.015	-	-

Table 6: Summary of initial and continuing losses used in RAFTS hydrological modelling.

Sub-catchment	Initial Loss (mm)	Continuing Loss (mm/hr)
Pervious	15.0	2.5
Impervious	1.5	0.0

Table 7: Summary of results of RAFTS hydrological modelling (total peak discharge for Moonee Creek catchment) for storms modelled.

Duration (minutes)	1 in 20 Year ARI Peak Discharge (m^3/s)	1 in 100 Year ARI Peak Discharge (m^3/s)	PMF Peak Discharge (m^3/s)
10	112.7	147.3	-
15	141.8	183.6	644.3
20	137.0	180.7	-
25	170.8	214.6	-
30	159.3	203.8	775.0
45	139.7	216.9	1,026.8
60	178.5	258.4	1,260.6
90	217.9	326.1	1,387.1
120	243.1	374.7	1,505.2
180	273.9	410.6	1,399.8
270	285.3	421.3	-
360	305.0	444.6	1,459.2
540	379.5	547.0	1,685.1
720	346.8	510.5	1,675.8
1080	304.1	429.5	1,448.8
1440	363.3	503.9	1,094.8

3.4 Site Flooding Assessment

3.4.1 Model set-up

The existing and proposed conditions models were set-up with the assumptions and conditions given in Section 3.2.2. Manning's Roughness by surface type used in the hydraulic model are summarised in Table 9. Hydrographs for the 1 in 20 and 1 in 100 year ARI and PMF 9 hour storms calculated in the hydrological model were used for site sub-catchments. Sea levels adopted at model boundaries for each scenario are summarised in Table 8.

Table 8: Summary of sea level boundary conditions adopted in hydraulic modelling.

Scenario	Sea Level adopted at model boundary (mAHD)
1 (1 in 100 year ARI sea level)	2.40
2 (1 in 20 year ARI sea level)	2.10
3 (neap tide)	0.60
4 (PMF flood – adopted as neap tide)	0.60
5 (climate change – 1 in 20 year ARI level with additional 0.91 m)	3.01

Table 9: Summary of Mannings Roughness used in hydraulic modelling.

Catchment Surface	Manning's Roughness used in Model
Buildings	0.200
Road and Hardstand	0.013
Beach	0.025
Riparian	0.070
Creek	0.04 < 0.3 m 0.01 – 0.04 for 0.3 – 0.6 m 0.01 > 0.6 m
Urban	0.150
Forested	0.070
Rural Residential / Agricultural	0.035

3.4.2 Hydraulic Modelling Results

Results of hydraulic flood modelling are presented graphically in the attached plans (Attachment B), with peak flood levels for each scenario modelled summarised in Table 11. The following general comments are made:

- Analyses utilised DA surface level designs and shall be further refined at detailed design stage.
- Results (D103 – D114 Attachment B) show that proposed site filling has no significant adverse effects on existing flood behaviour (height and extents) on adjacent properties (upslope and downslope) during the 1 in 100 year ARI and PMF flood events. Increases are within the margins of error for the model.
- Results indicate minimal change in velocity of floodwater as a result of site filling for both the 1 in 100 year ARI and PMF events. Changes to flood velocity appear to be generally confined to the area downslope of the driveway access to Lot 2 DP 1097743.
- 1 in 100 year ARI flood hazard mapping for the site indicates that inundated areas of the site for post-development conditions generally experience flows with velocity x depth products ("v.d product") of less than 0.4 m^2/s, indicating that hydraulic hazard across the site is generally low. Areas within Bucca Creek and adjacent to the eastern site boundary along the edge of Moonee Creek experience high hydraulic hazard flows. Hazard extents do not appear to change significantly for post-development conditions.

- The access to Lot 2 in DP1097743 will be inundated for the 1 in 100 year ARI flood event for existing conditions. Raising the access and the provision of new culverts underneath the driveway where it crosses Bucca Creek is recommended to ensure that the driveway is trafficable during the 1 in 100 year ARI for existing climate conditions.

- Results of the modelling have been assessed against previous modelling conducted for other local developments (Section 3.1). Flood heights, velocities and extents are consistent with other accepted flood models of Moonee Creek.

Table 10: Description of model observation points.

Observation Point	Description
1	Moonee Creek at Confluence with Cunninghams Creek
2	South-eastern site boundary corner
3	Driveway to Lot 2 DP 1097743
4	North-eastern site boundary corner
5	Bucca Creek adjacent to eastern site boundary
6	Moonee Creek at confluence with Bucca Creek
7	Bucca Creek downslope of Pacific Highway
8	Bucca Creek approximately 400 m downslope of Pacific Highway
9	Site northern boundary
10	Lawn area Lot 2 DP 1097743
11	Moonee Creek approximately 350 m upslope of Bucca Creek confluence

Table 11: Summary of peak flood levels (mAHD) per scenario modelled for selected observation points.

Observation Point	Scenario Modelled						Adopted 1 in 100 Year ARI Level	
	1		2		3			
	Existing Conditions	Proposed Conditions	Existing Conditions	Proposed Conditions	Existing Conditions	Proposed Conditions	Existing Conditions	Proposed Conditions
1	2.76	2.76	2.90	2.90	2.80	2.80	2.90	2.90
2	2.76	2.76	2.90	2.90	2.80	2.80	2.90	2.90
3	2.76	2.76	2.90	2.90	2.80	2.80	2.90	2.90
4	2.76	2.76	2.90	2.90	2.80	2.80	2.90	2.90
5	2.76	2.76	2.90	2.90	2.80	2.80	2.90	2.90
6	2.76	2.76	2.90	2.90	2.80	2.80	2.90	2.90
7	4.12	4.12	4.16	4.16	4.16	4.16	4.16	4.16
8	3.10	3.10	3.12	3.12	3.12	3.12	3.12	3.12
9	3.24	D[1]	3.27	D[1]	3.27	D[1]	3.27	D[1]
10	D[1]	D[1]	D[1]	D[1]	D[1]	D[1]	D[1]	D[1]
11	2.78	2.78	2.94	2.94	2.84	2.84	2.94	2.94

Notes: [1.] D denotes dry at peak flood level.

Table 12: Summary of peak flood levels (mAHD) for PMF conditions for selected observation points.

Observation Point	Existing Conditions (mAHD)	Proposed Conditions (mAHD)	Change (m)
1	4.64	4.64	0.00
2	4.65	4.65	0.00
3	4.66	4.66	0.00
4	4.66	4.66	0.00
5	4.65	4.65	0.00
6	4.65	4.65	0.00
7	4.67	4.68	0.01
8	4.66	4.67	0.01
9	4.66	D[1]	-4.66
10	4.65	4.65	0.00
11	4.67	4.67	0.00

Notes: [1.] D denotes dry at peak flood level.

3.5 Climate Change and Sea Level Rise

3.5.1 Anticipated Sea Level Rise

In the Floodplain Risk Management Guideline -- Practical Consideration of Climate Change (2010) indicated that average global sea level rise

is between 0.18m to 0.79m by between 2090 and 2100. However, the NSW coast is expected to rise more than the global mean and is expected to be in range of 0.18m to 0.90m.

To assess the likely impact of sea level rise on site flooding, the hydraulic model was re-run for the adopted 1 in 100 year ARI flooding scenario with the downstream boundary condition of the 1 in 20 year ARI sea level (i.e. scenario 2) increased by 0.91 m. Results of the model are summarised below.

Results (D115 – 117 Attachment B) show that flood levels at the site generally increase by 0.14 – 0.50 m. Peak velocities in the lower Moonee Creek system for climate change conditions are generally increased over the floodplain areas and decreased in the main channel. Flood hazard increases with increased depth and the site access driveway to Lot 2 DP1097743 will be inundated to a greater depth and for a longer period of time.

Modelling indicates that the development has minimal impact on flooding (compared to existing ground conditions) for climate change flood events modelled.

Table 13: Summary of peak flood levels (mAHD) for climate change - sea level rise for the 1 in 100 year ARI flood event.

Observation Point	Existing Conditions (mAHD)	Proposed Conditions (mAHD)	Change in level from existing climate conditions (m)
1	3.39	3.39	0.49
2	3.40	3.40	0.50
3	3.40	3.40	0.50
4	3.40	3.40	0.50
5	3.40	3.40	0.50
6	3.40	3.40	0.50
7	4.16	4.16	0.00
8	3.41	3.40	0.29
9	3.41	D[1]	0.14 (Existing only)
10	D[1]	D[1]	-
11	3.42	3.42	0.48

Notes: [1.] D denotes dry at peak flood level.

3.5.2 Climate Change and Rainfall Intensities

In the Floodplain Risk Management Guideline -- Practical Consideration of Climate Change (2007) shows the potential impacts of changes in current design ARIs due to increases in rainfall by 2030 and 2070. It shows that an average of 15% increase in extreme rainfall is adopted in

NSW catchments and an increase of 10% is adopted for catchment for Northern Rivers.

Accordingly, the hydrological and hydraulic models were re-run for the 1 in 100 year ARI storm events including the effects of climate change by increasing the rainfall intensities of existing 1 in 100 year ARI storms by 10%. Results of the hydrological model show that the 9 hour storm event remains to be the critical storm duration. Results are summarised in Table 14.

Table 14: Summary of peak flow rates (overall Moonee Creek catchment) for increased rainfall intensities for hydrological model sub-catchments.

Duration (minutes)	1 in 100 Year ARI with Climate Change Peak Discharge (m^3/s)
10	164.80
15	203.84
20	202.72
25	239.16
30	227.31
45	247.77
60	295.78
90	369.02
120	422.97
180	459.22
270	470.66
360	495.98
540	607.08
720	567.22
1080	472.49
1440	554.68

The hydraulic model was re-run using the hydrographs generated by the 1 in 100 year ARI with climate change 9 hour storm event, in conjunction with the 1 in 20 year ocean peak level with climate change as the downstream boundary condition. A summary of peak flood heights and change in flood heights at the site is provided in Table 15.

Table 15: Summary of peak flood levels (mAHD) for climate change – rainfall intensity increase and sea level rise for the 1 in 100 year ARI flood event.

Observation Point	Existing Conditions (mAHD)	Proposed Conditions (mAHD)	Change in level from existing climate conditions (m)	Difference in level from sea level rise only (m)
1	3.46	3.46	0.56	0.07
2	3.46	3.47	0.57	0.07
3	3.46	3.47	0.57	0.07
4	3.46	3.47	0.57	0.07
5	3.46	3.47	0.57	0.07
6	3.46	3.47	0.57	0.07
7	4.18	4.18	0.02	0.02
8	3.47	3.47	0.36	0.07
9	3.47	D[1]	0.20 (Existing only)	0.06
10	D[1]	D[1]	-	-
11	3.49	3.49	0.55	0.07

Notes: [1.] D denotes dry at peak flood level.

Results of the modelling (D118 – D120 Attachment B) indicate that the major factor in increased flood levels at the site as a result of climate change will be sea level rise as opposed to increased rainfall intensity. This result is expected given the relatively close proximity of the site to the Pacific Ocean and relative site levels.

3.6 Flood Planning Level

In accordance with the Council's (2009) Engineering Design guidelines, a freeboard of 0.5 m is required from site floor levels to the 1 in 100 year ARI level in open channels. On this basis, it is recommended that the Flood Planning Level (FPL) for the site be set at 3.97 mAHD on the basis of the 1 in 100 year with climate change flood level (1 in 100 year ARI rainfall plus 10% intensity and 1 in 20 year ARI sea level with sea level rise) in Moonee Creek adjacent to the site (3.47 mAHD) plus a freeboard of 0.5 m.

4 Recommendations and Conclusions

The following recommendations and conclusions are made based on the hydrological and flood assessments:

- The proposed development does not have an adverse flooding impact on neighbouring properties based on detailed hydraulic modelling completed.
- All flooding impacts arising from the proposed development are contained within the subject site.
- 1 in 100 year ARI flood hazard mapping for the site indicates that inundated areas of the site for post-development conditions generally experience flows with velocity x depth products ("v.d product") of less than 0.4 m^2/s, indicating that flood hazard across the site is generally low. Areas within Bucca Creek and adjacent to the eastern site boundary along the edge of Moonee Creek experience high hazard flows. Hazard extents do not appear to change significantly for post-development conditions.
- The access to Lot 2 in DP1097743 will be inundated for the 1 in 100 year ARI flood event for existing conditions. Raising the access and the provision of new culverts underneath the driveway where it crosses Bucca Creek is recommended to ensure that the driveway is trafficable during the 1 in 100 year ARI for existing climate conditions.
- Effects of climate change on existing and proposed conditions flood behaviour is to raise levels by as much as 0.5 m based on sea level rise only and by as much as 0.57 m based on sea level rise and a 10% increase in rainfall intensities. There is no significant effect of the development on flood behaviour for climate change events modelled.
- FPL for the site should be set at 3.97 mAHD based on 1 in 100 year ARI with climate change peak flood level in Moonee Creek adjacent to the site plus 0.5 m freeboard.

5 References

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