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UMWELT FLOOD STUDY 2003 & 2016

Astoria Developments Pty Limited

1 in 100 Year Flood Study

Lot 1 DP 789002, Lot 1 DP 26125 & Lot 12 DP 835612

Arrawarra Beach Caravan Park, Arrawarra

September 2003

Umwelt
Environmental Consultants

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1.0 INTRODUCTION

A Development Application is being prepared for the redevelopment of the Arrawarra Beach Caravan Park to residential development. Umwelt (Australia) Pty Limited (Umwelt) has been commissioned by Astoria Developments Pty Ltd to prepare a flood study to determine the 1:100 year Average Recurrence Interval (ARI) flood levels adjacent to the site.

The Caravan Park is situated at the confluence of Arrawarra Creek and Yarrawarra Creek adjacent to the Pacific Ocean. The aim of the flood study is to determine the peak 1 in 100 year ARI level of inundation on the caravan park site. In determining the peak level of inundation, flood flows from the Arrawarra and Yarrawarra Creek catchments, together with storm surge wave heights from the ocean, have been assessed. The wave heights, design tailwater levels and revetment design were investigated and detailed by SMEC (2003).

2.0 SITE DESCRIPTION

The Caravan Park site is located on Lot 1 DP 789002, Lot 1 DP 26125 and Lot 12 DP 835612 Arrawarra Beach Road, Arrawarra (refer to **Figure 1**). The site is currently being operated as a Caravan Park of approximately 2.5 hectares in area.

The site is bound by Arrawarra Creek to the south and Yarrawarra Creek to the east. An existing continuous sea wall comprising rock gabion baskets is located along the site boundary between the creeks.

Levels over the site vary from approximately RL 4.5 mAHD to RL 2 mAHD. The site is relatively flat with pockets of trees that have been underscrubbed for camp sites (refer to **Figure 2**).

The Arrawarra Creek catchment extends west of the Pacific Highway to the Wedding Bells State Forest. The catchment also includes parts of Mullaway and Little Arrawarra Gully. The catchment area of approximately 925 hectares is well-vegetated with little urban development.

The Yarrawarra Creek catchment extends both north and west of the site. Arrawarra Gully from the Wedding Bells State Forest west of the Pacific Highway enters Yarrawarra Creek north of the site. This catchment includes part of the town of Corindi Beach that drains into a large swampy area upstream of Yarrawarra Creek behind the sand dunes. From inspection of the Orthophoto Maps, the swampy area would act as a sink, only rarely discharging into Yarrawarra Creek. The catchment area of Yarrawarra Creek is approximately 842 hectares including the swampy area.

Surveyors Newnham Karl Weir & Partners provided a detail survey of the site and cross-sections of the Arrawarra and Yarrawarra Creek frontages for the site.

3.0 PROPOSED DEVELOPMENT

The proposed redevelopment of the site is to be residential development. At this stage, no layout has been provided.

Legend

Study Area

Umwelt (Australia) Pty Limited
Source: Topographic Map 1:25 000 9537-4-N

FIGURE 1
Locality Plan

A4 Scale 1:25 000 | Ref No.:R03_V1/1698_021.dgn

Legend

Study Area

FIGURE 2
Aerial Photo of Site

Umwelt (Australia) Pty Limited
Source: Public Works Photogrammetric Analysis (March 95)

A4 Approx. Scale 1:3000 | Ref No.:R03_V1/1698_020.dgn

4.0 BACKGROUND INFORMATION AND REFERENCES

Umwelt has referenced the following background information in order to model the catchment and prepare this flood study:

1. "*Arrawarra Caravan Park Revetment Design*" September 2003, Document No. 31390-001 prepared by SMEC.

2. Newnham Karl Weir & Partners – Detailed Plan and Cross Sections of the site – April 2003.

3. Woolgoolga Y1865-1, Corindi Beach Y1872-7, Y1872-4 1:4,000 Orthophoto maps.

4. 9537-4-N 1:25,000 Topographical map.

5. Arrawarra Caravan Park Revetment Design Report – prepared by SMEC (September 2003).

6. Bureau of Meteorology Daily Rainfall Data for Coffs Harbour (Station No.'s 59010 and 59040) for 1899-present. Daily Rainfall Data for Arrawarra Caravan Park (Station No. 59132) September 1986 to March 1992 and Daily Rainfall Data for Woolgoolga (Station No. 59039) 1887-present.

Historical records provided by Council indicate a maximum observed flood level of 2.6 mAHD at the eastern boundary and 2.7 mAHD at the northern boundary.

The Intensity Frequency Duration (IFD) Data used for this study was determined using Australian Rainfall and Runoff Data for Arrawarra.

5.0 CATCHMENT AREA

The catchment areas for both Arrawarra and Yarrawarra Creeks were divided into subcatchments. The subcatchment boundaries represented changes in vegetation or slope at landmark locations such as creek confluences and intersection with the Pacific Highway as shown in **Figure 3**. The 1:25,000 topographic and 1:4,000 orthophoto maps were used to define the subcatchments shown below in **Table 5.1**.

Table 5.1 – Subcatchments for Arrawarra and Yarrawarra Creek

Subcatchment Name	Subcatchment Node	Subcatchment Description	Size (ha)	Flows to
Little Arrawarra Gully	LAG	Well defined gullies and hills - 10%	245	AC_CON
Arrawarra Creek	AC_PH	Well defined gullies and hills - 10%	433	AC_CON
Confluence of LAG/AC_PH	AC_CON	Flat - 2%, well vegetated	147	AC_UL
Arrawarra Creek - Upstream of Lagoon	AC_UL	Flat - 1%, well vegetated	80	AC_DL
Arrawarra Creek - Downstream of Lagoon	AC_DL	5% some hills	20	Section 1
Corindi Town	COR_TOWN	Open fields, 5% slope, 10% res.	26.6	COR_SWAMP

Legend

- Catchment Boundary
- Nodal points
- Flow direction

Umwelt (Australia) Pty Limited
Source: 1:25 000 Topographic Map (LPI NSW)

FIGURE 3
Catchment Plan and Nodal Layout

A4 Scale 1:35 000 | Ref No.:R03_V1/1698_016.dgn

Table 5.1 – Subcatchments for Arrawarra and Yarrawarra Creek (cont)

Subcatchment Name	Subcatchment Node	Subcatchment Description	Size (ha)	Flows to
Upper Corindi Road	COR_ROAD	Well defined gullies and hills - 10%	250	PAC_VAN
Pacific Highway/ Caravan Park	PAC_VAN	Flat - 2%, well vegetated	110	COR_SWAMP
Corindi Swamp	COR_SWAMP	Very Flat, marshes, 0.5%	75.4	YARRA_CON
Arrawarra Gully	AG	Well defined gullies and hills - 10%	255	ABR_NORTH
North of Arrawarra Beach Road	ABR_NORTH	Flat - 2%, well vegetated	44.5	YARRA_CON
Confluence with Yarrawarra Creek	YARRA_CON	Flat - 1%, well vegetated	81	YARRA_SEC

6.0 MODELLING METHODOLOGY

The peak flows and flood levels for the 1:100 year ARI rainfall event for the site and contributing catchments were modelled using XP-STORM, which is a one-dimensional hydrodynamic model. The XP-STORM model can be used to model stormwater flows in watercourses, culverts and conventional street drainage systems. The model is suitable to calculate overland runoff generated from large natural or developed catchments. The model also has the capacity to predict flood levels as a result of backwater effects. These capabilities indicate that the XP-STORM model is suitable to determine the peak flows and flood levels for the catchment.

The equation used in the XP-STORM model analysis was the Laurenson Equation, that is:

$$S = BQ^{n+1}$$

Where, S = volume of storage (m^3/s)
B = Storage Delay Parameter,
Q = instantaneous rate of runoff (m^3/s),
n = -0.285.

The infiltration for the subcatchments was categorised into three (3) groups. The groups were defined by the topographical features within each subcatchment. XP-STORM has the flexibility to permit different rates of infiltration to be specified for each subcatchment. The infiltration was defined by initial loss/continuing loss parameters as shown below in **Table 6.1**.

Table 6.1 – Infiltration Parameters

Catchment Description	Initial Loss (mm)	Continuing Loss (mm/hr)
Sand/well vegetated	20	2.5
Flat swampy Marsh	35	2.5
Cleared slopes	15	2.5

The values in **Table 6.1** are within the design loss rates range specified in Table 6.2 of Australian Rainfall & Runoff (1987) for New South Wales, east of the western slopes. The range is an initial loss of 10-35 mm and a continuing loss of 2.5 mm/hr.

A range of Manning's 'n' values have been used to simulate and represent the changes to the creek and creek banks along both Arrawarra and Yarrawarra Creeks. **Table 6.2** represents a summary of the range of Manning's 'n' values adopted in the model to describe the creek. The orthophoto maps and photos of the creeks were used to define the Manning's 'n' values.

Table 6.2 – Manning's 'n' Values

Creek Description	Manning's 'n'
Tree lined banks	0.1
Main channel upper reaches of Arrawarra Creek	0.04
Main channel upper reaches of Yarrawarra Creek	0.05
Gabion Basket banks	0.05
Main channel sandy lower reaches of Yarrawarra and Arrawarra Creeks	0.03

As shown in **Table 6.2**, the main channel upper reaches of Yarrawarra Creek are described with model parameters as being slightly rougher than the main channel upper reaches of Arrawarra Creek. This is due the greater number of creek bends in Yarrawarra Creek.

The model was established with a series of nodal points used to describe the catchment (refer to **Figure 3**). The nodal points were located both upstream and adjacent to the site for each subcatchment (refer to **Table 5.1**). Cross sections of the upper reaches were defined from the Orthophoto maps and photos of the creeks. The creek cross sections adjacent to the site were derived from survey information provided by Newnham Karl Weir & Partners (April 2003). This information was used to describe the conveyance of both Arrawarra and Yarrawarra Creeks.

A cross-section, ORTHOSEC, as shown in **Figure 4**, was developed to describe the sand bar entrance of the creek confluence with the ocean. The section was developed by compiling information from cross-sections 9 to 11 (Newnham Karl Weir & Partners, April 2003) and the Orthophoto maps. The section extends from the dunal system to the north, over the sand bar entrance to the neck of the headland to the south. Whilst it is acknowledged that sand movement at the entrance is continually changing with rainfall events and storm surges, this section was used to describe the interface between the creek systems and the Pacific Ocean.

The swampy area downstream of Corindi Beach township, referred to as COR_SWAMP from **Table 5.1** and **Figure 3**, was modelled as a detention basin. It is evident from the Orthophoto Maps that this area is large, flat and only rarely overtops into Yarrawarra Creek. During regular rainfall events it is also evident that this area will pond water acting like a sink. Stormwater will be lost from the swamp via infiltration and evaporation losses.

The tailwater level used in the XP-STORM model for the 1 in 100 year ARI rainfall event were derived from SMEC (2003).

In order to analyse flooding impacts of peak flow velocity and peak flood levels, a range of tailwater scenarios were simulated in conjunction with the 1:100 year ARI rainfall event occurring.

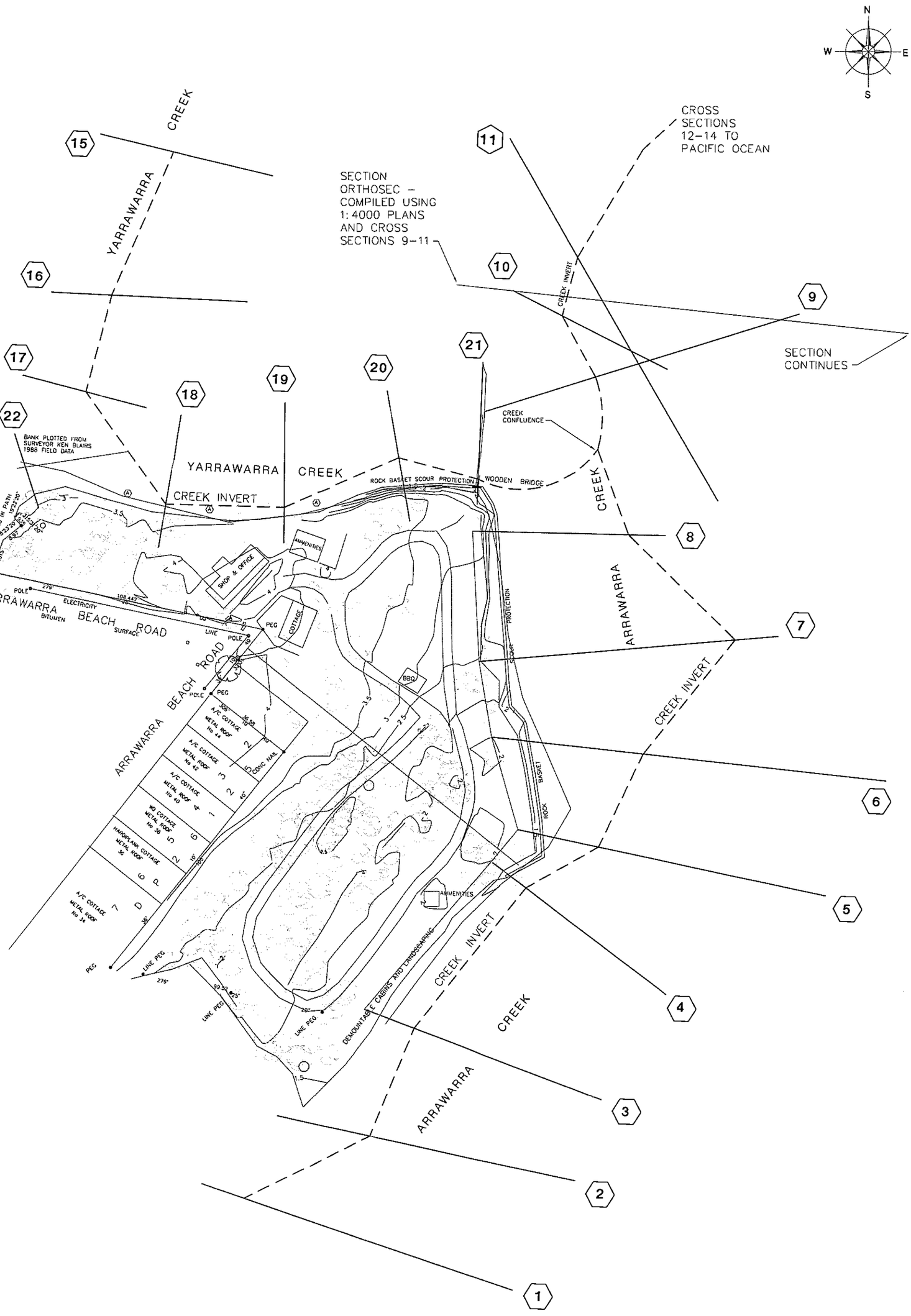


FIGURE 4
Cross Section Layout
– Site Plan

A3 Scale 1:1500	Ref No.:R03_V1/1698_017.dgn

Umwelt (Australia) Pty Limited
Source: Newnham Kari Weir & Partners

A low tidal level of 0.5 mAHD as a tailwater level, would produce the peak velocities necessary for assessment of the revetment design. SMEC (2003) specified tailwater levels as the nearshore still water levels for the Pacific Ocean, taking into account:

- storm surge;
- high tide ; and
- future sea level rises due to greenhouse effects.

7.0 MODELLING RESULTS

7.1 PEAK FLOOD LEVELS – 1:100 YEAR RAINFALL EVENT

A range of storm durations were simulated to determine the critical storm duration from the upstream catchment (i.e. the storm duration that produced the peak flow from the 1:100 year ARI rainfall event). It has been assumed conservatively within the model that the peak flow from the 1:100 year ARI rainfall event occurs at the same time as the moderate wave height peak tailwater level provided by SMEC (2003). The simulated peak flows measured at the outfall to the Arrawarra Creek and Yarrawarra Creek confluence are presented in **Table 7.1**.

Table 7.1 - Storm Durations and Flows for the 1:100 year ARI Rainfall Event

Storm Duration (hours)	2	3	6	9	12
Peak Flow (m^3/s) – Tailwater Level 2.85 mAHD	75.6	78.1	79.8	**86.6**	79

From **Table 7.1** it can be seen that the peak flow from the 1:100 year ARI rainfall event at the outfall to the confluence was 86.6 m^3/s for a critical storm duration of 9 hours. During this event, the peak flow is approximately 70.5 m^3/s in Arrawarra Creek and approximately 18.5 m^3/s in Yarrawarra Creek. The difference between the addition of these two flows to the total peak flow is due to the timing of the peak flows from each creek.

To determine the potential peak water level adjacent to the site during a 1:100 year ARI rainfall event, a tailwater level of 2.85 mAHD as modelled by SMEC (2003) was used. The results of this simulation are shown below in **Table 7.2**.

Table 7.2 - Model Results from XP-STORM for Moderate Wave Event

Section	Description of Location	Peak Flood Level (m AHD)	Peak Velocity (m/s)
SEC 2	Arrawarra Creek – southern site boundary	2.87	0.27
SEC 6	Arrawarra Creek – midway between southern site boundary and confluence	2.86	0.31
SEC 18	Yarrawarra Creek – western site boundary	2.87	0.16

Table 7.2 - Model Results from XP-STORM for Moderate Wave Event (cont)

Section	Description of Location	Peak Flood Level (m AHD)	Peak Velocity (m/s)
SEC 19	Yarrawarra Creek – midway between western site boundary and confluence	2.86	0.20
ORTHOSEC	Outfall to Pacific Ocean downstream of confluence	2.85	0.33

Table 7.2 indicates that the peak flood levels are very flat over the site as a result of backwater effects from the high tailwater level. Peak velocities are low due to the resistance to outflow from the high tailwater level.

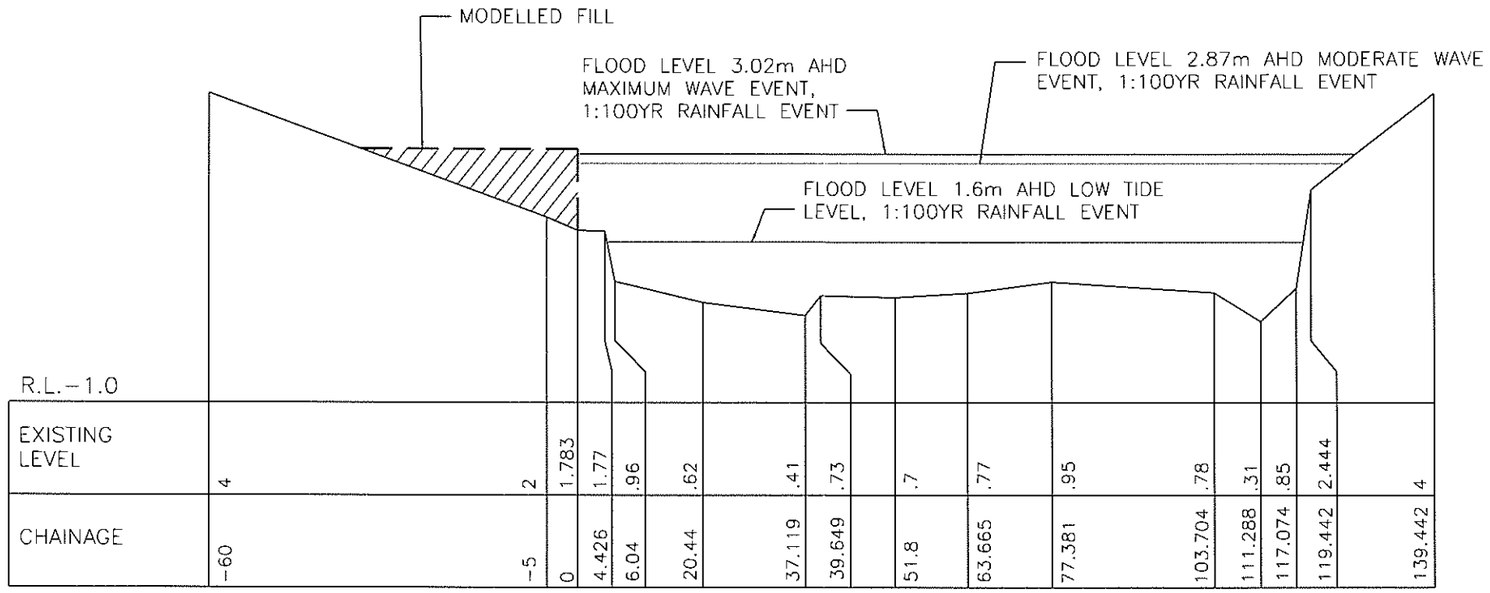
To assess the sensitivity of the tailwater level, peak flood levels at the site were modelled using peak discharges from a 1:100 year ARI rainfall event and the maximum tailwater level from a 1:100 year ocean storm event of 3.0 mAHD (SMEC 2003). The model results for this simulation are shown in **Table 7.3**.

Table 7.3 - Model Results from XP-STORM for the Maximum Wave Event

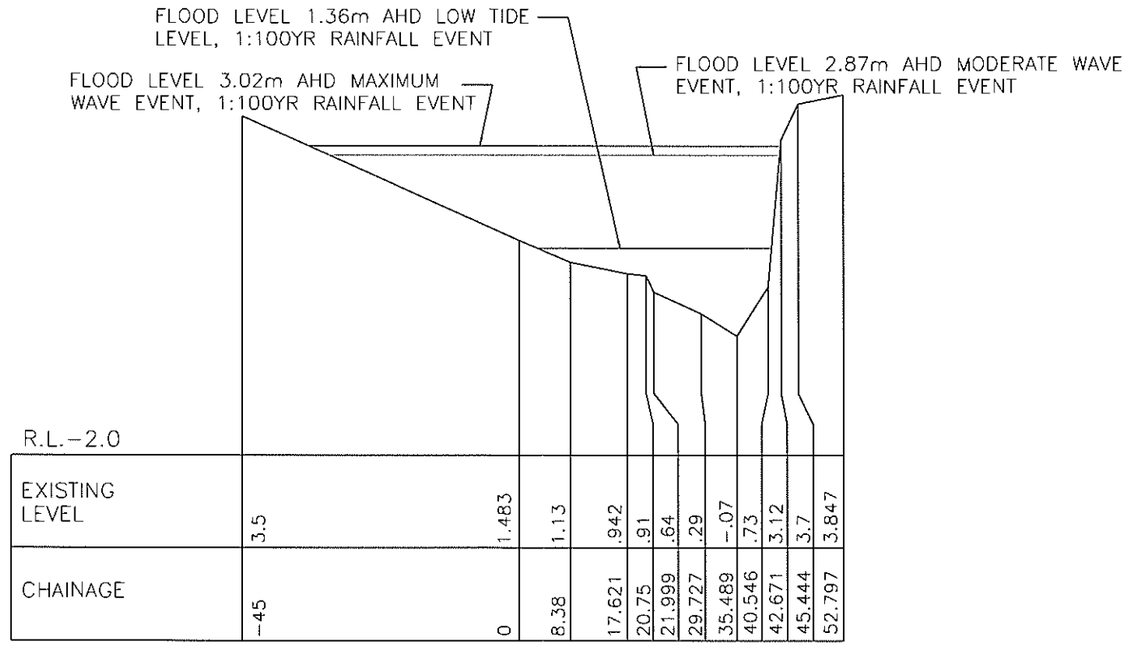
Section	Description of Location	Peak Flood Level (m AHD)	Peak Velocity (m/s)
SEC 2	Arrawarra Creek – southern site boundary	3.02	0.25
SEC 6	Arrawarra Creek – midway between southern site boundary and confluence	3.01	0.29
SEC 18	Yarrawarra Creek – western site boundary	3.02	0.15
SEC 19	Yarrawarra Creek – midway between western site boundary and confluence	3.01	0.18
ORTHOSEC	Outfall to Pacific Ocean downstream of confluence	3.00	0.31

These results for **Table 7.2** and **Table 7.3** indicate that the tailwater level determined by SMEC (2003) dictates the peak flood levels for the site. The modelling results indicate that the peak flood levels for the site occur in conjunction with the maximum wave event and these levels have been plotted in **Figures 5** and **6**.

Peak velocities from **Table 7.2** and **Table 7.3** for both scenarios are very low due to the backwater effects of the tailwater level at a high elevation. To assess the potential peak velocity during the 1:100 year ARI rainfall event for both creeks, a tailwater level of 0.5 mAHD was used. The results of the simulation are shown below in **Table 7.4.**



SECTION No.2



SECTION No.18

NOTE:
NOTE ALL 0 CHAINAGES ARE ON LEFTHAND SIDE OF CREEK LOOKING DOWNSTREAM

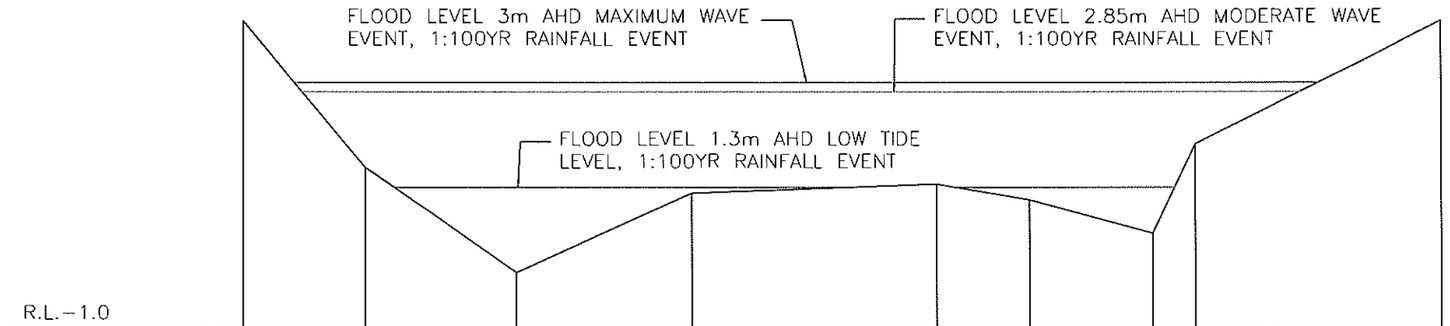
0 20 40 60 m
Horizontal Scale 1:1000

0 2 4 6 m
Vertical Scale 1:100

FIGURE 5
1:100 Year ARI Flood Level
-Cross Sections 2 and 18

A3 Scale: As Shown | Ref No.:R03_V1/1698_018.dwg

Umwelt (Australia) Pty Limited



R.L.−1.0										
EXISTING LEVEL	4.0	1.62	−0.09	1.2	1.35	1.09	0.55	2		4
CHAINAGE	0	20.0	44.5	73	113	128	148	155		195

SECTION ORTHOSEC

NOTE:
NOTE ALL 0 CHAINAGES ARE ON LEFTHAND SIDE OF CREEK LOOKING DOWNSTREAM

0 20 40 60 m
Horizontal Scale 1:1000

0 2 4 6 m
Vertical Scale 1:100

FIGURE 6
1:100 Year ARI Flood Level
−Cross Sections Orthosec

A3 Scale: As Shown

Ref No.:R03_V1/1698_019.dwg

Umwelt (Australia) Pty Limited

Table 7.4 - Model Results from XP-STORM with a 0.5 mAHD Tailwater Level

Section	Description of Location	Peak Flood Level (m AHD)	Peak Velocity (m/s)
SEC 2	Arrawarra Creek – western boundary	1.60	0.8
SEC 7	Arrawarra Creek – 70 m upstream of confluence	1.40	0.85
SEC 8	Arrawarra Creek – adjacent to confluence	1.30	1.23
SEC 18	Yarrawarra Creek – northern boundary	1.36	0.70
SEC 19	Yarrawarra Creek – 80 m upstream of confluence	1.35	1.1
SEC 20	Yarrawarra Creek – 30 m upstream of confluence	1.30	0.5
SEC 21	Yarrawarra Creek – adjacent to confluence	1.30	0.43
ORTHOSEC	Outfall to Pacific Ocean downstream of confluence	1.30	2.15

The modelling simulation indicates that the peak velocity of all creek sections for stormwater flows occurs at the interface of the combined creek system with the Pacific Ocean. All other sections adjacent to the site, including the sections at the confluence, have peak velocities that are less than 1.25 m/s. Peak flood levels for this simulation are also low, due to the wide cross sectional area for conveyance of stormwater. Revetment design by SMEC (2003) has been completed for erosion protection from wave action at the confluence. The design velocity used by SMEC (2003) was 2 m/s which is greater than the maximum predicted velocity adjacent to the proposed revetment of 1.25 m/s.

7.2 SENSITIVITY

A sensitivity analysis has been undertaken to account for variability in the modelled system. Sand movement over the beach berm between the Pacific Ocean and the confluence of Arrawarra and Yarrawarra Creeks is subject to changes in elevation as a result of wave action and stormwater flows. There is also the possibility that a bushfire may occur or that extensive clearing is undertaken in the upper subcatchments. The sensitivity of the flood levels and peak flows for the above scenarios has been analysed.

The beach berm between the Pacific Ocean and the confluence of Arrawarra and Yarrawarra Creeks is described by the cross section – ORTHOSEC. The beach berm and channel levels have been measured by photogrammetry survey since 1943. The peak levels occurred during 1993 with a bar height of 2.2 mAHD and channelised invert level of 1.6 mAHD. This peak level was also adopted by SMEC as a beach profile. The above levels are significantly higher than the bar height of the current survey level of 1.2 to 1.35 mAHD and a channelised invert level at -0.09 mAHD. Modelling the effects of the presence of an elevated sand bar with a maximum wave event and 1:100 year ARI rainfall event are shown below in **Table 7.5**.