Flooding and Hydrodynamics

Nunduk Retreat and Spa @ Seacombe West

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Prepared for

Seacombe West Pty Ltd

3 December 2018

Cardno

Contact Information

Cardno Victoria Pty Ltd
ABN 47 106 610 913

Level 4
501 Swanston Street
Melbourne 3000
Australia

www.cardno.com
Phone +61 3 8415 7777
Fax +61 3 8415 7788

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Author(s):

Name David Provis — 3 December 2018
Job title Senior Principal, Oceanography

Approved By:

Name Rob Swan — 3 December 2018
Job title Principal, Hydrology/Stormwater Management

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Glossary and Abbreviations

Term	Description
AEP	Annual Exceedance Probability. Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP event has a high probability of occurring or being exceeded each year; it would occur quite often and would be relatively small. A 1%AEP event has a low probability of occurrence or being exceeded each year; it would be fairly rare but it would be relatively large.
AHD	Australian Height Datum. A common national surface level datum approximately corresponding to mean sea level.
ARI	Average Recurrence Interval. The average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration. It is implicit in this definition that periods between exceedances are generally random.
Astronomical Tides	The regular rise and fall in sea level in response to the gravitational attraction of the Sun, Moon and Earth – excluding any meteorological effects.
Bathymetry	The measurement of the depth of water in oceans, estuaries, or other water bodies.
BoM	The Australian Bureau of Meteorology.
EPA, Victoria	Environment Protection Authority Victoria
WGCMA	West Gippsland Catchment Management Authority

1 Introduction

Cardno has been engaged by Seacombe West Pty Ltd to provide engineering advice pertaining to the proposed Nunduk Spa and Resort development on the southern shores of Lake Wellington in the Gippsland Lakes, Victoria. This report considers issues relating to flooding and related hydrodynamics issues on the site.

2 Development Proposal

Nunduk Retreat & Spa will be a premier luxury retreat and well-being spa facility. The retreat is located on Wellington Park on the southern shores of Lake Wellington, part of Australia's largest inland lakes system. The project consists of:

> Central Retreat, main building with 36 visitor rooms;

> secluded villas, with a total of 45 bedrooms. Flexibility for different configurations (1 ,2, 3 bedrooms);

> a private restaurant, lounge and bar;

> geothermally heated pools;

> spa and wellness services;

> a separate building for staff accommodation and parking;

> parking facilities;

> an infrastructure zone to allow the retreat to be a fully self-sufficient and sustainable development, and

> an emergency carpark located near the existing buildings well above any flooding level.

The location and layout of the Project have been selected to allow guests to be immersed in nature, allow peaceful interaction with wildlife and take maximum advantage of the proximity to and views across Lake Wellington. This provides a major draw to visitors seeking nature in an invigorating natural setting. The location of the Project provides a unique experience for guests to interact with the water and land and embrace the proximity of Lake Wellington.

Additionally, the salinity conditions of Lake Wellington are unlikely to be reversed, but the wetland conditions can be reinforced to revitalise the vegetation of the area near Lake Wellington, where the project has been located. Furthermore, native vegetation remnants surrounding the development will be protected. Vegetation chosen for landscape design will have a long-term focus on ensuring its viability irrespective of climate change. The development will look to minimise the environmental impact of the project.

3 Flooding

3.1 Background

The site is subject to flooding from Lake Wellington. Lake Wellington is the most westerly of the Gippsland Lakes and is connected to the sea via the other lakes and the artificial entrance at Lakes Entrance. The site is thus isolated from most of the effects of coastal inundation and coastal erosion, however it is subject to the effects of storm surge which can raise lake levels and will also be subject to the effects of sea-level rise. The site is inland of the present coastal barrier and thus will only be impacted by coastal flooding via the lake system.

The potential frequency of flooding has been examined by Grayson et al. (2004)[1]. The flood levels determined for various return intervals are shown in Table 3-1 (note 10% AEP case taken from Water Technology, 2014)

Table 3-1 Flood levels for Lake Wellington (Grayson et al., 2004)

Annual Exceedance Probability	10%	5%	2%	1%
Annual Recurrence Interval	10 years	20 years	50 years	100 years
Lake Wellington flood level (m AHD)	1.6	1.7	2.0	2.2

The extent of the 10% flood event is shown in Figure 3-1, taken from (WaterTechnology, 2014)

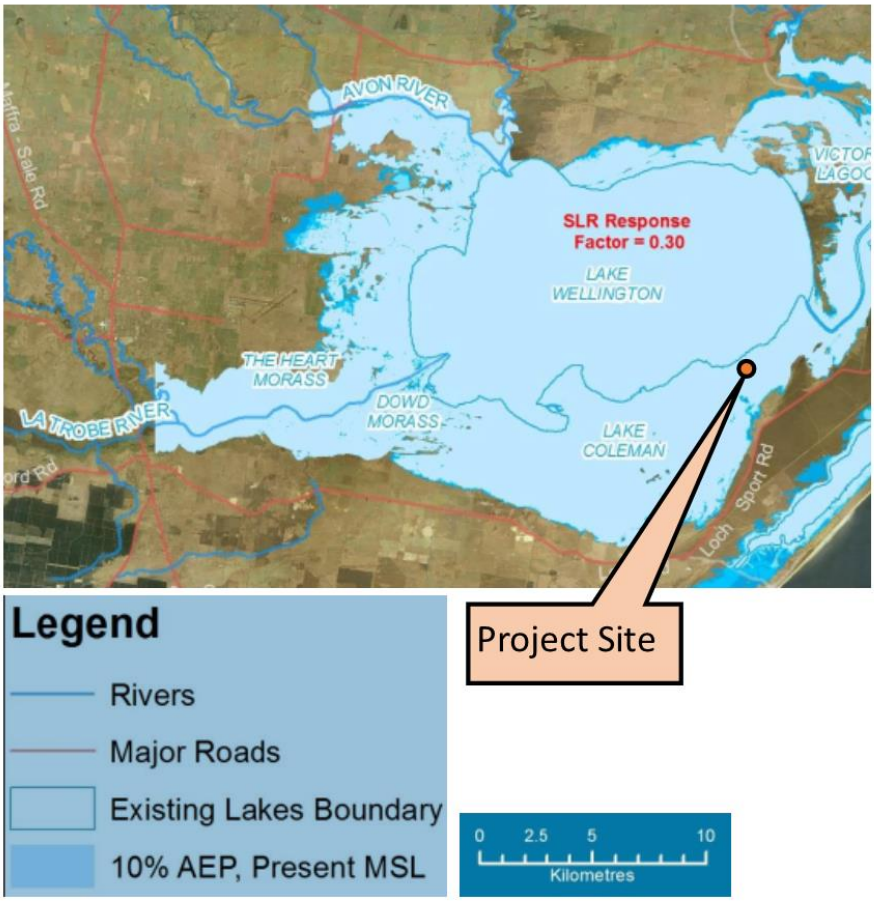

Figure 3-1 10% AEP flood extent for Lake Wellington, showing the project site. (from WaterTechnology, 2014)

The West Gippsland Catchment Management Authority (WGCMA) is a recommending referral authority for flooding approvals. In a response to the a Planning Permit Application dated 12 September 2018 addressed to Wellington Shire Council, WGCMA (2018) state:

"The 1% Annual Exceedance Probability (AEP) flood level (commonly known as the 1 in 100 year flood) under current climatic conditions is 2.2 metres AHD. Under future climatic conditions this level increases to 3.0 metres AHD.

The applicable 1% AEP flood level for this property is 3.0 metres AHD."

[1] Grayson, R., Candy, R., Tan, K.S., McMaster, M., Chiew, F., Provis, D., and Zhou, S. (2004). Gippsland Lakes Flood Modelling – Final Report. Centre for Environmental Hydrology, University of Melbourne. CEAH Report 01/01.

We note that the flood level of 3.0 m AHD in 2100 is a simple addition of the 0.8 m allowance for sea-level rise to the existing 1% AEP flood level of 2.2 m AHD. In the Gippsland Lakes/90 Mile Beach Local Coastal Hazard Assessment Project (WaterTechnology, 2014[2]) it is stated that the actual increase in flood level due to sea-level rise will be less than the assumed sea-level rise. This is because the increased overall water levels in the Gippsland Lakes system will increase the storage and conveyance capacity of the lakes and thus reduce the increase in level. For Lake Wellington, modelling shows that for a 1% AEP flood with a sea-level rise of 0.8 m the sea-level response factor is 0.45. That is, the increase in flood level for the same flood event under a sea-level rise scenario will only be 0.45 of the sea-level rise, that is, 0.36 m. The effect of this factor on projected flood-levels is shown in Table 3-2. This factor has not yet been adopted in the flood levels for planning.

Table 3-2 Application of the sea-level response factor from Water Technology (2014)

	Assuming full sea-level rise impact	Sea-level response factor of 0.45 for sea-level rise
1% AEP flood level at present	2.2 m AHD	2.2 m AHD
Sea-level rise allowance	0.8 m	0.36 m
2100 1% AEP flood level	3.0 m AHD	2.56 m AHD

The finished floor levels of all buildings and the walkways to the villas have been set at 3.3 m AHD

It is noted that control and extraction of water from the rivers feeding Lake Wellington are likely to result in reduced flood levels in the future, however no allowance has been made for any reduction in flood levels in this assessment.

There is significant experience with flooding at the site and the following summarises this knowledge:

- Flood events are preceded by a number of days warning, this warning comes from:
  - Forecasts of the meteorological event resulting in the rainfall in the catchments
  - Hydrological modelling predicting flood levels from rainfall
  - The time taken for the floodwaters to flow down the rivers feeding Lake Wellington
  - Observations of the lake level which is monitored in real time.
- Due to the lack of gradient in the water surface, the speed of water movement on the site is very low, described as “a slow rise and fall”. There are no hazardous currents.
- With the protection of the coastal barrier and relatively shallow water depths, wave heights on the site are small, even under strong wind conditions and high water-levels.

There are several other factors of relevance in considering flooding on the site including impacts on flood storage, flow velocities and site accessibility during a flood.

There is the potential for change in flood storage, that is, the volume of water held in the Lake Wellington flood plain. The effect of new buildings on the site flood storage is minimal, with proposed building area of less than 0.01 km^2. This should be compared with the area of Lake Wellington which is 150 km^2 at normal levels and far greater than this under flood conditions. The impact of the development on flood storage is thus assessed as insignificant (less than 0.01%, well below the accuracy and sensitivity of flood modelling).

Given the very low change in flood storage and the very low water-velocities, noting that Water Technology (2014) do not consider flow rates as a hazard, it is not considered that hydraulic modelling will provide any

[2] Water Technology (2014). *Gippsland Lakes/90 Mile Beach Local Coastal Hazard Assessment Project, Report 2: Inundation Hazard*. Prepared for Department of Environment and Primary Industries, report 2363-01 / R02 v04

additional information regarding potential off-site impacts of the development on flood height, extent or flow velocity.

It is also noted that WGCMA aim for a maximum flood level of 0.3 m over any roads used as the primary exit route from a dwelling or similar. The precise requirements may vary with circumstances, however it is prudent to plan for road levels with a maximum of 0.3 m water depth in a 1% AEP flood under normal circumstances.

The access road to the resort building has been set at 2.2 m AHD

It is noted that the proposed carpark is below flood levels and thus an emergency carpark is included which is located above the 1% AEP flood level. Provision will be included to allow increasing the road level in the future if required.

3.2 Project Design

The resort is being designed in full knowledge of the flood-prone nature of the site which is one of the features rendering the site unsuitable for other uses such as agriculture. The flood risk is recognised and is planned for.

- All floor levels are set at 3.3 m AHD (above the designated 2100 1%AEP flood level).
- All service and facilities buildings will be located above the flood level and service cables and pipes will be constructed to withstand flooding.
- There will be no release of untreated wastewater, geothermal water or treated wastewater into flood waters as all treatment and storage facilities will be above the flood level.
- All stormwater runoff will be captured and stored in tanks for later reuse.
- Villas separate from the main building will be connected by walkways at 3.3 m AHD, above the flood level
- Access to the main building will be via a raised causeway with the road surface set at 2.2 m AHD, the existing flood level and above the requirement of WGCMA of no more than 0.3 m water depth over access routes. The road will be lined with posts to clearly delineate the route.
- A detailed flood emergency plan will be prepared and activated in the event of a flood warning.
- The emergency plan will include
    - notification of all guests and staff of the approaching flood and clear warning of potential hazards and safety procedures.
    - consideration of any medical needs of guests and staff and evacuation if required
    - activation of preparation and inspection of infrastructure
    - notification of authorities of the plan’s activation
    - securing any access ways out of the buildings other than those to the main access road.
    - erection of flagging along the posts lining the access road to avoid people inadvertently leaving the road.
- An emergency car park is established well above any flood levels, adjacent to the existing buildings.
- An adaptation plan will be prepared detailing actions to be taken if the predicted changes in mean sea-level occur, where this will be defined by a set rise in the level of Lake Wellington. The adaptation may include raising the level of the access road, creating additional car parking at higher elevation and other contingencies.

The following summarises the issues related to flooding and the Project responses.

Issue	Response
Whether the proposed use or development could be located on flood-free land or land with a lesser flood hazard	The project depends on access to the natural environment, in particular the coastal environment and thus needs to be near the lake. The proposed site is at present degraded land which is not suitable for other uses.
The susceptibility of the development to flooding and flood damage	The project has been designed to be resilient to flooding and associated effects.
The potential flood risk to life, health and safety associated with the development. Flood risk factors to consider include: - The frequency, duration, extent, depth and velocity of flooding of the site and access way. - The flood warning time available. - The danger to the occupants of the development, other floodplain residents and emergency personnel if the site or access way is flooded.	The project is planned and designed with the site characteristics as a prime concern, this includes the possibility of flooding. The site experiences flooding approximately once in 7 years and the nature of the flooding is a slow rise and retreat with imperceptible water velocities. There is warning of 4-5 days (at least) including the forecasting of catchment rainfall and movement of water from the catchment into Lake Wellington. Design and operational systems are included to reduce any risk to personnel, both guests and staff, to minimal levels. Access road is set above the existing flood level and can be raised in the future if required.
The effect of the development on redirecting or obstructing floodwater, stormwater or drainage water and the effect of the development on reducing flood storage and increasing flood levels and flow velocities.	The development will have no impact on flooding in and around Lake Wellington. The change in flood storage is insignificant compared to the storage volume of the lake.
The effects of the development on river health values including wetlands, natural habitat, stream stability, erosion, environmental flows, water quality and sites of scientific significance.	The development will have no adverse impact on the natural environment and provides significant potential to improve the surroundings, though protective works and plantings.

4 Other Issues

Other potential issues related to the hydrodynamics of the development include the behaviour of the shoreline of Lake Wellington, the interaction of the proposed retreat with Lake Wellington. When considering these issues, a primary factor is the local wind climate and thus this section includes a discussion of wind data recorded at the East Sale Airport, the nearest Bureau of Meteorology weather station.

4.1 Interaction with Lake Wellington

The site boundary borders Lake Wellington, however there is a Crown Reserve between the property boundary and Lake Wellington. There will be no dredged channel or direct connection between the resort and Lake Wellington and no works on the Crown Land Reserve. As such, the retreat development will have no impact on the hydrodynamics of Lake Wellington.

4.2 Wind

Wind data is available from East Sale Airport from 1993 to 2012 and the following tables use this data.

Overall, the most frequent and strongest winds are from the west and west north-west (Table 4-1). In summer there are almost equal frequencies and strength winds from the east and west (Table 4-2). In winter, the winds are dominated by westerly and west north-westerly winds (Table 4-3).

Table 4-1 All wind data (Percentage occurrence)

Direction	Wind speed (m/s)								
bin centre	0 +	2.5 +	5.0 +	7.5 +	10.0 +	12.5 +	15.0 +	17.5 +	Total
0°	2.19	1.70	0.18	0.07	0.02	0.00	0.00		4.17
30°	1.44	1.39	0.19	0.03	0.00	0.00			3.05
60°	1.40	2.40	0.49	0.12	0.02	0.00			4.43
90°	1.39	4.09	3.37	2.16	0.54	0.05	0.00		11.59
120°	1.50	3.63	2.21	0.48	0.05	0.00	0.00		7.88
150°	1.43	2.40	1.14	0.20	0.02	0.01	0.00		5.19
180°	1.26	1.37	0.46	0.15	0.02	0.01	0.00	0.00	3.26
210°	1.25	1.76	0.59	0.21	0.03	0.00	0.00		3.84
240°	1.62	3.81	2.45	1.48	0.43	0.07	0.01	0.00	9.88
270°	2.31	7.93	6.59	4.23	1.37	0.33	0.05	0.02	22.82
300°	3.59	8.42	1.74	1.15	0.51	0.15	0.02	0.00	15.58
330°	2.76	4.01	0.77	0.51	0.20	0.05	0.01	0.00	8.30
Total	22.13	42.90	20.18	10.77	3.22	0.67	0.09	0.02	

Note : 0.00 occurs, but less than 0.005%

Table 4-2 Summer wind data (Percentage occurrence)

Direction	Wind speed (m/s)								
bin centre	0 +	2.5 +	5.0 +	7.5 +	10.0 +	12.5 +	15.0 +	17.5 +	Total
0°	1.75	1.05	0.08	0.05	0.02	0.00	0.00		2.96
30°	1.36	1.35	0.13	0.01	0.01				2.86
60°	1.35	2.88	0.84	0.22	0.04				5.33
90°	1.20	4.73	5.65	4.57	1.27	0.14	0.00		17.56
120°	1.48	5.16	4.99	1.13	0.09	0.01			12.86
150°	1.56	3.72	2.21	0.39	0.00				7.88
180°	1.47	2.24	0.71	0.29	0.01	0.00	0.00	0.00	4.73
210°	1.20	2.61	0.93	0.37	0.03	0.00			5.15
240°	1.46	3.99	2.90	2.03	0.64	0.10	0.02		11.14
270°	1.64	5.59	4.55	3.24	1.20	0.22	0.04	0.01	16.51
300°	2.26	4.62	0.81	0.55	0.19	0.06	0.01	0.00	8.49
330°	1.92	2.13	0.22	0.18	0.06	0.02			4.54
Total	18.65	40.06	24.04	13.03	3.55	0.56	0.07	0.02	

Note : 0.00 occurs, but less than 0.005%

Table 4-3 Winter wind data (Percentage occurrence)

Direction	Wind speed (m/s)								
bin centre	0 +	2.5 +	5.0 +	7.5 +	10.0 +	12.5 +	15.0 +	17.5 +	Total
0°	2.56	2.35	0.30	0.09	0.03	0.00			5.33
30°	1.44	1.32	0.25	0.03	0.00				3.05
60°	1.38	1.61	0.15	0.02	0.00				3.17
90°	1.52	3.12	0.79	0.18	0.00				5.62
120°	1.56	2.01	0.32	0.05	0.00				3.95
150°	1.32	1.07	0.32	0.13	0.05	0.02	0.00		2.91
180°	1.12	0.75	0.22	0.10	0.03	0.02	0.00	0.00	2.24
210°	1.24	0.95	0.27	0.11	0.03	0.00	0.00		2.61
240°	1.77	3.21	1.43	0.45	0.06	0.01			6.93
270°	3.00	10.03	8.44	4.57	1.22	0.28	0.03	0.01	27.58
300°	4.82	12.52	3.04	2.02	0.91	0.27	0.05	0.00	23.62
330°	3.67	6.09	1.67	1.02	0.43	0.10	0.01		12.99
Total	25.39	45.03	17.21	8.79	2.76	0.70	0.09	0.02	

Note : 0.00 occurs, but less than 0.005%

4.3 Wave Climate

It is known from local observations and analysis of aerial photographs of the foreshore of Lake Wellington in the project area is eroding. Some initial investigations were therefore undertaken into the local wave-climate in order to provide information relating to this erosion. Using the wind climate from east Sale, as described above, a SWAN wave model was established for Lake Wellington and the average wave climate along the foreshore adjacent to the project computed. The resulting wave-energy vectors are shown in Figure 4-1, Figure 4-2 and Figure 4-3.

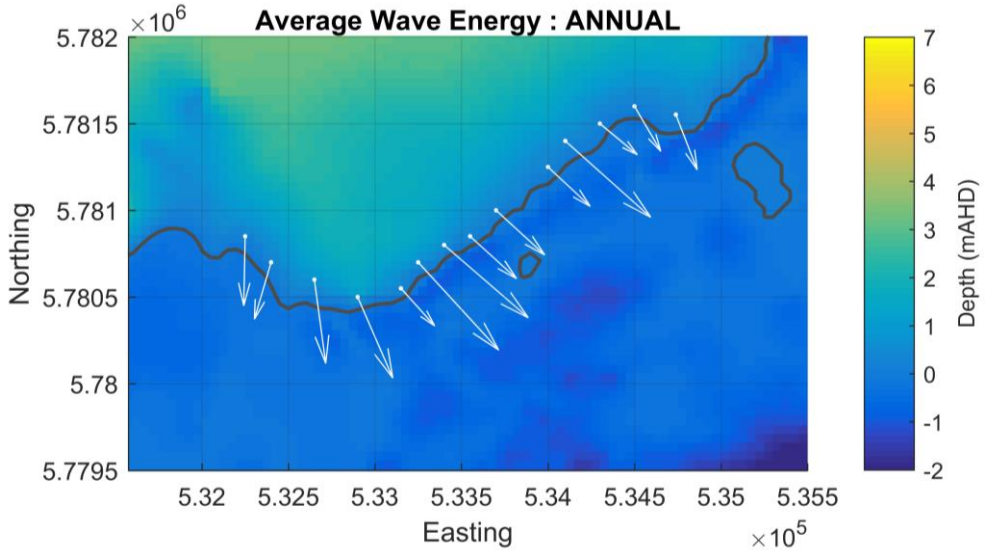

Figure 4-1 Annual-average wave-energy vectors (arbitrary units) for the study area. Dark line is the 0.0 m AHD contour.

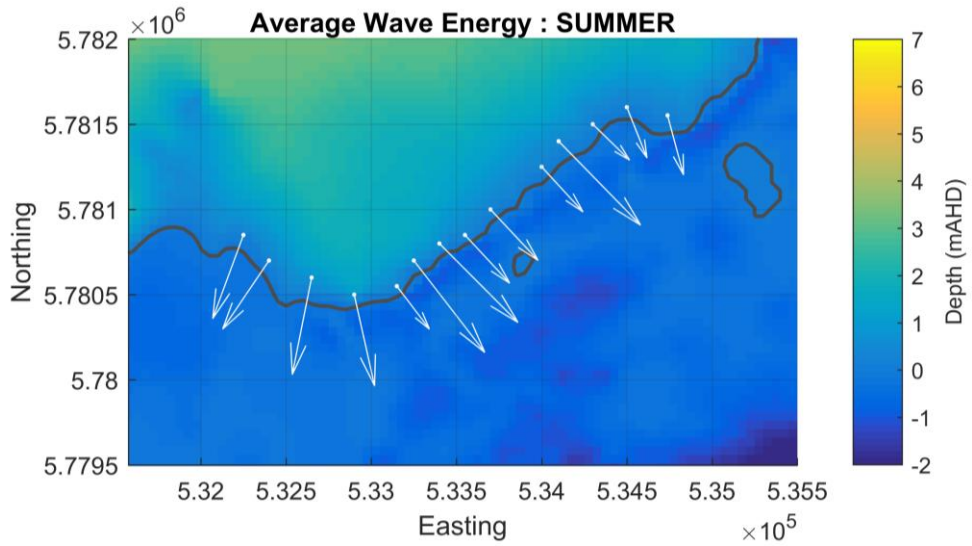

Figure 4-2 Summer-average wave-energy vectors (arbitrary units) for the study area. Dark line is the 0.0 m AHD contour.

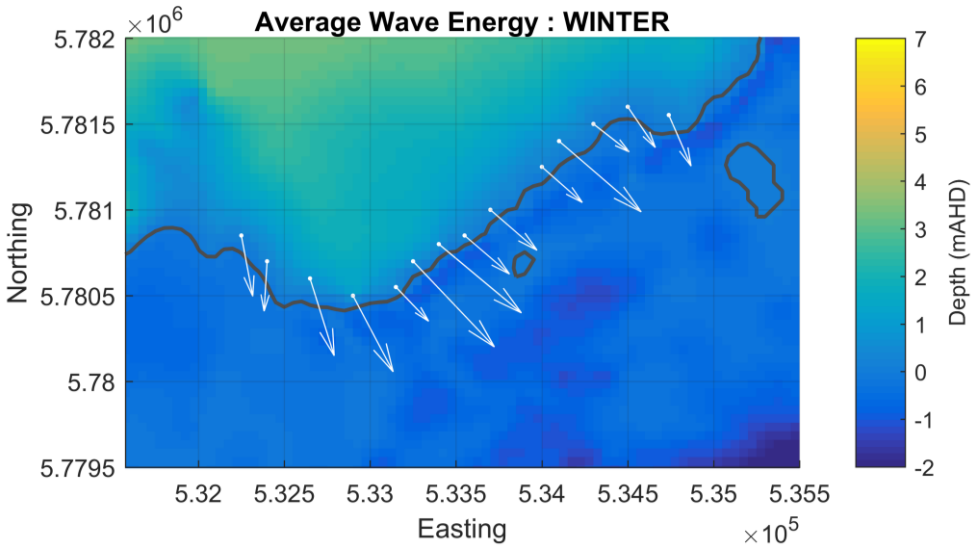

Figure 4-3 Summer-average wave-energy vectors (arbitrary units) for the study area. Dark line is the 0.0 m AHD contour.

There is little variability in the average wave-energy with seasons, although small changes can be identified with a more easterly orientation of the vectors in winter indicating a stronger tendency for sediment movement towards the east in this season. In general, the average wave-energy directions are close to perpendicular to the local orientation of the shoreline indicating a relatively stable coast, but with a tendency for sediment to move eastwards, especially in winter. More detailed computations can be carried out if required. This would include consideration of the potential movement of sediment in both directions along the shoreline under varying wind conditions and then calculation of the net flow of sediment.

It is not proposed to undertake any works on the Crown Land Reserve, however there would be opportunities for the project, in consultation and with the support of the relevant land managers, to assist in works to restore the foreshore and provide measures to limit or reverse the existing erosion trends. Preliminary examination suggests relatively few structures would be required to minimise the existing coastal erosion.

4.4 Water Quality

As there is no direct hydraulic connection between the retreat and Lake Wellington, there will be no impact on the water quality of Lake Wellington either during construction or operational phases on the project.

The major issue with water quality in Lake Wellington is salinity. The historical records of the salinity of Lake Wellington are reported by SKM (2010)[3]. This shows that the lake was originally (prior to about 1966) considered fresh or possibly brackish, but that since this time, there have been episodes of relatively high salinity (over 20 ppt compared with 35 ppt for sea water) and a general upwards trend in the average salinity levels. These changes are attributed to the maintenance of the opening from the Lakes to Bass Strait at Lakes Entrance and reductions in the freshwater inflow to the lakes from rivers. The proposed project will have no effect on the salinity of the Lake Wellington.

It is recognised that there is potential for acid-sulphate soils on the site. The treatment and management of these soils is included in the civil-engineering and geotechnical reports (Golder, 2018[4]) and works have been designed to minimise disturbance of such soils. The EPA, Victoria has agreed to a suitable process for management of any acid-sulphate soil risk at the Nunduk Spa Retreat site (EPA, 2018[5]).

[3] SKM, (2010). Lake Wellington Salinity, Preliminary Investigation of Management Options. Report prepared by Sinclair Knight Mertz Pty Ltd for Gippsland Lakes Taskforce.
[4] Golder Associates Pty Ltd, (2018). Preliminary Acid Sulphate Soil Hazard Assessment. Report to Seacombe West Pty Ltd, no. 18105358-001-R-Rev3.
[5] EPA Victoria, (2018). Letter to Wellington Shire (Mr John Traa) re planning permit application P125/2018, dated 4 October 2018.

5 Conclusion

The resort is being designed in full knowledge of the flood-prone nature of the site which is one of the features rendering the site unsuitable for other uses such as agriculture. The flood risk is recognised and is planned for.

- All floor levels are set at 3.3 m AHD (above the designated 2100 1%AEP flood level).
- All service and facilities buildings will be located above the flood level and service cables and pipes will be constructed to withstand flooding.
- There will be no release of untreated wastewater, geothermal water or treated wastewater into flood waters as all treatment and storage facilities will be above the flood level.
- All stormwater runoff will be captured and stored in tanks for later reuse.
- Villas separate from the main building will be connected by walkways at 3.3 m AHD, above the flood level
- Access to the main building will be via a raised causeway with the road surface set at 2.2 m AHD, the existing flood level and above the requirement of WGCMA of no more than 0.3 m water depth over access routes. The road will be lined with posts to clearly delineate the route.
- A detailed flood emergency plan will be prepared and activated in the event of a flood warning.
- The emergency plan will include
    - notification of all guests and staff of the approaching flood and clear warning of potential hazards and safety procedures.
    - consideration of any medical needs of guests and staff and evacuation if required
    - activation of preparation and inspection of infrastructure
    - notification of authorities of the plan's activation
    - securing any access ways out of the buildings other than those to the main access road.
    - erection of flagging along the posts lining the access road to avoid people inadvertently leaving the road.
- An emergency car park is established well above any flood levels, adjacent to the existing buildings.
- An adaptation plan will be prepared detailing actions to be taken if the predicted changes in mean sea-level occur, where this will be defined by a set rise in the level of Lake Wellington. The adaptation may include raising the level of the access road, creating additional car parking at higher elevation and other contingencies.
- There is no impact on the shoreline or water quality of Lake Wellington.