REPORT

Nalinga Creek, Flinders Island

Hydrology Summary & Hydraulic Discussion

October 2018

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Appendix A - Hydrological Catchment Analysis

1. Executive Summary

Climate change will affect inland hydrology at Whitemark. The 1:100 AEP peak runoff for Nalinga Creek will increase from some 44.2m^3/s in 2010 to 116.7 m^3/s in 2070-2100.

The planning allowance for sea level change on Flinders Island for 2100 AD is 0.92m and high Tide levels can be expected to approach RL 2.5 at the turn of the century.

The Outlet to Nalinga creek has been examined for Hydraulic impacts and it is recommended that a silted river mouth should be assumed to future mean tide level of RL 1.0 AHD. This assumption will reduce the assumed waterway area and therefore increase flood levels; however, this level is still up to 1.5 m below the assumed level of high tide and is considered reasonable, in the circumstances.

Accurate data is not available to perform detailed river profile modelling, however using broad channel assumptions a flood flow of 116.7 m3/s water level in the vicinity of the Nalinga Creek outlet can be expected to approach RL 3.1, but could approach RL 3.6 within 200 metres of the river mouth.

The adopted 1:100 AEP flood level in 2100 AD, including 0.5m of freeboard, would be RL 3.6 AHD, at the river mouth.

Higher levels may also result from coastal vulnerability to storm surge and sea level inundation and alternate references will need to be consulted.

An attempt to re-create fresh water wetlands by the building a sea wall at the mouth of the Nalinga Creek so that tidal salt water inundation is prevented may cause flood flows to be extremely high (up to RL 5.2m AHD) such that fringe land levels in Whitemark could be affected. An alternate sea barrier that did not collect all of Nalinga Creek runoff would see a significantly reduced flood level (down to RL 3.70), but the barrier may be up to 600 m long.

A sea barrier to only function until 2050 instead of 2100 may be more serviceable, notwithstanding its limited service life. It could be located directly at the mouth of the River, at 35 m length, and may only need to be built to RL 2.15. The flood level over the barrier would be RL 3.15. It would need to be removed or modified by 2050.

Any intention to construct a sea barrier and turn a virtual estuary into a freshwater wetland will need to examine the environmental consequences, not withstanding that the area may have not have always been an estuary. The impacts of a higher water table, including the effects on Whitemark's septic tank system, will also need to be considered. These impacts were beyond the scope of this report.

2. Introduction

Finders Island is seeking to asses community vulnerability for Whitemark.

GEO Environmental Solutions have undertaken a review of the coastal vulnerability in a report dated June 2018.

JMG's task was to assess the change in inland hydrology for Nalinga Creek due to climate change and to interpret the resulting impacts on inland water levels due to any changes in boundary conditions at the coastline. This may include increases in sea level and changes in the bathymetry that would alter river levels.

The Hydraulic task will involve commentary and discussion, as there is limited to no data sets available concerning channel or river base levels to perform any accurate water surface modelling.

A rare storm surge event and a simultaneously rare rainfall/runoff event will not likely occur with the same frequency of either event. The two results cannot be reasonably combined without demonstrably altering the probability to a much rarer combined event.

In the normal course of events, when dealing with average/50% confidence levels it is reasonable to assume high tide levels as the boundary condition against landside runoff. Whilst Storm surge and rainfall are both likely due to low pressure climatic events many rainfall storm events happen without extreme storm surge. Hydraulic impacts here have only been considered against High tide. Sand accumulation in the river mouth that will restrict flow and alter water levels will however be considered.

3. Hydrological Analysis

A separate report has been prepared for the hydrological catchment analysis.

The analysis process involved a Flood Frequency Analysis (FFA) to establish runoff values based on recorded flood events. The FFA study found:

Study Catchment Results	
AEP	**Flow m^3/sec**
1:2	7.3
1:5	15.5
1:10	20.8
1:20	25.9
1:50	32.5
1:100	37.4
1:200	42.2

There were only 19 annual maxima in the recorded records. It was considered that any AEP values above the 1:20 may not be reliable. To overcome this deficiency a RORB model was created and calibrated to match a 1:20 year event. By adjusting rainfall intensities more extreme events were able to be determined. Climate change impacts on rainfall intensities were then also able to be assessed.

The RORB analysis determined that a 12-hour event was critical, and the resulting table of flows were:

Study Catchment Results		
AEP	**Flow m^3/sec FFA**	**Flow m^3/sec RORB**
1:20	25.9	25.9
1:50	32.5	35.9
1:100	37.4	44.2

Climate change for the period 2070 to 2099 was assessed using a climate assist tool developed by Australian Research Council, Hydro Tasmania and Pitt & Sherry with funding support from the Australian Government's 'Natural Disaster Resilience Program' initiative,

and from the Tasmanian Government's Climate Change Office.
http://climateasyst.pittsh.com.au/app/

The increase in 24-hour 100-year rainfall at Whitemark was covered by two predictive squares with increases suggested as 72% and 88%, producing an average of 80%. Adjustments were made for the difference in storm duration between the 24-hour prediction and the 12-hour critical storm event. (See Appendix A)

The 1:100 AEP event runoff from the RORB model was found to be 116.7 m^3/s, an increase of over 169% from current conditions.

4. Hydraulic Impacts

To obtain a thorough understanding of the flood level impacts of a 1:100 rainfall event in the period 2070- 2099 it would be necessary to model the flow against predicted changes in Bathymetry and altered Tailwater conditions.

The GES report contained the statement that *"LIDAR is limited to a thin stretch of coastline to the north and south of Whitemark. Beyond these points, inundation hazards cannot be determined."* As such there is little surface and more particularly sub water surface level data to access to perform accurate modelling.

The Tasmania Government (Department of Premier and Cabinet) has assessed the impacts of climate change and introduced a sea level rise planning allowance. *(http://www.dpac.tas.gov.au/divisions/climatechange/climate_change_in_tasmania/impacts_of_climate_change/coastal_impacts)*

4.1 Sea Level planning Allowance

> *"Sea level rise planning allowances help to ensure consistency and certainty in how planners, developers, property owners and managers take into account sea level rise in any new coastal developments.*
> *In 2016 the Tasmanian Government engaged CSIRO to provide updated sea level rise planning allowances for the State. The updated allowances are based on the sea level rise projections provided in the Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5) and are based on the high emissions scenario RCP8.5.*
>
> *From the CSIRO work, Tasmania now has sea level rise projections and planning allowances for each coastal municipality in the State, as well as statewide averages for 2050 and 2100 (both relative to 2010 sea levels).*
>
> *The sea level rise planning allowances for each coastal municipality can be found in this table: Tasmanian Local Council Sea Level Rise Planning Allowances (PDF). More information on the sea level rise projections for Tasmania and coastal municipalities, as well as the methodology behind the projections, is detailed in the CSIRO report Sea-Level Rise and Allowances for Tasmania based on the IPCC AR5 (PDF)."*

The highlighted reference yields the sea level rise planning allowance for Flinders Council, relative to the 2010AD Base Line.

Tasmanian Local Council Sea Level Rise Planning Allowances – derived from RCP 8.5

Council	Sea Level Rise Planning Allowance (m)	Sea Level Rise Planning Allowance (m)
	2050	**2100**
Flinders	0.23	0.92

GES have advised that these increases correlate to a mean Sea level in 2100 of 1.04m AHD, with a tidal extreme (astronomical tide) range of 2.94m.

In simplistic terms this equates to a high tide of approximately 2.5m AHD.

The Tasmanian Government LISTMAP data sets includes layers for Sea level change for 2050 and 2100, and for Storm surge. These are reproduced as Figure 1 and Figure 2.

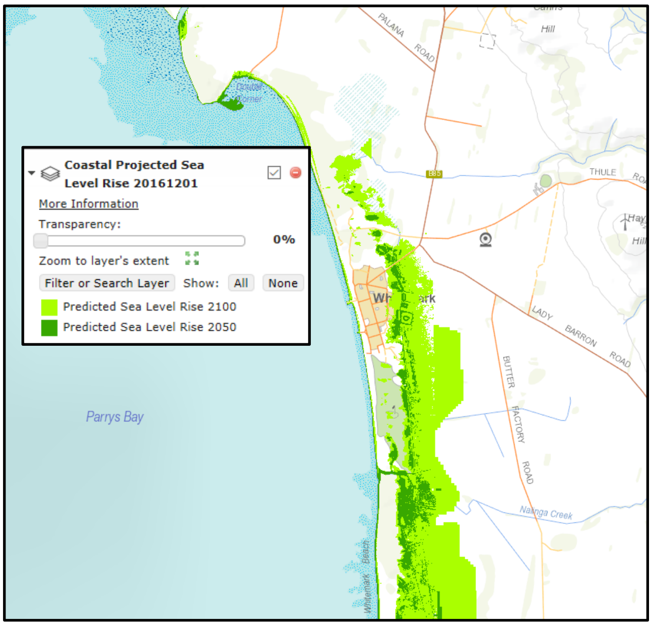


Figure 1 – Sea Level Rise

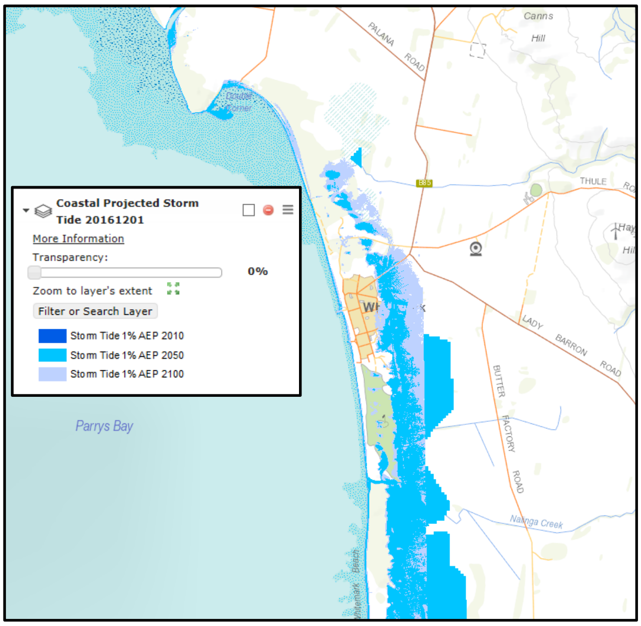


Figure 2 – Storm Tide

The LISTMAP data sets also include spot levels, however these are more indicative and not overly reliable.

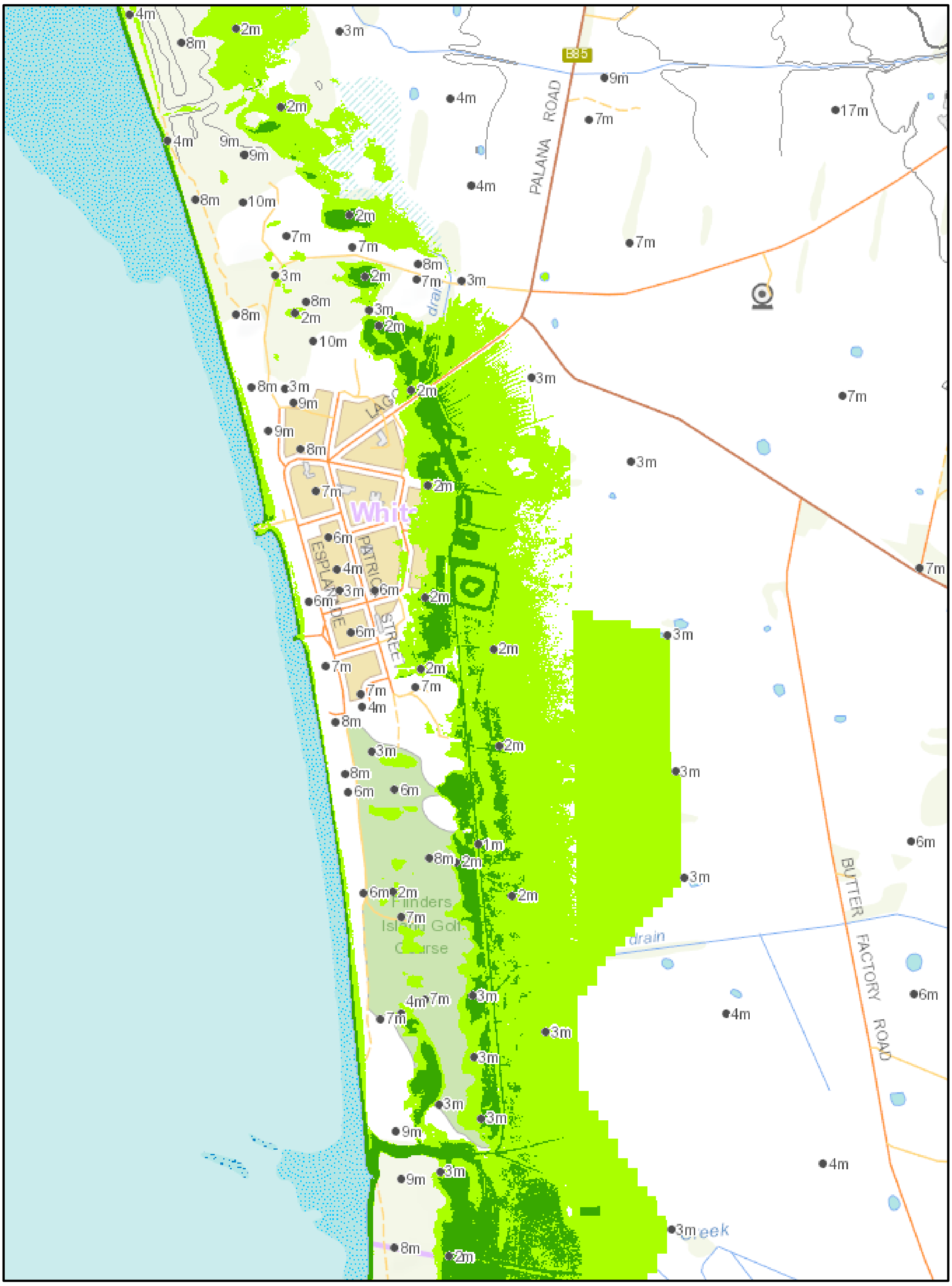


Figure 3 – Sea Level Rise and List Spot levels

This indicates a high-level ridge line running along the coast, up to RL 8 & 9 AHD, but in parts as low as 3M AHD to the north and South of Whitemark. Behind the ridge the low-lying land at risk of sea level rise inundation is between RL 1 and RL 3 AHD.

The Nalinga creek outlet is characterized by a narrow sea entrance restricted to a width of some 33m between the ridge levels approach RL 9.0.

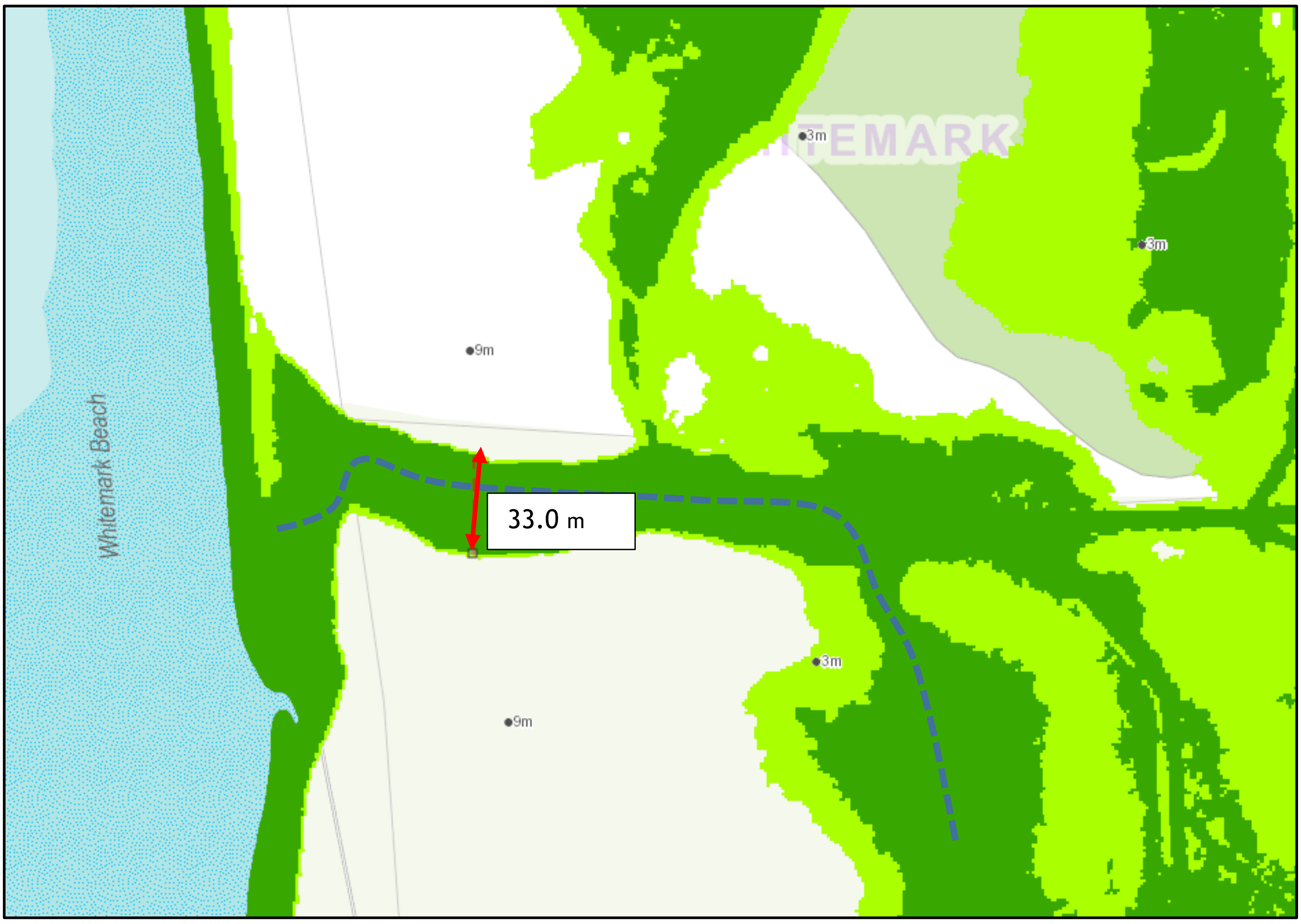


Figure 4 – Nalinga creek outfall

Assuming:

-a high tide sea level at RL 2.5

- a river mouth base-width of 33 m, silted to RL 1.5.

- a flat channel base for the first 200 m upstream of the mouth- then 0.2%

- Manning's N = 0.035 – clean and straight – no rifts or deep pools, some stones and weeds

- 1:100 AEP (2100AD) flow rate of 116.7 m3/s

The longitudinal water and surface profile of Nalinga Creek would be:

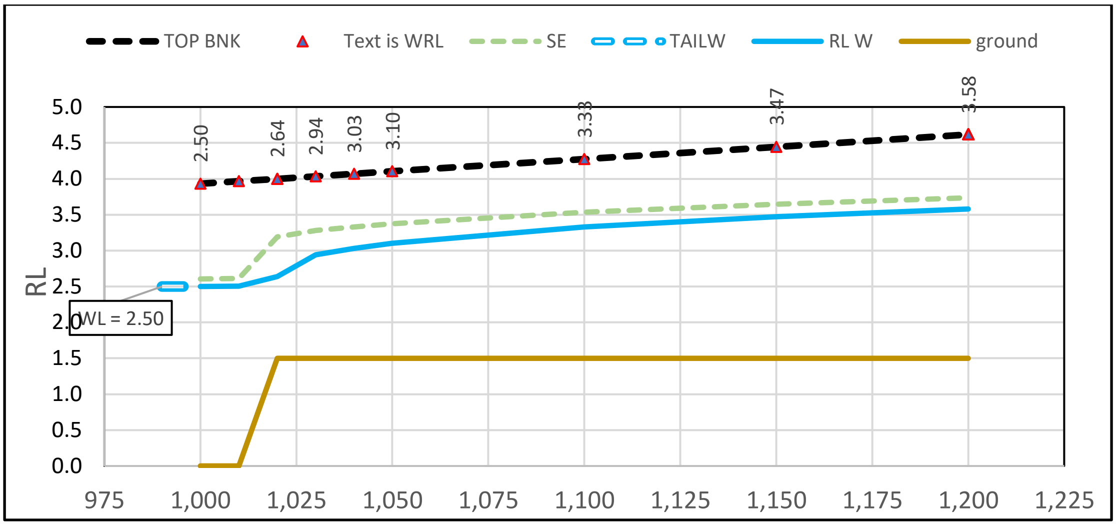


Figure 5 Nalinga Creek water profile [chn 1,000 at Sea Entry]

This is an aggressive assumption for the silting of the river against high tide at the turn of the century. It shows a peak RL within 200 m of the coastline of approximately RL 3.58.

Altering the silted creek bed level, but retaining the zero grade on the bed, will lower the calculated water level; as shown in the following table

Bed level AHD	Water Level AHD @ 200 m upstream	
1.50	3.58	
1.00	3.08	RL 1.00 is approx. Mean tide level at 2100 AD
0.50	2.77	

The GES study of coastal vulnerability has referred to a potential for creek deepening and indicated that *“extensive scour is already apparent, and a coastline recession is expected to progress well beyond the dune ridge in this part of the coastline” (Section 8).*

None the less putting long term trends aside it is considered reasonable and appropriate to consider some level of creek silting above the low tide level during a rare event. Any potential for pre-real scour will depend upon the tide level. Accordingly, a silted bed to mean tide level is considered reasonable and an appropriate flood levels at the river mouth is RL 3.1.

Levels higher than these may be experienced further inland due to the grade of the bed and banks of the creek and the surrounding land, data which is generally unavailable.

Storm surge levels for equally rare events may also be higher and reference should be made to the GES Coastal Hazard report.

5. Potential storm attenuation

Figures 1 & 3 indicates a large inland area of potential storage which may attenuate the flood discharge exiting to the sea from Nalinga lake. This is an area of some 90 Hectares that could store water by up to 1.5m (up to say RL 3.5). This could represent a considerable volume of storage of some 900,000 m^3.

In comparison, the volume of a triangular 12-hour storm hydrograph with a peak of 116.7 m^3/s, would be some 5,000,000 m^3. Trial storage routing of such a hydrograph shows attenuation from 116.7 m^3/s to 101 m^3/s. Longer durations storms are likely to have discharges higher then 101 m^3/s.

Backflow hydraulic calculations for this reduced flow of 101 m^3/s, with the same original bed and bank assumptions made earlier, indicate that water levels may only rise to 3.43m AHD instead of 3.58m AHD within 200m of the mouth. This level is not inconsistent with the water level resulting from the assumed pond storage level in the storage routing.

The potential storage volume is therefore considered to be relatively insignificant in relation to the volume of the inflow hydrograph, and reduction in flow or flood levels due to any storage attenuation is not considered meaningful or appropriate.

6. Reinstated Wetlands

6.1 Potential Closure of Nalinga Creek

An option has been put forward to close Nalinga creek at its sea entrance – so that the fresh water could be captured and the previous wetlands that have been drained over the decades, re-established. The inland wetlands are now only partially represented on the state mapping system, reproduced below. It is anticipated that they used to run further south to Nalinga Creek. This potential area of pondage is generally represented by the areas off Sea Level rise and storm tides shown in figures 1 and 2.

Council has generally identified this area as Area 6. This is shown on Figure 6 with current wetland areas, as mapped by the State Government.

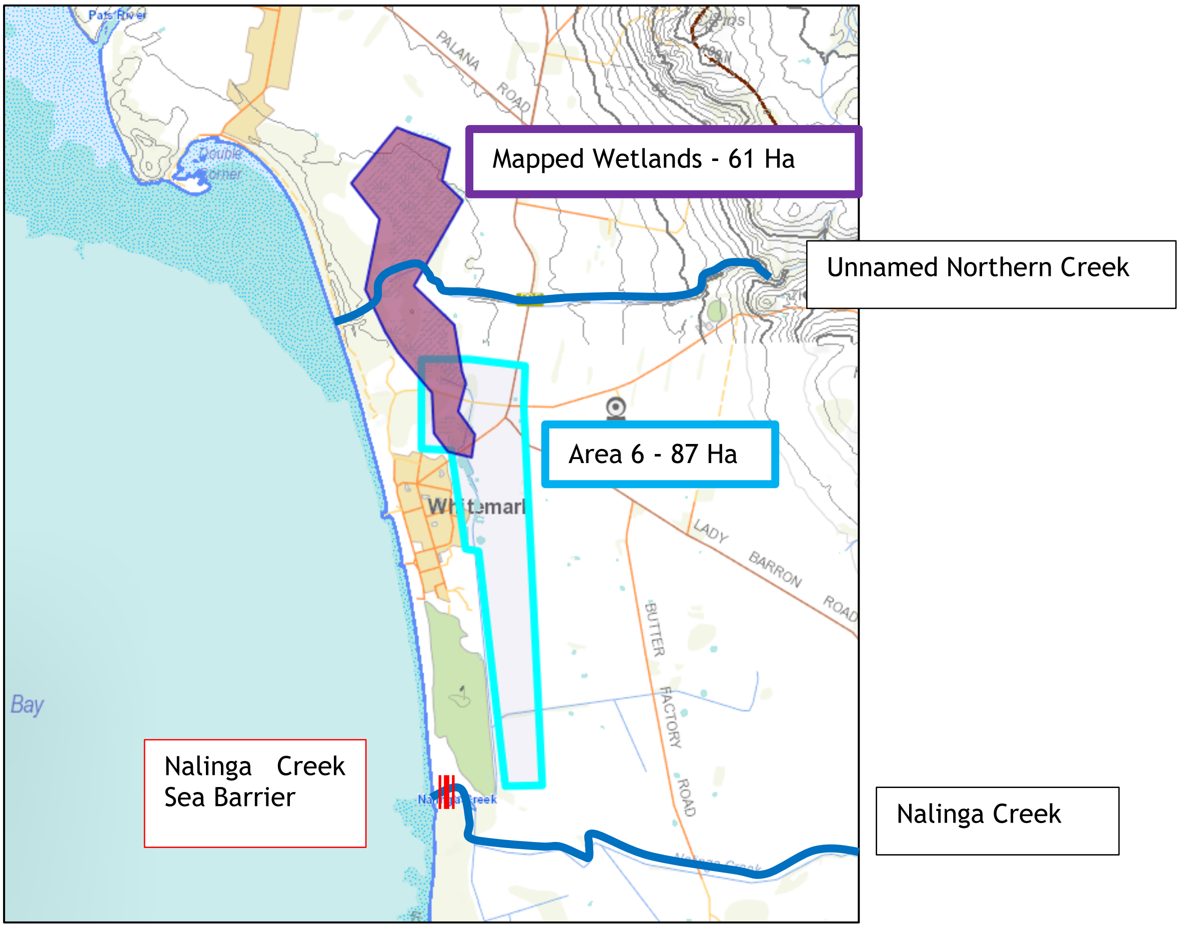


Figure 6. Area 6 – and identified Wetlands with Proposed Sea Barrier.

The existing wetlands are fed by Nalinga Creek, and an unnamed northern creek catchment. The boundary between these two catchments is therefore ‘marginal’, and/or variable as the whole area is low. There are however two sea outlets, one for each creek. This is further shown in Figure 7.

The Nalinga creek catchment can also be split into two, one part representing the catchment that contributes directly to Area 6, and the other part that contributes to the mainstream channel of Nalinga Creek. When in flood the runoff from these two catchments combine. The various areas are also shown in Figure 7

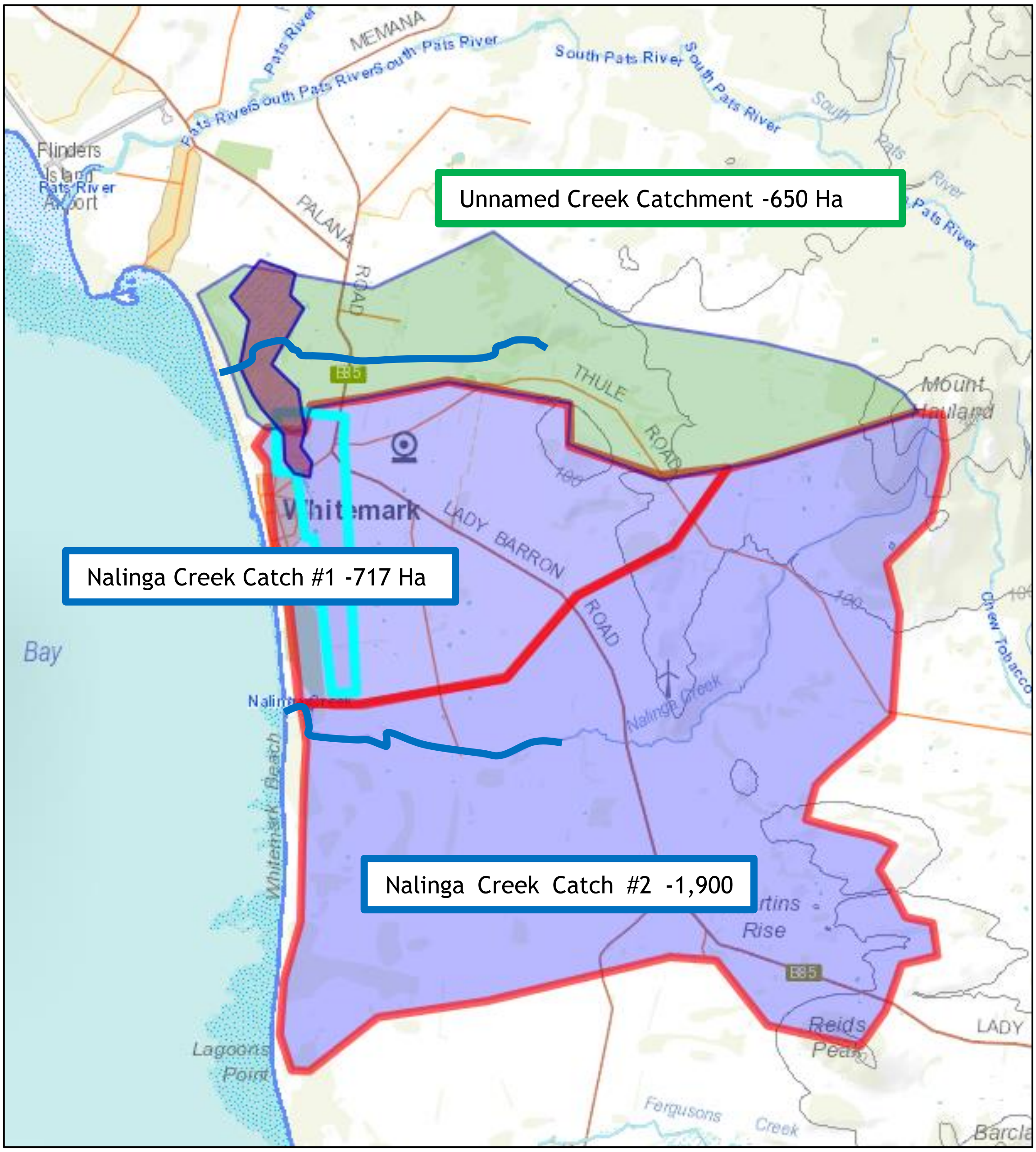


Figure 7 – Wetlands Catchment Areas

Any action to retain freshwater wetlands, rather than a tidal estuary in Area 6 will need to take steps to protected it from coastal salt water intrusion or inundation.

Current tide charts for Whitemark (published by the Bureau of Meteorology) show that the maximum high tide 2019 gauge **levels** is 0.32m above the mean high tide:

	High TIde	Low Tide
Maximum Tide	2.91	1.15
Mean Tide	2.63	0.64
Lowest Tide	2.30	0.11

Given that the mean high tide (AHD) in 2085 has been assumed at RL 2.50 m AHD, then to prevent extensive sea water infiltration volume any barrier would need to be at least 2.80 AHD to guard against the annual maximum high, (say 0.3m above mean tide). An additional 0.5m freeboard against wave action places the barrier at RL 3.30m AHD. This value compares well with the GES reported calculation for 1% AEP storm tide RL of RL 3.39 AHD in 2100.

If placed at the mouth of the river the sea wall would be some 35 m long. The entrapped freshwater basin could be maintained at levels less than the height of the sea water barrier. This could be achieved by including a bank of small pipes with tide flaps at the desired control level. Tide flaps are notoriously difficult to maintain in a fully functioning form and the pipe may need to extend a significant distance into the sea to avoid sand backup restricting any outflow. Tide flex valves are preferred over swing gate valves and these could be provided in a pit located within the Barrier wall (and extending to the wall height), rather than at the pipe outfall.

The distance required to extend the outfall to a sand free outlet has not been calculated at this stage.

Any control pipes would not be able to cope with the calculated flood flow of 116.7 m^3/s, arriving from Nalinga creek at the barrier. At best a single 1200 mm pipe might be able to convey up to 2.5 m^3/s, and a bank of say 20 only up to 50m^3/s. This would leave over 60 m^3/s to flow over the sea barrier. As such a large bank of pipes is unlikely it is recommended that the full flood flow of 116.7 m^3/s should be required to pass over any sea barrier as weir flow.

The tail water control level will be King High tide (2085) level of RL 2.80 AHD, and the calculated water profile is shown in Figure 8.

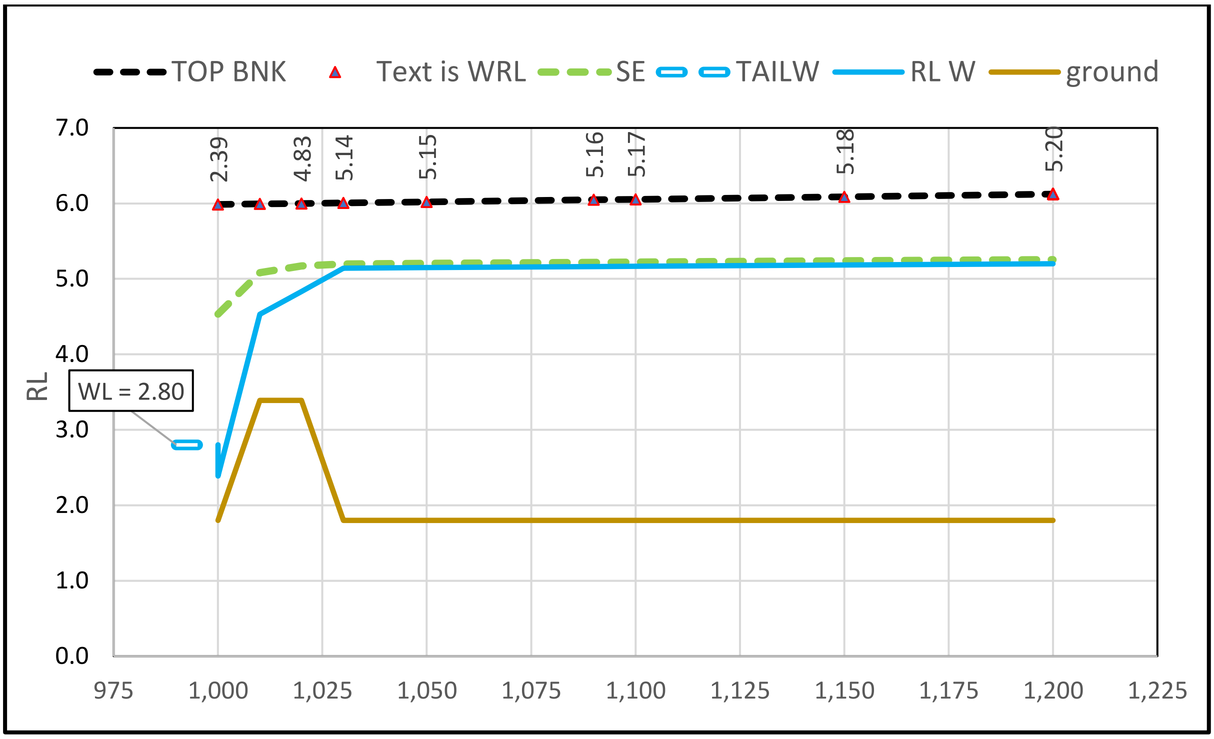


Figure 8 - Water Level Long section against Sea Barrier of RL 3.3

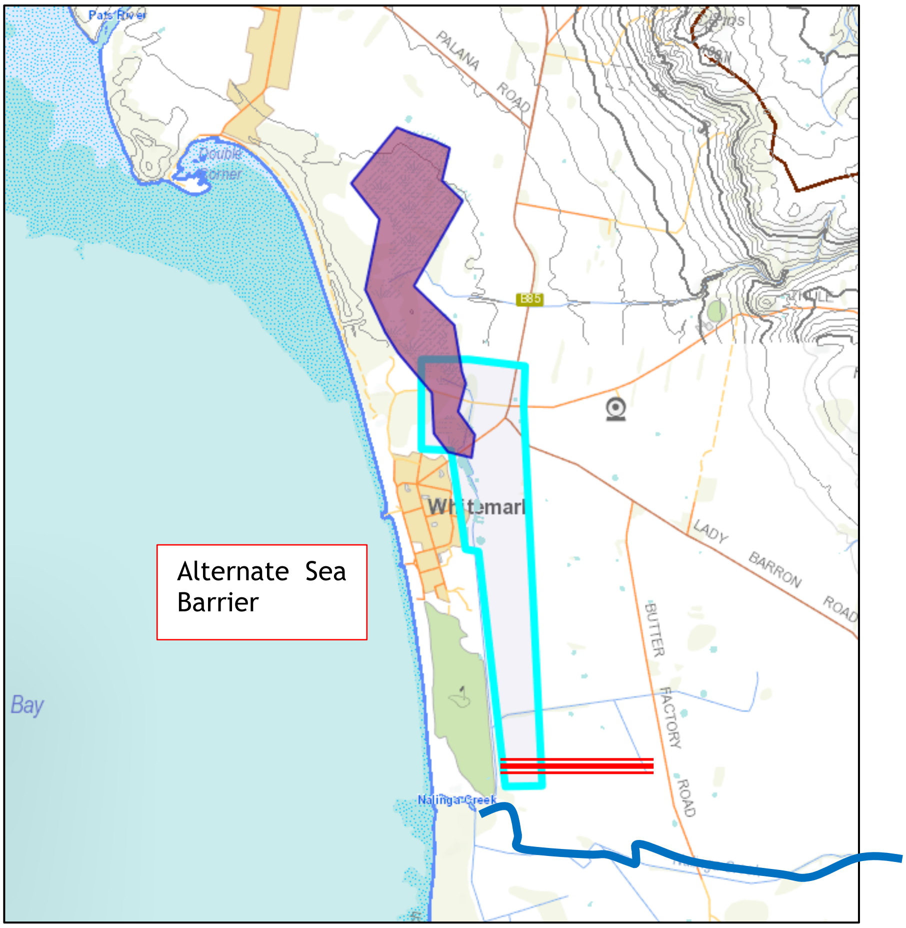
The depth of water over the sea barrier crest at RL 3.30 would be up to 1.53, or RL 4.83m AHD. Further upstream the water Level would approach the level of the Energy level at RL 5.20 AHD.

A flood control level of 5.70 m AHD would be appropriate. Residential street levels in Whitemark, as shown in Figure 3 are, in parts, below this level. A sea barrier across the whole of the Nalinga Creek is not likely to be an appropriate provision.

6.2 Alternate Sea Wall location

An alternate possibility may be to place the Sea Barrier only across the Area 6 tributary drains that join to Nalinga Creek. This would allow the major catchment of Nalinga Creek to flow to the sea unimpeded. This will require a much longer barrier, perhaps up to 600 m long, but it will significantly reduce the catchment area behind the sea barrier to only 717 Ha instead of 2,617 Ha. (refer Figure 7 for catchment areas). The longer length of the barrier will also reduce the depth of weir flow over the barrier - lowering the designated flood level upstream of the barrier.

The sea barrier would still need to be to the same height as the original barrier, but the control tail water level downstream of the weir will vary along its length, from RL 3.1m at the river mouth to RL 3. 60 at the inland extent of the weir (Section 4.1 (page 10) & Figure 5. For certainty a tail water of RL 3.6 will be assumed for the full length.



Alternate Sea Barrier

Figure 9 – Alternate Sea Barrier

No separate hydrology has been undertaken for the reduced catchment area, but for this analysis it is useful to first consider the runoff pro-rate to the catchment area, which would be 32 m^3/s, and then to assume an increased value, as the catchment size affect will be to increase the figure. The sub catchment flow has been assumed to be 40m^3/s.

In these circumstances, due to the long weir length of 600m, the upstream flood levels were calculated to be only marginally higher than the tailwater in Nalinga creek. The flood level would be RL 3.70 and an appropriate control level RL 4.2 AHD.

These are improvement on RL 5.7 but is still needs to be compared to existing ground levels in Whitemark – see Spot Levels in Figure 3.

6.3 Sea barrier discussion

If fresh water wetlands, rather than a salt water estuary is required in Area 6 at Whitemark at the turn of the century then a sea barrier wall will be required at a minimum level of RL 3.30 m AHD.

Flood control levels upstream of the sea barrier will depend upon where it is placed and what catchment is contained upstream. None the less the minimum flood control level is likely to be no less than RL 4.2. This is a still a considerable height and may conflict with existing land or development levels in Whitemark. This may also require the construction of a sea barrier wall that could be up to 600 m long.

If a sea wall barrier is to be advanced, it will need to be studied in much greater detail and with much greater data sets. The additional study must include a full environmental impact assessment on the changing the landform and biodiversity, and a review of likely water quality within the created wetlands. Given that there is no sewerage system in Whitemark the impact from Septic tanks that may gravitate to the wetlands by groundwater movement may need to form part of any review.

7. A Sea Barrier with climate change only to 2050.

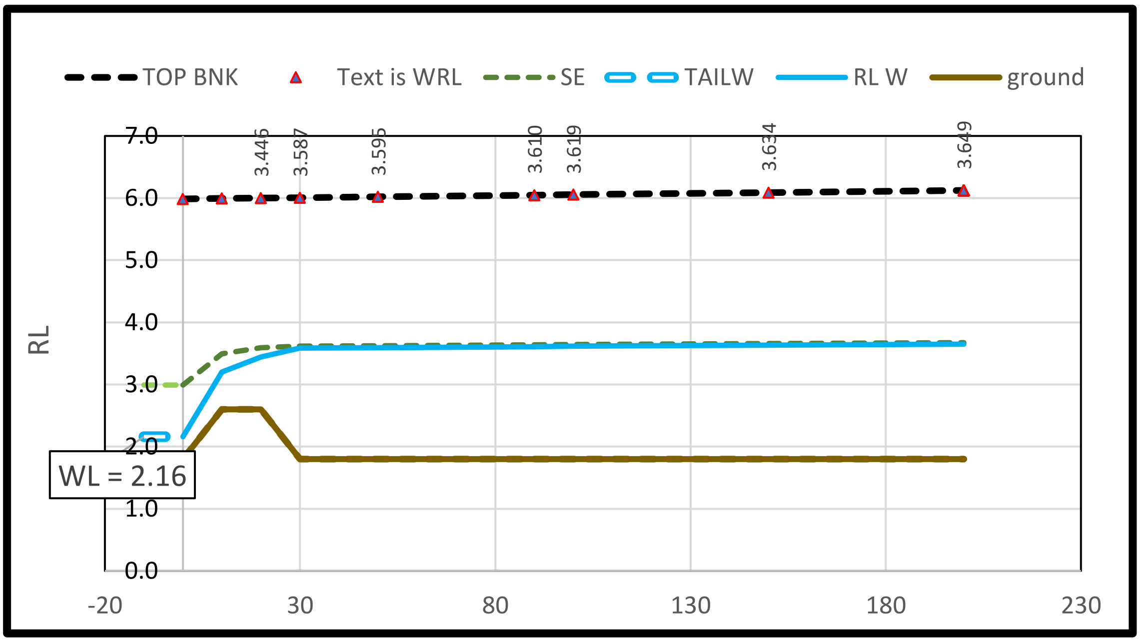
The analysis of Section 6 adopted several reasonable, but conservative assumptions required for serviceability of the created wetlands for the turn of the century. Where private property is concerned this is necessary.

The results are significantly affected by the increased height of the future tides and thus the height of the barrier required to prevent salt water inundation, and the increased 1:100 AEP runoff, from 44.2 m3/s to 116.7m3/s.

It is possible to consider a short 33m sea barrier at the Nalinga Creek outlet, but with a much shorter service life, say up to 2050. By this time sea level rise will be 0.23m (instead of 0.92m), and the 24-hour 100 year rainfall intensities may only increase by 0.13% rather than up to 80%[1] by 2100.

This means that the sea barrier level could be placed at current High tide (1.58) + King Tide allowance (0.32m) + Sea level rise (0.23m) + wave freeboard (0.5m) = 2.60m AHD, instead of the previous 3.30m used. The tail water will be assumed as 2.16m AHD (King Tide + Sea Level rise).

The 1:100 AEP flow rate to be passed over the weir could remain at the current 1:100 AEP flow rate at 44.2 m^3/s.



Under these conditions the weir flow to pass 44.2 m3/s over the sea barrier would cause water to rise to only RL 3.65 upstream, compared to RL 5.20 at the turn of the century.

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[1] Climate Assist "http:climateasyst.pittsh.com.au/app/"

This is a significant reduction, because the control parameters, particular rainfall intensity and stream flow, are not as extreme by 2050 as predicted for the turn of the century.

The service level will however deteriorate rapidly from 2050 onwards, if the climate change affects materialize as predicted. If such a barrier is not closely monitored for demolition or at least for review, it could become a large risk and the community could be caught by a 1:100 storm event passing over the weir at the predicted height of RL 5.2, such that Whitemark would be affected.

It may be prudent then to force a review of the sea barrier at or about 2050 by lowering it – by removing or reducing the wave freeboard allowance of 0.5 m – so that infrequent but regular ingress of sea water becomes a catalyst for review at or about 2050.

Instead of a sea barrier at RL 2.65 – a barrier at RL 2.15 would give some reasonable present-day protection against salt water inflow, and reduce the level to pass the 1:100 AEP flood water over the barrier to RL 3.15.

In the 2050 review the opportunity to remove the barrier at the mouth of the river – to install the 600 m barrier discussed at Section 6.2 could be examined.

8. Conclusion

Climate change can be expected to significantly increase the runoff from Nalinga Creek for a 1:100 AEP storm event. Flows are expected to increase from 44.2 m3/s in 2010 to 116.7m3/s in the time interval 2070-2099 AD.

It is recommended that a level of river mouth siltation ought to be considered in any hydraulic evaluation of Nalinga Creek. A reasonable level is a bed level at mean tide level, approximately RL 1.0 at 2070-2099AD.

Under this assumption creek flood levels at the mouth can be expected to be at least RL 3.1 based on 1:100 AEP (2100 AD) rainfall event against a high tide of RL 2.52

Allowing at least 0.5 m of freeboard the 1:100 AEP (2100 AD) control level in the vicinity of the Nalinga Creek outfall would be considered to be RL 3.6 AHD.

Away from the Creek outfall this figure would be expected to be higher where creek bed and bank slopes and water way area could become major influences.

Coastal vulnerability from storm surge may also exceed these levels and alternate references should be reviewed.

A sea barrier that would prevent salt water inundation of the interior wetlands (built to RL 3.30m), placed at the Nalinga creek outlet, would only need to be some 35 m long , but the depth of water over the barrier would be significant. Flood levels upstream of the barrier could rise to RL 5.2 m AHD by 2070-2099 AD.

A longer sea barrier (up to 600m) further inland, and with a reduced natural catchment, could reduce flow levels over the sea barrier to RL 3.7m AHD by 2070-2099 AD. This level would be much more acceptable for Whitemark.

Alternatively a reduced service life sea barrier, preventing sea water inundation only to 2050, which may then need to be removed or modified could be considered. It could be built only to RL 2.15 and 1:100 AEP storm flows over the barrier would only reach to RL 3.15.

There are a number of consequences that will need to be considered if any sea barriers are to be constructed to re-create any freshwater wetlands. This will include an increase in flood inundation levels, and possible environmental and water quality impacts and the impacts from overtopping, from flood and sea water.

APPENDIX A

Hydrological Catchment Analysis

Nalinga Creek Flinders Island

Hydrological Catchment Analysis

JMG

March 2018

Introduction

JMG have been invited to carry out a hydrological assessment of the Nalinga Creek Catchment which is located south of Whitemark on Flinders Island. The aim of the study is to develop flood hydrographs at various points in the catchment for both current and climate change conditions. To achieve this JMG constructed a RORB model and calibrated it to the 20 year flood frequency estimate and then used the model to estimate current and climate 100 year hydrographs.

Flood Frequency Analysis

Data was acquired for two gauged catchments on Flinders Island from DPIPWE and a flood frequency analysis (FFA) was carried out on both. The two catchment records were for the South St Pats River (19 annual maxima) and Samphire River (14 annual maxima). As the two records are relatively short but overlap for part of the record and cover slightly different periods the results were scaled for comparison to determine if they could be spliced together to provide an extended record.

However on inspection it became clear that the scaled peaks for the Samphire River were generally but not always smaller for the same events in the St Pats. This can be explained by the fact that the catchments are separated by Mt Strzelecki and that the Samphire catchment will be in a rain shadow when exposed to the dominant westerly systems, this explains the smaller peaks.

Consequently it was decided to just use the St Pats catchment annual maxima for flood frequency analysis and catchment scaling to translate the resulting values to the Nalinga Creek Bass Strait outlet. The South St Pats catchment has an area of 21 Km^2 and annual average rainfall of 799.43 mm the study catchment an area of 26.17Km^2 and an annual average rainfall of 752.89 mm.

With a flood record of only 19 annual maxima, predicting the 100 year event with any accuracy would be difficult as it is generally accepted that a minimum of 50 maxima are required to predict a 100 year event. However for the 20 year event there is a good chance that 19 maxima can be used to estimate the expected 20 year event peak. Figure 1 and table 1 below shows the results of the analysis.

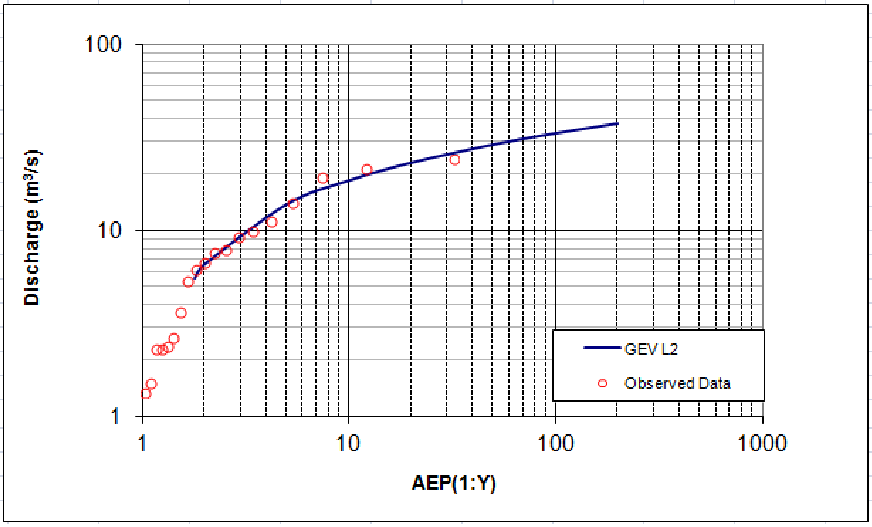


Figure 1

Study Catchment Results	
AEP	**Flow m³/sec**
2	7.3
5	15.5
10	20.8
20	25.9
50	32.5
100	37.4
200	42.2

Table 1

RORB Model Development

We considered that the best approach to estimating the 100 year event for current and climate change conditions would be to construct a RORB model and calibrate it to 20 year event peak i.e. 25.9 **m³/sec.**

The RORB sub-catchments were arranged so that they could provide input hydrographs to a 2D hydrodynamic hydraulic model at a later stage if required. Figure 1 shows the catchment coverage and sub-catchment delineation for Nalinga Creek.

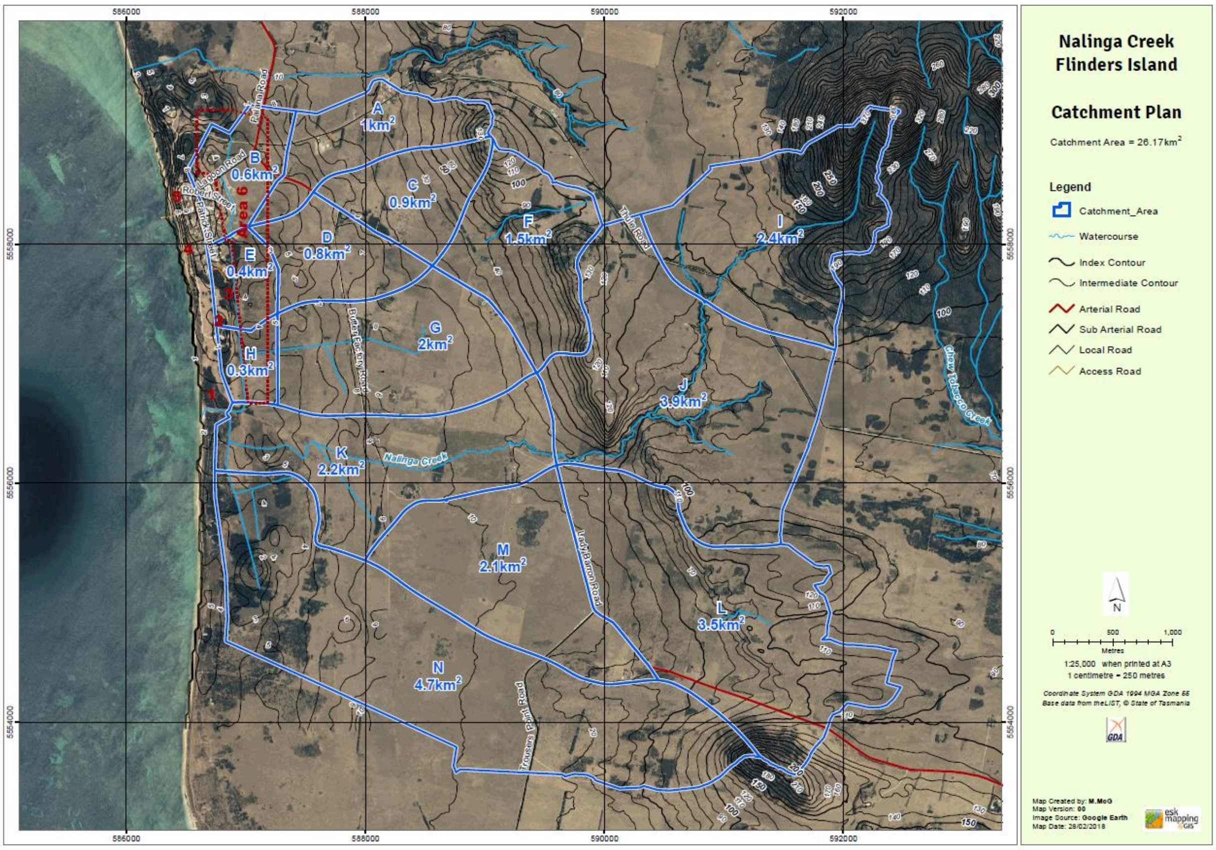


Figure 2, Nalinga Creek sub-catchment delineation.

The RORB network developed from the catchment plan to represent the sub-catchments and inter connectivity is shown in figure 3.

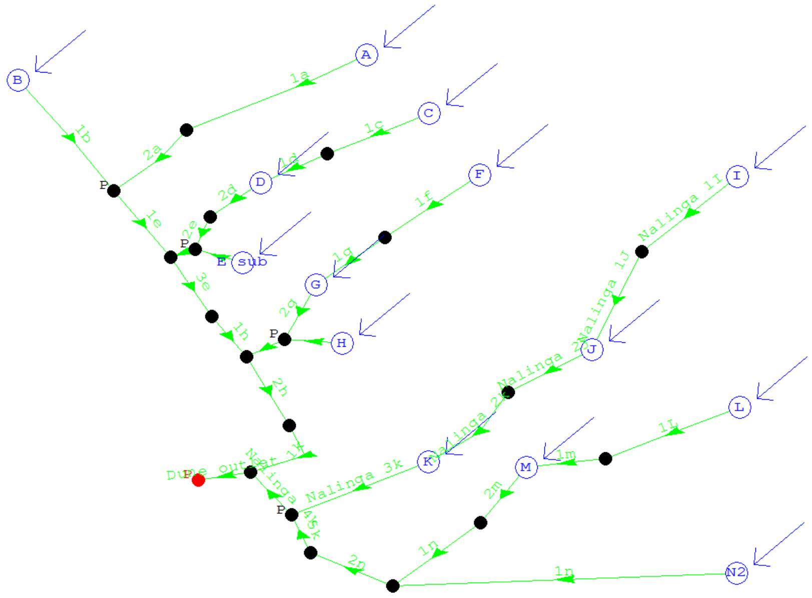
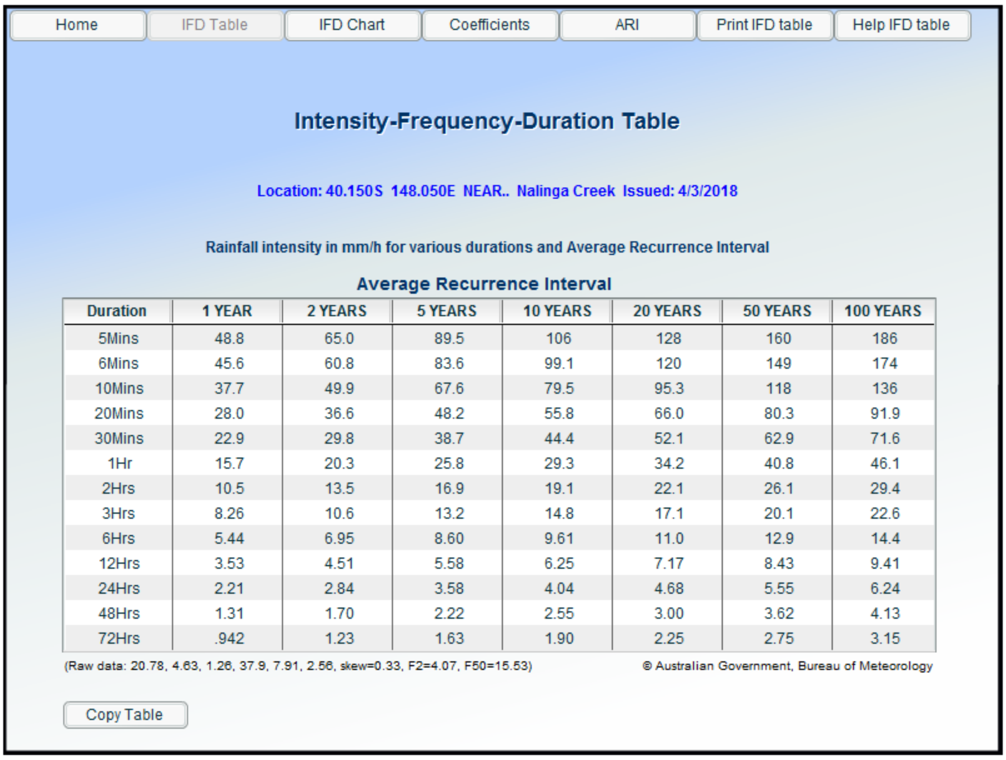


Figure 3 RORB network of Nalinga Creek.

Rainfall intensity frequency estimates and raw data inputs were derived for the approximate Nalinga catchment centre located at N:5556315, E:589464, figure 4.



Intensity-Frequency-Duration Table

Location: 40.150S 148.050E NEAR.. Nalinga Creek Issued: 4/3/2018

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

Average Recurrence Interval

Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	48.8	65.0	89.5	106	128	160	186
6Mins	45.6	60.8	83.6	99.1	120	149	174
10Mins	37.7	49.9	67.6	79.5	95.3	118	136
20Mins	28.0	36.6	48.2	55.8	66.0	80.3	91.9
30Mins	22.9	29.8	38.7	44.4	52.1	62.9	71.6
1Hr	15.7	20.3	25.8	29.3	34.2	40.8	46.1
2Hrs	10.5	13.5	16.9	19.1	22.1	26.1	29.4
3Hrs	8.26	10.6	13.2	14.8	17.1	20.1	22.6
6Hrs	5.44	6.95	8.60	9.61	11.0	12.9	14.4
12Hrs	3.53	4.51	5.58	6.25	7.17	8.43	9.41
24Hrs	2.21	2.84	3.58	4.04	4.68	5.55	6.24
48Hrs	1.31	1.70	2.22	2.55	3.00	3.62	4.13
72Hrs	.942	1.23	1.63	1.90	2.25	2.75	3.15

(Raw data: 20.78, 4.63, 1.26, 37.9, 7.91, 2.56, skew=0.33, F2=4.07, F50=15.53)

© Australian Government, Bureau of Meteorology

Figure 4 IFD and raw data estimates for Nalinga Creek.

Running the RORB model and calibrating it to the 20 year flood frequency estimate indicated that the critical storm duration for the 100 year, 50 year and 20 year events were all 12 hours (Figure 5).

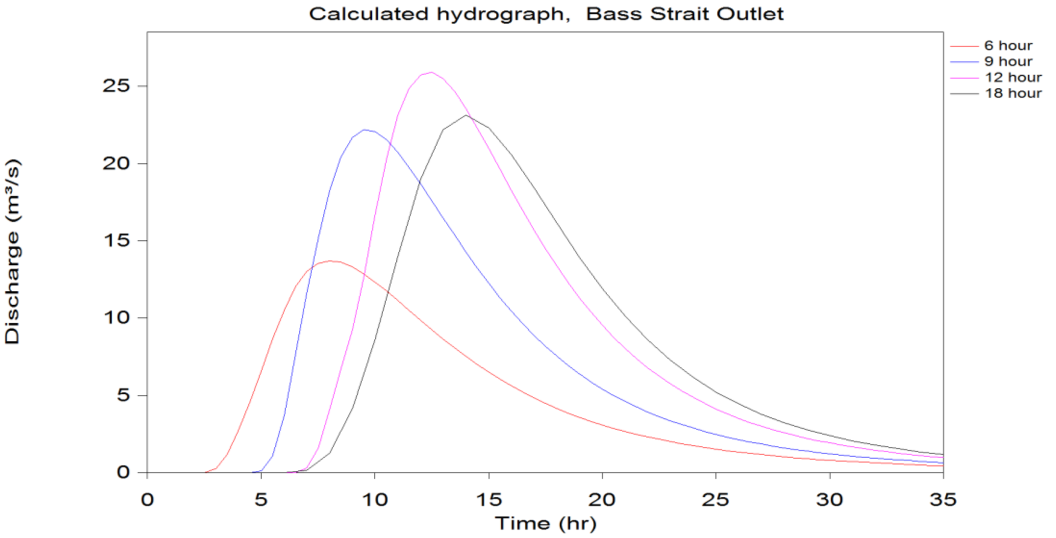


Figure 5, Multiple duration 20 Year ARI flood discharge of Nalinga Creek

The RORB model parameters adopted through the calibration process are as shown in table 2.

RORB Model parameter	Value
K_c	11.28
m	0.8
IL	29.35 mm
CL	3.1 mm/hr

Table 2

K_c and m were adopted from the RORB manual equation ($K_c = 2.2A^{0.5}[Q_p/2]^{0.8-m}$), one of many possible equations, as it gave a very good approximation to the 20 year Nalinga catchment discharge estimated from flood frequency analysis, using the median Region 3 values for initial loss (IL) and continuing loss(CL). The respective Region 3 median values are IL = 27.5mm and CL = 3.1mm/hr. The full range of Region 3 IL and CL values are include in Appendix A taken from the official on line AR&R 2016 guide.

As can be seen from table 2 only small changes had to made to the IL, increasing it to 29.35 mm to replicate the 20 year FF result which provides some confidence in the methodology. Figure 6 shows the hydrograph out puts at the Bass Strait outlet of the model.

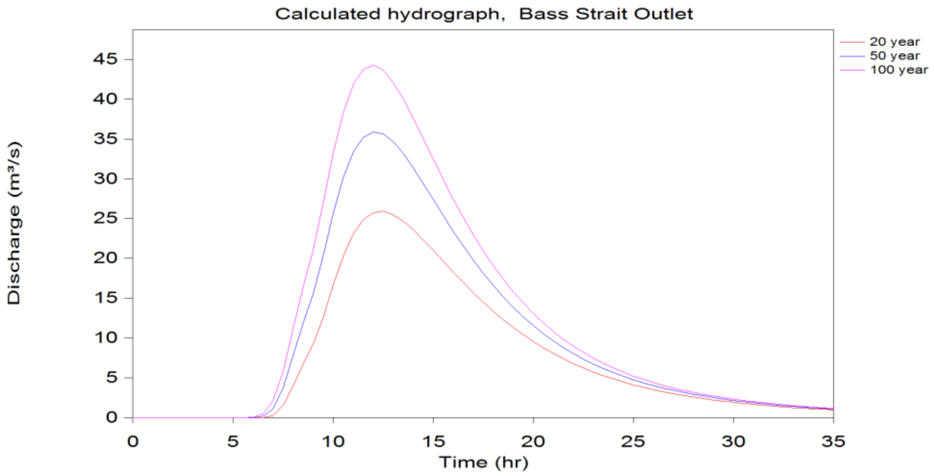


Figure 6, 100, 50 and 20 year flood hydrographs at the outlet to the Bass Strait

The peak values of the three hydrographs are shown in table 3 where they are compared with the results of the flood frequency analysis.

Flood Event years	Flood Frequency Analysis estimate Q_{FFA} m^3/sec	RORB model estimate Q_{RORB} m^3/sec
20	25.9	25.9
50	32.5	35.9
100	37.4	44.2

Table 3

The divergence is acceptable given the short record of annual maxima available for flood frequency analysis. Having developed hydrographs for current climatic conditions the model was used to investigate the impacts of climate change.

Climate Change

The projected impact of climate change (CC) on the Nalinga catchment rainfalls can be seen in the screen shot for the projected % increase in 24 hour rainfall for the period 2070 to 2099 over the base period 1961 to 1990, figure 7.

The catchment for the Nalinga Creek is dominated by two predictive squares which predict an increase in the 24 hour 100 year rainfall of 87.84% and 71.83% respectively. A simple average of the two predictive squares was deemed to apply to the study catchment i.e. 80%. Figure 7 is an image taken from the Climate*Assist* tool developed by the Australian Research Council, Hydro Tasmania and Pitt & Sherry.

Area weighting could have been applied but given that the critical catchment duration is 12 hours rather than the 24 hours for which projected values are available, area weighting could not be expected to increase accuracy meaningfully. This is because the predicted percentage increase for the 12 hour event is likely to differ from the 24 hour event.

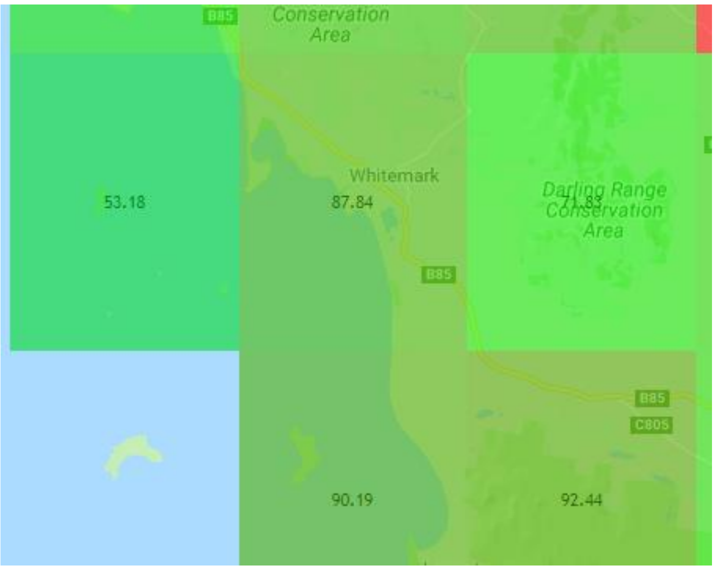


Figure 7, Projected % increase in 24 hour rainfall for the period 2070 to 2099

The burst depth multiplied by the areal reduction factor (0.99) in RORB for climate change conditions was determined to be 201.22 mm for the period 2077 to 2099. Figure 8 below shows the Nalinga Creek Bass Strait outlet hydrograph for the 100 year CC event.

The estimated peak discharge under climate change conditions for the 100 year event is 116.7 m^3/sec compared to 43.3 m^3/sec under current conditions, an increase of 169 % in peak flow. Assuming the predicted increase for the 24 hour 100 year event is correct then the increase in flow is not surprising.

In Appendix B we have included full set of climate change hydrographs. These can be used to determine the extent of flooding using a 2D hydrodynamic model if combined with tail water conditions reflecting the associated sea level rise.

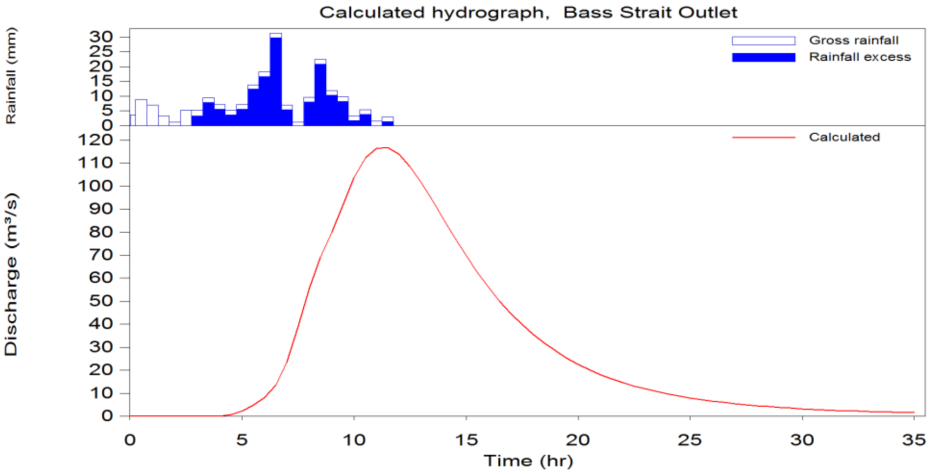


Figure 8

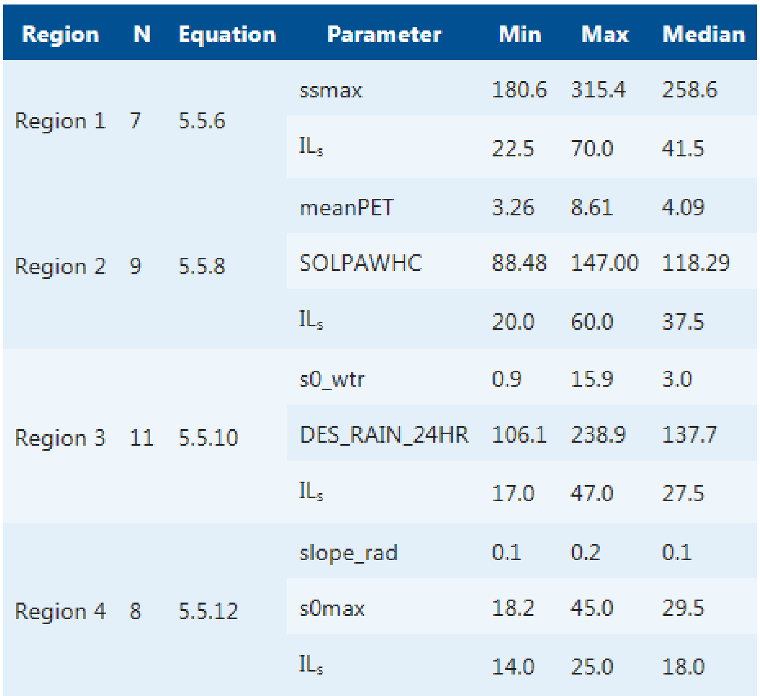
Conclusion.

A RORB model was developed for the hydrological study of the Nalinga catchment on Flinders Island. The RORB model has generated hydrographs for current and projected climate change conditions at various points in the catchment. These will be suitable for application to a 2D domain within a hydrodynamic model to calculate a flood surface.

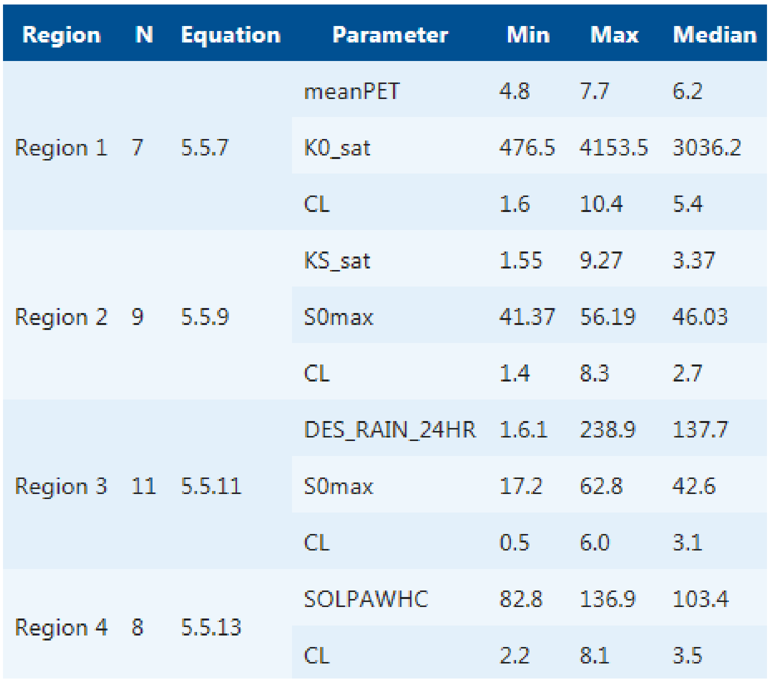
The 100 year current flood discharge at the Nalinga catchment mouth discharging into the Bass Strait was estimated at 43.3 m^3/sec. By applying the projected increase in rainfall for this part of Flinders Island we have estimated that the 100 year flood peak for Nalinga Creek could increase to 116.7 m^3/sec by 2070 to 2099.

APPENDIX A

Regional initial loss and continuing loss values taken from AR&R 2016. Tasmania is largely associated with Region 3.



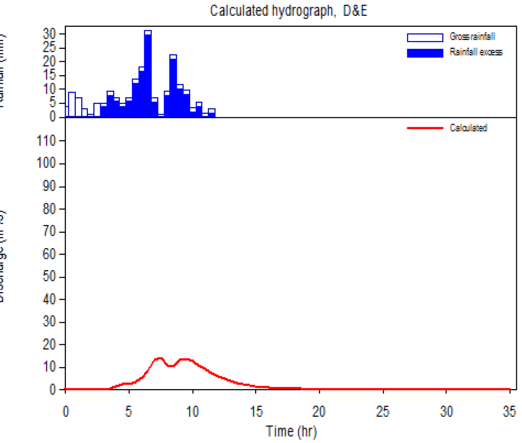
Region	N	Equation	Parameter	Min	Max	Median
Region 1	7	5.5.6	ssmax	180.6	315.4	258.6
			IL_s	22.5	70.0	41.5
Region 2	9	5.5.8	meanPET	3.26	8.61	4.09
			SOLPAWHC	88.48	147.00	118.29
			IL_s	20.0	60.0	37.5
Region 3	11	5.5.10	s0_wtr	0.9	15.9	3.0
			DES_RAIN_24HR	106.1	238.9	137.7
			IL_s	17.0	47.0	27.5
Region 4	8	5.5.12	slope_rad	0.1	0.2	0.1
			s0max	18.2	45.0	29.5
			IL_s	14.0	25.0	18.0

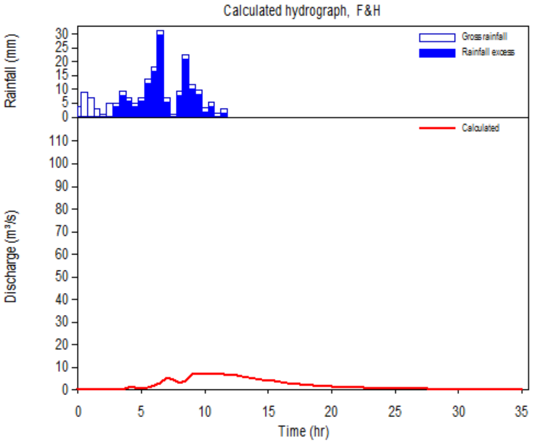


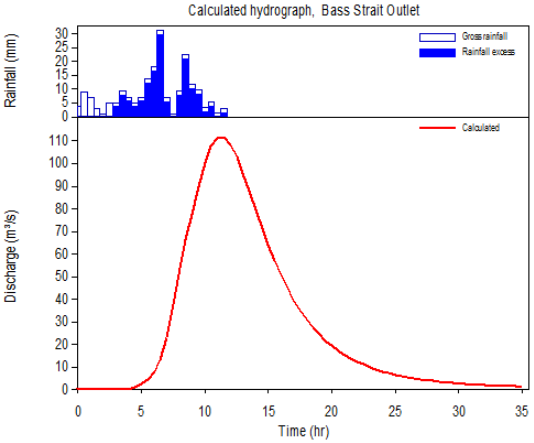
Region	N	Equation	Parameter	Min	Max	Median
Region 1	7	5.5.7	meanPET	4.8	7.7	6.2
			K0_sat	476.5	4153.5	3036.2
			CL	1.6	10.4	5.4
Region 2	9	5.5.9	KS_sat	1.55	9.27	3.37
			S0max	41.37	56.19	46.03
			CL	1.4	8.3	2.7
Region 3	11	5.5.11	DES_RAIN_24HR	1.6.1	238.9	137.7
			S0max	17.2	62.8	42.6
			CL	0.5	6.0	3.1
Region 4	8	5.5.13	SOLPAWHC	82.8	136.9	103.4
			CL	2.2	8.1	3.5

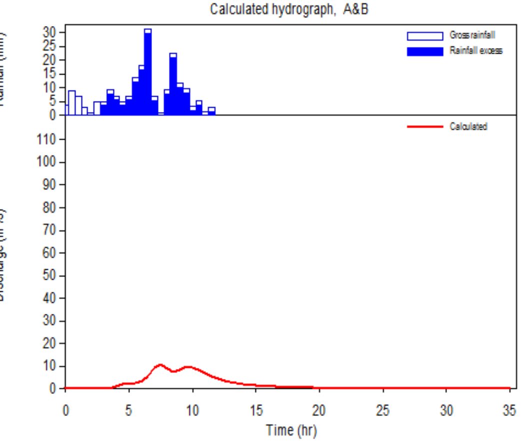
APPENDIX B

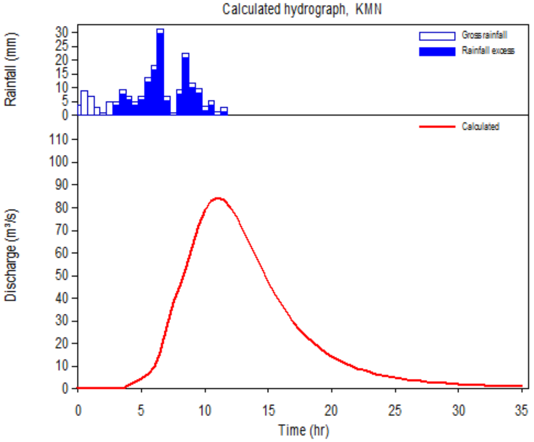
Climate Change Nalinga Creek sub catchment hydrographs


Calculated hydrograph, D&E


Calculated hydrograph, F&H


Calculated hydrograph, Bass Strait Outlet


Calculated hydrograph, A&B


Calculated hydrograph, KMN

ABN 76 473 834 852 ACN 009 547 139

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