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Date of Lodgment:	6/10/2023 4:59:29 PM AEDT
Date Accepted for Filing:	6/10/2023 4:59:34 PM AEDT
File Number:	VID622/2021
File Title:	PABAI PABAI & ANOR v COMMONWEALTH OF AUSTRALIA
Registry:	VICTORIA REGISTRY - FEDERAL COURT OF AUSTRALIA

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Australian Government Solicitor

Expert Report of Bruce Harper

Pabai & Anor v Commonwealth of Australia (VID622/2021)

October 2023

SEA Systems Engineering Australia Pty Ltd

Numerical Modelling and Risk Assessment

J2303-PR001A

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J2303-PR001A

TABLE OF CONTENTS

Page

LIST OF APPENDICES

1. Introduction

This report has been prepared at the request of the Australian Government Solicitor (refer Appendix A) to address specific questions (Appendix B) in regard to the expert report of Mr Stuart Bettington dated 3 Aug 2023.

I am the principal author of the study documented in SEA (2011) that was commissioned by the Torres Strait Regional Authority (TSRA) and is variously quoted in the Bettington expert report.

In preparing this report I've read the Expert Witness Harmonised Code of Conduct and have agreed to be bound by it.

My responses in the Sections below follow the Appendix B question sequence.

A brief Conclusion summarises the various elements of my report.

2. Basis of Expertise

Q1. Please describe your academic qualifications, professional background and experience that is relevant to your answering the questions in the letter of instruction. You may wish to do so by reference to a current curriculum vitae.

Academic Qualifications:

- Bachelor of Engineering - Civil (Hons), James Cook University (1975)
- Doctor of Philosophy in Civil Engineering (Numerical Fluid Dynamics), James Cook University (1982)

Professional Certifications:

- Chartered Professional Engineer (CPEng)
- National Engineering Register (NER)
- Registered Professional Engineer, Queensland. (RPEQ No. 4987)
- APEC Registered 811866
- International Engineer IntPE(Aus)

Affiliations:

- Adjunct Professor – Engineering, College of Science and Engineering, James Cook University 2017+.
- Fellow, Engineers Australia (FIEAust)
- Member, College of Civil Engineers, Engineers Australia (EA)
- Member, Australasian Wind Engineering Society (AWES)
- Member, Australian Meteorological and Oceanographical Society (AMOS)
- Member, American Meteorological Society (AMS)

I am a specialised civil engineer with over 45 years of experience in numerical modelling, statistical and natural hazards risk assessment, principally applied in coastal, ocean and wind engineering disciplines. After a wide range of experience in academia, industry, and commercial consulting I formed Systems Engineering Australia Pty Ltd (SEA) in 1996 to provide specialised consultancy services in the field of environmental risk assessment, especially where quantitative analyses are required.

I'm regarded as one of Australia's foremost authorities on the modelling of tropical cyclones (TCs) and their effects in the coastal and ocean environment, dating back to the mid-1980s when I was responsible for the series of Storm Tide Statistics reports extensively adopted by Local Government in Queensland. In 2000-2004 I led and was responsible for much of the analyses and recommendations for the landmark State and Federal Government sponsored Queensland Climate Change and Community Vulnerability to Tropical Cyclones (QCC) project, which was awarded the National 2004 Australian Safer Communities Award.

I have developed numerous original numerical and statistical modelling approaches to natural hazards risk assessment throughout my career. My SEAtide storm tide modelling software, used by the Bureau of Meteorology from 2005 to 2020, is such an example. I am a past Chairman of the Engineers Australia National Committee on Coastal and Ocean Engineering and authored the *Guidelines on Responding to the Effects of Climate Change* (2004, 2012 and 2017). I am a former member of the Standards Australia Wind Actions Sub-committee that oversees design wind speeds and have been a regular consultant to the World Meteorological Organisation and the

Bureau of Meteorology. In 2006 I was the only non-academic founding member of the worldwide Willis Research Network, which included Oxford, Cambridge, Princeton, Kyoto and many other leading universities and I had a prominent role in climate change science issues through my WMO involvement. I developed the first Australian insurance loss modelling capability for tropical cyclone wind and storm surge in the mid-1990s, as well as later severe thunderstorm downbursts, hail, and tornadoes.

I was named amongst Engineers Australia's *Most Innovative Engineers* in 2016 and have been the recipient of three Engineering Excellence Awards, the most recent of which was for the Coastal Hazard Adaptation Strategy for Townsville in 2013, which is the exemplar for the QCoast2100 programme.

I have undertaken scores of coastal hazard studies along the entire Queensland coastline and the northern Australian coast, as well as having past industry experience in the offshore industry of Western Australia.

Projects in the Torres Strait region and nearby include:

- Gove Storm Tide Study, Alcan Gove Pty Ltd, Gove, 2007.
- Torres Strait Extreme Water Level Study, Torres Strait Regional Authority, Qld, 2009-2010.
- Gulf of Carpentaria Storm Tide Study, Qld Dept of Environment & Resource Management, GHD Pty Ltd, 2010-2012.
- Townsville City Council coastal hazard adaptation strategy study, GHD Pty Ltd, 2013.
- A Coastal Vulnerability Assessment Methodology for Torres Strait Communities – Pilot Study, Torres Strait Regional Authority, 2014.
- SEAtide Probabilistic Storm Tide Modelling System for the Queensland Coast, Qld Dept of Science, Information Technology, Innovation, and the Arts, 2014.
- Statistical Tropical Cyclone Storm Surge and Wave Modelling for Torres Strait, GHD Pty Ltd, 2017.
- Burke & Carpentaria Shire Councils, 2018 (with BMT Pty Ltd).
- Mapoon Aboriginal Shire Council, 2018 (with BMT Pty Ltd).
- Coastal Hazard Adaptation Study, Torres Shire Council, 2017-2021 (with BMT Pty Ltd).

An abridged Curriculum Vitae is provided in Appendix C.

3. Extreme Sea Level Events

Q2. Do you agree with Mr Bettington's assessment, in his report dated 3 August 2023 (the Bettington Report), of extreme water levels on Boigu, Saibai, Poruma and Warraber (the Mapped Islands) as set out in tables 3 and 5 of that report? To the extent that you do not agree with the opinions Mr Bettington expresses in those tables, please provide your own opinion as to the proper extreme water levels on the Mapped Islands by reference to the same average recurrence intervals (ARI) considered by Mr Bettington.

In answering this question, please assume that the extreme water levels set out in tables 3 and 5 of the Bettington Report reflect Mr Bettington's assessment as at the present date of extreme water levels on the Mapped Islands.

1. Hereafter references to Mr Bettington's report (RHDV 2023) are termed 'BR' and 'Global Sea Level Rise' as it affects Mean Sea Level (MSL) at the various islands is referred to as 'SLR'. References to specific elements of SEA (2011)[1], which is extensively quoted by BR, are prefaced here by '§' for clarity. Where I have provided modified versions of BR Tables and Figures, they are presented here with **bold captions**. In such modified figures the graphical legends will indicate 'HR' for 'Harper Report'.

2. BR's Table 3 has a truncated caption, but the report context infers that it has been directly sourced from SEA (2011), where the study results were assigned to the year 2010 and apply to the MSL datum. As per the instruction in Q2, I have assumed that the results have then been adjusted to the present year 2023, using the estimated increase of 0.04 m in MSL from 2010 to 2023 as stated in BR 2.2.4. In part, the values do follow §Table 11-1, but there are several differences I note that are inconsistent with that assumption:
    a. Firstly, BR appears to have mistakenly assigned the Warraber ARI levels from §Table 11-1 into the Boigu ARI levels column. As a direct result of this, the Table 3 Boigu ARI levels are higher than the original §Table 11-1 values by 0.04 m for the 10-y, 0.06 m for the 25-y and 50-y, and 0.05 m for 100-y. All other site ARI values are identical to §Table 11-1, indicating that no adjustment has been made to them for 2010 to 2023 SLR.
    b. Meanwhile, the HAT values do not follow §Table 11-1. There are small differences as follows: Boigu is 0.06 m lower, Saibai and Warraber are 0.06 m higher, and Poruma is 0.08 m higher than §Table 11-1. I cannot reconcile these small changes as being SLR adjustments or find alternative sources for them.
    c. A modified **Table 3** is therefore given below, which reflects §Table 11-1 ARI levels but includes the 0.04 m SLR allowance from 2010 to 2023. Rather than simply increase the 2010 HAT estimate derived from SEA (2011) modelling, I have

[1] I note that there is another prominent link on the TSRA website to an earlier version of SEA (2011) that contains some typographical errors. Its cover page also incorrectly suggests that the study was undertaken by the CSIRO. I have advised TSRA that the link needs to be corrected and the outdated report removed from public access. The latest report is PR002C, dated 25/04/2013, accessible here.

preferentially updated it with official values that are now available for 2023 (DES 2023b). All these levels are relative to the MSL datum.

Table 3 Estimated storm tide levels, including wave setup (based on SEA (2011) but adjusted to 2023 MSL)

	Boigu	Saibai	Poruma	Warraber
	(m MSL)	(m MSL)	(m MSL)	(m MSL)
HAT	2.29	2.06	2.27	2.23
Average Recurrence Interval				
ARI (y)	Storm Tide	Storm Tide	Storm Tide	Storm Tide
10	2.53	2.18	2.51	2.57
25	2.59	2.23	2.55	2.65
50	2.63	2.26	2.59	2.69
100	2.66	2.3	2.6	2.71
500	2.76	2.39	2.64	2.76

3. I firmly disagree with the modified water levels presented in BR's Table 5[2]. The changes proposed seem to reflect a misunderstanding of the intended completeness of the SEA (2011) methodology. The proposed 'modest regional lift' in BR 2.2.3 is not only subjectively proposed without statistical justification, but it represents a very significant increase in estimated extreme water levels. Further, it is applied universally across all islands even though they are known to have significantly different exposures to water level hazard. This contrasts with the very careful, justified and verified aspects of the underlying SEA (2011) study.

4. My disagreement with Table 5 commences with BR's reasoning presented in Sections 2.2.1 and 2.2.2, namely:
    a. BR's statement in Section 2.2.1 that SEA (2011) is *'based on cyclonic events'*, which implies *only* cyclonic events, and the later confirmation on p 17 that *'It is important to note that this storm tide study is based on cyclonic events and forecast tides only. This study did not fully consider non-cyclonic water levels variation that occur across the region. This has meant that the levels forecast in this study are an underestimate of the conditions that are experienced on site'*.
    b. The above reasoning is incorrect in its various statements. In complete contrast, SEA (2011) is predominantly a study that seeks to represent and incorporate the very 'non-cyclonic' influences discussed in Section 2.2.2 and the example water level events witnessed in Section 2.2.3.

[2] I also note that in following the BR logic in transitioning from Table 3 to Table 5, the 100-y ARI value for Boigu is 0.1 m higher than it should be. This may be simply a transcription error.

c. To understand and predict the complex interactions known to impact water levels and wave impacts in the Torres Strait it is necessary to consider the hierarchy of ocean forcing phenomena across time and space. At the longer time scales there is global warming induced Sea Level Rise (SLR), then inter-decadal ocean oscillations typically associated with ENSO[3] (so-called El Niño and La Niña phases). On an annual scale there is the possibility of intense Tropical Cyclones[4] (TCs), although these are rare historically in the Torres Strait. Much more common, but less intense than TCs, is the annual Tropical Monsoon originating from the north-west. Finally, there are the countering 'fresh' South-East Trade Winds that are a persistent feature along the east coast of northern Australia. At the highest frequency of water level variation is the Astronomical Tide, which varies daily, weekly, and monthly in accordance with the influence of the Earth-relative position of the Moon and the Sun and is sensitive to the local water depth (bathymetry) and coastal features (large bays, estuaries, islands, and reefs). There is also the dynamical imbalance between the Coral Sea and the Arafura Sea that modulates the strait water levels.

d. With the above complexity in mind, and to avoid confusion over the commonly misused weather-related terms 'cyclonic'[5] and 'non-cyclonic', SEA (2011) characterised all the non-TC climatology influences as being 'broadscale' in time and space. The only exception was that future climate SLR values were based on State guidelines at the time (DERM 2009). This methodology appropriately separated the more acute hazard emanating from TCs, which typically exist at smaller time and space scales, from all the other influences[6]. Also, in contrast to the 'broadscale' phenomena, there is projected future climate guidance available for TCs, which are much rarer but much more energetic and potentially damaging systems.

e. In respect of the Astronomical Tide (aka tide), it is not a weather[7] phenomenon but it interacts with the current weather condition. In the absence of any significant weather, water levels due to the tide are predictable to a high accuracy at all time scales, provided that sufficiently long regionally representative tide gauge measurements are available. Without such measurements, numerical hydrodynamic (mathematical) ocean modelling is the preferred method in complex situations like the Torres Strait.

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[3] The El Niño Southern Oscillation, which is similar to the historical Southern Oscillation Index (SOI), are metrics associated with a large-scale intermittent variation in the ocean temperature, winds, and pressures across the tropical Pacific Ocean.

[4] A Tropical Cyclone (TC) is an intense low-pressure system with specifically defined minimum intensity and internal temperature structure. TCs can transform into broader but weaker structures at higher latitudes.

[5] A 'cyclonic' weather pattern in the Southern Hemisphere is one where surface winds circulate clockwise around a low-pressure centre. The corollary for a high-pressure system is an 'anti-cyclonic' weather pattern. Monsoon Lows, for example, are 'cyclonic' but are not TCs. Trade winds are anti-cyclonic.

[6] Common weather conditions are also often referred to as 'ambient', as opposed to the rare 'extreme'.

[7] However, persistent weather-related anomalies are traditionally 'absorbed' into tidal analyses by way of seasonal corrections.

f. In regard to the assertion '*and forecast tides only*', this is also incorrect. Other than as necessary for remote model open boundary forcing, forecast tides were only used 'after the event', using our model-derived tidal information for the various communities, and only used to calculate the commonly quoted tidal planes such as Highest Astronomical Tide (HAT)[8], which is the highest expected tide-only water level over a defined *tidal epoch* (approx. a 20-y period).

g. The SEA (2011) study then proceeded to individually address each of the aforementioned ocean and weather phenomena that can influence the water level hazard throughout the Torres Strait. The §Chapter 5 methodology clearly describes how a 60-y period[9] of tidal and broadscale wind forcing from the US NOAA NCEP[10] reanalysis was numerically hydrodynamically modelled, combined with open ocean boundary signals and inter-annual ENSO variability. The resulting tidal residuals at the long-term regional tide gauges were then statistically resampled to provide a very robust validation of the numerical model output, as demonstrated in §Fig 5-6 and §Fig 5-7. TC events were excluded from that process. The whole 60-y modelled sequence of Torres Strait water levels was then extended by empirical repetition and resampling to provide a base 1000-y simulation. TC events during the November to April seasonal windows were then separately simulated on the background broadscale ocean response out to 10,000-y based on historical Bureau of Meteorology data.

h. The SEA (2011) numerical modelling confirmed that the water level associated with the local 'tide only' HAT level is very frequently exceeded. This chronic condition is due to the combination of the tide and the various broadscale weather influences. In the marginal islands of Boigu and Saibai this means that minor flooding is historically a common feature. It is unrelated to the potentially acute influences of rare TCs.

5. BR's reasoning offers Table 4 with 9 examples of 'non-cyclonic' community flooding from 2006 to 2019 that are of the type proposed to have not been considered in SEA (2011). However, §Chapter 10 explicitly addresses several of these:

   a. Although there are 9 examples of community impacts listed, these are drawn from 5 weather events impacting the Torres Strait region during 2006, 2009, 2010, 2018 and 2019. Delineating the regional weather event statistics from the location impact statistics is important when quantitatively modelling these occurrences so that over-counting of regional event frequencies doesn't occur.

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[8] I note that HAT values for the various communities that now have the benefit of permanent tide gauge measurements, show that the SEA (2011) tide modelling component was accurate to within 0.01 m at some islands. At Boigu the model was actually slightly conservative (higher) by about 0.20 m.

[9] 60-y can be expected to be long enough to capture the majority of broadscale variability on water levels.

[10] The US National Oceanic and Atmospheric Administration, National Centers for Environmental Prediction published one of the first attempts to create a computer-generated dataset that estimated the near-surface global wind and pressures from 1948 to 2010. This enabled coupling to our regional ocean model, which we had already equipped to model tides, to mathematically drive ocean currents and surges throughout the Torres Strait region. The statistics from those weather events was then able to be analysed. The NCEP data, however, cannot reliably represent the winds and pressures due to extreme TCs.

b. The first BR Table 4 example event in Jan 2006, said to have affected Iama and Warraber, was described by EPA (2006) as associated with 'King Tides', but it was instigated by a significant meteorological[11] event. §Section 10.2 of the study report considers the event in detail, where §Fig 10-3 provides witness photographs and §Fig 10-4 graphs the numerical wind, wave and water level modelling that was undertaken to demonstrate the potential veracity of the study methodology. The regional wind, wave and water level modelling well-supported the reported flooding impacts at Saibai, and the potential for wave-related impacts at Warraber and Poruma. No impacts were reported at Iama by DES (2006), so that site was not considered by us at the time.

c. The second BR Table 4 example event, noted to have impacted Boigu and Saibai in Jan 2009, was due to a remote tropical cyclone (*TC Charlotte*) in the southern Gulf of Carpentaria. Its impacts within the Torres Strait were classified by the SEA (2011) methodology as 'broadscale' as its meteorology was almost identical to the previous example. §Section 10.1 of the study report considers the event in detail, where §Fig 10-1 provides witness photographs and §Fig 10-2 graphs the numerical wind, wave, and water level modelling at Saibai, Warraber and Poruma. The regional forcing in §Figure 5-11 and tide gauge responses in §Figures 5-10 were also numerically reproduced to a high standard at several regional tide gauges. We were not made specifically aware of impacts at Boigu, but the model would have also confirmed that it was similarly affected.

d. The remaining 3 events noted in Table 4 occurred post the active SEA study period. These impacts are expected to occur from time to time because the weather conditions that create them are relatively common.

6. The inclusion of the types of events argued by BR as not being included in the study estimates (i.e., BR Table 3) is made additionally clear throughout SEA (2011), with underlining added here:

a. Commencing with the §Executive Summary '*The extensive analyses required for these estimates have been based on robust numerical and statistical techniques that have been designed to capture the principal atmospheric, astronomic and other <u>broadscale forcing</u> that modulates ocean water levels in the region. <u>In addition</u>, the localised impacts of tropical cyclones have been considered. Wherever possible, the analyses have been checked and validated against reliable measured data for winds, tides, storm surge and community impacts*'.

b. The 'broadscale' methodology is clearly outlined in §Chapter 2 (also §Figure 2) and addressed in detail in §Chapters 3, 4 and especially 5. Only §Chapters 6 and 7 consider TCs specifically. §Chapter 8 addresses the wave climate and potential wave setup from both broadscale and TC sources. §Chapter 11 brings together the separately assessed broadscale and TC influences using a joint simulation approach. §Figure 11-7 presents the Total Storm Tide ARI estimates for 2010 climate <u>broadscale-only</u>. §Figure 11-8 presents the statistically combined Total

[11] As further examined in §Appendix H-1, p H-18, these impacts were due to an intense monsoonal low-pressure system that developed over the Northern Territory.

Storm Tide ARI estimates for 2010 climate broadscale and TC forcing, which is based on §Table 11-1. A total of 33,816 model TCs were simulated to represent the present (2010) and future 2050 and 2100 projected TC climates.

c. The associated commentary on §p125 emphasises that the broadscale influences dominate all islands at the shorter ARIs. It notes that '*From the graph it is evident that, compared with Figure 11-7, the local TC forcing begins to influence some communities at around the 100-y return period and dominates their response at the very low risk levels (high return periods). These communities are ones located closest to the mainland or in close proximity to other islands. The water level at the more remote isolated islands are largely unaffected by TC events*'.

7. In closing, I note that, with the passage of time, significantly more regional water level data has been accumulated and earlier doubts over tidal and land datums are now more easily resolved across many areas of the Strait. The modelling capability applied to SEA (2011), although very significant circa 2009, has also improved. For example, subsequent State and Local government studies that I led (e.g., GHD 2012, 2013) built on the SEA (2011) methodologies, and advances in describing the marginal TC climatology (e.g., Harper and Mason 2016) can now provide greater confidence in estimating the rare (higher ARI) extreme impacts. Finer resolution of wave setup, which affects coral cays like Poruma and Warraber, would also now be possible, albeit these will always be very approximate[12]. Future climate projections have also changed significantly since circa 2009, with the future climate TC threat typically now reduced. In short, there is certainly scope for further study.

Q3. In your view, is Mr Bettington's adjustment of the extreme water levels set out in table 5 by reference to the Australian Height Datum (AHD) appropriate?

If you do not agree with Mr Bettington's approach, please provide your own opinion about how, if at all, the extreme sea levels set out at table 5 of the Bettington Report (or your answer to question 2 above, to the extent that your answers differ to those in the Bettington Report) should be adjusted to take into account the relative height of the Mapped Islands.

8. The BR Table 5 relies upon the estimate of the MSL to AHD adjustment for each site shown in BR Table 6. The reference for those is given as MSQ (2010), which was commissioned by TSRA, and an earlier version (MSQ 2009) is also referenced in SEA (2011). I note that the MSQ reports recommended the installation of several tide gauges in the region to overcome the tidal complexity throughout the strait.

a. While the BR Table 6 values match those from MSQ (2010), the MSQ report itself specifically warns against using the estimated MSL-AHD offsets, and instead recommends use of MSL throughout:

i. *Executive Summary*

'Mean Sea Level (MSL) calculated for each of the thirteen sites should be used as an alternative to the Australian Height Datum (AHD) until further tide gauge and GPS ellipsoidal heights are available.'

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[12] Wave setup assumptions in SEA (2011) are a significant discriminator between island extreme water levels, depending on their exposure.

ii. *Conclusions*

'The large variations between AHD determined via GPS and the MSL calculated here should be taken seriously and due to the coherent nature of the MSL calculation, MSL should be used as an alternative for the AHD.'

b. SEA (2011) made no assumptions about AHD levels due to the lack of reliable tidal planes, and as it was understood there were planned upcoming changes to the Australian AHD geoid[13]. As stated in §Chapter 10, the island-specific Lowest Habitable Level (LHL) was devised to provide a community exposure metric. This required expert land surveyor input, and very significant local datum shifts away from conventional views of the time were recommended (§Table 9-1). LHL was then able to be linked to MSL in a transparently approximate manner.

c. I note that Australian Height Datum (AHD; GA 2023) is specifically designed to approximate Mean Sea Level (MSL) around the continental shoreline and nearshore islands. All mapped land elevations are then expected to be adjusted to the AHD datum to provide consistency. The BR Table 6 MSL-AHD adjustments are at face value very extreme and likely result from the uncertainties in land elevations that were problematical during the 2009-2011 study period.

9. The Department of Environment and Science, which installs and operates the new storm tide gauges in the area, was able to provide updated tidal plane estimates published as DES (2021) and most recently as DES (2023b).

a. The MSL-AHD value for the Boigu storm tide gauge was confirmed in the 2021 update as -0.030[14] m, while Poruma and Warraber advice remained to 'use MSL'. In the most recent 2023 report, these recommendations have not changed. However, to complicate matters, there is another newer but less capable tide gauge at the Boigu barge ramp that is closer to the actual community than the storm tide gauge, which is located on an offshore beacon to the NE of the island. The MSL-AHD offset at the barge ramp is greater at -0.23 m. Such variations are to be expected in complex shallow water environments.

b. When using available land elevation data (e.g., LiDAR[15]) it remains important to check what AHD datum has been applied relative to any local permanent benchmarks. So long as the metrics being compared have been adjusted to the same datum, then the conclusions in terms of inundation[16] and the like should be similar.

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[13] A "geoid" is a mathematical approximation to the sea level all over the earth, even where on land, from which all 'elevations above sea level' can be computed. My understanding was that the AHD geoid in 2010 did not officially encompass many of the northerly Torres Strait islands, so its application would likely result in significant errors relative to true sea level elevations (which at the time were also uncertain).

[14] A negative offset means that the AHD datum is below the MSL datum. Elevations measured from the AHD datum will then be higher than if measured from the MSL datum.

[15] Even LiDAR data derived land levels collected for Boigu in 2009 were later found to be inaccurate and were corrected in 2013 (Qld Spatial Catalogue).

[16] It seems possible that BR has similarly (inappropriately) adjusted its Digital Terrain Model (DTM) in producing the inundation mapping. If so, the extents of flooding would still be exaggerated due to the ARI 'regional lift' assumptions in BR Table 5.

c. For very low-lying, and typically 'flat' terrain such as at Boigu and Saibai, small differences in assumed elevations can significantly change perceptions of the ARI associated with a particular community inundation level. There is no confirmed MSL-AHD offset available for Saibai, so 'MSL' must be assumed.

10. Besides the 2021 and 2023 DES updates, the relative MSL-AHD offset at Boigu is evident when considering:
    a. The online real-time storm tide gauge at Boigu DES (2023a) indicates that HAT to AHD datum is 2.32 m. This contrasts with the BR Table 7 value of 3.08 m, which is a very significant difference of 0.76 m.
    b. Further confirmation of incorrect BR MSL to AHD adjustment can be demonstrated by considering DES (2018; Table 1, p5), which provides several examples of land elevation across the Boigu community by way of photographs and use of GPS levelling equipment. These are to assist the community in appreciating the mapped AHD values that accompany storm tide warnings. **Figure A** here shows a location near the airstrip terminal building taxiway, where the insitu elevation has been measured as 3.047 m AHD. In contrast, **Figure B** extracted from BR Figure 12 shows a mapped inundation level of 3.73 m AHD, where the airstrip centreline is still just showing as dry. This suggests an offset between the BR AHD shift and the DES (2018) AHD shift of approximately 0.68 m. This compares favourably to the BR Table 6 value of 0.66 m, which is clearly erroneous.
    c. Considering the above DES (2023b) confirmation, the SEA (2011) Table 11-1 simulated MSL water levels can therefore be directly applied at Saibai, Poruma and Warraber. For Boigu, I choose to use the storm tide gauge AHD offset rather than the barge ramp gauge because of its longer record and to avoid very localised effects that may well change the barge ramp gauge's response (e.g., damage from vessels, breakwaters, sea walls, dredging and such).
    d. Based on the above, a modified **Table 6** is given below. This differs from BR Table 6 due to the significantly lower MSL-AHD datum adjustments being applied here.

Table 6 Mean Sea Level (MSL) relative to Australian Height Datum (AHD) for different dates

Horizon	Boigu	Saibai	Poruma	Warraber
	(m AHD)	(m AHD)	(m AHD)	(m AHD)
MSL in 1900 (Base Line)	-0.24	-0.21	-0.21	-0.21
MSL in 2010	-0.07	-0.04	-0.04	-0.04
MSL 2023 (Present Day)	-0.03	0.00	0.00	0.00

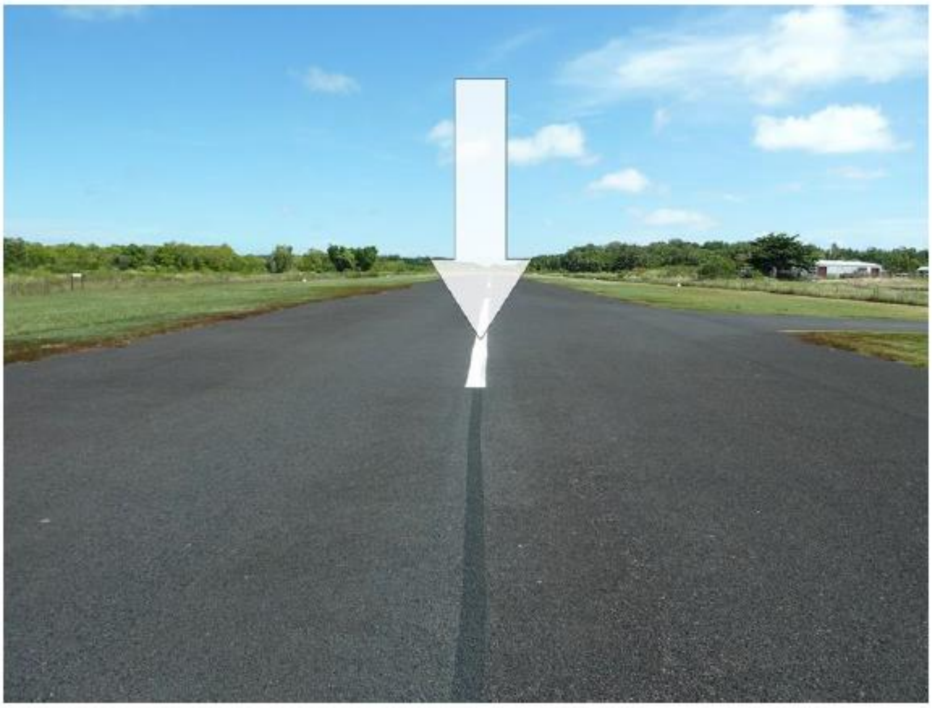

Figure A – Extract of Figure 31 (p27) in DES (2018) for Boigu Island airstrip with elevation of 3.047 m AHD (Table 1, p5).

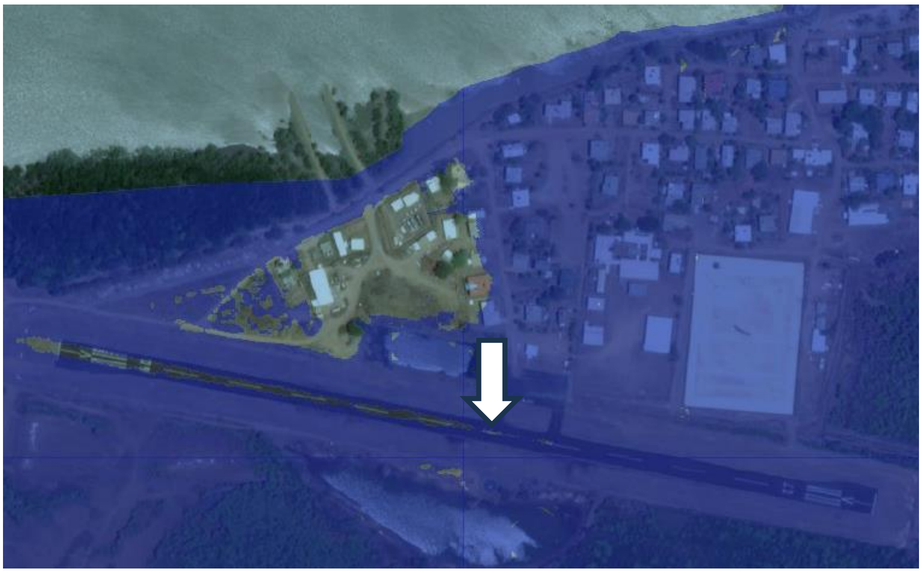

Figure B – Extract of BR Fig 12 (p25) with location arrow and shaded 3.73 m AHD level just showing the exposed airstrip centreline in the proximity of Figure A.

e. The various BR tables are then modified below for past and future SLR, where the official DES (2023b) HAT values to AHD datum replace the SEA (2011) MSL datum estimates throughout.
f. In summary, the BR Table 5 represents SEA (2011) Table 11-1 MSL water levels that have been increased by the BR-applied ‘regional lift’ adjustment, plus unsourced changes to the HAT levels. The actual values, in my view, should be identical to the earlier modified **Table 3** here (**p5**) if it is meant to represent the 2023 MSL condition.

Q4. On the basis of your answers to questions 2 and 3 above, do you agree with the conclusions set out in the following tables of the Bettington Report:

a. Table 7 (extreme water levels at 1900); and

b. Table 8 (current extreme water levels).

To the extent that you do not agree with the opinions Mr Bettington expresses in those tables, please provide your own opinion as to the proper extreme water levels on the Mapped Islands by reference to the same ARIs considered by Mr Bettington.

In answering this question, please assume the following:

a. Between 1900 and 2023, global sea levels have risen by 0.21m on average; and

b. Since 2010, global sea levels have been rising at 3.4mm per year (or a total of 0.04m between 2010 and 2023) on average.

11. As noted in response to Q3, the BR sequence of Tables 7, 8 and also 9 rely upon the estimate of the MSL to AHD adjustment shown in BR Table 6, which is known to be erroneous.
    a. Accordingly, I do not agree with the BR Table 7 and Table 8 water levels. Besides the AHD conversion error, the arbitrary application of an ‘regional lift’, as discussed in Q2, significantly misrepresents the various HAT and ARI-based water levels applicable to the communities being considered. Beyond the 10 y ARI this ‘lift’ assumption will lead to unrealistic inundation frequencies (BR Table 9) and flooding extents (e.g., BR Fig 12 through to Fig 23).
    b. Modified versions of **Fig 11** and **Tables 7, 8** follow below.

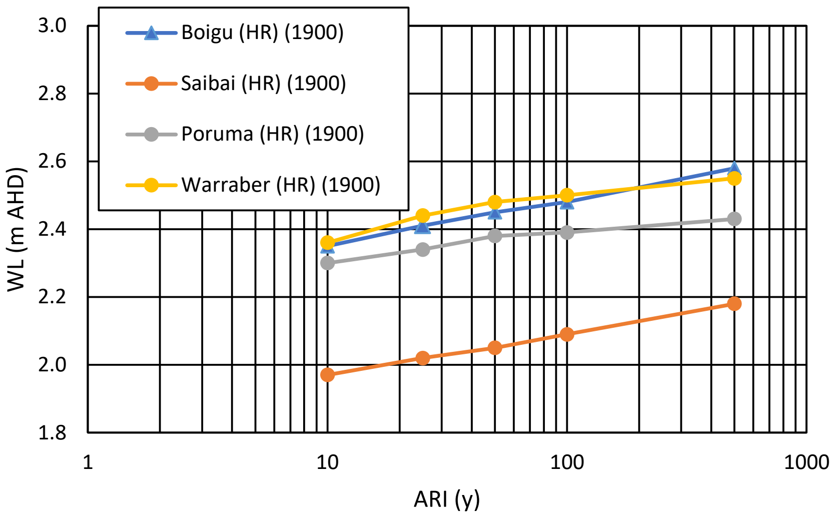

Figure 11 Baseline Extreme Water Levels for 1900

Table 7 Baseline (1900) Extreme Water Levels Relative to AHD

	Boigu	Saibai	Poruma	Warraber
	(m AHD)	(m AHD)	(m AHD)	(m AHD)
HAT	2.11	1.85	2.06	2.02
Average Recurrence Interval				
ARI (y)	Storm Tide	Storm Tide	Storm Tide	Storm Tide
10	2.35	1.97	2.30	2.36
25	2.41	2.02	2.34	2.44
50	2.45	2.05	2.38	2.48
100	2.48	2.09	2.39	2.50
500	2.58	2.18	2.43	2.55

Table 8 Baseline (2023) Extreme Water Levels Relative to AHD

	Boigu	Saibai	Poruma	Warraber
	(m AHD)	(m AHD)	(m AHD)	(m AHD)
HAT	2.32	2.06	2.27	2.23
Average Recurrence Interval				
ARI (y)	Storm Tide	Storm Tide	Storm Tide	Storm Tide
10	2.56	2.18	2.51	2.57
25	2.62	2.23	2.55	2.65
50	2.66	2.26	2.59	2.69
100	2.69	2.30	2.60	2.71
500	2.79	2.39	2.64	2.76

Q5. Do you agree with the Township Inundation Event Water Levels for the Mapped Islands set out in Table 9 of the Bettington Report? To the extent that you do not agree with the opinions Mr Bettington expresses in Table 9, please provide your own opinion as to the proper Township Inundation Event Water Levels on the Mapped Islands.

12. As noted under Q4, the erroneous AHD adjustment in BR Table 6 and the arbitrary 'lift' assumption in BR Table 5, which I disagree with, will likely substantially change these values. Without access to GIS-prepared land elevation data for each community I am unable to produce an updated BR Table 9. The frequency values expressed in ARI should appreciably increase.

4. Predicted Future Impacts

Q6. In light of your answers to the questions above, do you agree with the figures set out in the following tables of the Bettington Report:

a. Table 10 (Mean Sea Level relative to AHD) for various time horizons and climate change scenarios;

b. Table 11 (2050 projections SSP 1-1.9);

c. Table 12 (2050 projections SSP 1-2.6);

d. Table 13 (2050 projections SSP 3-7.0);

e. Table 14 (Township Inundation Event Water Levels Relative to AHD with 2050 Frequency of Exceedance);

f. Table 15 (2100 projections SSP 1-1.9);

g. Table 16 (2100 projections SSP 1-2.6);

h. Table 17 (2100 projections SSP 3-7.0); and

i. Table 18 (Township Inundation Event Water Levels Relative to AHD with 2100 Frequency of Exceedance).

To the extent that you do not agree with the opinions Mr Bettington expresses in those tables, please provide your own opinion as to how the figures in those tables should be calculated.

In answering this question, please use the following projected sea level rise for the following Shared Socioeconomic Pathways (SSPs):

j. SSP 1-1.9: assume that sea levels in the Torres Strait in 2050 will be 34cm higher than at 1900 (the Baseline), and 56cm higher than the Baseline in 2100;

k. SSP 1-2.6: assume that sea levels in the Torres Strait in 2050 will be 36cm higher than at the Baseline, and 62cm higher than the Baseline in 2100;

l. SSP 3-7.0: assume that sea levels in the Torres Strait in 2050 will be 38cm higher than at the Baseline, and 87cm higher than the Baseline in 2100.

13. I disagree with the tabulated values contained in all the above-mentioned BR Tables 10 to 18 solely on the basis that I believe the original BR Table 7 baseline levels are in error as noted earlier. Modified versions of **Tables 10, 11 12 and 13**, plus **Fig 47** for the AHD adjustment and future 2050 SSP levels follow:
    a. **Table 10** is formed by simply applying the assumed (as per Q4) **Table 6** baseline SLR water level adjustment of -0.21 m for 1900 but expressed as a water level relative to the 2023 AHD datum (only Boigu has an AHD-MSL offset). The variously projected SLR values for each SSP and future years of 2050 and 2100 are then added to the base levels for 1900.
    b. **Table 11 to Table 13** then apply each of the incremental **Table 10** SSP SLR values to the baseline 1900 levels in **Table 7**.
    c. The additional rows in **Table 11** to **Table 13** mimic the BR format of providing the changing theoretical tidal plane elevations over time due to the specified SLR. HAT (Highest Astronomical Tide) as defined previously, is the expected highest

tide-only level over a 20-y period (but assuming there is no SLR). The lower but more frequently realised MHWS (Mean High Water Springs) applies to those sites classed as 'semi-diurnal' (meaning two high and 2 low tides per day) and MHHW (Mean Highest High Water) applies to 'diurnal' sites (a single high and low tide per day). The latter are simply informative for those either involved in maritime activities, where they provide a typical indication of the tide range and hence available depth under keel, or indeed for fishers. The fact that there is a desire to distinguish between 'semi-diurnal' and 'diurnal' tides in this case speaks to the unusual complexity of the astronomical tide in the Torres Strait.

14. I note, on a similar subject, that numerous tables and figures in the BR report from Table 11 onwards are annotated by 'HAT (≈4.5 year)' or similar. The footnote of Table 11 describes this '4.5 y' as being the estimated ARI of HAT and suggests why it does not get assigned the theoretical ≈20 y ARI based on tidal theory. However, this is a misleading explanation.
    a. It is true that the level associated with HAT is more frequently experienced because of the weather-related influences. Also, as stated, it is more affected here by the application of the 'regional lift' that unrealistically steepens the ARI curves, thus appearing to possibly intersect the HAT level at around the 4.5 y ARI. Firstly, HAT levels vary across the sites and not all have a similar associated ARI. Secondly, extrapolating the water levels in this log-linear way is not accurate enough to estimate HAT ARIs. SEA (2011) provides simulated ARIs as low as 1 y, and this at least provides a much better estimate. Accordingly, I estimate that in present 2023 climate, HAT at Saibai is around 2 y and at the other sites is around 2 months. Clearly this is much more frequent than 4.5 y. Considering the 1900 baseline, these ARIs have likely not varied too much over time, but the elevations have increased due to SLR.
    b. In closing, HAT level frequencies should not be assessed for the sites whose water levels include a wave setup component because tide gauges, by and large, will not measure that component. The SEA (2011) study simulation has the ability to separate out wave setup to facilitate that if necessary. In any case, it is not the exceedance of the HAT level in any future SLR scenario that is critical to the ongoing habitability of the communities, but rather the actual inundation depth that occurs and how frequent that incursion becomes.

Table 10 Mean Sea Level (MSL) relative to Australian Height Datum (AHD) for various time horizons and climate change scenarios

Horizon	SLR	Boigu	Saibai	Poruma	Warraber
	(m)	(m AHD)	(m AHD)	(m AHD)	(m AHD)
MSL in 1900 (Base Line)	0.00	-0.24	-0.21	-0.21	-0.21
MSL in 2050 SSP 1-1.9	0.34	0.10	0.13	0.13	0.13
MSL in 2050 SSP 1-2.6	0.36	0.12	0.15	0.15	0.15
MSL in 2050 SSP 3-7.0	0.38	0.14	0.17	0.17	0.17
MSL in 2100 SSP 1-1.9	0.56	0.32	0.35	0.35	0.35
MSL in 2100 SSP 1-2.6	0.62	0.38	0.41	0.41	0.41
MSL in 2100 SSP 3-7.0	0.87	0.63	0.66	0.66	0.66

Table 11 2050 SSP 1-1.9 (SLR = 0.34m) Projections for Water Levels Relative to AHD

	Boigu	Saibai	Poruma	Warraber
	(m AHD)	(m AHD)	(m AHD)	(m AHD)
MHWS or MHHW	1.53	1.19	1.35	1.23
HAT	2.45	2.19	2.40	2.36
Average Recurrence Interval				
ARI (y)	Storm Tide	Storm Tide	Storm Tide	Storm Tide
10	2.69	2.31	2.64	2.70
25	2.75	2.36	2.68	2.78
50	2.79	2.39	2.72	2.82
100	2.82	2.43	2.73	2.84
500	2.92	2.52	2.77	2.89

Table 12 2050 SSP 1-2.6 (SLR = 0.36m) Projections for Water Levels Relative to AHD

	Boigu	Saibai	Poruma	Warraber
	(m AHD)	(m AHD)	(m AHD)	(m AHD)
MHWS or MHHW	1.55	1.21	1.37	1.25
HAT	2.47	2.21	2.42	2.38
Average Recurrence Interval				
ARI (y)	Storm Tide	Storm Tide	Storm Tide	Storm Tide
10	2.71	2.33	2.66	2.72
25	2.77	2.38	2.70	2.80
50	2.81	2.41	2.74	2.84
100	2.84	2.45	2.75	2.86
500	2.94	2.54	2.79	2.91

Table 13 2050 SSP 3-7.0 (SLR = 0.38m) Projections for Water Levels Relative to AHD

	Boigu	Saibai	Poruma	Warraber
	(m AHD)	(m AHD)	(m AHD)	(m AHD)
MHWS or MHHW	1.57	1.23	1.39	1.27
HAT	2.49	2.23	2.44	2.40
Average Recurrence Interval				
ARI (y)	Storm Tide	Storm Tide	Storm Tide	Storm Tide
10	2.73	2.35	2.68	2.74
25	2.79	2.40	2.72	2.82
50	2.83	2.43	2.76	2.86
100	2.86	2.47	2.77	2.88
500	2.96	2.56	2.81	2.93

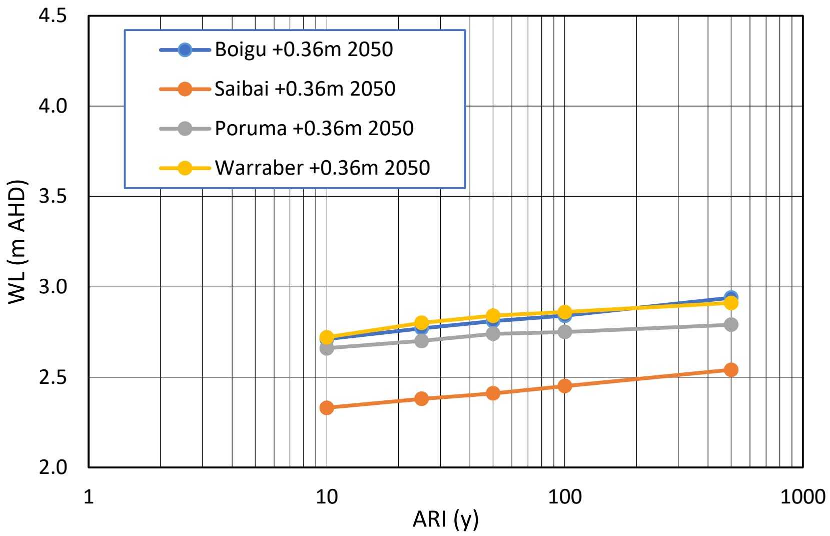

Figure 47 SSP 1-2.6 2050 Extreme Water Levels

15. Without access to GIS-prepared land elevation data for each community I am unable to produce an updated BR Table 14. As noted under Q4, the erroneous AHD adjustment in BR Table 6 and the arbitrary 'lift' assumption in BR Table 5, which I disagree with, will likely substantially change these values. The frequency values expressed in ARI should appreciably increase.

16. Modified versions of **Tables 15, 16 and 17** plus **Fig 52** for the future 2100 SSP levels follow, analogously constructed to the 2050 tables.

Table 15 2100 SSP 1-1.9 (SLR = 0.56m) Projections for Water Levels Relative to AHD

	Boigu	Saibai	Poruma	Warraber
	(m AHD)	(m AHD)	(m AHD)	(m AHD)
MHWS or MHHW	1.75	1.41	1.57	1.45
HAT	2.67	2.41	2.62	2.58
Average Recurrence Interval				
ARI (y)	Storm Tide	Storm Tide	Storm Tide	Storm Tide
10	2.91	2.53	2.86	2.92
25	2.97	2.58	2.90	3.00
50	3.01	2.61	2.94	3.04
100	3.04	2.65	2.95	3.06
500	3.14	2.74	2.99	3.11

Table 16 2100 SSP 1-2.6 (SLR = 0.62m) Projections for Water Levels Relative to AHD

	Boigu	Saibai	Poruma	Warraber
	(m AHD)	(m AHD)	(m AHD)	(m AHD)
MHWS or MHHW	1.81	1.47	1.63	1.51
HAT	2.73	2.47	2.68	2.64
Average Recurrence Interval				
ARI (y)	Storm Tide	Storm Tide	Storm Tide	Storm Tide
10	2.97	2.59	2.92	2.98
25	3.03	2.64	2.96	3.06
50	3.07	2.67	3.00	3.10
100	3.10	2.71	3.01	3.12
500	3.20	2.80	3.05	3.17

Table 17 2100 SSP 3-7.0 (SLR = 0.87m) Projections for Water Levels Relative to AHD

	Boigu	Saibai	Poruma	Warraber
	(m AHD)	(m AHD)	(m AHD)	(m AHD)
MHWS or MHHW	2.06	1.72	1.88	1.76
HAT	2.98	2.72	2.93	2.89
Average Recurrence Interval				
ARI (y)	Storm Tide	Storm Tide	Storm Tide	Storm Tide
10	3.22	2.84	3.17	3.23
25	3.28	2.89	3.21	3.31
50	3.32	2.92	3.25	3.35
100	3.35	2.96	3.26	3.37
500	3.45	3.05	3.30	3.42

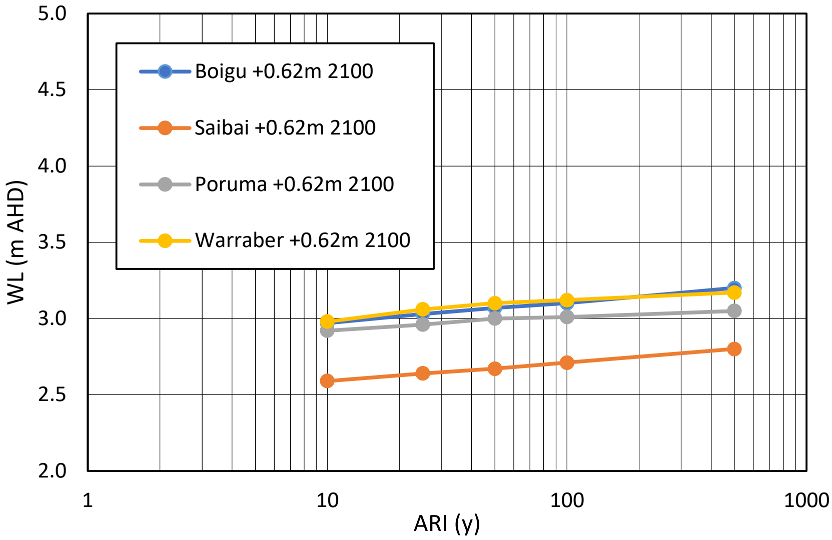

Figure 52 SSP 1-2.6 2100 Extreme Water Levels

17. Without access to GIS-prepared land elevation data for each community I am unable to produce an updated BR Table 18. As noted under Q4, the erroneous AHD adjustment in BR Table 6 and the arbitrary 'lift' assumption in BR Table 5, which I disagree with, will likely substantially change these values. The frequency values expressed in ARI should appreciably increase.

18. I note that the future inundation risk for 2050 and 2100 as it is presented here, is solely modified by SLR adjustments, and ignores the likelihood of future tide, or wind, or TC changes. The derived '2010' climate from SEA (2011) therefore underpins the climatological risk and is assumed constant with SLR. However, SEA (2011) also included the projected contemporary allowances for TC intensity and frequency change[17] by 2050 and 2100, such that the climatological risk profile in the original study changes with increasing ARIs as well as with SLR. In addition, the effect of changing water levels was included in the hydrodynamic modelling to account for the non-linear interactions that will prevail, especially regarding waves and wave setup. For example, with increasing water levels alone, and all other things being equal, storm surge magnitudes are expected to decrease slightly. This then acts to offset some of the direct impact of continuing SLR.

[17] I note that recent future climate projections have reduced the regional tropical cyclone threat over that assumed in the SEA (2011) study.

5. Conclusion

I cannot agree with the ARI-based water levels in the Bettington report. The *ad hoc* addition of a 'regional lift', as applied at BR Table 5 is without analytical justification and seems to derive from a misunderstanding as to the completeness of the SEA (2011) methodology.

The issue of incorrectly assigned conversions of MSL to AHD is likely secondary, as it appears that the Digital Terrain Models (DTMs) utilised may have been similarly incorrectly adjusted. This is based on a rudimentary comparison of the estimated Lowest Habitation Levels (LHL) in SEA (2011) §Table 9-1 compared with Fig 14 for Poruma and Fig 15 for Warraber, where initial community encroachment is visible. The comparisons in **Figure A** and **Figure B** herein for Boigu also support the above conclusion.

Notwithstanding the use of incorrect MSL-AHD datum offsets in all values noted as '(m AHD)', the extents of community flooding (BR Fig 48 - 51 and 53 - 56) and changes in the frequency of 50% of community flooding (BR Table 14 and 18) would still be exaggerated due to the arbitrary 'lift' assumption in BR Table 5. The actual impact of that will vary between the communities depending on the community exposure (i.e., where buildings are located and at what elevation), plus the vulnerability of the structures and also the resilience and expectations of the residents.

As noted, I am not equipped to generate replacement high-resolution mapping or to estimate the water level associated with the arbitrary '50% of community' hazard exposure metric for each island. While the detail of that statistic is unstated, I expect that it refers to seawater encroachment onto cadastral or traditional land parcels and not where water levels exceed habited floor levels.

Given the importance of understanding potential Torres Strait Islander Community impacts from climate change I would like to advocate the use of more comprehensive approaches than the ones selected for consideration by or for the BR review. Choosing arbitrary risk levels (e.g. 100-y, 500-y, 50% flooded land, etc) does not provide a firm basis for exposure analysis or indeed understanding of the phenomena. Instead, much more insightful analyses will come through more advanced study approaches like those of GHD (2012) or SEA (2014).

In closing, I offer the following extract from the SEA (2011) *Executive Summary*:

'The analysis concludes that ocean water levels in the region are dominated by the highly variable astronomical tide but that extreme water levels are caused by often subtle combinations of relatively small inter-annual changes in the regional ocean level, strong seasonal variability due to the prevailing winds and occasional high energy weather events (monsoon surges and tropical cyclones). The interplay of these components on a range of time and space scales likely leads to periods of both enhanced and reduced impacts of the ocean water levels on the various communities. This would appear consistent with community experiences during recorded history.'

6. References

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DES (2021) Torres Strait tidal datum: review of datum and tidal planes 2021: preliminary report. Queensland Department of Environment and Science, Brisbane, 23pp.

DES (2023a) Storm tide data and tide predictions for Boigu Island monitoring site. https://www.qld.gov.au/environment/coasts-waterways/beach/storm/storm-sites/boigu

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SEA (2014) A coastal vulnerability assessment methodology for Torres Strait communities – Pilot Study. Prepared by Systems Engineering Australia Pty Ltd for the Torres Strait Regional Authority, Aug, 54pp. [Available online]

SEA (2011) Torres Strait Extreme Water Level Study. Prepared by Systems Engineering Australia Pty Ltd for Torres Strait Regional Authority (TSRA), July, 129pp.

SEA (2020) SEAtide V3.3 User Guide (Qld-Gulf). Jan, 92pp. [Available online]

7. Declaration

I have read the Federal Court's Expert Evidence Practice Note (GPN-EXPT) and the Harmonised Expert Witness Code of Conduct. I agree to be bound by them and I have complied with them in preparing this Report.

All opinions expressed herein are my own and are based wholly or substantially on my specialised knowledge arising from my training and experience.

I have made all the inquiries that I believe are desirable and appropriate and that no matters of significance that I regard as relevant have, to my knowledge, been withheld from the Court.

Regards,

Bruce Allan Harper

Director

BE PhD FIEAust CPEng RPEQ

Dated:

06-Oct-2023

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Appendix A

AGS Commissioning Letters

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25 August 2023

Dr Bruce Harper
Adjunct Professor
College of Science and Engineering
James Cook University

By email: bruce.harper@systemsengineeringaustralia.com.au

PRIVILEGED & CONFIDENTIAL

Dear Dr Harper

Pabai & Anor v Commonwealth of Australia (VID622/2021) | Provisional engagement letter

PROVISIONAL ENGAGEMENT

1. We confirm we act for the Commonwealth of Australia (the **Commonwealth**) in the above class action before the Federal Court of Australia.

2. The applicants (Pabai Pabai and others) commenced this class action on 26 October 2021 on their own behalf and on behalf of all persons who at any time during the period from about 1985 and continuing, are of Torres Strait Islander descent and suffered loss and damage as a result of the alleged acts and omissions of the Commonwealth (**Group Members**).

3. The proceeding relates to the impacts of climate change in the Torres Strait. In summary, the applicants allege that the Commonwealth:

   a) owes a legal duty to Torres Strait Islanders to take reasonable steps to protect Torres Strait Islanders, their traditional way of life and the marine environment in and around the Torres Strait from the current and projected impacts of climate change, and breached that duty by (amongst other things) failing to identify a GHG emissions reduction target consistent with the 'best available science'; or

   b) further or alternatively, owes a legal duty to Torres Strait Islanders to take reasonable steps to avoid causing property damage, loss of fulfilment of *Ailan Kastom* and other damage arising from a failure to implement or adequately implement adaptation measures to prevent or minimise the impacts of climate change in the Torres Strait, and breached that duty.

4. The Commonwealth (amongst other things) denies that it owes the pleaded duties of care, and denies that it breached any such duties of care.

5. We are instructed to engage you, on a provisional basis, as an expert in this matter.

6. The provisional engagement will consist of an initial conference between you and the Commonwealth's legal team. The purpose of this conference will be to determine the capacity, if any, in which you may be able to act as an independent expert retained by the Commonwealth in this proceeding.

7. Following that conference, the Commonwealth may offer you an ongoing engagement as an independent expert in this proceeding.

8. We confirm that any engagement would be with you as an individual independent expert. Any opinions expressed by you should be your own.

9. We enclose the following documents by way of general reading for you before the conference with us:

   a. The Federal Court's Expert Evidence Practice Note (GPN-EXPT). This Practice Note sets out guidelines for expert witnesses to follow in proceedings before the Court. Please read these guidelines carefully. You are requested to follow this Practice Note in your dealings with us.

   b. The pleadings in the proceeding, namely the:

      – Applicants' second further amended statement of claim dated 11 April 2023 (**SFASOC**).

      – Respondents' defence to the SFASOC dated 9 May 2023.

      – Applicants' amended concise statement dated 15 May 2023.

      – Respondents' amended concise statement in response dated 29 May 2023.

OTHER MATTERS

10. Your communications with us are confidential and subject to the Commonwealth's legal professional privilege.

11. To ensure that the Commonwealth retains legal professional privilege in relation to your work, we request that you comply with the following communication and information management protocol during the course of this engagement:

   a. Unless instructed otherwise, communications (written or oral) should be with Dejan Lukic, Grace Ng, Jacqueline Yates and Zoe Maxwell of the Australian Government Solicitor.

   b. This letter, any other materials provided to you, and any working notes prepared by you, should also be maintained in a file clearly marked 'Confidential and subject to legal professional privilege – for the Commonwealth of Australia'.

12. Subject to any orders of any court, our instructions, and any information obtained and working notes prepared by you in relation to this matter (including this engagement) must not be disclosed to any other person.

PRIVILEGED & CONFIDENTIAL

Australian Government Solicitor

13. If you have any questions please contact us.

Yours sincerely

Jacqueline Yates
Senior Lawyer
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jacqueline.yates@ags.gov.au

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Our ref. 21008585

8 September 2023

Dr Bruce Harper
Director
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By email: bruce.harper@systemsengineeringaustralia.com.au

Dear Dr Harper

Pabai & Anor v Commonwealth of Australia (VID622/2021) | Engagement as independent expert

1. We refer to our provisional engagement letter dated 25 August 2023. We confirm we are instructed to engage you as an independent expert in the above class action before the Federal Court of Australia.

BRIEFING MATERIALS AND INSTRUCTIONS

2. **Annexure A** contains a list of documents briefed to you.

3. You are required to undertake a review of the documents briefed to you and prepare a report responding to the questions set out in **Annexure B** to this letter.

4. Any expert evidence to be relied on by the Commonwealth is due to be filed **by 6 October 2023**. Please let us know if you consider it will not be possible to meet that date and we will consider what arrangements can be made.

5. You may also be required to give oral evidence before the Court. The hearing is listed from 6 to 27 November 2023, in Melbourne. We will advise you closer to the date if you will be required to give oral evidence and, if so, on which dates.

YOUR ROLE AS AN EXPERT

6. We enclose in Annexure A the Federal Court of Australia Expert Evidence Practice Note (GPN-EXPT) (**Practice Note**) and Part 23 of the *Federal Court Rules 2011* (Cth). These documents set out guideline for expert witnesses to follow in proceedings before the Court. Please read these guidelines carefully. You are requested to follow these guidelines in your dealings with us, and in preparing your report.

7. We draw your attention to the following sections of the Practice Note:

   a) Section 4 'Role and Duties of the Expert Witness': Paragraph 4.1 provides that your role is to provide relevant and impartial evidence in your area of expertise. You should never mislead the Court or become an advocate for the Commonwealth (as the retaining party).

b) Section 4 'Role and Duties of the Expert Witness': Paragraph 4.4 provides that every expert witness giving evidence must read and agree to be bound by the Expert Witness Code of Conduct. You are required to strictly comply with the terms of the Expert Witness Code of Conduct. Please ensure your report/s contains an acknowledgment that you have read and agree to be bound by the Expert Witness Code of Conduct.

c) Section 5 'Contents of an Expert's Report and Related Material': Paragraph 5.2 sets out the requirements for the contents of any report, in addition to those requirements set out in the Expert Witness Code of Conduct.

CONFIDENTIALITY AND LEGAL PROFESSIONAL PRIVILEGE

8. Your communications with us are confidential and subject to the Commonwealth's legal professional privilege.

9. To ensure that the Commonwealth retains legal professional privilege in relation to your work, we request that you comply with the following communication and information management protocol during the course of this engagement:

   a. Unless instructed otherwise, communications (written or oral) should be with Dejan Lukic, Grace Ng, Emily Nance, Zoe Maxwell and Jacqueline Yates of the Australian Government Solicitor.

   b. This letter, any other materials provided to you, and any working notes prepared by you, should also be maintained in a file clearly marked 'Confidential and subject to legal professional privilege – for the Commonwealth of Australia'.

   c. Include on the front page of any draft report and any other document produced in the course of this engagement the following wording: 'Confidential and subject to legal professional privilege – for the Commonwealth of Australia'.

10. Subject to any orders of any court, our instructions, and any information obtained and working notes prepared by you in relation to this matter (including this engagement) must not be disclosed to any other person.

ANY ASSISTANCE IN PREPARING YOUR REPORT

11. It is not expected that you will require assistance from any other person to prepare the evidence requested. If you wish to involve another person, please let us know.

NEXT STEPS

12. Please proceed to prepare your written report.

13. If, after you have had the opportunity to consider the materials in Annexure A and questions in Annexure B, you consider there are further materials or information you require in order to answer those questions, please let us know.

14. If you have any other questions please contact us.

Australian Government Solicitor

Yours sincerely

Grace Ng
Senior Lawyer
T 02 9581 7320
grace.ng@ags.gov.au

Appendix B

AGS Annexure B Questions

ANNEXURE B – QUESTIONS FOR REPORT

Basis of expertise

1. Please describe your academic qualifications, professional background and experience that is relevant to your answering the questions in the letter of instruction. You may wish to do so by reference to a current curriculum vitae.

Extreme Sea Level Events

2. Do you agree with Mr Bettington's assessment, in his report dated 3 August 2023 (the Bettington Report), of extreme water levels on Boigu, Saibai, Poruma and Warraber (the Mapped Islands) as set out in tables 3 and 5 of that report? To the extent that you do not agree with the opinions Mr Bettington expresses in those tables, please provide your own opinion as to the proper extreme water levels on the Mapped Islands by reference to the same average recurrence intervals (ARI) considered by Mr Bettington.

In answering this question, please assume that the extreme water levels set out in tables 3 and 5 of the Bettington Report reflect Mr Bettington's assessment as at the present date of extreme water levels on the Mapped Islands.

3. In your view, is Mr Bettington's adjustment of the extreme water levels set out in table 5 by reference to the Australian Height Datum (AHD) appropriate?

If you do not agree with Mr Bettington's approach, please provide your own opinion about how, if at all, the extreme sea levels set out at table 5 of the Bettington Report (or your answer to question 2 above, to the extent that your answers differ to those in the Bettington Report) should be adjusted to take into account the relative height of the Mapped Islands.

4. On the basis of your answers to questions 2 and 3 above, do you agree with the conclusions set out in the following tables of the Bettington Report:

a. Table 7 (extreme water levels at 1900); and

b. Table 8 (current extreme water levels).

To the extent that you do not agree with the opinions Mr Bettington expresses in those tables, please provide your own opinion as to the proper extreme water levels on the Mapped Islands by reference to the same ARIs considered by Mr Bettington.

In answering this question, please assume the following:

a. Between 1900 and 2023, global sea levels have risen by 0.21m on average; and

b. Since 2010, global sea levels have been rising at 3.4mm per year (or a total of 0.04m between 2010 and 2023) on average.

5. Do you agree with the Township Inundation Event Water Levels for the Mapped Islands set out in Table 9 of the Bettington Report? To the extent that you do not agree with the opinions Mr Bettington expresses in Table 9, please provide your own opinion as to the proper Township Inundation Event Water Levels on the Mapped Islands.

Predicted Future Impacts

6. In light of your answers to the questions above, do you agree with the figures set out in the following tables of the Bettington Report:

a. Table 10 (Mean Sea Level relative to AHD) for various time horizons and climate change scenarios;

b. Table 11 (2050 projections SSP 1-1.9);

c. Table 12 (2050 projections SSP 1-2.6);

d. Table 13 (2050 projections SSP 3-7.0);

e. Table 14 (Township Inundation Event Water Levels Relative to AHD with 2050 Frequency of Exceedance);

f. Table 15 (2100 projections SSP 1-1.9);

g. Table 16 (2100 projections SSP 1-2.6);

h. Table 17 (2100 projections SSP 3-7.0); and

i. Table 18 (Township Inundation Event Water Levels Relative to AHD with 2100 Frequency of Exceedance).

To the extent that you do not agree with the opinions Mr Bettington expresses in those tables, please provide your own opinion as to how the figures in those tables should be calculated.

In answering this question, please use the following projected sea level rise for the following Shared Socioeconomic Pathways (SSPs):

j. SSP 1-1.9: assume that sea levels in the Torres Strait in 2050 will be 34cm higher than at 1900 (the Baseline), and 56cm higher than the Baseline in 2100;

k. SSP 1-2.6: assume that sea levels in the Torres Strait in 2050 will be 36cm higher than at the Baseline, and 62cm higher than the Baseline in 2100;

l. SSP 3-7.0: assume that sea levels in the Torres Strait in 2050 will be 38cm higher than at the Baseline, and 87cm higher than the Baseline in 2100.

Appendix C

Curriculum Vitae for Bruce Harper

Dr Bruce Harper

BE(Hons) PhD

FIEAust CPEng NER RPEQ APEC IntPE

A specialist Research Engineer with over 45 years of investigation and design experience in the fields of wind, coastal, ocean and offshore engineering, climate extremes, statistical modelling, risk analysis, adaptation, applied meteorology, data measurement and analysis and systems analysis and design.

Qualifications:

- Bachelor of Engineering - Civil (Hons), James Cook University (1975)
- Doctor of Philosophy in Civil Engineering (Numerical Fluid Dynamics), James Cook University (1982)
- Chartered Professional Engineer (CPEng)
- National Engineering Register (NER)
- Registered Professional Engineer, Queensland. (RPEQ No. 4987)
- APEC Registered 811866
- International Engineer IntPE(Aus)

Affiliations:

- Adjunct Professor – Engineering, College of Science and Engineering, James Cook University 2017+.
- Fellow, Engineers Australia (FIEAust); EngExec invitation.
- Member, College of Civil Engineers, Engineers Australia.
- Chairman, 1996/97 National Committee on Coastal and Ocean Engineering, Engineers Australia; Member 1989 to 2008.
- Member, Australian Wind Engineering Society (AWES).
- Member, Australian Meteorological and Oceanographical Society (AMOS).
- Member, American Meteorological Society (AMS).
- Member, Standards Australia, BD6-002 Wind Actions Sub-Committee 2006-2021.
- WMO TMRP Expert Panel of Tropical Cyclone Landfall Processes 2009+.
- Willis Research Network 2006-2010.
- Member, QCoast$_{2100}$ Coastal Adaptation Expert Panel, Local Government Association of Queensland and Department of Environment and Science, 2017-2020.

EXPERIENCE (recent, abbreviated, and commercial clients withheld)

COASTAL AND OCEAN INVESTIGATIONS / ADAPTATION

- Tweed River Sand Bypassing Project, Dept of Environ & Science, 2022.
- Middle Arm Infrastructure Studies, NT Govt – Darwin, 2021.
- City of Gold Coast, Storm Tide Risks Review, 2021.
- Infrastructure Design Criteria – Darwin, 2020.
- Infrastructure Design Criteria – Gulf of Carpentaria, 2019.
- Infrastructure Design Criteria – Port of Townsville, 2019.
- Infrastructure Design Criteria – TMR Cairns Region, 2018.
- Infrastructure Design Criteria – TMR Sunshine Coast, 2018.
- QCoast$_{2100}$ storm tide hazard assessments, 2017-2021.
  - Whitsunday Regional Council, 2017.
  - Torres Shire Council, 2017-2021.
  - Cairns Regional Council, 2018.
  - Northern Peninsula Area Council, 2018.
  - Gympie Regional Council, 2018.
  - Burke & Carpentaria Shire Councils, 2018.
  - Livingstone Shire Council, 2018-2019.
  - Mapoon Aboriginal Shire Council, 2018.
  - Cook Regional Council, 2019
  - Hinchinbrook Shire Council, 2019
  - Fraser Coast Regional Council, 2019.
- Tropical Cyclone Storm Tide Hazard - Fiji, 2018.
- Storm Tide Resilient Homes Guideline, QRA, 2011 & 2019
- LGAQ, QCoast2100 Expert Reviewer, 2017-2021.
- Statistical TC Storm Tide Modelling for Bowen, 2017.
- Statistical TC Storm Surge and Wave Modelling for Torres Strait, 2017.
- Statistical Tropical Cyclone Wave Modelling for Darwin, 2016-2017.
- Australia-wide Tropical Cyclone Storm Tide Simulation, 2016.
- NT Remote Communities Storm Tide Inundation Study, 2015-2016.
- Qatar Flood Study - Design Coastal Water Levels and Potential Impacts of Climate Change, 2015.
- A Coastal Vulnerability Assessment Methodology for Torres Strait Communities – Pilot Study, Torres Strait Regional Authority, 2014.
- SEAtide Probabilistic Storm Tide Modelling System for the Queensland Coast, DSITIA, 2014.
- Coastal Plan Implementation Study, Brisbane City Council, 2014.
- Coastal and Inland Flood Hazard Adaptation Study, Mackay, 2013-14.
- Queensland Storm Tide Interpolation Study, DSITIA, 2013.
- Coastal Hazard Adaptation Study (CHAS), Townsville, 2011-2012.
- Storm Tide Management Study, Moreton Bay Regional Council, 2011.
- Gulf of Carpentaria Storm Tide Study, Qld DERM, 2010-2012.
- Fraser Coast Storm Tide, Fraser Coast Regional Council, 2010-2011.
- Gold Coast Storm Tide Study, Gold Coast City Council, 2010-2011.
- Sutherland Shire Climate Change Risk, City of Sutherland, NSW, 2010.
- Torres Strait Extreme Water Level Study, TSRA, Qld, 2009-2010.
- High Resolution Darwin Storm Tide Study, NT, 2010.
- Kakadu Storm Tide Study, 2009.

- Sunrise LNG Development, 2008.
- Storm Tide Study, NT, 2009.
- Peer Review, J-P Analysis of Waves and Storm Surge, Abu Dhabi, 2008.
- Johnstone Shire Storm Tide Study, Brisbane, 2008.
- Assessment of the Effectiveness of the Australian Tsunami Warning System for Queensland, EPA Coastal Sciences, Brisbane, 2007.
- Review of Storm Tide Studies in SE Qld, SEQDMAG, Brisbane, 2007
- Cairns Base Hospital Storm Tide Investigation, 2007.
- Houghton Highway Storm Tide, Brisbane, 2007.
- Gove Storm Tide Study, Gove, 2007.
- Scope of Work for Moreton Bay Councils Storm Tide, Study SEQDMAG, Brisbane, 2007.
- Darwin Storm Tide Mapping Study, NT, 2006.
- Climate Change Trends in TC Archives, Woodside Energy Ltd, 2006.
- Townsville/Thuringowa Storm Tide Study, 2004/2005.
- Rarotonga Coastal Protection Study, SOPAC, 2004/2005.
- NT Storm Tide Prediction Project, Bureau of Meteorology, 2004/2005.
- Queensland Climate Change and Coastal Vulnerability to Tropical Cyclones, Synthesis Report, Bureau of Meteorology, Queensland, 2004.
- Whitsunday Storm Surge Study, 2003.
- Queensland Climate Change and Coastal Vulnerability to Tropical Cyclones, Stage II, Bureau of Meteorology, Queensland, 2002.
- 10^{-4} Waves Study, Woodside Energy Ltd, Perth, WA, 2001-2002.
- Cocos (Keeling) Island Storm Surge Study, 2001.
- Queensland Climate Change and Coastal Vulnerability to Tropical Cyclones, Stage I, Bureau of Meteorology, Queensland, 2000.
- Mackay Coastal Processes Investigation, Dept of Environment, 1999.

EXTREME WINDS / CLIMATE RISK ASSESSMENT

- Natural Hazards Risks specialist consultant, MASDP Darwin, GHD, 2022.
- TC *Debbie* Impacts, JCU Cyclone Testing Station (CTS), 2017.
- Tropical Cyclone Wind Risk, (various engineering clients), 2016-2023.
- TC *Yasi* Impacts, JCU CTS, 2011.
- Wind Storm Damage Investigations, The Gap, JCU CTS, 2009.
- TC *Larry* Impacts, JCU CTS, 2006.

INSURANCE LOSS RISK ASSESSMENT

- Wind Risk Modelling Technical Advice, (insurance client withheld), 2021.
- Australia-Wide Tropical Cyclone Storm Tide and Wind Swath Modelling System, (insurance client withheld), 2019.
- Insurance Loss Model Development, 2016-2017.
- Australia-Wide Tropical Cyclone Wind Event Set Study, 2014-2015.
- Member, Expert Elicitation on Future Hurricane Activity, Risk Management Solutions Inc., Miami, 2008.
- Contributor to Economic Analysis of Identified Impacts of Climate Change for the Australian Greenhouse Office and CSIRO, 2003.
- Flood Insurance Rating Study, RACQ-GIO Insurance Limited, 2000.
- Development of the SEA MIRAM insurance loss risk assessment model, 1996-2010 (numerous insurance and reinsurance clients).

POLICY & MANAGEMENT STRATEGIES

- Operational Storm Tide Advice TC Marcia, QFES, Brisbane, 2015.
- Reviewer - Australian Rainfall & Runoff Revision Project, EA, National Committee on Water Engineering, 2014.
- Wivenhoe Somerset Dams Optimisation Study (WSDOS), DEWS, 2014.
- Brisbane River Catchment Floodplain Studies Technical Scoping Framework, DSDIP, 2012.
- Brisbane River Catchment Floodplain Studies, Qld, DSDIP, 2012.
- World Meteorological Organization, Wind Averaging Guidelines, 2010.
- National Emergency Risk Assessment Guidelines, 2008.
- Cairns Tropical Cyclone Catastrophe Scenario, Geoscience Australia for AEMC / OWG Catastrophic Disasters Working Group, Cairns, 2004.
- Guidelines for Responding to the Effects of Climate Change in Coastal and Ocean Engineering, Engineers Australia, National Committee on Coastal and Ocean Engineering, 1999/2004/2012 and 2017.
- Coastal Engineering Guidelines for working with the Australian coast in an Ecologically Sustainable Way, Engineers Australia, 1998/2004.
- AGSO Cities Project, for Bureau of Meteorology, Mackay & SE Qld, 2000.

AWARDS

- Engineers Australia, *Australia's Most Innovative Engineers*, Consulting Category, July 2016.
- Engineers Australia, Queensland Division, Engin. Excellence Award, 2013. *Townsville Coastal Hazard Adaptation Strategy*. GHD Pty Ltd.
- Engineers Australia, Queensland Division, Engin. Excellence Award, 2003. *Wind Storm Risk Study*. Jointly with Powerlink Queensland.
- Engineers Australia, Queensland Division, Engin. Excellence Award, 2002. *Queensland Climate Change and Community Vulnerability to Tropical Cyclones: Ocean Hazards Assessment Stage 1*.
- Emergency Management Australia, Queensland Safer Communities Award 2004 for *Queensland Climate Change and Community Vulnerability to Tropical Cyclones Project*.
- Emergency Management Australia, National Safer Communities Award 2004 for *Queensland Climate Change and Community Vulnerability to Tropical Cyclones Project*.

PUBLICATIONS (abbreviated)

- Harper B.A. and Mason L.B., A Tropical Cyclone Wind, Wave and Storm Tide Risk Design and Warning Toolbox for Australia. ICCE, Oct 2020,
- Harper B.A., Guidelines for Responding to the Effects of Climate Change in Coastal and Ocean Engin.. EA NCCOE, 2017 (also 2012, 2004, 1999).
- Harper B.A. and Mason L.B., A Tropical Cyclone Wind Event Data Set for Australia.18th Australasian Wind Engineering Society Workshop, 2016.
- Ginger, J. Holmes J. and Harper B., Gust Wind Speeds for Design of Structures, Eighth Asia-Pacific Conf Wind Engin, 2013.
- Harper B., Smith M., Erhart D., Anderson G. and Sultmann S., A Coastal Hazard Adaptation Study for Townsville: Pilot Study. EA, C&P, 2013.
- Smith M., Harper B., Mason, L., Schwartz R. and Acworth C., Gulf of Carpentaria Storm Tide and Inundation Study. EA, C&P, 2013.
- Harper B.A., Best Practice in Tropical Cyclone Wind Hazard Modelling, Keynote Address, 16th Australasian Wind Engin. Soc. Workshop,0,

2013.
- Holmes J., Ginger J. and Harper B., What's the Gust Wind Speed?, Proc. 16th Australasian Wind Engin. Soc. Workshop, 2013.
- Harper B.A., Holmes J.D., Kepert J.D., Mason L.M. and Vickery P.J., Comments on "Tropical Cyclone Wind Hazard for Darwin:". *JAMC*, 2012.
- Harper B.A. et al. , Estimating Extreme Water Levels in Torres Strait. Proc. Coasts and Ports Conference, *Engineers Australia*, Perth, 2011.
- Leitch C. et al. Performance of housing in Brisbane following storms on 16 November 2008. *Australian J. Structural Engin*, Vol 11, No 1, 45-61, 2010.
- Knaff J.A. and Harper B.A., Tropical cyclone surface wind structure and wind-pressure relationships. Keynote KS1, WMO IWTC-VII, 2010.
- Harper B., Kepert J. and Ginger J., Guidelines for converting between various wind averaging periods in tropical cyclone conditions. *World Meteorological Organization*, WMO/TD-No. 1555, 2010.
- Harper B.A., Modelling the Tracy Storm Surge - Implications for Storm Structure and Intensity Estimation. Cyclone Tracy Special, AMOS, 2010.
- Masters F., Vickery P., Harper B., Powell M., and Reinhold T., Engineering Guidance Regarding Wind-Caused Damage Descriptors. 2009.
- Harper B.A., Forecasting Surface Wind, Wave and Storm Surge Impacts. Keynote Address, WMO IWTCLP II, Shanghai, 2009.
- Dube S.K et al. Storm surge modeling and applications in coastal areas. In Global Perspectives on Tropical Cyclones, *World Scientific*, 2010.
- Harper B. Managing Sea Level Rise and Climate Change, IPWEA 2008.
- Harper B. et al., Review of historical tropical cyclone intensity in NW Australia and implications for trend analysis. Aust. Met. Mag., 2008.
- Harper B. et al., Developments in Storm Tide Modelling and Risk Assessment in the Australian Region. Nat Haz Jnl, 2009.
- Kossin J.P. et al., A globally consistent reanalysis of hurricane variability and trends, Geophysical Research Letters, 34, L04815, 2007.
- Velden C., Harper B., et al., The Dvorak tropical cyclone intensity estimation technique: a satellite-based method that has endured for over 30 years. AMS BAMS, Vol 87, 2006. [plus online supplement].
- Landsea C.W., Harper B.A., Hoarau K., and Knaff J., Can we detect trends in extreme tropical cyclones?, Science, Vol 313, 28 July 2006.
- Harper B.A. and Callaghan J., On the importance of reviewing historical tropical cyclone intensities. AMS 27th Conf Hurricanes, 2006.
- Hardy T., et al., 10,000 year wave statistics for a tropical cyclone region. Proc. WAVES 2005, Madrid, 2005.
- Harper B.A., Recent advances in storm tide modelling in Australia, WMO IWTCLP I, Macau, 2005.

RESEARCHGATE STATISTICS

https://www.researchgate.net/profile/Bruce-Harper-2

969.8	23,958	1,545
Research Interest Score	Reads	Citations

Research Interest Score is higher than 92% of ResearchGate members.

PROFESSIONAL HISTORY

2022 – 2023 (temporary, May to May)

	Qld Dept of Environment and Science, Queensland Government Hydraulics Laboratory (QGHL), Brisbane.
	Senior Engineer & A/Project Director, Tweed River Sand Bypassing Project; also A/Science Leader QGHL (Sept).
2017 – present	Adjunct Professor – Engineering, College of Science and Engineering, James Cook University, Townsville.
2010 –2014	GHD Pty Ltd., Brisbane.
	Principal Professional Environment and Risk, and Global Service Line Leader for Climate Change.
1999	The University of Queensland, Brisbane.
	Senior Lecturer (Part Time), Civil Engineering.
1996 - present	Systems Engineering Australia Pty Ltd, Brisbane.
	Founder and Managing Director.
1991 - 1996	Rust PPK Pty Ltd, Brisbane.
	Principal Coastal & Ocean Engineer, and Principal Engineer Risk Assessment.
1986 - 1991	Woodside Offshore Petroleum Pty Ltd, Perth.
	Senior Metocean Engineer; Chief Ocean Engineer.
1983 - 1986	Blain Bremner & Williams Pty Ltd, Brisbane.
	Senior Design Engineer.
1978 - 1983	NSW Public Works Dept., Manly Hydraulics Laboratory (MHL), Sydney.
	Hydraulic Engineer.
1975 - 1978	James Cook University of North Queensland, Townsville.
	1976 - 1978 Programmer (Systems Engineering)
	1975 - 1976 Research Officer (Civil Engineering).