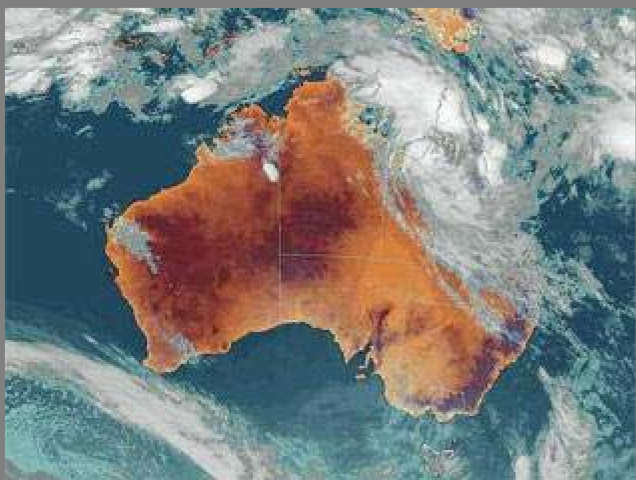
INVESTIGATION OF TC CHARLOTTE IMPACTS IN THE TOWNSVILLE AREA



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Executive Summary

This report documents analyses and surveys undertaken following the unexpected coastal impacts of ex-Tropical Cyclone *Charlotte* in the Townsville region over 12th and 13th January 2009. While *Charlotte* was a weak tropical cyclone located far from the Townsville region, its outer circulation subsequently created a background storm surge as high as 0.7 m at Townsville tide gauge. This large scale surge persisted for several days above 0.5 m and coincided with a sequence of "king tides" that were the highest during any 20 year period. The resulting high water levels extended up to 0.4 m above the Highest Astronomical Tide (HAT) levels and allowed waves accompanying the weather system to attack beaches. In many locations, wave setup and runup then combined to produce some overtopping of coastal dunes and destroyed or damaged coastal protection works and adjacent infrastructure.

While the wind-generated waves accompanying this event were modest and not unusual, the combination of the persistent (although low) storm surge and the sequence of "king tides" resulted in a reasonably unlikely (extreme) event, with an estimated average Return Period of about one in 200 years. This can be compared with, for example, Severe Tropical Cyclone *Althea* in 1971, which delivered an extreme storm surge of 2.9 m but on a low tide, resulting in slightly lower tide plus surge water levels (2.53 m AHD) than the significantly more benign *Charlotte* event (2.57 m AHD). During *Althea* however, the wave and wave setup heights were higher, thus causing much more significant coastal impacts.

The recent GHD/SEA Townsville Storm Tide Study (GHD 2007) provided a solid basis for reference material used in this report although this type of very remote and large scale cyclonic event was not specifically modelled in the 2007 study.

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1 Introduction

Townsville City Council requested an investigation into the coastal impacts associated with TC *Charlotte* during the period 12th and 13th of January 2009 to assess the likely return period of such an event in the context of Council's existing storm tide planning framework. The cyclone occurred during a period of "king tides" that reached to the Highest Astronomical Tide (HAT) level of about 2.2 m AHD. The decaying cyclone added around a further 0.5 m in background persistent storm surge, peaking at 0.7 m, plus strong winds created additional wave impacts caused by breaking wave setup and runup. As a result, many low lying beach areas experienced minor overtopping of the coastal dunes, some beaches suffered localised erosion and/or accretion and there was widespread damage to coastal protection works and beach access infrastructure.

In support of this review an inspection and field survey of beach erosion and debris levels was carried out on 16th January in association with Council surveyors.

2 Tropical Cyclone *Charlotte*

Category 1 TC *Charlotte* formed in the southern Gulf of Carpentaria on 11th January and crossed the SE corner near Karumba on the 12th (Figure 1). At this time there is no formal report on the storm available from the Bureau of Meteorology (BoM), however an overview of the large scale synoptic fields is provided in Figure 2. This shows that the storm quickly mobilised a quite large circulation, even though it had crossed land and was attenuating. Over the next 24 h period the circulation created strong onshore winds in the Townsville region, veering SE on the 13th.

Figure 3 summarises 9am and 3pm recorded wind speeds across the region over the preceding fortnight, showing an already active monsoonal development into which the *Charlotte* wind field merged and intensified. The Townsville Airport winds on 12th and 13th are also detailed, showing a strong ESE.

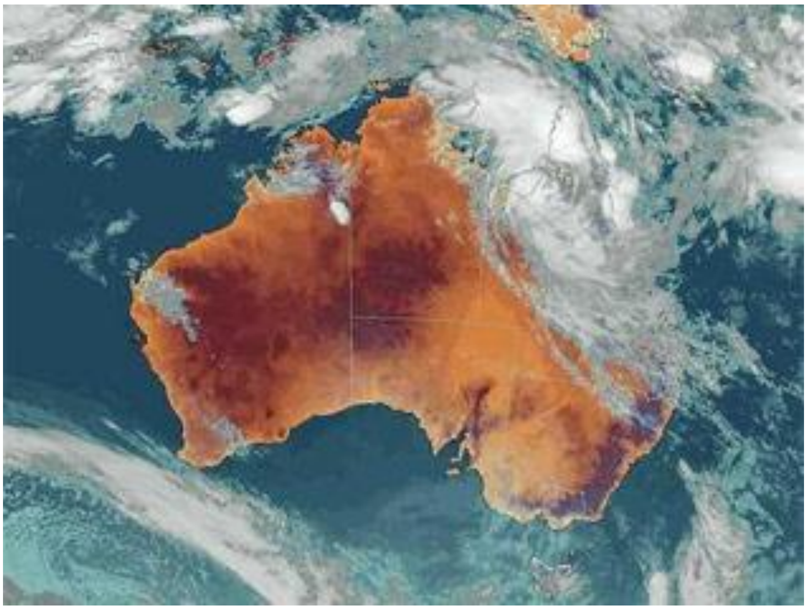


Figure 1 BoM satellite image of ex-TC *Charlotte* on 12th Jan 2009.

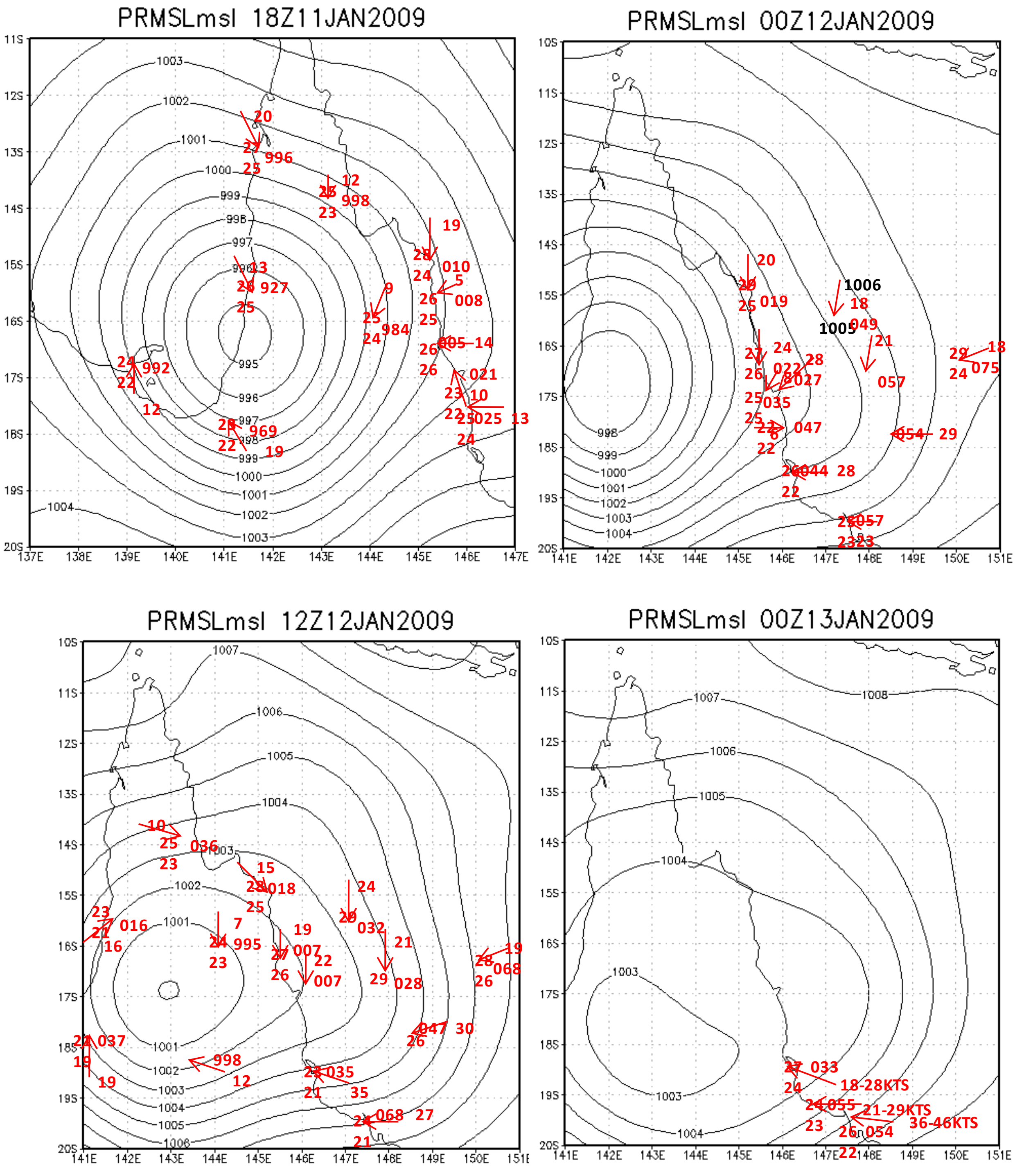
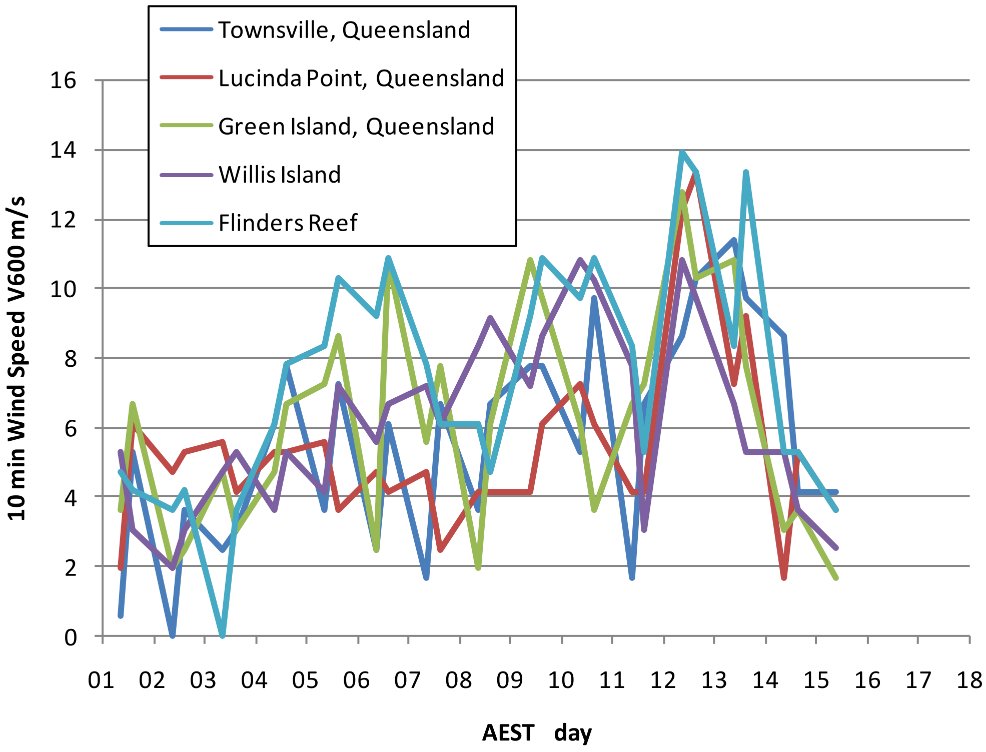


Figure 2 Synoptic development of the ex-TC *Charlotte* wind and pressure field.
(Courtesy J. Callaghan).



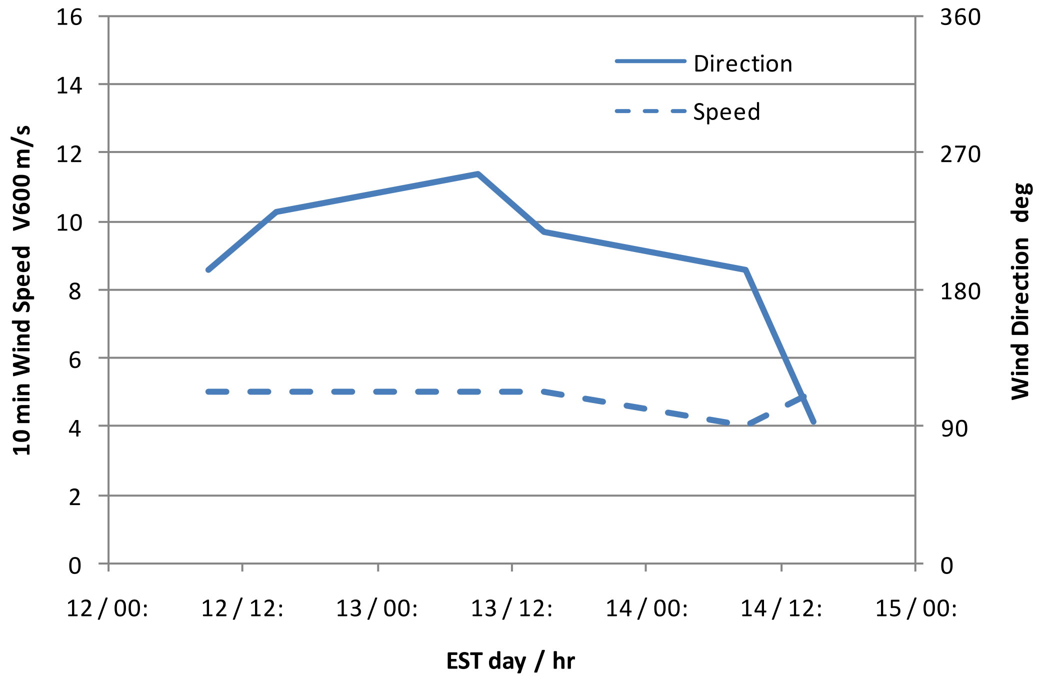


Figure 3 BoM recorded regional wind speeds

(Top: Evidence of monsoonal development over time; Bottom: Townsville Airport)

3 Recorded Water Levels

The Townsville Harbour tide and storm surge gauge is the principal water level reference for this event, supplemented by surveyed debris levels and photographic evidence. Figure 4 shows gauge-measured residual water levels building from the 11th, reaching a peak around midday on the 13th and then subsiding by the 15th. During this time the predicted astronomical tides reached their highest levels in approximately 20 years, just exceeding the nominal HAT value of 2.2 m AHD on the 11th, with a similar value on the 12th, reducing to 2 m AHD on the 13th. In association with the rising storm surge influence, the combination of predicted tide and meteorological tide on the 13th resulted in the highest stillwater level for this event of 2.57 m AHD at 13/01/2009 10:40 EST. The highest residual was 0.70 m at 13/01/2009 02:50 EST.

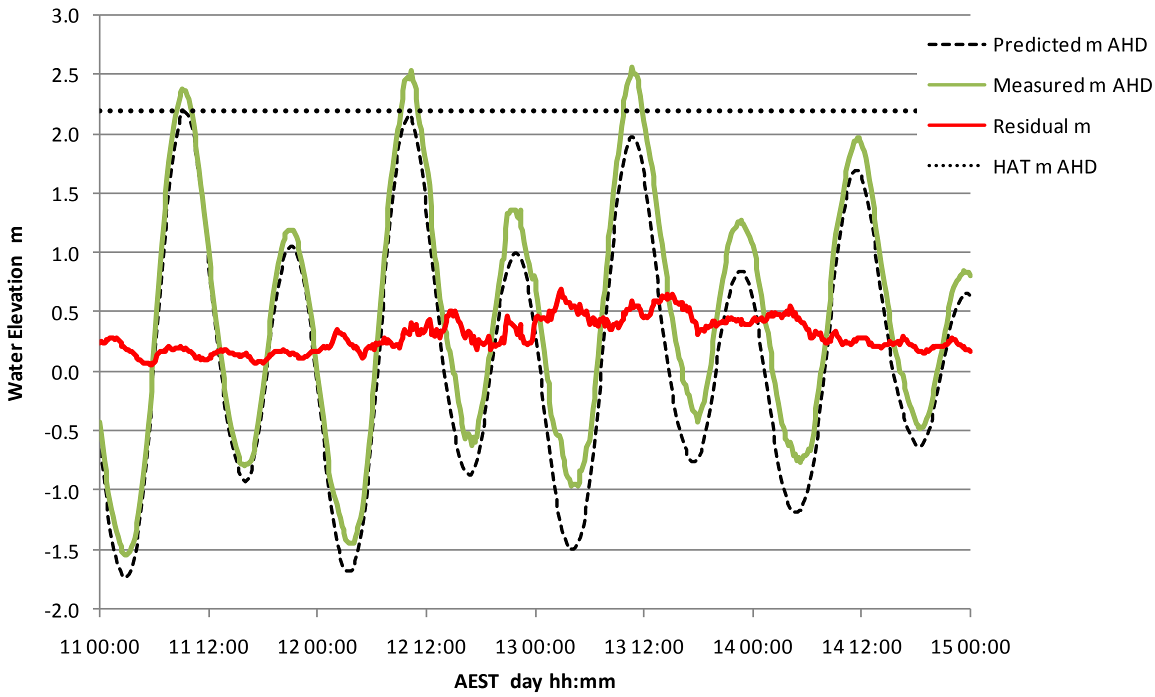


Figure 4 Townsville tide gauge measured and predicted water levels.

(Data supplied courtesy Maritime Safety Queensland includes a post event adjustment of -0.078 m)

4 Photographic Records

A large number of photographs taken during the event were made available from Council sources (principally beach inspectors) and others, a selection of which are shown in Figure 5 through Figure 7 for illustration. The water levels, where indicated, have been inferred from Council's TIM system or surveyed levels. The exact timing of the images is unknown but generally is understood to be near the time of high tide on the 13th.

In Figure 5, the Ross Creek levels are consistent with the nearby tide gauge maximum (refer Figure 10 also). The Picnic Bay level is slightly lower but consistent with the expected slight tidal attenuation relative to the Harbour. The Harbour levels are considerably higher and the ponding evident may be due to poor drainage in that vicinity or perhaps some wave setup affecting the drain tailwater. The debris line at the car park is amongst the highest levels found in the region, indicating added wave setup and runup at the exposed rubble-mound revetment.

Figure 5 Selected water levels Ross Creek, Harbour and Picnic Bay.

Figure 6 Selected beach impacts along The Strand.

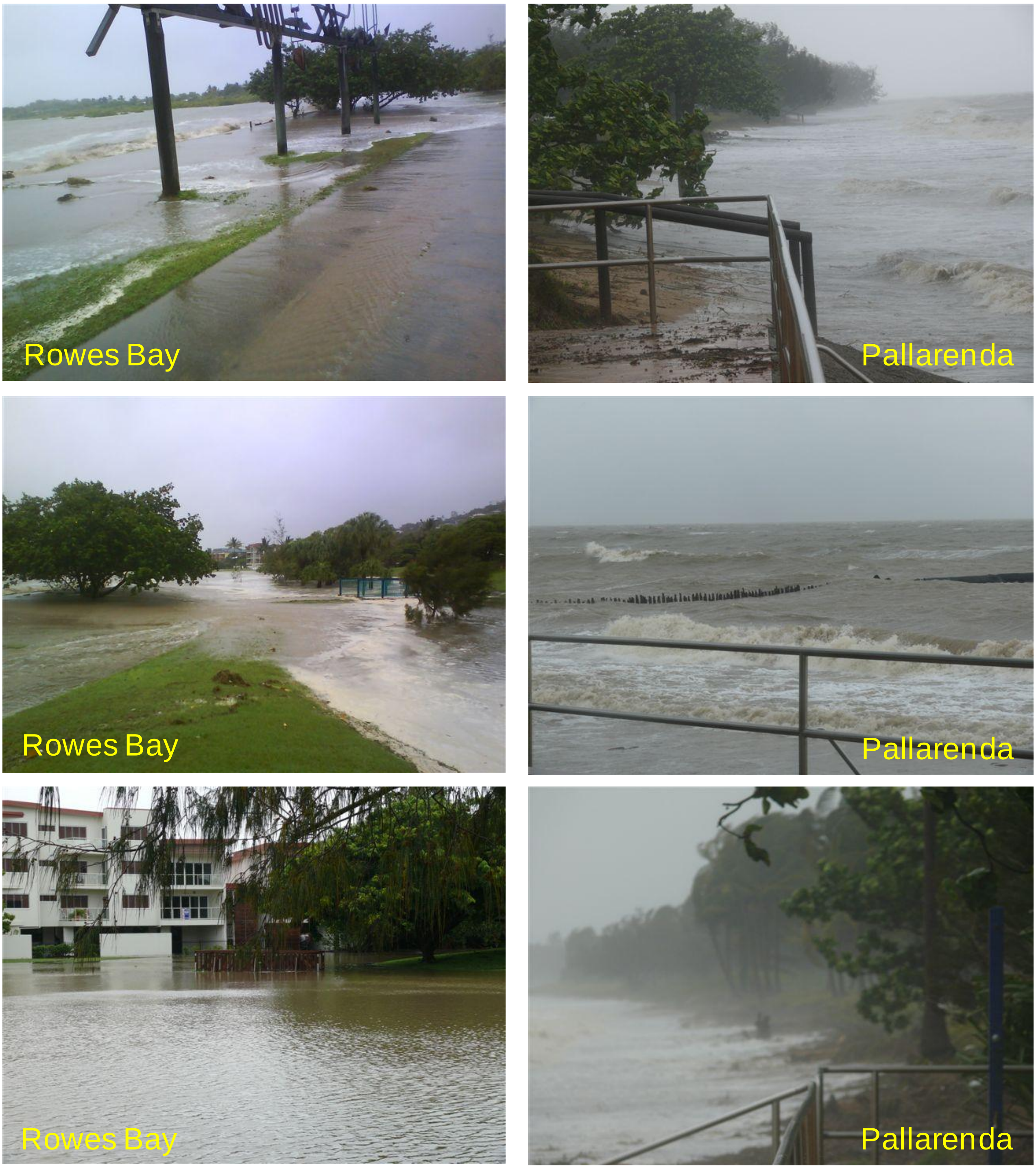


Figure 7 Selected beach impacts Rowes Bay and Pallarenda.

In Figure 6, wave effects on top of the elevated levels eroded portions of the beaches, mainly on the southern side of the revetment headlands. At the Rock Pool, wave setup and runup was significant and dislodged some armour stone, depositing it in the enclosure. The ground levels of the life saving club and restaurants were inundated and appear to have been the highest stillwater levels in the area.

In Figure 7, properties near Rowes Bay / Belgian Gardens were affected and Soroptimist Park was overtopped. The Pallarenda foreshore was also impacted (these photos apparently taken on 14/01).

5 Estimated Wave Conditions

The EPA has a directional Waverider buoy located offshore Cape Cleveland and the real-time data from the buoy is summarised here in Figure 8 showing significant wave heights Hs between 3 and 3.5 m on the morning of the 13^{th}, with a spectral peak period of around 8 s and zero crossing period of 5.5 to 6 s[1]. These values are consistent with exposed conditions outside of Cleveland Bay.

Inside the bay there are no wave recording instruments but a photograph taken at the Stuart St headland jetty (Figure 9) provides some insight into the nearshore conditions. Scaling from the jetty railings suggests maximum waves possibly about 1 m to 1.5 m (Hs 0.5 to 0.75 m). However, at least two wave directions are noticeable, one seemingly from near north and the other more easterly than the jetty alignment of 25 degrees, which are interacting to form the visibly higher waves.

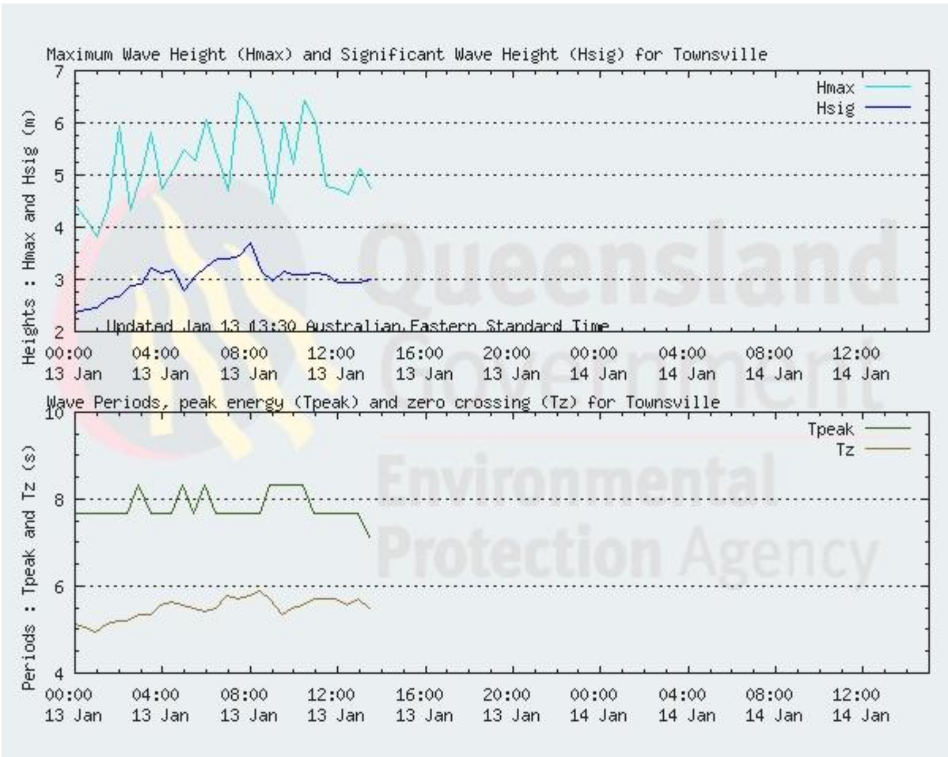


Figure 8 Real-time EPA waverider buoy data.

[1] Analysed directional wave data was unavailable from the EPA at time of writing.

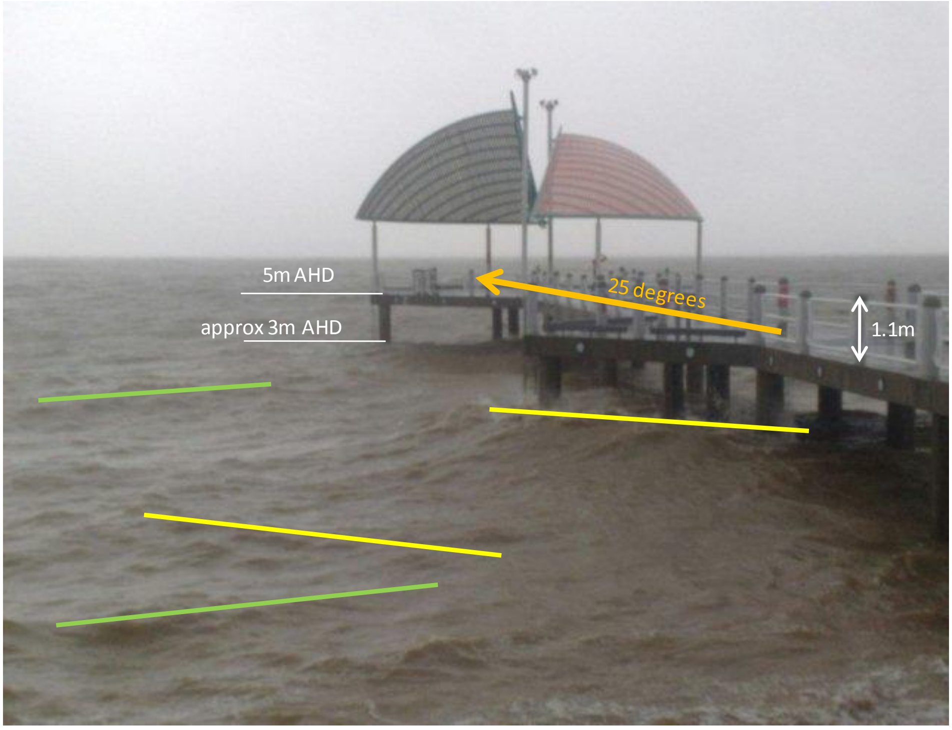


Figure 9 Waves at Stuart St headland on 13th.

6 Site Inspection and Surveys

The site inspection confirmed widespread upper beach sand depletion (scarps plus some exposure of geofabric), some bank erosion at revetment abutments and rock displacement, damage to landscaping, deposition of sand in some southern corners and destruction of beach access infrastructure.

The author met with Council surveyors on the morning of Friday 16th January and briefed the survey crew in locating and measuring the position of the upper beach debris line (often marked by pumice and other flotsam), which was sometimes located amongst dune vegetation. Any erosion scarp was also surveyed (top and bottom of bank). A series of crossbeach profiles were also requested for more detailed future analysis. Beach slopes adjacent the revetment walls were also surveyed. All data is held by Council.

The survey crew completed debris and scarp levelling of The Strand and Rowes Bay on the 16th while the author inspected Saunders Beach and Bushland Beach. The survey crew completed levelling of Pallarenda, Saunders and Bushland Beach and the beach crossections over subsequent days.

Examples of the site inspection and survey work are given in Figure 10 through Figure 12. Figure 10 provides a key diagram for The Strand beaches and indicates typical areas suffering erosion (normally northern corners) or accretion (normally southern corners), consistent with the angle of wave attack. Effects along beaches 1 through 4 were similar, with evidence of lee sheltering from the harbour breakwater at the southern end of beach 5. Erosion occurred at the abutment of each headland revetment as a result of concentrated wave energy and was often greatest on the more exposed southern sides. All floating swimming enclosures appeared undamaged, albeit clogged by seagrass flotsam and sand. The Kissing Point rock pool suffered superficial damage and scour.

Figure 10 Surveyed areas of The Strand and Rowes Bay.

Figure 11 Site inspections The Strand and Rowes Bay.

Figure 12 Site inspections Saunders Beach and Bushland Beach.

Figure 11shows photographs taken on the 16th during the site survey and inspection of The Strand and Rowes Bay areas. Only the southern portion of Beach #5 (near Tobruk Baths) experienced accretion, with the forebeach being loaded with about 0.3 m of sand over a distance of 50 to 100 m. The northern end near Gregory St headland suffered bank erosion adjacent to the revetment abutment with the loss of several established palm trees. At Rowes Bay the southern corner near Soroptimist Park was accreted with up to 0.5 m of sand deposited over some areas. The nearby entrance to the Lynam St drainage canal was heavily eroded, possibly also due to streamflow, and a beachside carpark to the north was destroyed. Beach access infrastructure between Rowes Bay and Pallarenda was mostly destroyed.

Figure 12 summarises the author's findings at Saunders Beach and Bushland Beach. At Saunders Beach there was evidence of dune overtopping at some locations and a beach erosion scarp was evident that damaged beach access infrastructure. At Bushland Beach, which is very flat, no scarp was evident but large deposits of seagrass covered the beach and debris lines encroached onto the nearshore parklands within 50 m of some residences. The inspection at Bushland Beach was limited to the area near the hotel/motel at the beach end of Mount Low Parkway.

7 Analysis and Interpretation

The results of the water level and erosion survey for The Strand have been summarised in Figure 13. The red triangles show the surveyed debris lines generated mainly by wave runup, which are highest at the northern end of Beach #1 immediately next to the Rock Pool. Moving south along the beaches, the debris line rises and falls slightly depending on the northern or southern side of each headland but steadily decreases to the protected Tobruk Pool end of Beach #5. The green dots trace the height of the toe of the beach scarp and the yellow squares indicate the absolute height of the scarp, which was highest at the southern side of the Gregory St headland. The solid green line shows the tide gauge peak level of 2.57 m AHD, which correlates well with the photographic evidence in Ross Creek. The Outer Harbour site ponding and debris levels are then shown

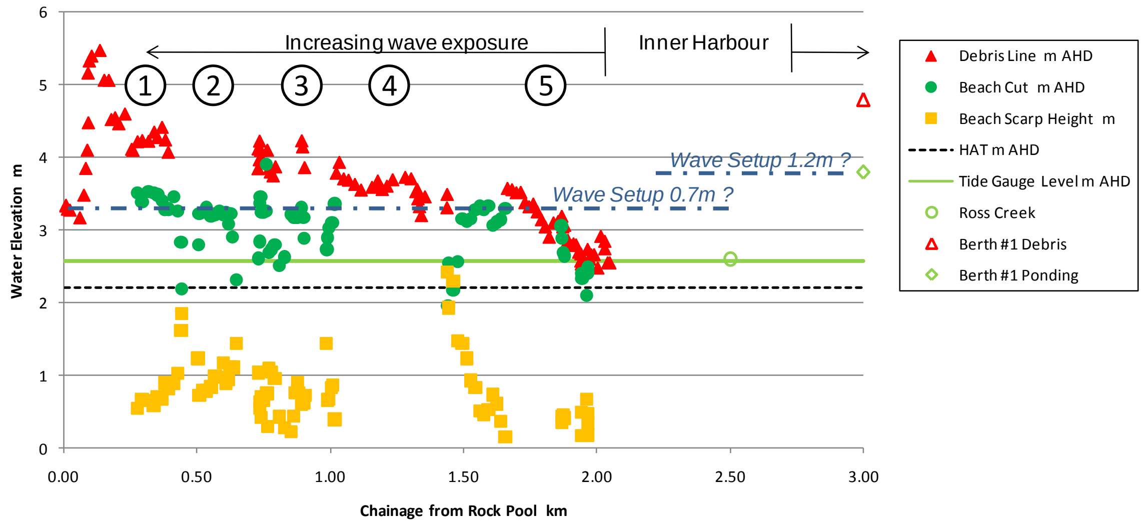


Figure 13 Analysis of The Strand survey data.

It is possible to infer wave setup contributions based on these levels. Firstly, the Rock Pool stillwater debris level itself is likely a reasonable estimate of the wave setup immediately offshore. Secondly, the toe of the beach scarp might also be considered an order of magnitude estimator of wave setup. In this case, the higher scarp toe and the Rock Pool levels are similar, suggesting a wave setup component of the order of 0.7 m at its highest. Similarly, taking the Berth #1 ponding level as perhaps indicative, a setup of about 1.2 m is possible at this more exposed location.

8 The Statistical Context of the TC *Charlotte* Event

The recent GHD/SEA Townsville storm tide study (GHD 2007) provided a solid basis for estimating the return period of extreme storm tide events caused by close approach tropical cyclones. However, the weak TC *Charlotte* event is not fully represented in such modelling and loosely falls into the excluded category of “long period shelf waves” as discussed in §Section 1 of that study report. These larger scale but weaker synoptic weather patterns differ from the severe TC scenario in that the ocean forcing is spread out over a very large area and over an extended period of time. Although the magnitudes of the resulting storm surges are quite small, the persistence of the small surges ensures that they will interact with several high tide episodes and any concurrent coastal flooding events caused by stormwater runoff. In contrast, a severe landfalling tropical cyclone is most unlikely to interact with more than one high tide episode. In this specific case, the coexisting “king tide” sequence, where the tides also reached their 20 year high, makes the combined event reasonably rare. Such events have typically not been explicitly included in tropical cyclone storm tide studies because there is no reliable database available that provides a suitable climatology and also because their impacts are unlikely ever to be life threatening.

However, in the Queensland Climate Change Study (Hardy et al. 2004), some consideration was given to these types of events and a specific case study was included for Townsville as an example. An analysis was undertaken of the residual water levels from the Townsville tide gauge over a 44 year period, specifically excluding times when tropical cyclones were known to have been active in the area. While this would also tend to exclude events like TC *Charlotte*, it remains somewhat representative of this type of phenomenon. The resulting water levels then represented situations when “other” types of weather events had influenced the total water level. This was then sampled in a statistical model and randomly combined many hundreds of times with real tide records for a period of 250 years. In this way a “non-cyclonic” tide plus surge water level return period curve was obtained, which extended from slightly above HAT to merge with the “cyclonic” return period line at about the 200 year return period. The “cyclonic” and “non-cyclonic” probability curves were then appropriately merged, as shown in Figure 14 (part of §Fig 16 from Hardy et al. 2004). No wave setup analyses are available for this situation.

In any case, the data for *Charlotte* can be usefully compared with the results from the GHD study, as shown in Figure 15 for Pallarenda as an example. This shows the GHD/SEA predicted “cyclonic only” levels and also the Hardy et al. (2004) “cyclonic only” results for this location, which are quite similar. Overplotted on this are the various water levels for *Charlotte* obtained from this investigation and the approximate intersection with “cyclonic” return periods (open black circles). This shows that the *Charlotte* wave setup and storm surge are relatively low return period events in a “cyclonic” situation, but the tide + surge and total water levels are relatively rare even for “cyclonic” conditions, being in excess of a 200 year average Return Period.

By allowing for the slight raising of the return period curves as per the Hardy et al. (2004) analyses for "combined non-cyclonic and cyclonic", this indicates a total water level probability of about one in 200 years for this unusual *Charlotte* "pseudo-cyclonic" event.

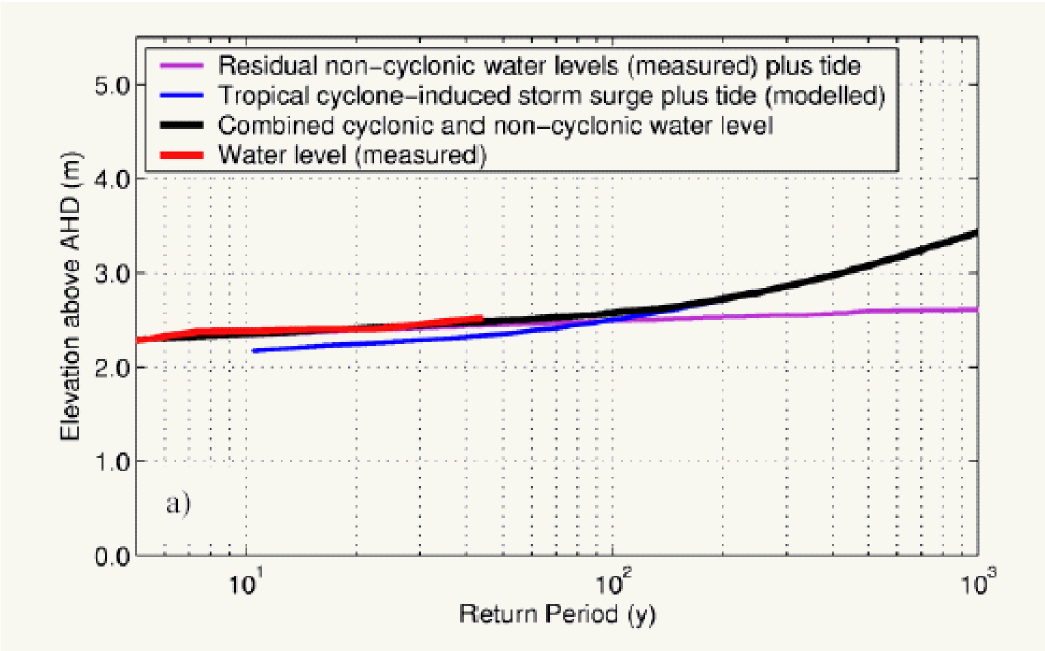


Figure 14 Cyclonic and non-cyclonic analysis for Townsville from Hardy et al. (2004)

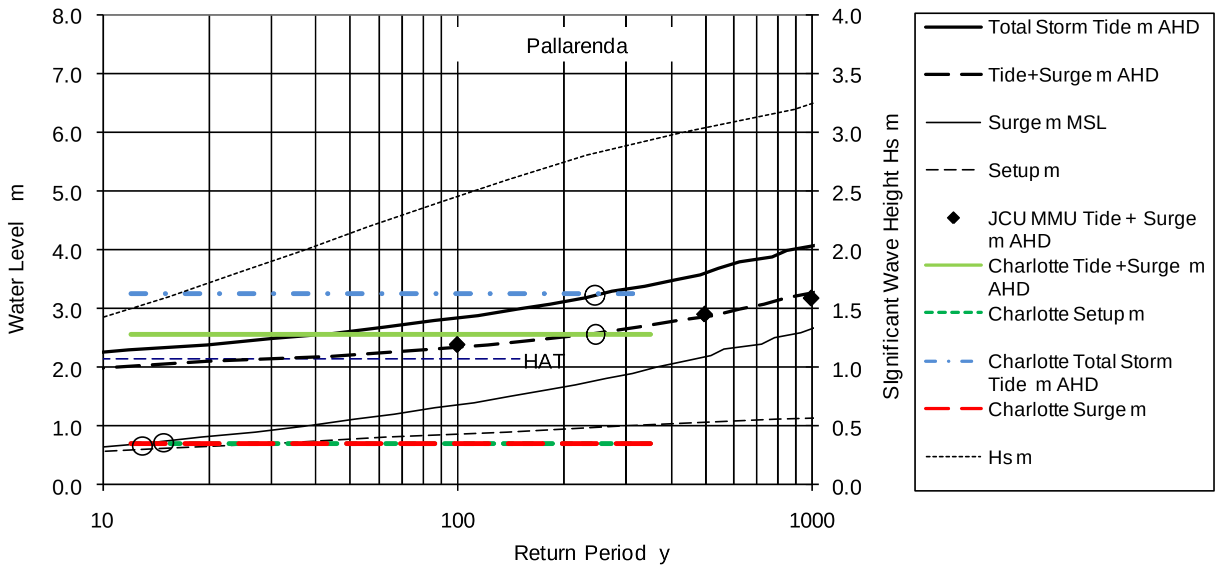


Figure 15 Comparison with cyclonic-only analysis for Townsville from GHD (2007)

9 Conclusions and Recommendations

This limited investigation of the impacts of ex-Tropical Cyclone *Charlotte* on the Townsville region has highlighted the influence of the astronomical tide in modulating total storm tide levels. Even though the storm surge from *Charlotte* was relatively small, its persistence over many high tides and the coincidence of the highest tides within any 20 year period resulted in a combined water level that is estimated to have an average return period of about one in 200 years. This places *Charlotte's* impact into the "extreme event" class. The tide plus surge level recorded at the Townsville harbour tide gauge of 2.57 m AHD just exceeded the 2.53 m AHD level recorded during *Althea* in 1971, where a 2.9 m storm surge fortuitously occurred at low tide (Harper 2001).

More detailed analyses of this event could be undertaken. In particular, the EPA directional wave data was not available, thus limiting the interpretation of wave height, setup and runup available from the surveyed beach levels. Also, no analysis has been done of the beach crossections versus previous surveys and no interpretations have been made in respect of beach slopes. Also, only The Strand survey levels have been analysed in detail, whereas survey data is available for many other areas and may yield valuable information for numerical model validation and the like.

It would also be instructive to make further direct comparisons with the previously documented debris levels from TC *Althea*, especially the issue of wave setup along The Strand

10 References

GHD (2007) Townsville-Thuringowa Storm Tide Study. Prep for Townsville and Thuringowa City Councils in association with Systems Engineering Australia Pty Ltd. April, 210pp.

Hardy T.A., Mason L.B. and Astorquia A. 2004: Queensland climate change and community vulnerability to tropical cyclones - ocean hazards assessment - stage 3: the frequency of surge plus tide during tropical cyclones for selected open coast locations along the Queensland east coast. Report prepared by James Cook University Marine Modelling Unit, *Queensland Government*, June.

Harper B.A. (ed.), 2001: Queensland climate change and community vulnerability to tropical cyclones - ocean hazards assessment - stage 1, Report prep by Systems Engineering Australia Pty Ltd in association with James Cook University Marine Modelling Unit, *Queensland Government*, March, 375pp.

11 Acknowledgements

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