Queensland Government
Environmental Protection Agency
Queensland Parks and Wildlife Service

TROPICAL CYCLONE INFORMATION SERVICE

Prepared by Coastal Services Unit, Environmental Sciences Division

Tropical Cyclone Ingrid field inspections

Introduction

Tropical Cyclone Ingrid crossed the coast just north of Cape Sidmouth, North Queensland on Thursday, 10 March between 5 and 7am. A 960hPa central pressure was estimated at the time of crossing with accompanying wind gusts of 240km/h. TC Ingrid, although very intense, was spatially small as characterised by its 15km radius to maximum winds. The land crossing point is remote from populated towns and no evacuations were necessary.

The objectives of the inspection were to determine the extent of the destructive winds and undertake preliminary estimates of the height of observed debris lines and watermarks. Photographs and video were used to record the damage.

A community meeting was also held at Lockhart River to discuss cyclone preparation activities and warnings as well as any experiences that would provide further relevant information about the cyclone crossing.

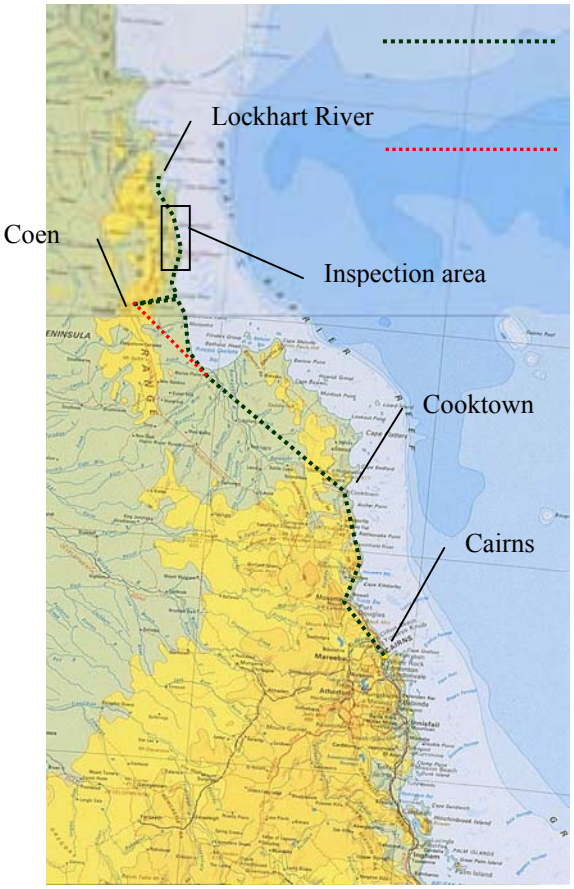


Figure. 1: Flight Plan

Depart Cairns	21/3/2005 7:30am
Arrive Lockhart River.	21/3/2005 4:00pm
Depart Lockhart River.	22/3/2005 9.30am
Arrive Cairns	22/3/2005 4.00pm

A Robinson 44 helicopter was chartered by the Bureau of Meteorology to fly to the inspection area. Refuelling stops were made at Cooktown, Coen, and Lockhart River.

A more detailed aerial view of the inspection area that depicts the activities undertaken during the inspection is provided below in Figure 2.

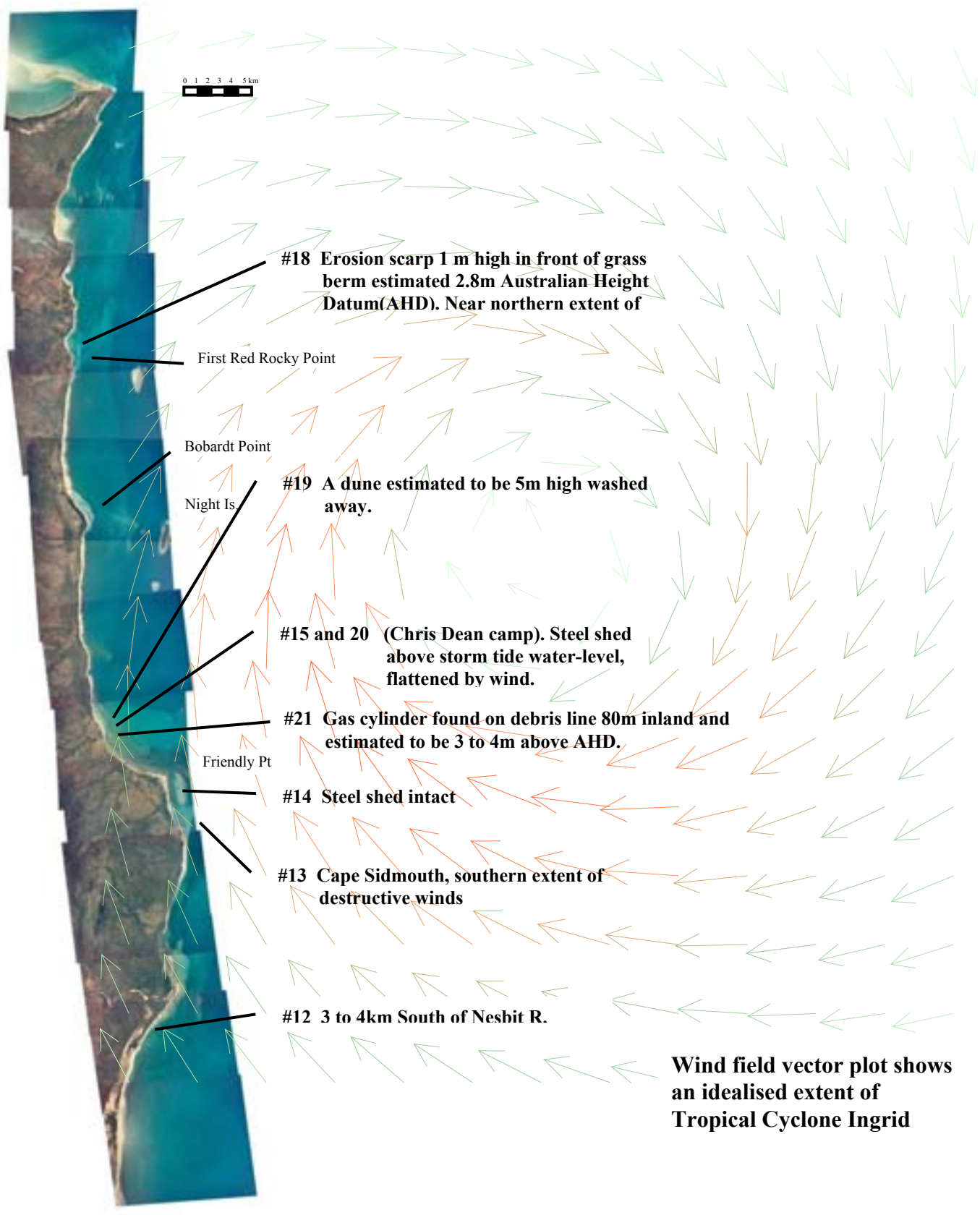


Figure 2: Aerial view of inspection area with reference to # activities in Table 1

Sequence of inspection activities

A chronology of the inspection activities is summarised below in Table 1.

Table 1: Inspection activities during 21 and 22 March 2005

#	Time	Location	Remarks
1	7:30am	Cairns	Departure
2		Cape Tribulation	Video from helicopter
3		Archer Point	Video from helicopter
4		Annan River.	Video from helicopter
5	9.00am	Cooktown	Land and refuel
6		Princess Charlotte Sound	Video from helicopter
7		Nth Kennedy R.	Video from helicopter
8		Breakfast Creek 13.942ºS 143.6228ºE	Video from helicopter
9	11.30am	Coen 13.7623ºS 143.115ºE	Land and refuel
10		Massy Creek. 13.93ºS 143.6123ºE	Video from helicopter
11		Chester River. 13.073ºS 143.5446ºE	Video from helicopter
12	1.30pm	3 to 4km south of the Nesbit River (Campbell Point).	Land and inspect. Low lying swamp behind. Boat fender and empty toilet cistern in mangroves. Fender about 0.5m above ground in vegetation. Pumice provides indicator of maximum level of inundation closer to shore on the dunes. Wash-over of foredune sand appears to be substantial.
13	1.45pm	Cape Sidmouth	Video from helicopter. Start of defoliation is just to the south and the north face of the hill on the coast is almost bare.
14	2.00pm	Steel shed at first camp 13.39442ºS 143.5854ºE Halfway between Cape Sidmouth and Friendly Point.	Land and inspect. Structure is still intact. Water did not appear to have come up to level of shed, however substantial volumes of pumice found in a debris line 20m seaward of structure and about 80m inland from shoreline. Heavy boat mooring rope, plastic boat-fuel container (empty enough to float well) found in dry inland estuary area 50-100m south of landing site.
15		Chris Dean camp. Voaden Point. North bank of Hayes Creek.	Video from helicopter. Steel shed structure flattened.
16	3.45pm	Lockhart River.	Community meeting and overnight stay.
17	9.30am	Lloyd Bay	Video from helicopter

#	Time	Location	Remarks
18	10:50am	13.044ºS 143.509ºE	Land and inspect. Top of grass berm ≈2.7m above sea level at time of measurement (=2.85m AHD). Coffee rock showing and 1m high erosion scarp. Rutile present in beach sand. Trees inland pointing towards beach with bearing 110ºS.
19	12.30pm	South of Voaden Point 0.5km north of Chris Dean camp.	Land and inspect. Dune that according to Chris Dean used to be 5m (estimated) is washed away. Coffee Rock exposed. Large volume of sand in wash-over. Wood log wedged in mangroves near creek edge behind dunes.
20	1.00pm	Chris Dean camp 13.336ºS 143.534ºE (taken 1.5mins after take-off flying south so estimated position of camp: 13.341ºS 143.534ºE)	Land and inspect. Video flattened structure close to shore and get evidence of debris line around the camp. Sand-spit in front of camp (from Hayes Creek entrance) washed-over. Water did not reach second steel shed further inland, but structure flattened by wind. Pumice deposited inland of two vehicles.
21	2.00pm	0.5km south of Chris Dean camp 13.346ºS 143.536ºE	Floats found in trees and gas tank (≈30kg) washed up on pumice line. Rough estimate of water line height is 3 to 4m above shoreline.
22		Friendly Point	Video from helicopter
23		Cape Sidmouth	Video from helicopter
24		Coen	Land and refuel
25		Cooktown	Land and refuel
26		Mossman River.	Video from helicopter
27		Port Douglas	Video from helicopter
28		Yorkey's Knob	Video from helicopter
29		Cairns	Video from helicopter
30	4.00pm	Cairns Airport	Land and depart.

Observations at inspected sites

The majority of the inspection was undertaken on the afternoons of 21 and 22 March around low tide. A correction of 1.48m was applied to convert tide levels to Australian Height Datum (AHD).

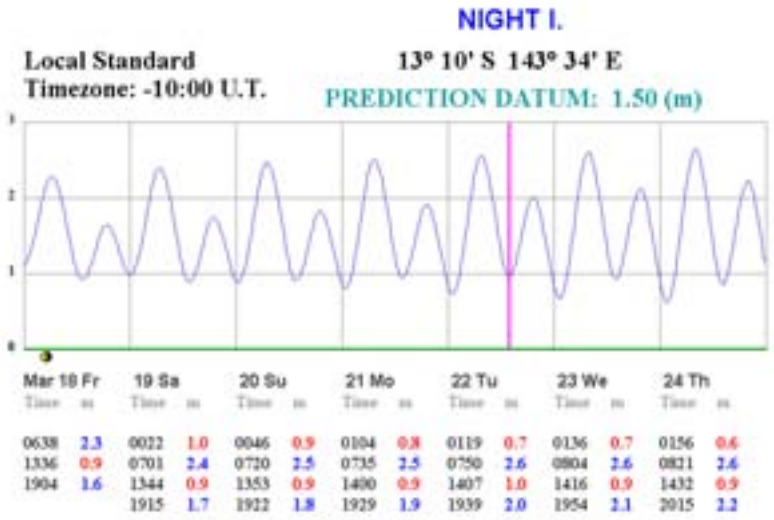


Figure 3: Tide predictions during inspection.

Levels of debris lines were determined by referring them to the predicted tide levels at the time of observation.

Photo 1
Looking south towards Friendly Point.
A 20km wide corridor of coastal vegetation was affected by TC Ingrid. Many trees were defoliated and some can be seen lying down. The beach is relatively steep and over-wash can be seen behind the first stand of trees.

Photo 2
Just south of Chris Dean's property.
Looking inland across the direction of over-wash that has covered the base of the trees with about 0.5m of sand. Floats tied together with rope can be seen hanging in a tree and were most likely snagged as they floated past on the waves. This level correlates with the debris line found further inland.

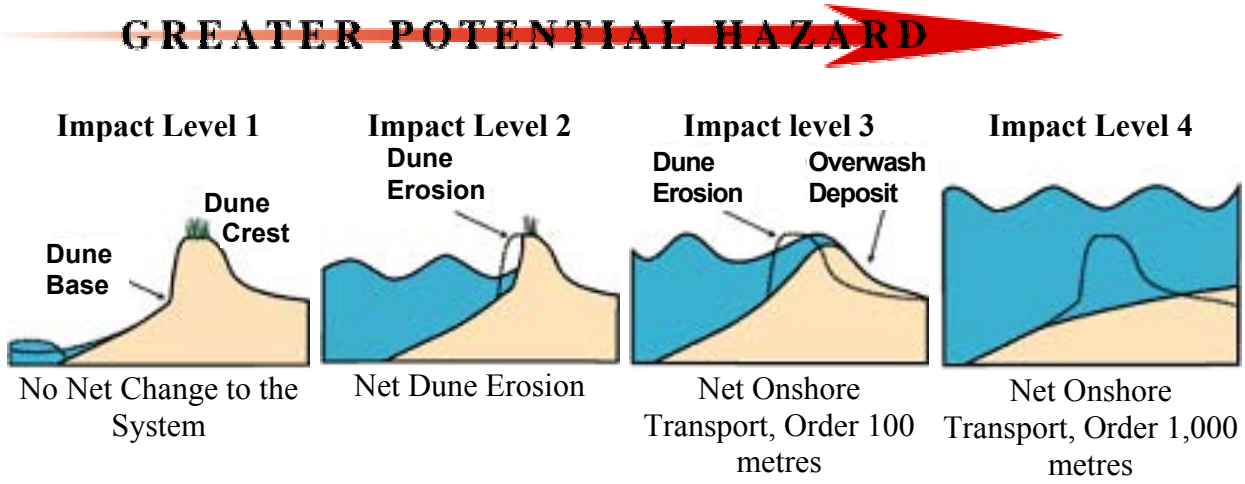
Photo 3
Just south of Chris Dean's property as in previous photo. Debris line of pumice, floats, containers, a 30kg gas tank, and vegetation was found approximately 80m inland at this location. It was deduced that the level of this debris line was somewhere between 3 and 4 metres above AHD.

Photo 4
Vegetation on the frontal dune was destroyed and the dune was washed inland leaving behind an exposed 'coffee rock' substrata and previously buried vegetation.

Coastal hazard rating

Tropical cyclones have the potential to make substantial morphological changes to the coastline because of the wave energy dissipated along the shoreline as the water level increases. These changes depend on many things besides the magnitude of the waves and wind associated with the cyclone, such as the initial beach profile, whether a dune is present, and if so, what type of vegetation is established on it. A scale has been developed by the United States Geological Survey(USGS) to describe, in a simple way, the net erosion or accretion occurring at the coastline.

For a natural beach system the USGS Inundation Hazard Scale applied to the Tropical Cyclone Ingrid event would be rated at Impact Level 3 (Overwash Regime) described in Figure 4:



Images from USGS web site http://coastal.er.usgs.gov/hurricanes/mappingchange/scale.html

Figure 4: USGS Inundation Hazard Scale

The Impact Level 3 coastal hazard depicts a situation in which the wave runup exceeds the elevation of the dune, or in the absence of a dune, the beach berm. In this instance the system will be overtopped, transporting sand landward. This is a net change contributing to the migration of the frontal dune landward.

For a developed beach system the EPA is forming a separate list of coastal hazard ratings similar to the above but associated with urban environments.

Remote observations of TC Ingrid

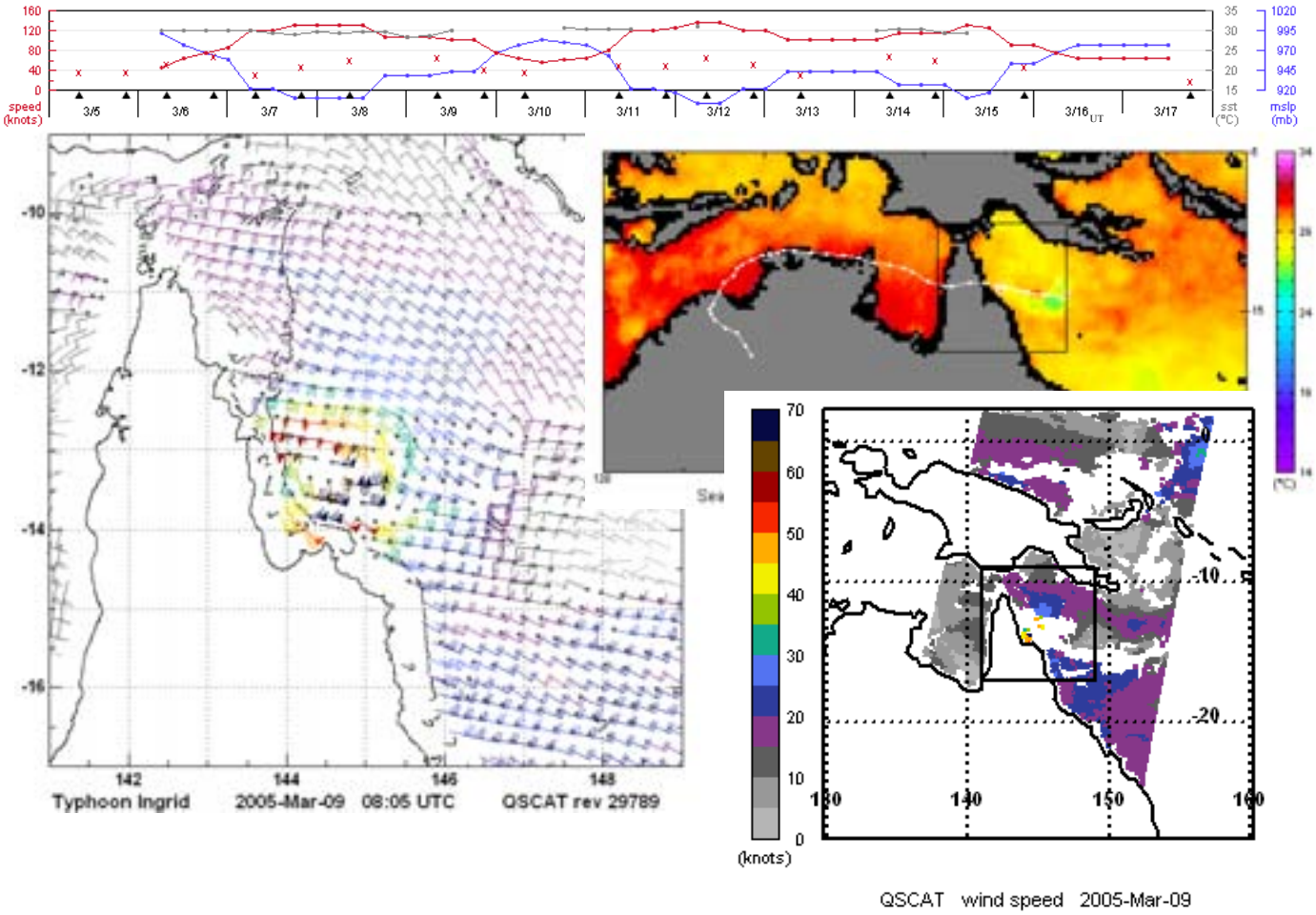
Satellites provide a welcome source of information in regard to the cyclone characteristics and behaviour.

Figure 5: Eye-wall of TC Ingrid 8/3/2005 07:00 UTC

Image from *NOAA-12* satellite received and processed by Bureau of Meteorology courtesy of NOAA (USA).

During the storm event satellites and radar are used to locate the cyclone and provide information on speed of forward movement, central pressure, radius to maximum winds and wind speed. This data is used when predicting the storm tide waterlevel at the time of landfall. Figure 6 below summarises the data remotely sensed while following the path of TC Ingrid.

Figure 6 Remotely sensed cyclone data (QuikScat and SSM/I data are produced by Remote Sensing Systems and sponsored by the NASA Ocean Vector Winds Science Team and NASA Earth Science REASoN DISCOVER Project respectively. Both sets of Data are available at www.remss.com.)



Storm tide predictions

Leading up to the time TC Ingrid crossed the coast, predictions were made of the storm-tide water level that might be expected. It is always conservatively assumed in Bureau of Meteorology predictions (for counter disaster purposes) that the cyclone will cross land at the time of high tide. In fact, TC Ingrid reached landfall between 5 and 7am on 10 March around mid-tide. Table 2 shows the magnitudes of the components used to make up the best estimates for the total storm tide water level.

Figure 7: storm tide water level prediction

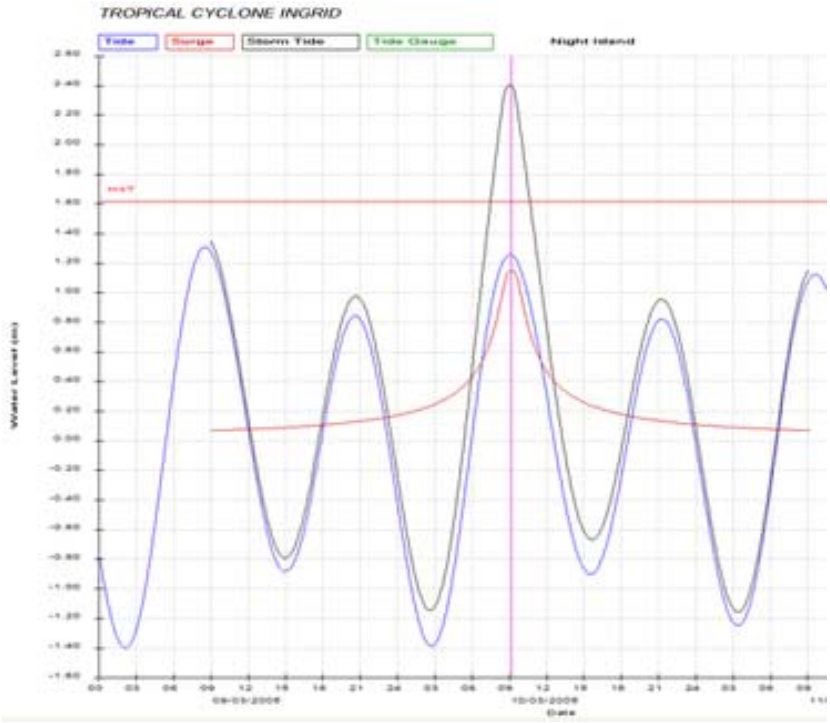


Table 2: Storm tide components used in predictions

Note: Figure 7, unlike Table 2, does not include wave setup or wave runup.

Component	AHD(m)	AHD(m)
	High tide	Mid tide
Tide	1.25	0.0
Surge	1.15	1.15
Wave setup	0.5	0.5
Wave runup	0.5	0.5
Total	3.4	2.2

Survey of TC Ingrid debris line – 7-8 April 2005

A survey of the debris line and profiles of the beach were undertaken by Queensland Parks and Wildlife Services on behalf of the EPA and Bureau of Meteorology on 7 and 8 April 2005. This survey resulted in seven profiles of the storm surge debris line and these are plotted in Figure 8 below and detailed in Table 3.

The survey's purpose was to compare measured peak storm tide levels with predictions made by the Bureau and the EPA. A total station theodolite was used to measure (within a centimetre) the elevation of the debris line level relative to the tide. A Differential Geo-Positioning System (DGPS) was used to provide a reference for the total station horizontal location. Two permanent survey marks were established that could be surveyed to a more accurate vertical control in the future if required. Marine Safety Queensland (MSQ) provided the tide predictions (Night Island) used for the survey measurements' datum and conversion to Mean Sea Level (MSL). Allowance was made for meteorological conditions on the day by transferring residuals from the Cooktown storm tide gauge.

The predicted tidal level at Night Island at the time of TC Ingrid landfall (approx 6:10am 10/3/2005) was 0.14m MSL. The maximum debris line measured was 2.81m MSL. This level suggests that storm surge with wave setup and wave runup was 2.67m. This value represents a storm tide height of 1.19m above Highest Astronomical Tide(HAT - Night Island).

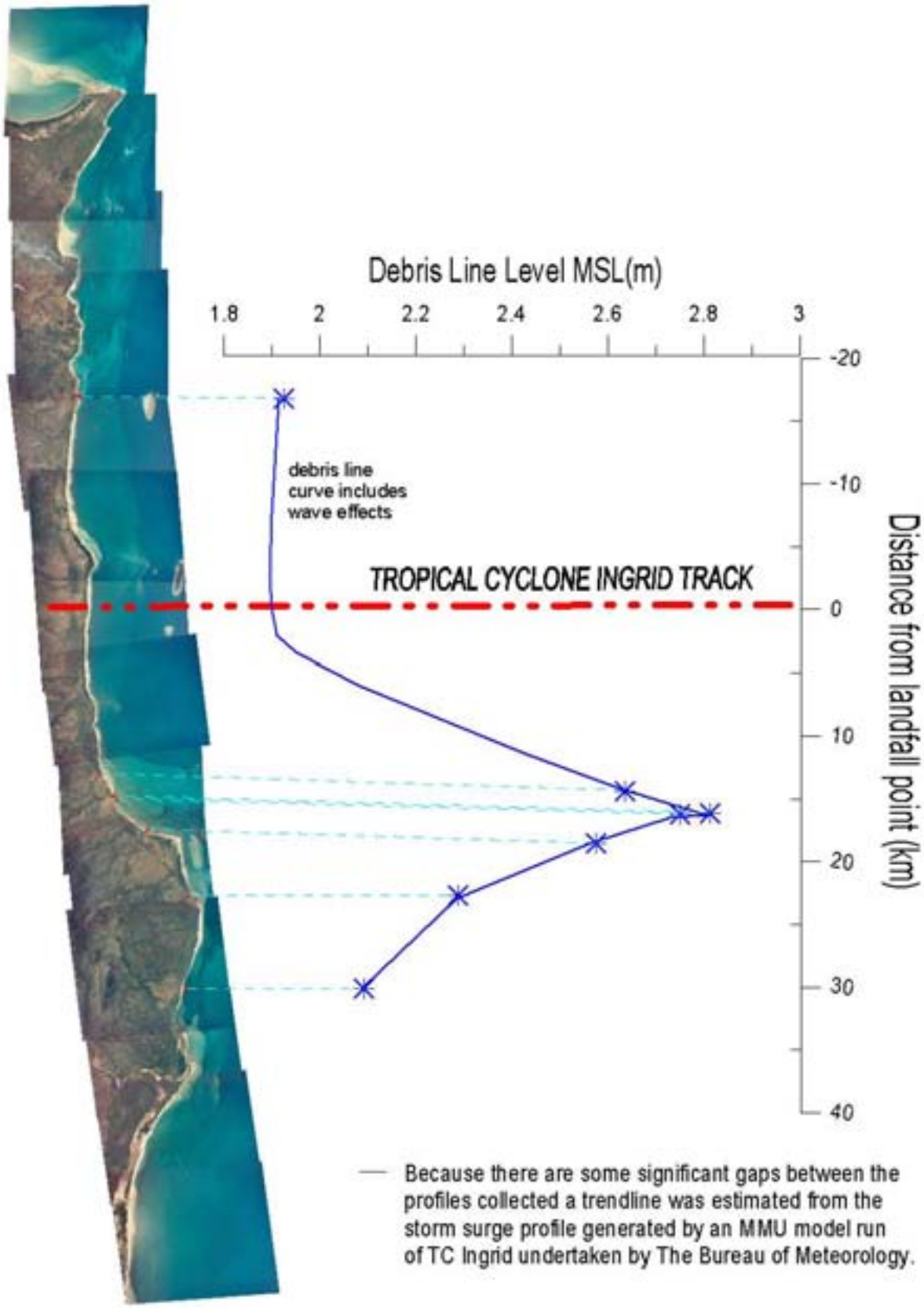


Figure 8: Plot of Tropical Cyclone Ingrid debris line levels along coast. It is assumed that the high debris level at the northern site was a result of wave effects as the cyclone approached landfall.

Comparison of predicted and measured storm tide peak

Prior to Tropical Cyclone Ingrid making landfall, the Environmental Protection Agency predicted a peak storm tide level of 2.9m using a high tide of 1.25m, a surge of 1.15m, and allowance for wave setup of 0.5m. High tide is always assumed as the convention prior to landfall in a potential evacuation situation.

Now that the survey information is available, and it is believed that the tide would have been 0.14m relative to MSL at the time of landfall, the predicted peak storm tide level could be calculated as 1.8m MSL due to 0.14m (tide) and 1.15m (surge) and 0.5m (allowance for wave setup).

The peak debris line level, measured on the profile surveyed at site 2 was 2.81m MSL, i.e. almost one metre higher than the calculated peak storm tide level. An allowance for wave runup needs to be introduced to the calculated value, assumed as 0.6m, and the surge value may need to be increased slightly to 1.6m to achieve the level of the debris line.

A number of factors need to be considered in this comparison. The Jelesnianski storm surge prediction method simplifies local bathymetric conditions into a depth correction factor (0.45 at Night Island) and does not consider inundation processes. If the depth correction factor were adjusted to 0.59 this would increase the surge level to match measurements. The peak storm tide site (Figure 8) has a concave north-facing shoreline that could focus and magnify the surge to some extent. However, the wave runup process over a barred beach is not well understood and irregular waves (including wave grouping) are likely to reach inland a long way if they travel as wave bores.

Given the simplified methodology used to predict storm tide, it compared favourably with the measured levels. The advices for TC Ingrid proved to be conservative because they assume the storm tide level is a result of tropical cyclone landfall at high tide. However, some further consideration should be given to the extent of wave runup, and for that matter, wave setup, and perhaps the re-evaluation of the depth correction factors when measured data permits a comparison to be made.

Acknowledgements

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- Queensland Parks and Wildlife Service, Northern Region for providing survey assistance.
- Marine Safety Queensland for predicted tidal levels.
- Queensland Department of Emergency Services for resources provided to this investigation.

References

Interim Report on Severe Tropical Cyclone Ingrid, April 2004
http://www.epa.qld.gov.au/publications/p01584aa.pdf/Interim_report_on_severe_tropical_cyclone_Ingrid.pdf

Table 3 Survey Data Collected 7-8 April 2005

Profile ID	Longitude	Latitude	MSL levels (m) (Night Is. tides)	Description
Site 1				
2	143.3145185	13.1942038	-0.95	Water-line 7/04/2005 3:14:00 PM
3	143.3143104	13.19439838	-0.09	Natural surface
4	143.314159	13.19456686	1.86	Natural surface
5	143.3141016	13.19462136	0.91	Natural surface
6	143.3140767	13.19464806	2.43	Vegetation line
1PSM	143.3140537	13.19466836	2.63	PSM star picket
7	143.3139641	13.19474094	2.64	Surge line
Site 2				
21	143.3211267	13.20430919	-0.30	Water-line 7/04/2005 5:05:00 PM
22	143.3210669	13.20431908	1.76	Natural surface
23	143.3210086	13.20432873	2.34	Natural surface
24	143.3209623	13.20433362	1.61	Natural surface
20PSM	143.3209106	13.20434493	1.96	Star picket
25	143.3207828	13.20430084	2.81	Surge line
Site 3				
31	143.3212555	13.20457989	-0.12	Water-line 7/04/2005 5:27:00 PM
32	143.3211492	13.20467647	0.12	Natural surface
33	143.3211056	13.20470281	2.75	Surge line
Site 4				
41	143.3044717	13.02520667	0.25	Water-line 8/04/2005 11:15:00 AM
42	143.3043745	13.02523497	1.93	Surge line
Site 5				
51	143.3332416	13.21551922	-0.46	Water-line 8/04/2005 12:50:00 PM
52	143.3331347	13.21590639	2.56	Surge height
53	143.3331456	13.21591781	2.45	Surge height
54	143.3328295	13.21597893	2.58	Surge height
55	143.3328296	13.21597902	1.63	Top of Dune
Site 6				
61	143.3516635	13.24148616	-0.95	Water-line 8/04/2005 2:06:00 PM
62	143.3515402	13.2414861	1.59	Last high tide mark
63	143.3515155	13.24147743	2.29	Surge line
Site 7				
71	143.3511341	13.28173749	-1.05	Water-line 8/04/2005 3:03:00 PM
72	143.3507636	13.28164871	2.09	Surge line