# Maximum Storm Tide Level Recorders (pilot) Project

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## Introduction

The purpose of the Maximum Storm Tide Level Recorders Pilot project (MaxSTLR) was to record the magnitude, timing and extent of coastal storm surge inundation associated with tropical storms. The project was funded by the Natural Disaster Mitigation Program (NDMP).

For the duration of the 2010-11 Australian cyclone season (November to April) the Queensland Government Department of Science, Information Technology, Innovation and the Arts (DSITIA) deployed a series of 13 pressure transducers at 10 sites between Cairns and Townsville in tropical north Queensland. All 10 sites had sensors to record hydrostatic water pressures which were converted, in post-processing, to water depths above Australian Height Datum (AHD). Co-located barometric pressure sensors were installed at three sites to compensate for atmospheric pressure variations during tropical storms.

## Background

The MaxSTLR Project was conceptually based upon short-term storm surge data collection deployments undertaken ahead of hurricanes by the United States Geological Survey (USGS) along the Gulf and East Coast of the United States. Such deployments have yielded valuable information about the 'real' magnitude and timing of storm surges as hurricanes approach the coast. The information collected by the USGS was used for mapping, modelling and increasing capability for disaster management, and to increase awareness of the risk of storm surge / tides associated with tropical storms.

After completing site inspections of 27 coastal settlements between Cairns and Townsville (11-15 July 2010), site suitability was evaluated using multiple criteria: infrastructure; proximity to permanent survey marks; spatial distribution; existing equipment; and historical information. Consequently, the 10 sites (displayed in Figure 1) deemed most suitable for the initial 2010-11 deployment were: Bramston Beach; Etty Bay; Clump Point; Hull Heads; Cardwell; Lucinda; Forrest Beach; Balgal Beach; Saunders Beach; and Pallarenda (Townsville).

## Methods

### Instrumentation

Each of the deployed instruments is a self-contained pressure sensor/data logger. Its approximate dimensions are 230 mm in length with a diameter of 20 mm. All sensor casings are made from titanium to avoid corrosion while deployed in seawater. Protecting the membrane of the sensor is a black ABS plastic cone. An acrylic spacer was manufactured to reduce movement of the sensor due to fluid fluctuation once inside the housing.

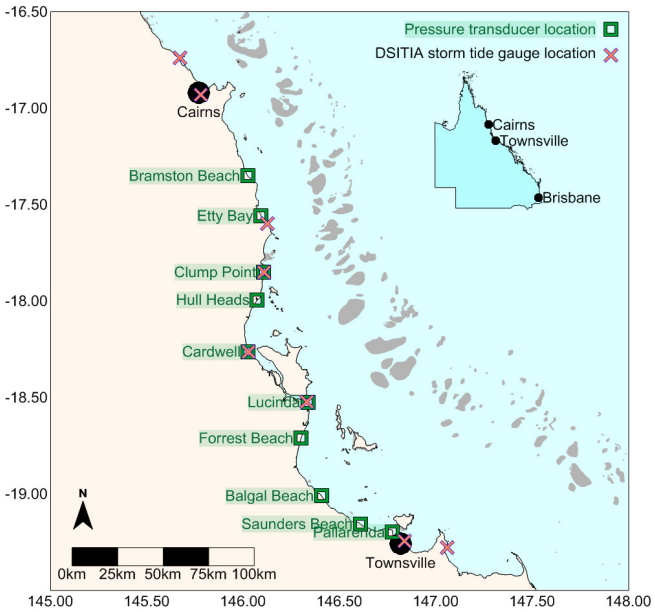


***Figure 1: MaxSTLR Project sites for the 2010-11 cyclone season***

The instruments were housed in perforated ABS plastic pipe approximately 510 mm long and 50 mm in diameter. The instrument housing was then fixed with steel banding to a pre-existing structure such as a jetty pile, stinger net cage or swimming enclosure.

**Setup and Sampling Rate**

Four main factors had to be considered to maximise the efficiency of the instrument setup: battery life; memory capacity; sample resolution; and environmental constraints such as natural variation in atmospheric pressure and tidal extremes.

The sensors were setup to log at 30 second intervals when the high trigger (>30 mm water depth over sensor) or the change trigger (20 mm change in pressure) was satisfied in reference to the last sample taken. If neither of these conditions were met, the instrument logged every 30 minutes until one of these conditions was satisfied. This setup was selected on the basis of conserving battery life and physical memory while still recording a high resolution dataset during an inundation event.

**Installation**

All 13 pressure transducers (10 hydrostatic and 3 barometric) were deployed at the selected sites during the first week of the 2010-11 Cyclone season (1-5 November 2010).
The three barometric sensors were installed at locations which were spatially distributed to provide maximum barometric monitoring in the project area. This distribution was based on the presence of other barometric instrumentation at some sites. All water pressure (hydrostatic) sensors were placed at or near 'high water'. The determination of 'high water' and location of installation was based on two factors - site morphology and available structures.

In the aftermath of Tropical Cyclone Yasi (TC Yasi) in February 2011, data from the water level pressure transducers was retrieved, and the instruments were redeployed for the remainder of the cyclone season. However, two sites had been compromised by the effects of TC Yasi and were relocated (Bramston Beach) or removed (Saunders Beach).

Following the success of the 2010-11 data capture, a refined deployment strategy was implemented for the 2011-12 cyclone season. The approach was to select sites with proximal offshore islands, and co-locate sensors on the mainland and islands with the aim to

compare collected values. Two deployment 'clusters' were selected in individual LGAs – Cassowary Coast region: Clump Point, Dunk Island, Bedarra Island and Hull Heads; and Townsville City region: Balgal Beach, Pallarenda, Picnic Bay & Arcadia (Magnetic Island) and Cape Ferguson.

## Results

### 2010-11 Cyclone Season

The only significant data capture event recorded during the MaxSTLR project was Tropical Cyclone Yasi (TC Yasi), which crossed the coast near Mission Beach just after midnight on 3 February 2011 (see Figure 2). This event resulted in successful data recording of the timing and magnitude of storm tide inundation at all 10 sites, with the peak storm tide occurring at Cardwell (5.38 m AHD, Table 1), approximately 3.11 m above Highest Astronomical Tide (HAT).

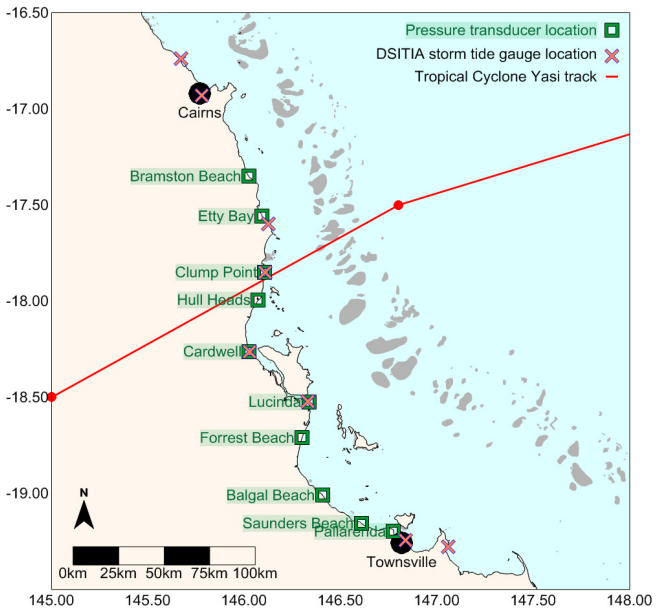


***Figure 2: Tropical Cyclone Yasi track relative to MaxSTLR instrument sites and existing DSITIA storm tide gauges***

DSITIA's Storm Tide Gauge (STG) network also recorded the peak storm tide inundation at six of the seven existing STG sites between Cairns and Cape Ferguson. The peak storm tide recorded by the STG network was also at Cardwell (4.5 m AHD, Table 2), approximately 2.23 m above HAT, which correlated well with the peak timing and magnitude of the MaxSTLR data.

***Table 1: Maximum water levels collected by MaxSTLR instruments deployed for the 2010-11 cyclone season***

| Site | Maximum water level (m AHD) | Date and time | Distance from Yasi crossing (km, direction North or South of crossing) |
|---|---|---|---|
| Bramston Beach | 1.95 | 03-Feb-2011 09:52 | 55 N |

| | | | |
|---|---|---|---|
| Etty Bay | 2.63 | 02-Feb-2011 20:02 | 33 N |
| Clump Point | 3.53 | 03-Feb-2011 00:17 | 0 |
| Hull Heads | 4.04 | 03-Feb-2011 00:34 | 17 S |
| Cardwell | 5.38 | 03-Feb-2011 01:12 | 46 S |
| Lucinda | 3.09 | 03-Feb-2011 08:08 | 75 S |
| Forrest Beach | 4.13 | 02-Feb-2011 20:35 | 95 S |
| Balgal Beach | 3.92 | 03-Feb-2011 08:33 | 129 S |
| Saunders Beach* | 5.54 | 03-Feb-2011 09:03 | 144 S |
| Pallarenda | 3.27 | 03-Feb-2011 08:36 | 148 S |
| ** The structure at Saunders Beach collapsed at approximately 09:00 03-Feb-2011* | | | |

***Table 2: Maximum water levels collected by DSITIA Storm Tide Gauge network during Tropical Cyclone Yasi***

| Storm tide gauge | Maximum water level (m AHD) | Date and time |
|---|---|---|
| Cairns | 1.83 | 03-Feb-2011 09:10 |
| Mourilyan | 1.80 | 03-Feb-2011 09:30 |
| Clump Point | 2.42 | 03-Feb-2011 00:40 |
| Cardwell | 4.50 | 03-Feb-2011 01:20 |
| Townsville | 2.63 | 03-Feb-2011 08:40 |
| Cape Ferguson | 2.41 | 03-Feb-2011 09:20 |
| *The Lucinda STG was damaged just prior to TC Yasi crossing the coast.* | | |

## Validation of Data

Quality assurance of the data obtained from the 10 pressure transducers (PT) was assessed via direct comparison with water level data from DSITIA storm tide gauges (STG) which were co-located to hydrostatic sensors at Clump Point and Cardwell. Due to the dampening effects of the STG stilling well, wave action is not detected in the STG records (which are sampled instantaneously every 10 minutes). Subsequently, issues arose when attempting to compare dampened 10 minute STG data to raw, irregular (30-second to 30-minute) pressure transducer data over the same time period. To overcome this data mismatch, a 30-second timestamp was created for the event period (00:00 2-Feb-2011 to 00:00 4-Feb-2011) and both datasets were re-sampled (via linear interpolation) to this timestamp. The raw PT and STG data, and the resampled data are compared in Figures 3 to 5.

The raw water level data collected at Clump Point and Cardwell during TC Yasi is displayed in Figure 3, along with the atmospheric pressure data used to correct for the inverted barometer effect. Figure 4 displays the residual Water Level (**red** line), between the raw PT and STG data, in which fluctuations of ±1 m exist between the raw data sets. This fluctuation is the result of near-shore wave action (pressure transducers at both sites were located greater than 100 m landward of the corresponding STG). In order to compare the dampened STG data to the hydrostatic sensor data, a 10 minute low-pass filter was applied to the pressure transducer data (to negate the effect of waves), yielding results that are comparable (±0.2 m) to the STG data, Figure 5 below.

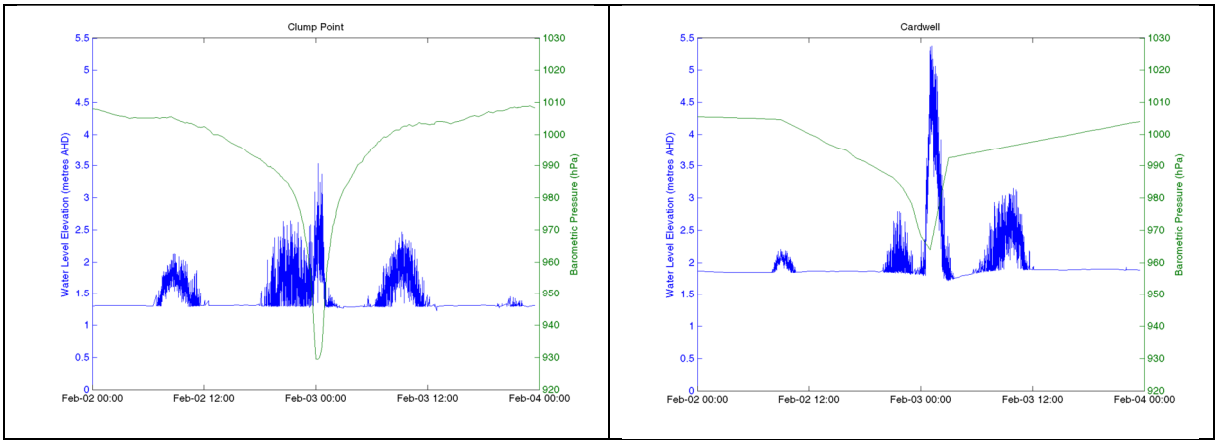


***Figure 3: Clump Point (left) and Cardwell (right) raw water level (pressure transducer) and nearest barometric data collected during TC Yasi***

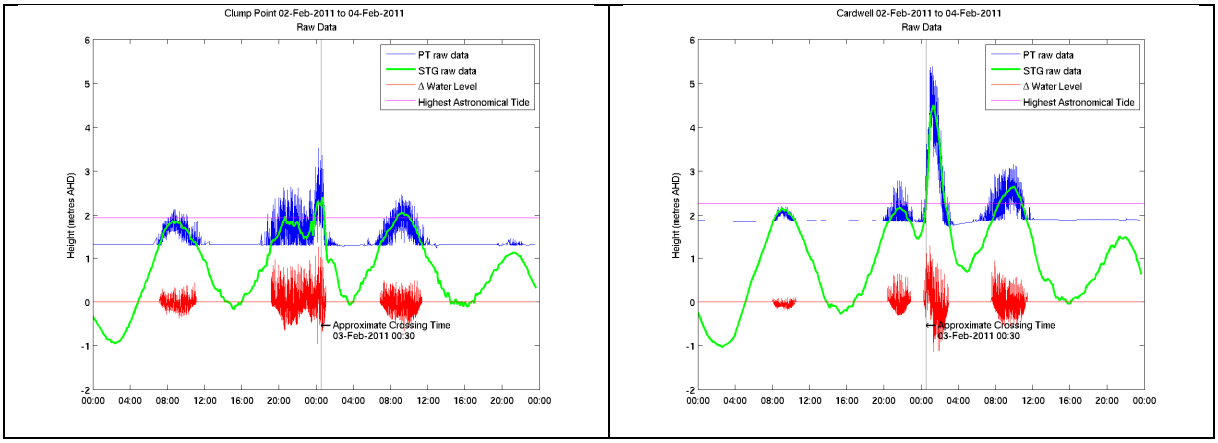


***Figure 4: Comparison of raw data sets from Pressure Transducers (interpolated) and Storm Tide Gauges (interpolated) at Clump Point (left) and Cardwell (right)***

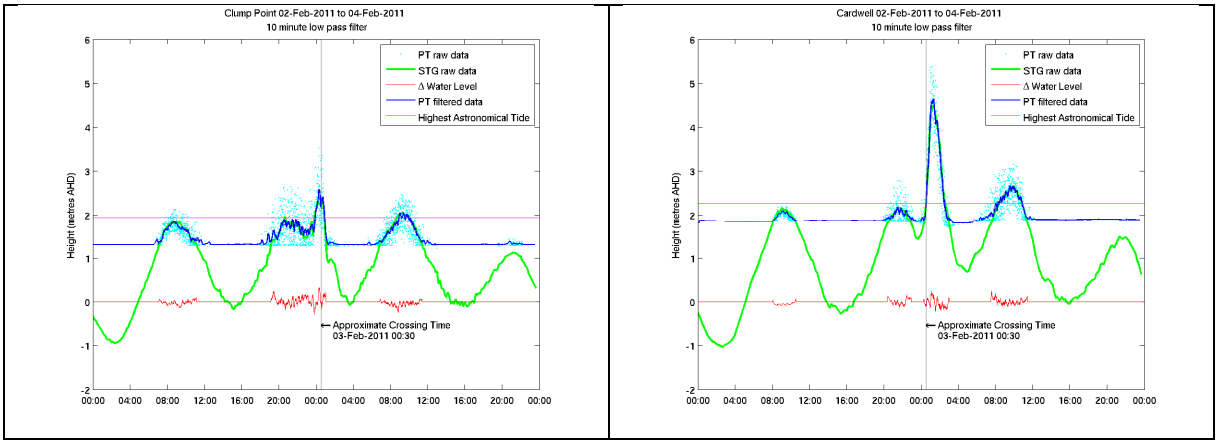


***Figure 5: Comparison of data sets from Pressure Transducers (10-min smoothed) and Storm Tide Gauges at Clump Point (left) and Cardwell (right)***

## 2011-12 Cyclone Season

No significant storm inundation events occurred throughout the 2011-12 MaxSTLR deployment, however 7 of the 8 instruments which were inundated during the 2011-12

cyclone season recorded the highest water levels during the January 2012 king tide, which correlate directly with local storm tide gauge readings.

## Discussion

The aim of this pilot exercise was to record the magnitude, timing and extent of coastal storm surge inundation events associated with tropical storms. The project successfully collected surge data from all sensors deployed during TC Yasi. The maximum verified water level recorded by the sensors during the event was 5.38m at Cardwell (03-Feb-2011 01:12).

The data captured by the MaxSTLR project highlights the pronounced difference in water levels which can occur under extreme conditions in the near-shore zone. Wave-induced phenomena such as setup and run-up contribute significantly to the total water level translated onshore during storm events as is illustrated in Table 1-2 and Figure 5. Data collection projects such as the MaxSTLR project assist in quantifying these contributions, aiding decision makers to better prepare for and respond to storm surge impacts in coastal communities.

## Take Home Messages

This project has delivered a unique dataset of coastal inundation events. It has also demonstrated the feasibility of using simple off-the-shelf technologies to provide a rapid response capability to measure coastal inundation events. The results have provided a better understanding about the associated physical processes and impacts for future emergency response and land-use planning purposes.

## Acknowledgments

1. All the local contacts at project sites and within government agencies between Townsville and Cairns, for their assistance and advice throughout the MaxSTLR project.
2. The U.S. Geological Survey for providing the technical foundation for the MaxSTLR project through publication of information about various storm surge data collection campaigns (www.usgs.gov)
3. Cyclone Yasi barometric and tracking data courtesy of Bureau of Meteorology (www.bom.gov.au)
4. Queensland mapping data provided by Maritime Safety Queensland (www.msq.qld.gov.au)
5. Great Barrier Reef data courtesy of the Great Barrier Reef Marine Park Authority (www.gbrmpa.gov.au)

## References

Queensland Government, DSITIA (2013). *Maximum Storm Tide Level Recorders (Pilot) Project – Technical Report*. Coastal Impacts Unit. Publishing pending.