Tsunami Effects along the Western Australian coastline

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1) Introduction

In order to improve tsunami modelling in the Indian Ocean, *Geoscience Australia* contracted *Guria Consulting* to collect and collate as much (mainly tsunami runup) information as possible along the W.A. coastline in the aftermath of the Sumatran Tsunami (26th December 2004). The resultant trip concentrated on the main towns between Port Hedland in the northwest to Augusta in the southwest corner and was completed during the period September 2005 and April 2006. Because of the time-lag between the tsunami and the fieldwork, little direct effects remained and hence the observations were based predominantly on anecdotal and photographic evidence. This article summarises some of the key results from this work.

The term *Tsunami runup,* at a given point along the coastline, refers to the peak vertical rise of the water during the complete passage of the surges of the tsunami above the normal tide at that point and at that time. In a lot of cases, levelling observations were made during this trip to quantify this parameter.

2) The "Levelling Measurements"

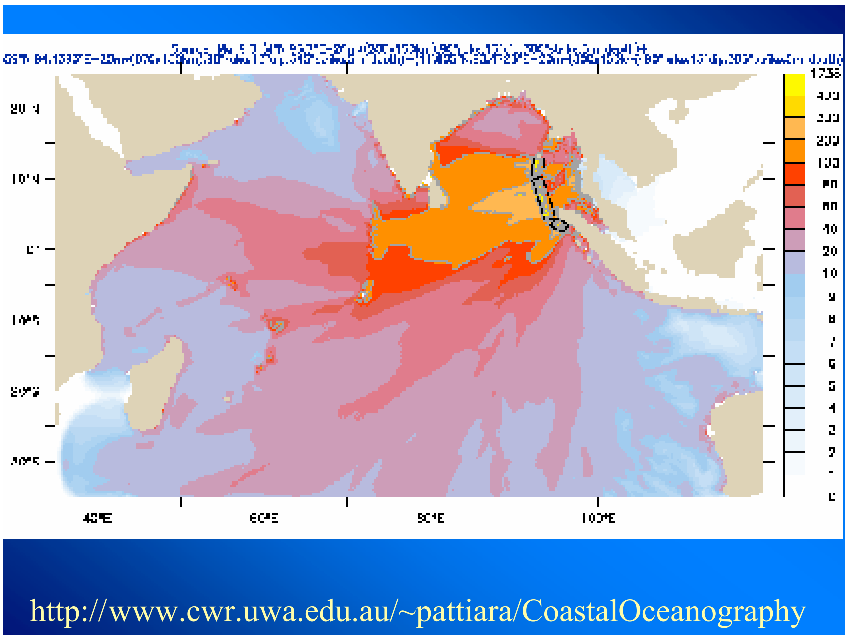
The instrument used for this purpose was a Series Automatic Levelling device by CST/ Berger. It is basically an optical "Builders' Dumpy Level".

To find the (uncorrected) runup, it was decided to observe the height of the Dumpy level above where the mean sea level (MSL) was at the time of the observation. This MSL was taken as the point on the beach/ water interface at which half of the time there was water passing over it and half of the time there was none. This estimate (of MSL) clearly introduces some error dependent on the amount of wave and wind activity at the time. Coastal engineer with the Department of Planning and Infrastructure (DPI), Matt Eliot (pers com, 2005) said, it typically introduced a vertical error of 0.1 metres. It was decided that because of the inherent problems trying to tie the observations in with nearby survey markers, using the MSL for a base became the preferred option.

Hence for each levelling observation, a calibrated staff was positioned at the MSL. The height of the optical axis of the Dumpy was then subtracted from the height observed on the staff to arrive at the (uncorrected) "runup" estimate. To complete the estimate of the *tsunami runup,* the vertical difference in MSL at the time of the observation and that at the time of the peak tsunami runup must be subtracted as another correction to the apparent runup observation. This then becomes the *true* or ***corrected tsunami runup***.

A digital photograph was taken at each levelling observation site. For consistency this photograph was taken from behind the levelling instrument showing the setup of the instrument on the tripod, the staff at the water's edge and the surroundings, as seen in the example below.

3) Source effects



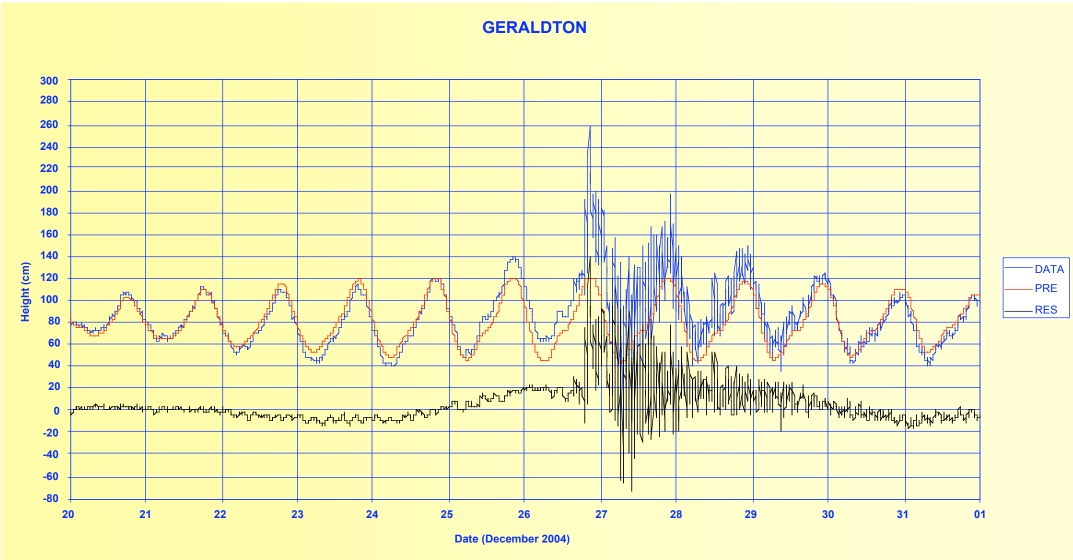
It is seen from the above slide (from Professor Pattiaratchi at UWA) that the greatest tsunami wave amplitudes was directed primarily to the east towards Banda Aceh in Sumatra (up to 35 m) and the west towards the sub-continent (up to 5-10 m). This bias can be explained by the focal mechanism and strike of the 1200 km submarine mega-thrust fault which was generated by the Mw 9.3 earthquake. Australia was fortunate not to be in the path of these large tsunamigenic amplitudes.

The challenge before the tsunami wave modellers now is what amplitudes would be estimated along the Western Australian coastline if the same event should occur on the southern flank (the east-west-trending part) of the Sunda Arc. Such a Great shallow earthquake located on the north-trending subducting Australian Plate would be expected to bias most of the wave energy primarily north, back towards the Indonesian islands such as Java, Bali etc and south towards Australia. Matt Eliot (pers com, 2005) predicts that such an event is likely to produce a runup of 4 metres in W.A.

4) Significant Results

A) Residual tidal data for the period of the tsunami at 15 stations along the W.A. coastline can be found at the DPI Website at: http://www.dpi.wa.gov.au/imarine/coastaldata/1879.asp). They show that considerable variation in the effects of the tsunami along the coastline was observed. Going from north to south the following observations of these data were noted:

1) Tidal movements were visibly disturbed for several days at most gauges;
2) No significant effects could be seen at Wyndham and Broome;
3) Residual tidal effects from Pt Hedland to Carnarvon were of the order of half a metre, the smallest amplitudes seen were at Exmouth Gulf.
4) Geraldton was the standout with residual tidal amplitudes up to one and a half metres registered. This together with a peak tide in the evening of the 26/12/04 gave rise to a water level 0.6 metre greater than had hitherto been recorded. It was suggested by Matt Eliot (personal communication, 2005) that entrapment and resonance between the Abrolhos and the Central Coast of W.A. may have been the cause of these exceptional wave amplitudes. The full DPI chart data including the residual tidal data has been presented immediately below.



5) Heading further south from Geraldton, the residual tidal amplitudes at main centres returned to "normal" (about _ m) until Bunbury when amplitudes up to about a metre were seen.
6) No amplification effect was seen in Fremantle, as in Geraldton; but there was a noticeably much longer period (2-3 hours) associated with the surges in Gauge Roads (the protected water between Fremantle and the nearby islands of Garden, Carnac and Rottnest Islands).
7) Small effects were observable at the Perth Barracks St Jetty, some 20 km along the Swan River from Fremantle.
8) The tsunami arrived first in Exmouth, then in Jurien, ahead of the other 14 reporting towns. This implies the most consistently deep seafloor path between the epicentre and the WA Coastline emerges at Exmouth.
9) Low amplitude (about 1/4 m double amplitude), long period diffracted tsunamigenic effects were also observed in Albany and Esperance.

B) Runup data based on levelling observations as described above are provided hereunder. Except for the Geraldton results, tidal corrections have still to be applied.

1) Credible anecdotal evidence suggests that the water from the tsunami crossed the isthmus at Pelican Point beach near Carnarvon (see photo below).

For this to take place, minimum water heights estimated were between 2.66 and 2.89 metres above MSL. This compares with a runup on the other side of the isthmus of the order of 0.5m, which is consistent with the tide gauge observations. It is thought that because the coastline at Pelican Point is unprotected and the sand spit (See marker on RHS of photograph above) may have directed the water towards the beach and in so doing the surge height was amplified.

2) Coral Bay – Two blokes were sitting under a tree about 75 m from the water, drinking beer and watching the Boxing Day cricket on TV (as you would!). They didn't mind getting their feet wet, as it was a warmish sort of a day but when their esky started floating off they became alarmed. The uncorrected observation of runup to this point was 1.5 metres; this is consistent with another observation that we made further up the beach based on information from an independent observer.
3) A reliable witness reported water in a carpark above a beach on the west coast of NW Cape (just south of the Yardi Creek Caravan Park). A levelling observation showed that the water had to rise more than 2 metres from the mean level (MSL) of the ocean at the time of the observation for this to occur. It is interesting to note that the equivalent runup observations in Exmouth Gulf, on the other side of the Cape, were very much attenuated at about 0.5m.
4) Anecdotal and photographic evidence showed that the (preliminary) corrected runup estimates at various places in Geraldton varied between about 1.0-2.0 metres. Considerable damage was incurred at the "Fisherman's wharf"; eg water inundated the local "fish-n-chip" shop to a reported 0.8 m and caused havoc for the boats tied to the wharf (see photographs on the next page).
5) The newspaper photograph following the boat photos mentioned in point 4) above, was taken looking towards the main wharf in Geraldton and depicts perhaps the lowest tide experienced during the tsunami. On the 27/12/04 the tide receded to equal Geraldton's historical low tide (DPI staff, Fremantle).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6) Other (preliminary) corrected runup estimates in the northern suburbs of Geraldton (Bluff Point and Drummond Cove) were between 1.4 – 1.9 m with about 0.2 m less in the marina. These figures generally show slight amplification compared with the official residual tide at the DPI tide gauge of about 1.4 m (see chart in section 4 above). Hence, the (preliminary) corrected runup varied by only _ m along the northern beaches down to Geraldton, including the marina, the harbour and Fishermen's wharf. There is little doubt that one of the major contributors to greater effects in Geraldton was the runup corresponded with a 1.2 m high tide.
7) However, West Beach on the other side of Geraldton must have been sheltered from the main surge as the corrected runup there of 1.0 m was significantly less. This is just as well, as the water had passed through the dunes and almost crossed the road and therefore could have caused much damage had it been in the range experienced further north.
8) Uncorrected runup observations diminished on the way south from Geraldton as seen at Pt Denison and Jurien Bay, where of the order of 1.5 m were observed.
9) Heading south from Fremantle including Mandurah, Bunbury, Busselton (marina), the Margaret River region including Augusta (Flinders Bay), uncorrected runup estimates diminished in amplitude further overall resulting in observations of between about 0.6 and 1.5 metres.
10) The Flinders Bay boat ramp and jetty was left high and dry (see photo below), showing that extremes of tide were common along the west coast of Australia.
11) A professional fisherman from Hamelin Bay (south of Margaret River) said that Pelagic (Deep-Sea) "Oar Fish" 10 to 12' long (deep sea) were stranded up on beach! The surges also swept much debris onto many beaches of W.A.

FLINDERS BAY — BOXING DAY 2004

12) Another fisherman from that region said according to his echo-sounder his boat rose and fell a total of 2 fathoms (about 3.5 m) when out Cray fishing, during the passage of the tsunami.
13) It is uncertain the exact number of people swept away in the strong currents generated by the tsunami in Western Australia, but we are aware of two campers at d'Alambre Island off Dampier getting washed into the sea still inside their tents; more than 100 people were rescued when trying to cross to and from Penguin Island via a sandbank which stretches to the island from the mainland at Safety Bay (south of Perth); a further three people that had to be saved after being swept away near Busselton and one man was rescued by boat 200 metres off Flinders Bay, near Augusta.

5) Recommendations

1) It was quite apparent from this survey of both governmental and other authorities in disaster management that there is a profound need for an effective tsunami warning system in Australia. It appears that few people in disaster management were aware of the tsunami until they saw the TV news after it had passed. Furthermore, we heard that some, who were aware, were confused with the instructions that came with the information, as to how to use it. There is no doubt that because no lives were lost this time, we had a near miss, but I hasten to add we may not be so fortunate next time.
2) Hence, it is paramount that politicians, scientists and bureaucrats learn from this event and work towards organising a reliable warning system that a) Allows us to estimate likely runups and their expected times of arrival along the coastline of W.A. and b) Includes a more efficient chain of command which unambiguously disseminates the technical information along with clear instructions for action.
3) Better education of the general public is required as some who saw the early effects of the 2004 tsunami, became afraid as to what might happen next.
4) For the engineers, it is suggested that more research may be required to better understand the impact of tsunamigenic surges on edges of marina openings and fluctuating pore pressures in foundations of coastal infrastructure.